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Does Financial Inclusion Facilitate Solar Panels' Adoption? Evidence from Tanzania

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Abstract

Worldwide, 820 million people still live without electricity, with Sub-Saharan Africa alone being home to 80% of these people. Affordability, lack of access to financial services and credit are often identified as important barriers. This paper studies the effect of mobile money adoption on households' decision to buy solar panels for electricity access in Tanzania. Using a logit model and an instrumental variable (IV) approach to account for the potential endogeneity issue arising from mobile money adoption, we find positive effect of mobile money services on solar panels' acquisition. Results from the logit model reveal that the odds of adopting solar panel is 1.85 times higher for households that use mobile money services than non-using households. Additionally, our IV results show that mobile money adoption, holding all other variables constant, leads to a 140% increase in the probability of adopting a solar panels. Furthermore, our findings indicate that the overall impact of mobile money adoption, conditional on being in poverty, having a migrant member, owning a mobile phone, and owning a house, is positive and statistically significant. Finally, our analysis reveals that the receipt of remittances, access to credit and information, and engagement in off-farm income-generating activities serve as mediating channels through which mobile money influences the likelihood of adopting solar panels..

JEL Classification: D14, L14, N47, Q42

Keywords: electricity access, Africa, mobile money, solar panels, Household Saving, Tanzania.

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1 Introduction

Access to electricity is widely acknowledged as an important determinant of economic development. For instance, electricity is essential to development of human capital (Lipscomb et al. 2013), industrial activities (Rud 2012, Allcott et al. 2016, Fisher-Vanden et al. 2015) and enhancement of living conditions (Lee et al. 2020). Moreover, access to electricity facilitates the diffusion and adoption of innovative technologies in key sectors of the economy (i.e. telecommunication, banking, education and healthcare). Nevertheless, over 820 million people, worldwide, still live without electricity. More than 80% of these people are located in Sub-Saharan Africa (SSA), particularly in rural areas. In urban areas, due to prohibitive connection fees, there is still an important share of the population living under the grid without access to electricity. Energy poverty[1] has detrimental economic and welfare effects. It constitutes a major impediment to economic growth and poverty reduction.

The traditional approach to electrification in SSA has long been through grid extension. While grid extension in densely populated areas can be cost effective, in rural settings, the dispersed nature of settlements makes grid extension expensive and financially unviable. However, with the declining cost of solar panels, improvement in storage capacity and energy efficiency, off-grid solutions (standalone solar panels or mini-grids) play a key role in bridging the access gap in rural areas. Although this is true, the uptake rate of solar panels is still very low. This technology, due to its high up-front investment costs, remains unaffordable to many households in developing countries.

Credit constraints and lack of access to financial services, which could allow households, for instance, to gradually save up small amounts of money and overcome the up-front investment costs, are often identified as the main barriers to technology adoption in developing countries (Dupas & Robinson 2013, Tarozzi et al. 2014, Batista & Vicente 2020). However, while it is documented that relieving credit constraints and introducing flexible payment mechanism increase the uptake of welfare improving technologies (e.g. bed nets and solar panels) in developing countries (Tarozzi et al. 2014, Barry & Creti 2020), little is known on the impact of financial services more specifically, on the use of mobile money services on technology adoption. Mobile money is an innovative mobile banking service that relies on Global System for Mobile (GSM) technology. It allows its users to make basic banking operations such as payment, reception of remittances and saving solution. Understanding how financial inclusion and specifically, the use of mobile money services enables poor households to adopt welfare improving technologies is of utmost importance to policy makers. Clearly, extending financial services to the unbanked, living mostly in rural areas, might reduce high transaction costs and affordability solar products distributors face in serving the last mile, and hence spur energy access.

The purpose of this paper, therefore, is to estimate the impact of mobile money adoption on households' decision to buy solar panels in Tanzania. Specifically, we would like to know if house-

[1] It is defined by the International Energy Agency (IEA) as a lack of access to modern energy services

holds that use mobile money services are more likely to adopt solar panels than non-using households. Tanzania offers an interesting setting for this study. The country not only has the lowest electrification rate of the East African region, but also a widespread use of mobile money services. On top of this, Tanzania's off-grid solar energy market is among the most dynamic of the East African region. By addressing this research question, we contribute to the growing literature on the role of financial inclusion, more specifically the nexus between mobile money services and technology adoption in developing countries. Previous studies on mobile money in developing countries have so far focused on assessing the welfare effects (Tadesse & Bahiigwa 2015, Sekabira & Qaim 2017) and mainly on risk sharing mechanisms (Jack & Suri 2014, Riley 2018). To the best of our knowledge, this is the first paper to examine the impact of mobile money on technology adoption in developing countries. We present new insights of the development effects of mobile money services in a poor developing country.

To shed light on the effect of mobile money services on households' decision to adopt solar panels, we use the first ad second wave of the refreshed sample of Tanzania's National Panel Survey conducted between 2014-2015 and 2020-2021, respectively. We find strong evidence of mobile money use on households' decision to adopt solar panels. Specifically, we find that the odds of buying solar panels is 1.85 times higher for mobile money using households than non-using ones. We address the potential endogeneity issue of mobile money adoption by setting an instrumental variable (IV) approach. To establish a causal relationship between the adoption of mobile money and solar panels, we use the presence of mobile money services within a district as an instrument. Our IV results reveal that mobile money leads to a 140% increase in the probability of adopting solar panels. Additionally, we investigate the heterogeneous effects of mobile money adoption with regard to households' poverty status, ownership of mobile phone and house, as well as having a migrant member. Our findings indicate that the overall impact of mobile money adoption, conditional on being in poverty, having a migrant member, owning a mobile phone, and owning a house, is positive and statistically significant. Finally, we delve into the potential mechanisms underlying these effects. Our analysis reveals that the receipt of remittances, access to credit and information, and engagement in off-farm income-generating activities serve as mediating channels through which mobile money influences the likelihood of adopting solar panels.

The remainder of the paper is organized as follows: Section 2 reviews the relevant literature. Tanzanian economic situation is summarized in Section 3, together with the specificity of its electricity sector. Section 4 describes the data and summary statistics of the main variables used in this study. The empirical strategy and results are presented respectively in Section 5 and 6. While Section 7 covers heterogeneous effects, Section 8 presents the economic drivers at stake. Section 9 presents robustness checks. Section 10 briefly concludes.

2 Literature review

Over recent years, there has been a growing interest among scholars in solar panels diffusion in emerging countries. Up to now, the literature has focused on estimating socioeconomic impacts of solar home systems (SHS). Overall, SHS have been shown to increase children study time (Furukawa 2014, Kudo et al. 2017, Grimm et al. 2017), improve social inclusion and communication (Komatsu, Kaneko & Ghosh 2011), reduce kerosene expenditure (Komatsu, Kaneko & Ghosh 2011, Arraiz & Calero 2015, Grimm et al. 2017, Yuya et al. 2015, Khandker et al. 2014, Buragohain 2012, Chen et al. 2017), but little evidence on income generating activities and productivity.[2] Although assessing socioeconomic impacts of solar technology remains an interesting avenue of research, it is not the scope of this paper.

We take a different perspective by focusing on energy demand. Surprisingly, only a handful of papers investigate this question in developing countries. For instance, Smith & Urpelainen (2014) using data from a nationally representative household survey in Tanzania, study the determinants of solar panels adoption. They find that poorer households are less likely to purchase solar panels while large households with grid connection are more likely to adopt solar panels. Similar results were also found by Guta (2018) in rural areas of Ethiopia. In the same vein, Komatsu, Kaneko, Shrestha & Ghosh (2011) study non income factors behind solar panels adoption in rural Bangladesh. They reveal that beyond household income, there are other factors positively affecting solar adoption. These factors include ownership of rechargeable batteries, kerosene consumption, and the number of mobile phones. Again in four districts of the Kagera and Rukwa regions in Tanzania, Klasen & Mbegalo (2016) study the effect of livestock ownership on households' decision to adopt solar panels. They find that livestock ownership is positively correlated with solar panels adoption. Put differently, the probability of adopting solar panels is higher for households with livestock ownership than households without. Such findings underline the important role of assets in developing countries, where the vast majority of the population lack access to financial services. Hence, investment in assets (i.e. durable goods or livestock) remains the only saving alternative.

While many studies on solar panels adoption have so far focused on socioeconomic determinants, several other studies have underlined the key role of social interactions or peer effects. For example, Bollinger & Gillingham (2012) using a large dataset of photovoltaic (PV) system adoptions in California examine the effect of previous nearby adoptions on actual PV system adoption. They show that an additional previous installation in a zip code increases the probability of a new adoption in that zip code by 0.78%. Altough the effects are small, Richter (2013) finds positive and statistically significant social effects on solar panels adoption in the United Kingdom. Recently, a growing body of research has dedicated attention to examining the relationship between financial inclusion and access to modern energy services. Notably, researchers such as Aarakit et al. (2022) have delved into this topic by investigating the impact of financial inclusion on the adoption of solar panels

[2] For a comprehensive literature review on the impact of SHS see Lemaire (2018).

in Uganda. Their study reveals a robust positive relationship between financial inclusion and the adoption of solar photovoltaic (PV) systems among households. Furthermore, they observe that the utilization of mobile money, as an aspect of financial inclusion, exerts the most substantial influence on the adoption of solar PV systems compared to other components. Another study conducted by Dogan et al. (2021) analyzes the effect of financial inclusion on energy poverty within Turkish households. Their findings demonstrate that financial inclusion mitigates energy poverty, with a more pronounced effect observed among female-headed households. Similarly, Koomson & Danquah (2021) examine the relationship between financial inclusion and energy poverty in Ghana, reporting a significant reduction in energy poverty associated with greater financial inclusion.

While the majority of papers exploring the nexus between financial inclusion and energy poverty rely on micro-level data, some studies have approached this question using macroeconomic data. For instance, Said & Acheampong (2023) investigate the relationship between financial inclusion and energy poverty in Sub-Saharan Africa (SSA), revealing a substantial reduction in energy poverty as a result of enhanced financial inclusion in the region. Conversely, Mukalayi & Inglesi-Lotz (2023) focus their attention on the interplay between digital financial inclusion and energy and environment, finding that higher proxies of financial inclusion are associated with increased energy consumption and CO2 emissions. The cumulative evidence reviewed here suggests the importance of various factors, including education, income, peer effects, and notably, financial inclusion, in influencing the decision to use solar panels.

The use of telecommunication services, more specifically mobile money services is another strand of the literature our paper is related to. Over the last decade, developing countries have experienced an unprecedented penetration rate of mobile phones. Mobile phones have become an essential part of the daily life of millions of people in the developing world. Today, the widespread use of mobile money perfectly illustrates this trend. Moreover, mobile money is not only revamping the way basic services are delivered, but it is also enabling adoption of welfare improving technologies by the poorest. In this regard, there has been growing recognition of the development effects of improved telecommunication services (Aker & Mbiti 2010).

It is now well established from a variety of studies that the use of mobile phones, for instance, reduces price dispersion and increases market participation of rural farmers. Jensen (2007) is among the first papers to rigorously examine the effect of the introduction of mobile phone network on market performance and welfare. Using micro-level data of the South Indian fisheries sector, he finds that the introduction of mobile phones induced a reduction in price dispersion from 60-70% to 15%. Overall, the introduction of mobile phone was welfare improving as it not only eliminated waste, but also decreased consumer's price by 4% while fishermen's profit increased on average by 8%. In the same vein, Aker (2010) studies the impact of mobile coverage on market performance in Niger. She finds that the introduction of mobile phones was associated with a 10 to 16% reduction in price dispersion across markets, with a larger impact for market pairs with higher transport costs. Unlike Aker (2010) and Jensen (2007) who focus on price dispersion, Muto & Yamano (2009) examine the effect of mobile phone network coverage expansion on market participation of farmers producing perishable crops in Uganda. Their results reveal that network expansion has a positive impact on market participation for farmers of perishable crops. However, while the impact is larger for areas farther away from district centers, they did not find any impact of network expansion on marketing for less perishable crops like maize. If the study mentioned above focuses on the use of mobile phone, more recently, interest has shifted toward mobile banking or mobile money services.

Several studies have demonstrated that the use of mobile money, by reducing transaction cost, facilitates informal risk sharing. Jack & Suri (2014) are the first to provide an empirical evidence of the attenuating effect of mobile money in the advent of negative shocks. Using a large panel data of Kenyan households, they reveal that while the consumption of households that use mobile money is unaffected in the advent of shocks, the consumption of nonusers declines by 7%. Increases in remittances received and the diversity of senders are the underlying mechanisms of these consumption effects. Riley (2018) examines the impact of mobile money services on Tanzanian households' consumption after a rainfall shock (i.e. flood or drought). Contrary to Jack & Suri (2014), she examines the spillover effects of mobile money services at the village level. Her objective is to verify if remittances received by households that use mobile money services are shared with non-using households within the same village. She finds that after a village-level rainfall-shock, only mobile money using households that do not experience a drop in their consumption. In other words, she finds no spillover effects at the village level.

More recently, several studies have also confirmed that the use of mobile money not only allows farmer to adopt best practices, but also to have access to high value markets. Tadesse & Bahiigwa (2015) examine the impact of mobile money on agricultural income, input use and commercialization of rural farmers in Kenya. They find that commercialization increased by 37% for mobile money using households, while also users of mobile money experienced an increase in their agricultural income and input use by US$ 224 and US$ 42, respectively. Similarly, Sekabira & Qaim (2017) examine the nexus between mobile money usage and access to higher-value markets by rural farmers in Uganda. Using a panel data of smallholder coffee farmers, the authors find that the use of mobile money increased the share of shelled beans sold by 12%. The underlying mechanism is that mobile money facilitates transactions with buyers outside the local regions.

Together, these studies indicate that telecommunication services and more particularly, mobile money may considerably impact economic development. Recognizing the key role of financial inclusion in reducing poverty (Burgess & Pande 2005), mobile money could not only help in bridging the financial services access gap, but also improve the welfare of the financially excluded population. However, little is known on the effect of improved access to financial services on technology adoption. The aim of this paper is, therefore, to fill this gap by examining the role of mobile money services on solar panel adoption.

3 Background on Tanzania

Tanzania is located in East Africa. In 2017, it had an estimated population of 57.31 million people. Despite Tanzania's growing urbanization rate, still 66% of Tanzanians live in rural areas (World Bank)[3]. Agriculture is the mainstay of 70% of Tanzanian households. The sector employs nearly 80% of the active labor force. The share of agricultural sector in the country's economy is still very important. In 2017, the sector's contribution to Tanzania's GDP stood at 28.7% (WB). Over the last decade, Tanzania has experienced rapid economic growth, averaging 6-7% per year. However, after more than a decade of buoyant economic growth, poverty is still prevalent. Rural areas are home to the country's poorest people. The government's efforts to extirpate millions of Tanzanians out of poverty is, however, undermined by its rapid population growth.

Electrification rate in Tanzania is among the lowest of the East-African region. According to the World Bank statistics, only 32.8% of Tanzanians had access to electricity in 2017. This figure hides huge heterogeneity between urban an rural areas. While 65.3% of urban population had access to electricity in 2017, the proportion in rural areas was 16.8%. The low electrification rate is indicative of the country's low level of economic development. Tanzania is not only ranked among the countries with the lowest electrification rate in Sub-Saharan Africa but also with the lowest per capita energy consumption. In 2014, its per capita energy consumption stood at 104 KWh (WB). Although significant efforts have been done over recent years in promoting the use of modern and efficient energy technology, still a bulk of Tanzanians rely on pollutant sources of energy. Traditional biomass remains their primary source of energy. This source of energy is not only expensive and inefficient, but it also has huge detrimental health and environmental impacts. Besides the low electrification rate, the unreliable nature of electricity provision in Tanzania is another major problem. Recurrent power outages are detrimental to industrial development and leads to huge economic losses. Recognizing the key role of access to electricity in unlocking the country's economic potential, Tanzania's government, over recent years, has been at the forefront of institutional reforms. These reforms have the dual aim of addressing both the pending issue of access to electricity in rural areas and the low participation of the private sector in the energy sector.

Providing electricity to rural areas of mainland Tanzania is challenging. Communities are not only sparsely dispersed in a hilly landscape, but also with low electricity consumption. Obviously, rural electrification through grid extension does not seem to be a cost effective solution. However, with declining costs of solar panels and the ongoing development of high capacity battery, solar technology has emerged, among energy specialists, as a cost effective solution to providing electricity to rural areas of developing countries.

Furthermore, under the supervision of the Ministry of Energy and Mineral, the vertically integrated national utility, TANESCO, is undergoing huge structural changes. The government's goal is to totally unbundle the generation, transmission and distribution activities of TANESCO with

[3]https://data.worldbank.org/indicator/sp.urb.totl.in.zs

a sole objective of giving more room to the private sector. Public-private partnership is, indeed, a rapid way of filling the huge investment deficit in the energy sector of developing countries. Nowadays, many energy projects in SSA are developed or expected to be developed under the public-private partnership scheme.

In Tanzania, the development of decentralized mini-grids is at the heart of the government's energy access program in rural areas. In this regard, over the recent years, the country has taken proactive actions in not only regulating the sector but also by providing financial support to developers.[4] More, to better address the energy access issue in rural areas, the government has established a Rural Electrification Agency (REA) to pilot rural electrification programs. Its primary goal is to oversee the implementation of the electrification projects in rural areas, using the Rural Energy Fund as provided in the REA. These projects include mini-grids development in villages with economic potential (i.e. productive use of electricity) and support the adoption of standalone solar panels in remote rural areas to leave no one behind.

4 Data and summary statistics

4.1 Data

The data used in this study come from two different sources. The first set of data comes from the Tanzania National Panel Survey (TNPS). Recently, due to rapid demographic shifts and new administrative boundaries, the National Bureau of Statistics (NBS) renewed its original sample to ensure a proper representativeness of Tanzanian population. Therefore, in this study we use the first and second wave of the refreshed sample of the TNPS. The first wave survey was conducted between 2014-2015, while the second wave survey was administered between 2020-2021.

The Tanzania National Panel Survey is a nationally representative survey that collects a range of information both at the community, household and individual level. As we are interested on the determinants of solar panel adoption in Tanzania, the unit of observation is the household. The main household level data retrieved from the National Panel Survey includes socioeconomic characteristics such as the household's assets, head gender, age, level of education, female ratio, dependence ratio, use of financial and telecommunication services such as mobile money services and mobile phone, respectively. In addition to these variables, we also use several other variables to complete our approach. These include district level variables such as the existence of mobile money agents within the ward. Having presented the data sources used in this paper, we will now move on to the descriptive statistics of the main variables of our study.

[4] Developers are small power producers with generation capacity below 1 megawatt.

4.2 Summary statistics

Table 1 shows the summary statistics of the main variables used in this study by year. As you can see, solar technology is gaining popularity in Tanzania. The share of households using solar for electricity access increased from 9% in 2015 (see figure 1) to 28% in 2021 (see figure 2). Although access to electricity is still low, significant progress has been made over the past decade. In 2015, 29% of households had access to electricity. This number increased to 41% in 2021. However, at the current rate of electrification, the country is not on track to achieve universal access to electricity by 2030. The vast majority of the population without access to electricity lives in rural areas. Despite the rapid urbanization rate in recent decades, 50% of households in 2021 were rural.

Upon examining the composition of households, we observe that the average size of a Tanzanian household is approximately 5 individuals, with a female ratio of nearly 3 women per household. Furthermore, over 70% of households are led by males with an average age of 45 years. In terms of human capital development, household heads demonstrate a relatively favorable level of education. Between 2015 and 2021, education levels improved. The percentage of household heads with secondary education has increased from 18% in 2015 to 22% in 2021. Additionally, the proportion of household heads with university degrees reached 3% in 2021. However, there was a decline of 3 percentage points in the share of household heads with primary education between 2015 and 2021. While the proportion was 57% in 2015, it decreased to 54% in 2021.

Furthermore, there has been a notable decrease in the proportion of household heads involved in off-farm revenue-generating activities between the two periods. It declined from 36% in 2015 to 30% in 2021. This decline can be attributed to the adverse effects of the COVID-19 pandemic, which significantly disrupted economic activities. Similarly, the percentage of households receiving income also experienced a substantial drop during the same period, declining from 33% in 2015 to 19% in 2021.

Moreover, an examination of telecommunication services revealed the pervasive presence of mobile phones in nearly every Tanzanian household. The penetration of mobile phones witnessed a significant increase between 2015 and 2021. While 80% of households had a mobile phone in 2015, this proportion rose to 88% by 2021. Additionally, the adoption of mobile money services has seen a considerable increase, with the percentage of households using such services increasing from 52% in 2015 to 74% in 2021. Furthermore, the availability of mobile money agents within districts has also expanded. In 2015, only 52% of households had access to mobile money services within their district, whereas by 2021, this figure rose to 86%. However, access to credit remains limited in Tanzania. Only 11% of households reported having obtained formal or informal credit in 2015, and by 2021, the percentage of households with credit stood at 9%.

Lastly, we analyze the differences in characteristics between individuals who adopt mobile money services and those who adopt solar panels, as presented in Table 2 and Table 3, respectively. Table 2 demonstrates that mobile money users exhibit notable distinctions compared to non-users.

Generally, mobile money users tend to have higher socioeconomic status, possess a higher level of education, receive more remittances, have access to credit, adopt solar panels, utilize television as an information source, and engage in off-farm revenue-generating activities.

Conversely, Table 3 provides insights into the mean differences associated with solar panel adoption. Overall, the results suggest that solar users are more inclined to utilize mobile money services, possess a mobile phone, own a greater number of livestock, and, most importantly, reside in rural areas.

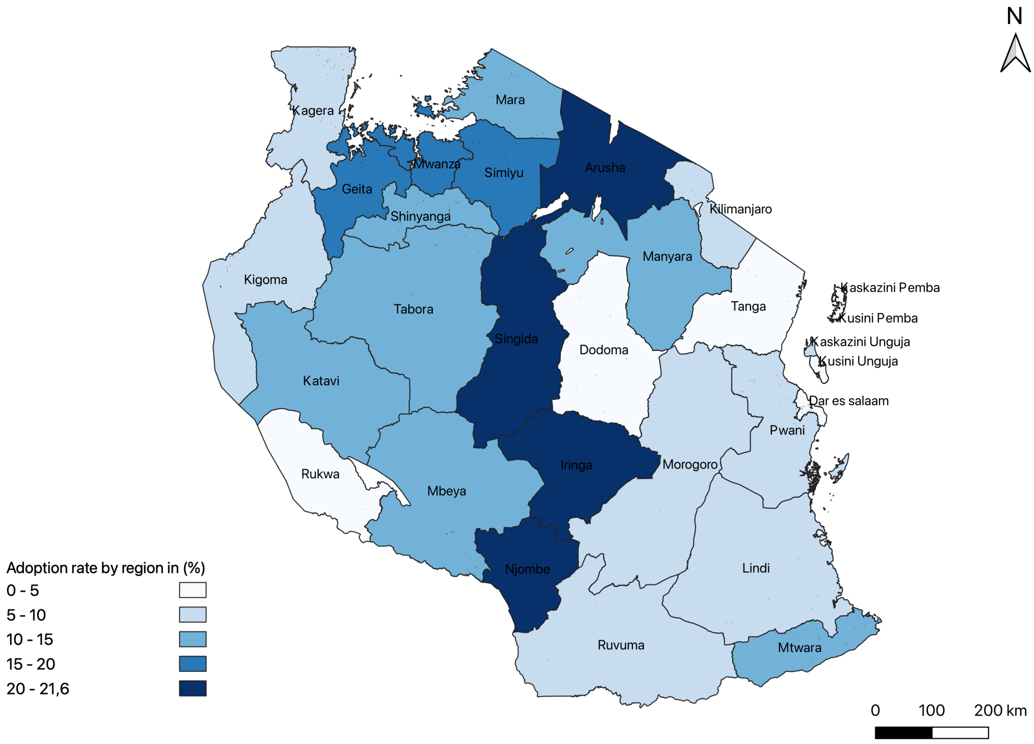

Figure 1: Solar panel adoption rate by region in 2015
Source : author's elaboration from survey data

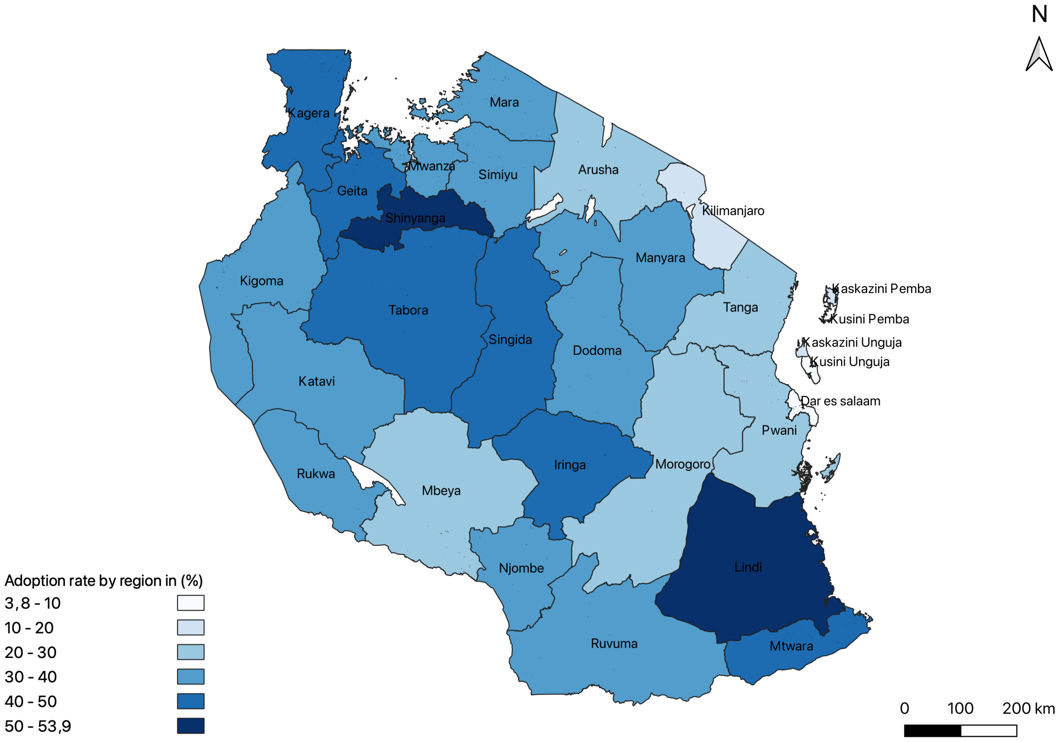

Figure 2: Solar panel adoption rate by region in 2021
Source : author's elaboration from survey data

5 Empirical strategy

5.1 Modelling solar adoption

In order to identify the effect of mobile money on households' decision to adopt solar panels, we rely on a logit model and estimate the following specification :

$$Solar_{it} = \alpha_i + \beta MM_{it} + \gamma X_{it} + \epsilon_{it}$$

Where $Solar_{it}$ is a binary variable that indicates whether household i uses solar panels at time t. It is equal to one if household i uses solar panels at time t and zero otherwise. MM_{it} is a dummy variable that is equal to one if household i uses mobile money services at time t and zero otherwise. X_{it} is a set of socioeconomic control variables. α_i represents the individual-specific fixed effects or (random effects), capturing unobserved heterogeneity across individuals and ϵ_{it} the error term that follows a logistic distribution. The parameters β and γ are estimated using the Maximum Likelihood Estimator (MLE). MM_{it} is the variable of interest. If β is positive and statistically different from zero, then the odds ratio of adopting solar panels is higher for mobile money users than non users. In some specifications, region fixed-effects are added to control for unobserved regional characteristics that might both influence mobile money and solar panels adoption. Not controlling for the correlated effects might potentially bias the estimated parameters. Having presented our solar panel adoption model, we will now move on to discuss some identification issues and how these are addressed.

5.2 Endogeneity

The main threat to our identification strategy stem from the variable MM_{it}, which is potentially endogenous. For instance, mobile money users are more likely to be better off, well educated and also better informed of the benefits of mobile money and solar panels than non-users. There are thus both observable and unobservable household characteristics that affect the household's decision to use mobile money. While observed household heterogeneity (difference in education and wealth) can be controlled for, unobserved heterogeneity (aversion to risk and preferences) is difficult to rule out. In the presence of unobserved heterogeneity in mobile money adoption, the estimated parameter β will be biased since mobile money adoption will be correlated with the error term.

Similarly, reverse causality stemming from the fact that solar adoption is likely to lead to mobile money adoption is another source of endogeneity. This is possible since Tanzania's current standalone solar panels market, mainly led by international private enterprises, relies on mobile money, an innovative way of financing access to modern energy services. Also known as the pay-as-you-go (PAYG) energy service, it allows budget-constrained households that cannot make a lump sum payment of the solar panel to use its electricity while paying it through, small, weekly installment payments. The repayment period depends on the price of the solar panel, which depends on its capacity. The market's cheapest solar home system is sold at US$305.25, with 36 months of installments of US$8.25 per month, while the highest solar capacity is sold at US$1,794, with US$46 per month for a repayment period of 36 months (Sanyal et al. 2016).

Generally, an upfront payment has to be done before starting the weekly installments. The upfront payment depends on the solar panel's capacity. It is estimated to be as much as 15% to 20% of the cost of the solar panel. However, while nearly 70% of Tanzanians leave with less than US$2 per day (World Bank),[5] it is more likely that households that decide to buy solar panels do it through weekly installment payments. And, since the payments have to be made through mobile money, the adoption of solar panel is likely to lead to the adoption of mobile money, hence, introducing a simultaneity bias between solar panel and mobile money adoption.[6]

To address the endogeneity issue, we use a Linear Probability Model (LPM) with an Instrumental Variable (IV) approach. The most common instrument used in the economic literature on mobile

[5]https://www.worldbank.org/en/country/tanzania/publication/tanzania-mainland-poverty-assessment-a-new-picture-of-growth-for-tanzania-emerges

[6]It is possible to have households that buy solar panels in a one lump sum payment. However, given the level of poverty in Tanzania, the number is likely to be very limited.

banking is generally the distance separating a household to its nearest mobile money agent (Jack & Suri 2014, Riley 2018, Munyegera & Matsumoto 2016). The idea behind the use of this instrument is that the farther a household is to the nearest mobile money agent, the less likely the household is to use mobile money services. However, in our setting, the use of this instrument is not appropriate. The distance separating a household to its nearest mobile money agent might be, indeed, correlated with the outcome variable and consequently violate the exclusion restriction. For example, when a mobile money agent is located near a road, it implies that the residents have convenient access to solar panels. Therefore, the proximity of the agent to a road will have a direct impact on the outcome variable, as it improves both the availability and accessibility of solar panels.

In this paper, we follow Riley (2018) and use as an instrument the availability of mobile money services within the ward of each household. It is dummy variable that indicates whether a household lives within a ward where mobile money service is available. Since mobile money heavily relies on agents to operate basic financial transactions such as cash in or cash out services, the availability of the service closer to its users is pivotal to its adoption. Indeed, a household living within a ward where the mobile money service is available is more likely to use this service than a household living in an area without the service. We expect this variable to be positively correlated with mobile money adoption. Additionally, for this instrument to be considered as a valid, there should be no self-selection of mobile money agents into wards. Put differently, the location choice of mobile money agents should be random and not correlated, for instance, with the level of development of the ward. In the Tanzanian context, the location choice of mobile money agents is unlikely to have been influenced significantly by the development level of wards.

Indeed, according to Riley (2018), before the introduction of mobile money services in Tanzania, the largest mobile network operator, Vodacom, had a very dense network of wholesalers, who distributed airtime to thousands of resellers. Hence, when Vodacom launched its mobile money services in 2008, it relied on its extensive distributor network to quickly establish a mobile money agent network. This process was facilitated by the relatively low fixed costs associated with becoming a mobile money agent. The main requirement was having a business capable of generating sufficient cash flow to ensure payments to mobile money users. However, although agents' location appear to be random, the density of mobile money agents is likely to be correlated with the level of development of a district. Typically, mobile money agents are concentrated in densely populated areas with significant economic prospects.

5.3 Modelling the Economic Drivers

In this section, we examine the channels through which mobile money adoption might affect the uptake of solar panels. The impact of mobile money on solar panel adoption might be direct, for example, if a household decides to purchase a solar panel through the PAYG scheme. While this direct effect might be at play, we unfortunately cannot test this hypothesis. The data we have do not provide any information on how the solar panel was bought. Put differently, if the solar panel was bought through the PAYG scheme via weekly installments or in a lump sum payment. Apart this direct effect, there are also other mechanisms through which mobile money could enable households to adopt solar panels. These include the remittances, information, credit and income generating activities channels. Since mobile money not only reduces transaction costs but also allows access to basic financial services, naturally, mobile money users are more likely to receive remittances, to contract a credit, have access to information and also, to engage in off farm revenue generating activities. To test these channels, we estimate the specification below:

$$y_{it} = \alpha_i + \mu MM_{it} + \delta X_{it} + \epsilon_{it},$$

where y_{it} stands respectively for reception of remittances, access to credit participation in off-farm income generating activities and access to information. The variable y_{it} is equal to one if household i receives remittances, contracts a credit, owns a television and participates in off-farm income generating activities at time t, respectively and zero otherwise. MM_{it} is a dummy variable indicating whether household i uses mobile money services. It takes one if household i uses mobile money services at time t and zero otherwise. X_{it} represents a set of socioeconomic control variables ; ϵ_{it} the error term that follows a normal distribution and α_i represents the individual-specific fixed effects. If μ is positive and statistically different from zero, it means that mobile money using households are more likely to receive remittances, engage in revenue generating activities and to have access to credit and information. These elements, combined together, are welfare improving as they increase the household's revenue and awareness of the benefits associated with the adoption of such technologies. This in turn, relaxes the household's liquidity-constraints, which enables investment in durable assets such as solar panels. Since we are interested in the correlation between our variable of interest and our outcome of interests, the parameters are estimated using a probit model. We now move on to the presentation of the main results.

6 Results

Table 6 reports the determinants of solar panels adoption and in particular, the impact of mobile money on households' decision to adopt solar panels. In columns (1)-(2) we report the odds ratio or exponentiated coefficients. The odds ratio can be interpreted as the estimated odds of change in solar panel adoption as a unit change in the independent variable (Murendo et al. 2018). In column (1) we present the results of the logit model without controlling for region fixed effects while in column (2), we account for regional fixed effects. In all specifications, mobile money is positive and statistically significant at 1% level indicating that the use of mobile money is positively associated with the adoption of solar panels.

Because of the similarities between the specifications presented in columns (1) and (2), we focus our analysis on the results in column (2), which is our preferred specification. In Column (2), mobile money, which is our variable of interest, has an odds ratio of 1.85. This odds ratio implies that the probability of adopting a solar panel is 1.85 times higher for mobile money users than for non-users. This result highlights the important role of financial inclusion in facilitating households' investment in welfare-improving assets. Access to financial services as rudimentary as mobile money can have a significant positive impact on people's welfare. In the context of Tanzania, mobile money not only allows its users to save small amounts of money, which would not have been possible in the traditional banking system, but also to receive internal remittances safely and at a lower price.

In addition to our variable of interest, mobile money, other control variables affect solar panel adoption. Specifically, our results indicate that living in rural areas, household size, and education level are statistically significant and positively correlated with solar panel adoption.

The odds ratio of adopting solar panels for households living in rural areas is 2.13 times higher than those living in urban areas. This result is not surprising, as those lacking access to electricity in Tanzania live in remote rural areas where the grid is almost nonexistent. Moreover, male-headed households and mobile phone ownership are also significantly and positively associated with solar panel adoption.

Column (3) reports the results of the linear probability model. Again, mobile money is positive and statistically significant at the 1% level. Column (3) shows that mobile money adoption is associated with a 11.7 % increase in the probability of adopting a solar panel. However, since mobile money is endogenous, the estimated parameters are likely to be biased. Columns (4)–(5) account for the potential endogeneity of mobile money adoption using a 2SLS linear probability model. This allows us to establish a causal relationship between mobile money usage and solar panel adoption. Columns (4) and (5) report the first- and second-stage estimations, respectively. In column (5), mobile money is positive and statistically significant at the 1% level, indicating that mobile money usage increases the probability of solar panel adoption. Specifically, we find that mobile money adoption leads to a 140% increase in the probability of solar panel adoption. Furthermore, the results of the first-stage estimation reveal that mobile money service availability is a key determinant of mobile money adoption. The instrument is positive and strongly correlated with mobile money adoption. Moreover, the first-stage F-statistic (12.98) passes Staiger and Stock's rule of thumb for the weak instrument problem ($F > 10$), implying the instrument's power in establishing a causal link between mobile money and solar panel adoption.

In addition to the positive impact of mobile money usage on solar panel adoption, living in rural areas is positive and statistically significant. However, we find no effect of household head's age and gender on solar panel adoption. Taken together, our results support the existence of a strong positive association between mobile money and solar panel adoption.

7 Heterogeneity

In this section we examine the heterogeneous effect of mobile money adoption on households' decision to adopt solar panel. Table 5 presents the estimation results concerning the heterogeneous effects of mobile money on various factors, including the household's poverty status, ownership of house and mobile phone, and the presence of a migrant. The parameters are estimated using a linear probability model with an instrumental variable approach. The endogenous variable is instrumented using a variable that indicates the availability of mobile money service within a district.

We commence by examining the poverty status of households. It is evident that in many developing countries, impoverished households are typically the ones lacking access to financial services. Hence, the impact of mobile money adoption on the decision to purchase a solar panel is likely to vary depending on whether the household is poor or not. To investigate this hypothesis, we introduce an interaction term between the variables poverty and mobile money. A household is categorized as poor if its per capita consumption falls below the median consumption.

As demonstrated in column (1), the interaction term (Mobile money×Poverty) exhibits a negative and statistically significant relationship. This indicates that poorer households utilizing mobile money are less inclined to adopt solar panels. However, we observe a positive overall[7] effect of mobile money. Specifically, among poorer households, the adoption of mobile money is associated with a 51% (3.526-3.018) increase in the likelihood of solar panel adoption. This outcome underscores the crucial role of financial inclusion in facilitating the adoption of welfare-enhancing technologies by impoverished households.

In column (2), we examine the varying impact of mobile money on solar panel adoption based on the presence or absence of a migrant in the household. The likelihood of receiving remittances, which is generally dependent on the presence of a migrant, plays a crucial role in this analysis. To explore this heterogeneous effect, we incorporate an interaction term between migration and mobile money. The findings indicate that households with a migrant, using mobile money are less inclined to purchase solar panels for electricity access. The interaction term exhibits a negative and statistically significant relationship at the 1% level. However, when considering the overall effect of mobile money on households with migrants, there is a positive impact. Specifically, the adoption of mobile money is associated with a 48.1% (1.476-0.995)increase in solar panel adoption for households with migrants.

Column (3) explores the heterogeneous impact of mobile money on solar panel adoption in relation to the ownership status of the house. The decision to invest in solar technology may be influenced by whether or not an individual resides in their own house. To investigate this possibility, we introduce an interaction term between mobile money and house ownership status. The interaction term indicates a statistically significant and negative relationship at the 1% level. This suggests that individuals who own houses and utilize mobile money are less inclined to adopt solar

[7] $\frac{\partial solar_{it}}{\partial MM_{it}} = 3.526 - 3.018 Poverty$

panels. However, when considering the overall effect of mobile money, we observe a positive impact on solar panel adoption. Specifically, house ownership, conditional on mobile money utilization, is associated with a 50% increase in the adoption of solar panels.

Finally, in column (4), we investigate the heterogeneous effect of mobile money in relation to mobile phone ownership. To do so, we introduce interaction terms between mobile phone ownership and mobile money. The interaction term demonstrates a statistically significant negative relationship. However, when considering the overall effect of mobile money, conditioned on having a mobile phone, we find a positive impact. Mobile money utilization is associated with a 20% (5.919-5.722) increase in the adoption of solar panels.

In a nutshell, the main lesson we can draw from this analysis is that the overall effect of mobile money on household's decision to buy solar panels is positive. All together, these findings support the welfare effect of financial inclusion and calls for expansion of financial services to the poor, in particular, to improve access to electricity. In the next section, we examine the mechanisms at play.

8 Economic Drivers

In this section, we examine the mechanism through which mobile money usage might affect the uptake of solar panels by households. Since mobile money reduces transaction cost and also provides access to basic financial services to the unbanked, we hypothesize that households that use mobile money are more likely to receive remittances, contract a credit, improve their access to information and engage in off-farm revenue generating activities.

Table 6 exhibits the results of the underlying mechanisms. All models are estimated using a probit model. In all specifications, we report the marginal effects. Focusing on the remittances channel, our estimations reveal that mobile money is positively correlated and statistically different from zero at the 1% level, implying that the probability of receiving remittances being higher for households that use mobile money than households that do not use the service. More precisely, the use of mobile money is associated with a 6.1% increase of in the probability of receiving remittances. This result is at odds with previous studies that found that the use of mobile money increases the likelihood of receiving remittances (Jack & Suri 2014, Sekabira & Qaim 2017, Riley 2018). If remittances are, often, seen as an informal mechanism of insurance against negative shocks, they can also serve as an additional source of revenue to a household. Indeed, the reception of remittances might relax the household's budget constraint and so, facilitate investment in welfare improving assets like solar panels. Additionally, remittances are also associated with the reduction of energy poverty. A study by Barkat et al. (2023) report that international remittances positively affect access to energy, supporting the view that remittances are a key determinant in alleviating energy poverty in developing countries.

Turning now to the credit channel, we find a positive effect of mobile money adoption on access to credit. Specifically, mobile money adoption induces a 4.2% increase in the probability of contracting a credit. Indeed, the reduction in transaction costs associated with the use of mobile money might facilitate the access to a wider network money lenders nationwide. Similarly, by providing basic financial services, mobile money might also facilitate the transition toward the traditional banking system and hence, ease the access to formal credit. Overall, our result suggests that providing financial services as basic as mobile money can be a catalyst for technology adoption in developing countries by relaxing credit constraints.

Analyzing the information channel, we observe a noteworthy and statistically significant association between mobile money usage and television ownership. Specifically, the results indicate that utilizing mobile money services is linked to a 13.5% increase in the likelihood of owning a television. This finding is significant because owning a television can greatly enhance a household's access to information and increase awareness regarding the advantages of adopting solar technologies. This finding aligns with the research conducted by Dendup & Arimura (2019), who discovered that households in Bhutan with access to information are approximately 39% more inclined to adopt clean cooking fuels.

Examining the off-farm revenue generating activity channel, we observe a positive and statistically significant relationship between mobile money usage and engagement in such activities. This suggests that individuals who use mobile money are more likely to be involved in off-farm revenue generation. In fact, the adoption of mobile money leads to a 3.1% increase in the probability of operating such activities. One possible explanation for this relationship is the reduction in transaction costs associated with mobile money services. This reduction allows households, particularly those located in rural areas, to not only access high-value markets (Tadesse & Bahiigwa 2015), but also to develop their businesses. As a result, mobile money usage is likely to boost household revenue and facilitate investments in assets that improve overall welfare.

Last but not least, since investment in solar panels requires huge amount of money, which most Tanzanian households lack, the use of mobile money could help households in building up savings to undertake such investment. Unfortunately, due to data limitation we cannot test this hypothesis. The Tanzania National Panel Survey (TNPS) do not provide any information on households' savings behavior. However, there is evidence in the economic literature that mobile money increases the likelihood of saving money (Ky et al. 2018).

Finally, the impact of mobile money on solar panel adoption might be direct. This is particularly possible if a household decides to purchase a solar panel via the pay-as-you-go mechanism. Again, we cannot test this hypothesis. The Tanzania National Panel Survey (TNPS) does not provide any information on how the solar panel was bought. In other words, if the solar panel was bought in a lump sum payment or through the pay-as-you go mechanism. Clearly, over the recent years, Tanzania has witnessed a rapid expansion of pay-as-you-go energy services providers. Therefore, we argue that the surge in solar panels adoption might, in part, be imputed to the presence of pay-as-you-go energy services providers.

9 Robustness check

In this section we would like to ascertain if we are estimating the effect of financial inclusion through mobile money. Indeed, it is possible that mobile money is not measuring financial inclusion, but rather the flow of information. If mobile money is indeed measuring financial inclusion, replacing this variable with another proxy of financial inclusion should yield the same results. To test this possibility, we use an alternative definition of financial inclusion: ownership of a bank account.

Table 7 shows the results from the logit and linear probability model. In columns (1) we presents the odds ratio, while in columns (2) we present the results from the linear probability model. As it can be noticed, in column (2), the ownership of a bank account is positive and statistically significant suggesting that financial inclusion is positively correlated with solar panel adoption. Results from the linear probability model suggest that having a bank account leads to a 3.3% increase in the probability of adopting solar panels. To sum up, the results from our robustness check suggest that financial inclusion is positively associated with solar panel adoption. We can, therefore, be confident that mobile money is effectively measuring financial inclusion an not the information flow.

10 Conclusion

This paper examines the effect of mobile money adoption on solar panels' adoption and the underlying mechanisms through which mobile money adoption affects the uptake of solar panels in Tanzania. Mobile money is a basic banking solution that relies on Global System for Mobile (GSM) technology. It allows its users, via secured text messages, to make basic banking operations such as payment, reception of remittances. Although savings are not remunerated, yet mobile money remains an attractive saving solution for the unbanked.

Using the first and second wave of the refreshed sample of the Tanzania National Panel Survey, we find that households that use mobile money services are more likely to adopt solar panels than households that do not use. Specifically, we find the odds of adopting solar panels to be 1.85 times higher for mobile money using households than non-using ones. More, using an instrumental variable approach to account for potential endogeneity issues arising from mobile money adoption, we find mobile money adoption to lead to a 140% increase in the probability of adopting solar panels. Furthermore, we examine the heterogeneous effects of mobile money adoption with respect to households' poverty status, mobile phone and house ownership status and having a migrant. We find the overall effect of mobile money adoption conditional on being poor, having a migrant, owning a mobile phone and a house to be positive and statistically significative. Finally, we investigate the potential mechanisms at play. We show that reception of remittances, access to credit, information and participation in off-farm income generating activities are the mediating channels through which mobile money affect the probability of adopting solar panels.

Our paper shows that promoting the use of mobile money can enable the adoption of welfare improving technology. Hence, efforts should be concentrated in reaching those at the bottom of the pyramid mainly living in remote rural areas. Energy services providers should systematically offer mobile money payment solutions in their business model to allow, for example, flexible payment of costly electricity connection fees. This might, for instance, help households in overcoming the high upfront grid connection fees.

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Appendix

Table 1: Summary statistics

	2015				2021			
	Mean	Sd	Min	Max	Mean	Sd	Min	Max
Mobile phone	0.80	0.40	0	1	0.88	0.32	0	1
Mobile money	0.52	0.50	0	1	0.74	0.44	0	1
Mobile money serv availability	0.69	0.46	0	1	0.86	0.35	0	1
Remittance	0.33	0.47	0	1	0.19	0.39	0	1
Credit	0.11	0.31	0	1	0.09	0.29	0	1
Solar	0.09	0.29	0	1	0.28	0.45	0	1
Electricity	0.29	0.45	0	1	0.41	0.49	0	1
Television	0.30	0.56	0	11	0.38	0.63	0	21
House ownership	0.67	0.47	0	1	0.67	0.47	0	1
Off farm activity	0.36	0.48	0	1	0.30	0.46	0	1
Primary	0.57	0.50	0	1	0.54	0.50	0	1
University	0.02	0.12	0	1	0.03	0.17	0	1
Secondary	0.18	0.38	0	1	0.22	0.42	0	1
Lands	1.05	1.30	0	13	0.97	1.65	0	70
Livestock	3.18	10.65	0	204	3.02	15.03	0	603
Household size	4.86	2.85	1	33	4.90	3.01	1	29
Head age	44.42	14.99	16	100	45.41	15.32	13	95
Head gender	0.72	0.45	0	1	0.71	0.45	0	1
Female ratio	2.50	1.70	0	14	2.57	1.82	0	16
Rural	0.59	0.49	0	1	0.54	0.50	0	1
N	3352				4709			

Table 2: Difference in characteristics between mobile money users and non-users

Variables	Non-users	Mean	Mobile money users	Mean	MeanDiff
Mobile phone	2797	0.620	5264	0.970	-0.35***
Mobile money serv availability	2736	0.680	5114	0.840	-0.17***
Remittance	2796	0.220	5264	0.250	-0.03***
Credit	2797	0.0600	5264	0.120	-0.07***
Solar	2797	0.170	5264	0.220	-0.05***
Electricity	2797	0.150	5264	0.480	-0.33***
Television	2795	0.110	5264	0.470	-0.37***
House ownership	2797	0.810	5264	0.600	0.21***
Off farm activity	2797	0.220	5264	0.380	-0.15***
Primary	2797	0.540	5264	0.560	-0.0200
University	2797	0	5264	0.0300	-0.03***
Secondary	2797	0.0900	5264	0.260	-0.17***
Lands	2795	1.170	5264	0.910	0.25***
Livestock	2795	3.900	5263	2.660	1.24***
Household size	2797	5.060	5264	4.790	0.27***
Head age	2797	47.80	5264	43.50	4.30***
Head gender	2797	0.690	5264	0.730	-0.04***
Female ratio	2797	2.610	5264	2.510	0.10**
Rural	2797	0.790	5264	0.440	0.35***

Table 3: Difference in characteristics between solar users and non-users

Variables	Non-users	Mean	Solar users	Mean	MeanDiff
Mobile phone	6419	0.840	1642	0.900	-0.06***
Mobile money	6419	0.640	1642	0.710	-0.07***
Mobile money serv. availability	6281	0.800	1569	0.740	0.06***
Remittance	6418	0.250	1642	0.210	0.05***
Credit	6419	0.100	1642	0.0900	0.0100
Electricity	6419	0.450	1642	0	0.45***
Television	6417	0.390	1642	0.170	0.22***
House ownership	6419	0.630	1642	0.820	-0.19***
Off farm activity	6419	0.330	1642	0.300	0.03**
Primary	6419	0.530	1642	0.640	-0.10***
University	6419	0.0300	1642	0.0100	0.02***
Secondary	6419	0.230	1642	0.130	0.10***
Lands	6417	0.880	1642	1.480	-0.60***
Livestock	6416	2.330	1642	6.040	-3.71***
Household size	6419	4.690	1642	5.670	-0.98***
Head age	6419	44.89	1642	45.42	-0.530
Head gender	6419	0.700	1642	0.760	-0.05***
Female ratio	6419	2.450	1642	2.910	-0.46***
Rural	6419	0.510	1642	0.780	-0.27***

Table 4: Impact of mobile money on solar panel adoption

	Logit		Linear Probability with IV		
	(1)	(2)	(3)	(4)	(5)
	Odds ratio	Odds ratio	Coef./se	Coef./se	Coef./se
Mobile money	2.078***	1.850***	0.117***		1.398***
	(0.164)	(0.148)	(0.016)		(0.280)
MM ser. availability				0.102***	
				(0.017)	
Primary	0.990	1.001	0.020	0.047*	-0.043
	(0.082)	(0.082)	(0.022)	(0.024)	(0.042)
University	0.374***	0.445**	-0.072	0.096*	-0.206**
	(0.120)	(0.143)	(0.045)	(0.057)	(0.095)
Secondary	0.636***	0.878	0.035	0.149***	-0.174***
	(0.075)	(0.106)	(0.027)	(0.030)	(0.065)
Lands	1.080***	1.012	0.007	0.007	-0.001
	(0.024)	(0.020)	(0.007)	(0.008)	(0.012)
House ownership	1.840***	1.936***	0.060***	-0.060***	0.127***
	(0.162)	(0.171)	(0.018)	(0.020)	(0.037)
Livestock	1.007***	1.004*	0.000	0.000	0.000
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Household size	1.023	1.025	0.000	-0.004	0.006
	(0.020)	(0.020)	(0.006)	(0.006)	(0.010)
Head age	0.993***	0.996	0.001*	0.001	0.000
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Head gender	1.122	1.162*	-0.007	0.020	-0.022
	(0.088)	(0.090)	(0.022)	(0.022)	(0.038)
Female ratio	1.012	1.016	0.012	0.016*	-0.010
	(0.032)	(0.032)	(0.009)	(0.010)	(0.016)
Rural	3.153***	2.134***	-0.051*	-0.223***	0.249***
	(0.264)	(0.192)	(0.030)	(0.041)	(0.095)
Mobile phone	1.757***	1.969***	0.119***	0.401***	-0.408***
	(0.191)	(0.212)	(0.023)	(0.023)	(0.122)
Constant	0.027***	0.003***	-0.157		
	(0.005)	(0.002)	(0.120)		
lnsig2u	0.470***	0.219***			
	(0.110)	(0.095)			
Region fixed effects	No	Yes	Yes	Yes	Yes
Observation	8058.000	8058.000	8058.000	6889.000	6889.000
Log likelihood	-3671.271	-3481.794	-888.598	-1202.549	-4521.036
LR Chi2	563.609	693.773			
Pseudo R2					
R-Square			0.057	0.128	-1.564
First stage F-statistic			5.777	12.988	2.407
Kleibergen-Paap underidentification test					33.347
Underidentification test χ^2 p-val					0.000
Model	re	re	fe	fe	fe

Note: Robust standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Heterogeneous effects of mobile money on solar panel adoption

	Linear Probability with IV			
	(1)	(2)	(3)	(4)
	Coef./se	Coef./se	Coef./se	Coef./se
Mobile money	3.526***	1.476***	6.750**	5.919***
	(1.070)	(0.295)	(3.099)	(1.617)
Mobile money×Poverty	-3.018***			
	(0.968)			
Poverty	1.959***			
	(0.636)			
Mobile money×Migration		-0.995***		
		(0.233)		
Migration		0.619***		
		(0.163)		
Mobile money×House ownership			-6.252**	
			(2.947)	
House ownership			4.496**	
			(2.102)	
Mobile money×Mobile phone				-5.722***
				(1.590)
Mobile phone				1.061***
				(0.255)
Controls	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes
Observation	6889	6889	6889	6889
R-Square	-5.281	-1.596	-12.674	-3.402
Kleibergen-Paap underidentification test	12.658	32.507	5.032	15.760
Underidentification test χ^2 p-val	0.000	0.000	0.025	0.000
Model	fe	fe	fe	fe

Note: Robust standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Mechanisms at play

	Probit (marginal effect)			
	Remittances	Credit	Television	Off farm activity
	(1)	(2)	(3)	(4)
Mobile money	0.061***	0.042***	0.135***	0.031**
	(0.012)	(0.009)	(0.011)	(0.013)
Mobile phone	-0.067***	0.006	0.235***	0.074***
	(0.014)	(0.012)	(0.025)	(0.018)
Primary	-0.006	0.037***	0.055***	0.120***
	(0.012)	(0.010)	(0.013)	(0.014)
University	-0.091**	0.104***	0.318***	-0.018
	(0.036)	(0.022)	(0.032)	(0.040)
Secondary	-0.026	0.039***	0.166***	0.100***
	(0.017)	(0.013)	(0.015)	(0.019)
Lands	0.001	0.002	-0.001	-0.002
	(0.003)	(0.002)	(0.003)	(0.004)
Livestock	-0.001*	-0.000	-0.000	-0.001
	(0.001)	(0.000)	(0.000)	(0.001)
Household hsize	-0.017***	0.003	0.008***	-0.000
	(0.003)	(0.002)	(0.003)	(0.004)
Head age	0.004***	-0.001**	0.001***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
Head gender	-0.141***	-0.015*	0.049***	-0.135***
	(0.010)	(0.008)	(0.011)	(0.013)
Female ratio	0.009*	0.001	0.004	0.007
	(0.005)	(0.003)	(0.005)	(0.005)
Rural	-0.001	-0.029***	-0.204***	-0.100***
	(0.013)	(0.009)	(0.011)	(0.014)
House ownership	-0.045***	-0.010	-0.022**	0.008
	(0.011)	(0.009)	(0.011)	(0.013)
Region fixed effects	Yes	Yes	Yes	Yes
Observation	8058	8058	8058	8058

Note: Robust standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Impact of financial inclusion on solar panel adoption

	Logit	Linear Probability Model
	(1)	(2)
	Odds ratio	Coef./se
Bank account	0.968	0.033*
	(0.088)	(0.018)
Primary	1.078	0.028
	(0.085)	(0.022)
University	0.489**	-0.073
	(0.173)	(0.045)
Secondary	0.950	0.048*
	(0.116)	(0.027)
Lands	1.036	0.010
	(0.026)	(0.007)
Livestock	1.004	0.000
	(0.003)	(0.001)
Household size	1.038*	0.001
	(0.021)	(0.006)
Head age	1.001	0.002***
	(0.002)	(0.001)
Head gender	1.167**	-0.009
	(0.089)	(0.022)
Female ratio	1.021	0.014
	(0.031)	(0.009)
Rural	2.137***	-0.073**
	(0.204)	(0.028)
Mobile phone	2.689***	0.167***
	(0.273)	(0.022)
Constance	0.003***	-0.142
	(0.002)	(0.119)
lnsig2u	0.200***	
	(0.097)	
Region fixed effects	Yes	Yes
Observation	8058.000	8058.000
Log likelihood	-3538.290	-949.867
LR Chi2	670.958	
R-Square		0.042
Model	re	fe

Note: Robust standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1.