

Article

Towards Auspicious Agricultural Informatization—Implication of Farmers’ Behavioral Intention Apropos of Mobile Phone Use in Agriculture

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Abstract: The success of agricultural development programs in Sub-Saharan Africa (SSA) is subject to the extent and nature of information communication technology (ICT) usage, particularly mobile phones. In comparison to other ICTs, the mobile phone is less demanding in terms of user capabilities, infrastructure requirements, and affordability. Mobile phone technology plays a vital role in facilitating the realization of benefits for farmers through access to useful agricultural information. However, up till now farmers' behavioral intention towards mobile phone use has hardly been evaluated yet it is a critical issue that policymakers and development partners need to comprehend. Is mobile phone use in agriculture dependent upon farmers' behavioral intention? We address this topic using cross-sectional data from Zambia obtained through a two-stage sampling procedure. Our results establish that a strong association consistent with the theory of planned behavior (TPB) exists. This suggests that positive behavioral intention has a substantial likelihood to elicit auspicious agricultural informatization and consequently, household economic development. We further find that mobile phone ownership, family size, wealth, and marital status can significantly influence smallholders' behavioral change towards mobile phone use in agriculture. Therefore, in an effort to promote sustainable agricultural information access in rural settings, our study strongly demonstrates the relevance of farmers' behavioral intent towards mobile phone use, and also enriches the discussion on the implementation of mobile phone use for collecting agricultural information.

Keywords: agricultural informatization; behavioral intent; rural telecommunication; mobile phone use; Zambia

1. Introduction

The use of mobile telephony continues to grow swiftly in Sub-Sahara Africa (SSA) achieving 39% (347 million subscribers) penetration rate in 2014 [1]. It is anticipated that the mobile phone will not only reduce the information asymmetry existing between rural and urban areas but also bridge the information gap between large and smallholder farmers. This is because in response to the low mobile subscription in rural Africa [2,3], the mobile telephone operators are now ubiquitous. The Global System for Mobile Communications Association (GSMA) predicts that by 2020 subscription in SSA is expected to reach 504 million representing 49% penetration rate [4]. In support, James and Versteeg [2] assert that the rapid growth of mobile phones in SSA plays a crucial role in driving employment and economic growth. Evidence to this claim indicates that in 2014, 5.7% (\$100 billion) of GDP in SSA was from mobile ecosystems in various sectors [2,5]. The underlying reason for this achievement is

that in comparison to other information communication technologies (ICTs), the mobile phone is less demanding in terms of user capabilities, infrastructure requirements, and affordability [6,7]. These ICTs include mobile phones, television, radio, personal computers and the internet.

Following its success in many sectors, policymakers and development practitioners are hopeful that mobile phones will aid smallholder farmers to access various information highly needed for their productivity. More than ever, farmers need information to be productive because unlike in the past, adding on new land for agricultural use is overwhelmingly costly and unlikely [8]. Also, urbanization, desertification salinization, soil erosion, and other social uses remain the most magnificent avenues through which productive agricultural land is lost in SSA [9]. When coupled with the occurrence of armed conflicts and weak agricultural support and infrastructure [10,11], the situation demands both policymakers' and researchers' swift consideration on best approaches to information access that will lead to increased agricultural productivity and sustainability.

In this study, we define information as relevant data that is systematically collected, serving as a resource for the users [12]. Therefore, to improve farm production in general, information access is pivotal [13] as it is the most effective among the critical variables influencing the adoption of useful practices in agriculture [14–19]. In fact farm level empirical analysis indicates that mobile phones enable farmers to quickly access information on new markets [5,20–23], financial services [24–26], agricultural techniques [27–30], crop prices [16,23,27], advice from experts [29,31] and input sources [32,33]. In addition, Aker [34] adds that productivity of farmers is enhanced as geographic difficulties preventing remote areas from receiving up-to-date information are easily overcome especially that certain transaction and search costs are reduced on account of mobile phone use.

In Zambia, one of the significant accomplishments with regards to agricultural informatization (the extent by which agricultural societies becomes information-based) is the expansion of mobile services in rural agricultural communities [35]. At present, the level of mobile phone ownership and mobile-enabled information services in rural Zambia could reduce information asymmetry [36]. The subscription of mobile users in the country has been on the rise consistent with the penetration rates in Africa (Figure 1), presenting an opportunity for information transmission and access. Thus, seizing the opportunity and leveraging full benefits associated with it could be subject to farmers' behavioral intent (readiness to carry out a particular behavior). Given that mobile phone use reduces the vulnerability of farmers, increased yields and productivity is eventually achieved consistent with the primary goal of any agricultural system [9,37,38]. However, despite being a critical issue that policymakers need to comprehend, the existing literature on the implication of farmers' behavioral intention towards innovative information access remains scant and limited. Arguably, there is as yet no analysis on how farmers' behavioral intentions affect the adoption of mobile phones to access agricultural information. Lack of satisfactory empirical evidence of this nature hinders policymakers from effectively enhancing smallholder farmers' adoption of mobile phone use in agriculture.

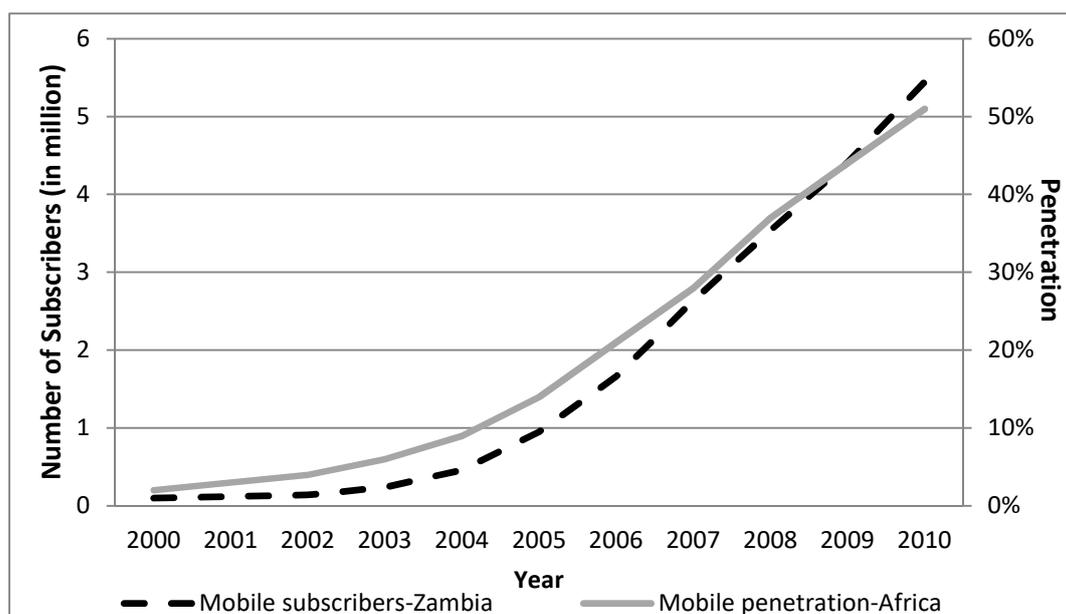


Figure 1. Mobile phone growth trend in Africa and Zambia (10 years). Source: Statista [39].

A limited number of studies exist on smallholders' behavioral intention, a subject that is highly critical and of interest for farmers and policymakers alike. For example, the recent studies of Arunrat et al. [40] and Zamasiya et al. [41] emphasize the relevance of behavioral intention in adaptation programs in agriculture. Regarding studies on behavioral intention towards mobile technology, Hameed and Qayyum [42] note that attitudes play a mediating role between the determinants and behavioral intention towards mobile learning. In addition, Mohamed et al. [43] contend that recognizing the factors that influence mobile technology device acceptance can generate favorable behavioral intention (increase the readiness to adopt such technology). Pudke [44] found that majority of farmers have favorable attitude towards use of mobile phone services in transfer of agricultural technology, however, the researcher noted that trainings on use of mobile phone, price minimization of mobile phone and internet access, and timely information availability that is easier for farmers to comprehend would significantly improve behavioral intention towards mobile phone use. Likewise, in assessing the attitudes of farmers towards mobile phones in Zambia and Kenya, Wyche et al. [36] conclude that a mismatch exists between farmers' perception and the design of the mobile phone applications. Impliedly, the authors suggest that farmers have negative behavioral intention on account of the influx of counterfeit and substandard mobile phones, distrust of the content being delivered via SMS and reservations about the health consequences of interacting with handsets. Nevertheless, the major limitation of the aforementioned studies is that a pattern is evident in that the researchers were confined to rudimentary methodologies, leading to failure of providing a comprehensive answer. For instance, Zamasiya et al. [41] used the ordered Logit without empirically linking behavioral intention with observed behavior (the action taken by farmers). In the case of Arunrat et al. [40], the link was done but omission of criteria to address endogeneity and selection bias compromises the results of the estimation strategy employed.

Therefore, this study aims at evaluating the role of behavioral intention on the adoption of mobile phone by smallholder farmers and whether it augments household income after adoption. First, we investigate the determinants of behavioral intention and also evaluate whether behavioral intention influences adoption of mobile phones. Finally, we establish whether adoption holds any economic benefits for smallholder farmers. Overall, our results suggest that understanding the implication of farmers' behavioral intention apropos of mobile phone use in agriculture can aid in addressing the vulnerability of farmers that tends to increase with changing socio-economic and environmental conditions [45]—high productivity variations, scanty and uncertain rainfall, accumulative gap between

availability and demand of water, and deteriorating underground water and land quality. This is so because the economic rationale for agricultural information access is to empower farmers to improve their risk and uncertainty management, thereby enhancing productivity and promoting agricultural sustainability.

Consequently, the present study contributes to the literature in three aspects. First, we try to link behavioral intent to mobile phone use. This is important because agricultural development programs' success is subject to the extent and nature of mobile phones usage [46]. Second, to the best of the authors' knowledge, to date, there appear to be no study of this sort. Bearing in mind that farmers are the agents who actually undertake adoption of such agricultural innovations, their behavioral intention is a significant determinant of the success or failure of such projects. Thus, results from this study essentially provide policymakers with valuable insights on how to successfully implement the innovation. The uniqueness of the variable (behavioral intent) being assessed in this study is a major contribution in the existing literature. Finally, we estimate marginal effects by employing a multivariate analysis to explore the factors that impact farmers' behavioral intention. Given that mobile phone adoption requires interventions with a multidisciplinary viewpoint, our approach in the analysis is essential in supporting policy formulation seeking to enhance smallholder farmers' adoption of mobile phones in agriculture.

2. Materials and Methods

2.1. Data

The study is based on a cross-sectional data of smallholder farmers collected from Mkushi district in central Zambia from July to November 2018. Maize, beans, groundnuts, millet, cassava, cotton, sorghum, sweet potato, and tobacco are grown in this area and the farmers are considered significant contributors to the nation's food basket. All the three (MTN, Airtel and Zamtel) mobile network operators (MNOs) operating in the country have a presence in the study area. As reported by Mwalupaso et al. [38], farmers in this area are actively involved in exchanging text messages, receiving and making calls to agricultural extension officers, farmer organization and fellow farmers. Precisely, through mobile phones, farmers easily access information relating to agricultural practices, the price of seeds and fertilizer, agricultural extension services, cooperative meetings, mobile money transfers, and weather.

Farmers were selected using a two-stage sampling procedure where the first stage comprised of a selection of three agricultural camps (Fiwila, Lweo, and Nshinso) out of 22 and stage two involved random selection of 201 farm households. To accurately collect data, a structured questionnaire was developed and pretested. The latter aided in removing all the ambiguities before actual data collection. By employing this procedure and engaging experienced enumerators, we ensured that quality data is obtained for the analysis. Information on smallholder farmers' socio-economic and attitudes towards the use of the mobile phone for collecting agricultural information was solicited via this instrument.

We explicitly asked in the questionnaire whether households adopted mobile phones for agricultural information access. This aided in coming up with control (non-adopters) and treatment groups (Adopters). We found 41 adopting and 159 non-adopting households. In order to deal with the endogeneity problem caused by self-selection, we adopted a two-stage residual inclusion (2SRI) and endogenous switching regression (ESR). These methods are discussed in Section 2.4.

Also, key informant interviews and focus group discussions (FGDs) were also employed to collect qualitative data in an effort to provide explanations for the quantitative data. The FGDs aided in ascertaining farmers' access to information through mobile phones. For data reliability, farmers selected for FGD had a minimum of 40 years in age and 10 years of farming experience in the district. Regarding key informant interviews, model farmers and agriculture extension officers were interviewed using interview checklists.

Ethical and research clearance was acquired from Nanjing Agricultural University, College of Economics and Management. Approvals were also obtained from local and regional authorities in central Zambia—the Ministry of Agriculture, Mkushi local government, and Farmers' Union. All the participants were adult household heads and through the assistance of Ministry of Agriculture officers, surveying procedures were elucidated and verbal consent was obtained from each participant. On grounds of limited available resources, only verbal consent was done for every participant and this was documented using a mobile phone recorder. Independent community members (Headmen and Village Chief) also approved the consent and served as witnesses for farmers' voluntarily informed decision to participate in the study. Minors (under 18 years) were not used as respondents in this study. To the best of the researchers' knowledge, the data collection procedures, analysis and depository were made anonymously in a manner that prevents identification of participants by name and number.

2.2. Conceptual Framework

Agricultural informatization in SSA has been prominent over the past decade [47]. The adoption of various ICTs, particularly radio, television and mobile phones, has provided opportunities for farmers to increase crop production as well as improve household income and food security [1,17,34]. Interestingly, among the existing ICTs, mobile phones have been widely accepted as an advent of delivering useful agricultural information in a convenient manner [48]. Particularly in rural areas, access to information through other ICTs is projected to be extremely poor, less credible, ill-timed, and cost-ineffective [49].

Despite its popularity, not all the farmers are able and willing to use mobile phones in the agricultural sector. This is due to the deterrents imposed by various socioeconomic, institutional and environmental factors which are also the factors behind the formation of farmers' behavioral intention towards mobile phone use. Regardless of the skepticism about mobile phone use in agriculture and the misconceptions portrayed, as a platform for communication, the use of mobile phones for collecting agricultural information narrows the gap in the adoption of beneficial agricultural technology resulting in higher crop yields [38]. Such behavior responses are a function of belief and perception [50] as these provide the foundation from which actions and attitudes towards mobile phone use are formed. The theory of planned behavior (TPB) by Ajzen [51] explains the role of attitudes in influencing observed behavior. The theory posits that behavioral intention is a function of attitudes. Accordingly, if the latter is positive towards mobile phone use, it is likely to lead to adoption. Attitude in this sense could reflect less willingness (negative attitude), high willingness (positive attitude) or being unsure (undecided) of whether or not to adopt mobile phones for agricultural information access. Therefore, improving farmers' attitudes, a major determinant of behavioral intention [52–54], could be very critical for facilitating auspicious agricultural informatization (particularly mobile phone use) which ultimately enhances agricultural productivity [38] and household economic development [55]. Evidence from Mwalupaso et al. [38] shows that use of mobile phones for collecting agricultural information is associated with improved technical efficiency, a measure of productivity. The authors argue that the information accessed prevents farmers from making decisions blindly and improves their resource use. However, mobile phones alone cannot perform this function, but they are more suitable to provide customized and timely content which facilitates improved crop productivity and income if the appropriate models are established.

TPB, an extension of the theory of reasoned action (TRA), is one of the widely used socio-psychological approaches [56,57] employed to identify farmers' intention and behavior [58]. To a very large extent, TPB predicts the intention to perform a particular behavior based on attitudes towards the behavior. As depicted in the constructed conceptual framework (Figure 2), we postulate that, given ideal policy measures and support, farmers will develop high preference leading to positive attitudes towards mobile phone use. In turn this will drive mobile phone usage for collecting agricultural information, which according to Parmar et al. [48], equips farmers with knowledge on how to successfully conduct their farming during changing times, i.e., enhancing their adaptive capacity.

In view of the growing population and rising incomes, this is important to realize as it assures increased productivity and agricultural sustainability.

It should be noted that internal (gender, education and family size) and external (cooperative membership, market access and income) factors may also affect farmers' attitudes and behaviors and thus a high degree of attention need to be paid to these elements when evaluating determinants of usage and attitudes. Ultimately, it is inclusion of these elements in the behavioral intention investigation which gives reliable implications for practice and sustainability.

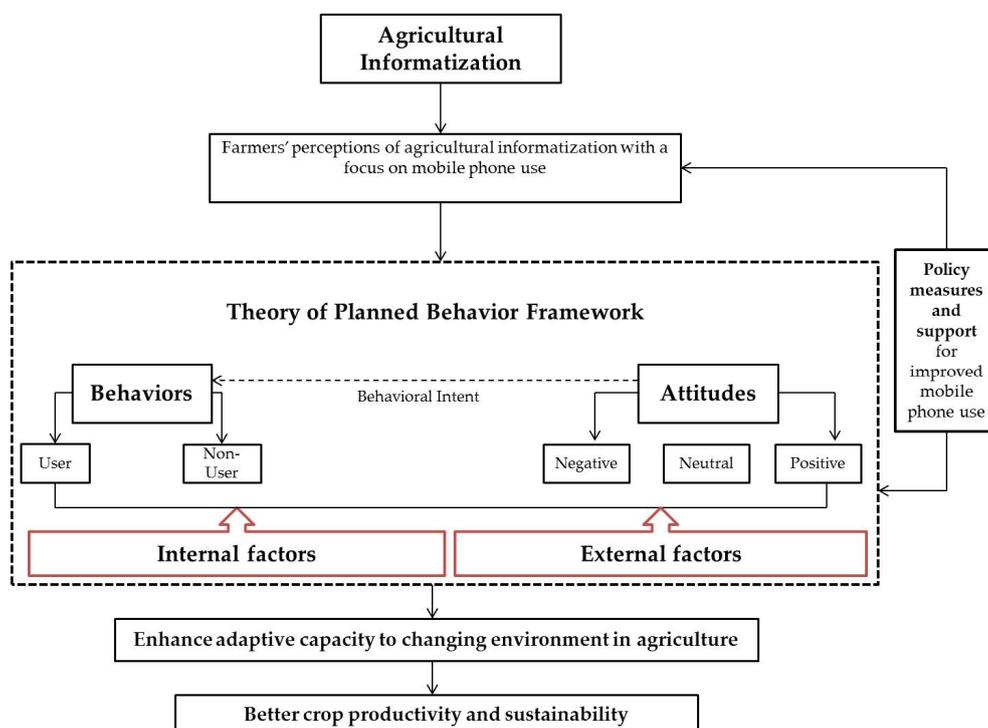


Figure 2. Conceptual framework.

2.3. Variable Selection and Measurement

To elicit information on farmers' behavioral intention towards the use of the device, two key variables were selected—behavioral intent and mobile phone use.

2.3.1. Behavioral Intent

Behavioral intent expressed through three mutually exclusive choices was the response to the question posed to smallholder farmers as to whether they believed they should take steps to collect information through the mobile phone to increase their crop yields. To measure the TPB variable, behavioral intent, a five-point Likert scale using two items was adopted as follows: (i) based on the perceived importance of using mobile phones for the next five years—1 = not important to 5 = very important; and (ii) based on the perceived usefulness of adopting mobile phone use in agriculture—1 = very useless to 5 = very useful.

Three distinct categories were derived after a mean score with a cut-off point of 0.5 was computed, i.e., negative attitude (−0.5 to −2), undecided (0.5 to −0.5) and positive attitude (2 to 0.5) coded as 1, 2 and 3 respectively. In assessing behavioral intention, capturing of respondents' attitude in this manner is a standard practice [51]. Such measurement was also employed by Zamasiya et al. [41] and Arunrat et al. [40] when evaluating farmers behavioral intention towards climate change adaptation.

2.3.2. Mobile Phone Use

Since the study focused on investigating farmers' behavioral intent towards mobile phone use in agriculture, we considered mobile phone use (adopted behavior) as the primary dependent variable. The variable was captured through a dummy where 1 represents a household that owned and used the mobile phone to access information during the survey year and 0 otherwise. Sekabira and Qaim [59] and Mwalupaso et al. [38] also measured mobile phone use using the approach adopted in this study.

2.4. Empirical Strategy and Analytical Framework

To accurately evaluate the role of behavioral intention in mobile phone adoption, a two stage model was applied while endogeneous switching regression (ESR) was used to validate household income differences between adopters and non-adopters.

2.4.1. Role of Behavioral Intention in Mobile Phone Adoption

In an attempt to explicitly account for endogeneity of behavioral intention (self-reported) in the estimation, two-stage residual inclusion estimation (2SRI) proposed by Terza, et al. [60] was applied so that the effect on mobile phone use was causally interpretable [61]. Unlike two-stage predictor substitution (2SPS), 2SRI is generally consistent. In this study, the first stage was the auxiliary regression (ordered probit) while stage two (ordinary probit) was the outcome equation. Use of ordered and ordinary probit in stage one and two respectively was also done by Jafari Bidgoli [62].

In the auxiliary regression, determinants of behavioral intention are modelled. Following Vella [63], we then calculated the generalized residuals (GR) in ordered probit model, which were to be included in the second stage. The first stage model is expressed as follows:

$$Y^* = X_i\beta + u_i, \quad (1)$$

$$Y = j \text{ if } \alpha_{j-1} < Y_i^* \leq \alpha_j, \quad (2)$$

where Y^* is the latent unobservable continuous variable which will be formed into three groups (denoted by j) and two thresholds (denoted by α) which are cut off points between the three categories, X_i is a vector of factors that determine behavioural intent for each i th farmer, β is the parameter to be estimated and u_i are random errors. Y is the dependent variable (attitudes towards mobile phone use in agriculture) with three categories –negative (1), undecided (2) and positive (3).

In the second stage, we use the first stage residuals, endogeneous variable and other explanatory variables as regressors in the ordinary probit model. This facilitates robust and consistent estimation of the influence of behavioral intention on mobile phone adoption. Since the assumption for TPB is that farmers have mobile phones (in our case), usage is only observed for those who own the device. Thus, a naïve estimator would produce biased estimates because usage of mobile phone for information access cannot be appropriately measured for those who do not own mobile phone. Therefore, as implemented in Tadesse and Bahigwa [23], predicting the probability of mobile phone ownership and calculating the inverse mills ratio (IMR) for each observation (included as a predictor) is a useful solution to correct for selection bias. The probit function employed is specified as follows:

$$MPuse_i = BI_i\beta_1 + \sum_j G_{ij}\beta_i + \varepsilon_i, \quad (3)$$

where $MPuse_i$ is a dummy capturing adopters and non-adopters, BI_i represents behavioral intention using three categories, G_{ij} is a vector of other variables likely to influence behavior (adoption of mobile phone use), β_1 and β_i are parameters to be estimated and ε_i are random errors.

As a robust check, the Pearson's chi-square test for association was used to establish whether there is an association between farmers' attitudes and the actual use of mobile phones for collecting agricultural information. For robust estimation, Fisher's exact test verifies the authenticity of the

chi-square results while Cramer's V gives the strength of the association. As an alternative to the chi-square especially for small sample sizes, the Fisher's exact test is a procedure also employed in the assessment of the association between categorical variables [64]. Cramer's V, on the other hand, is a post-test technique (with values ranging 0–1) after Chi-square used for determining the strength of association with the following interpretation; 0–0.19 is considered as “very weak”, 0.2–0.39 as “weak”, 0.40–0.59 as “moderate”, 0.6–0.79 as “strong” and 0.8–1 as “very strong” association [65].

2.4.2. Mobile Phone Adoption and Household Income

We analyzed the impact of mobile phone adoption on household income, derived from the sales of their agricultural produce. However, in most cases treatment and control groups (adopters and non-adopters) are not randomly formed. Thus, the true impact may be overestimated or underestimated on account of selection bias, one of the prominent sources of endogeneity. This is because the observed or unobserved household and farm characteristics could affect the probability of technology adoption (mobile phone use) and the outcome (household income) simultaneously. The solution for this is application of an endogenous switching regression [66].

Switching regression with an inclusion of IMRs in the regime equations is often accomplished using a two-stage procedure and details can be found in Noltze et al. [67]. However, in this study we adopted an efficient procedure proposed by Lokshin and Sajaia [68] which uses the full information maximum likelihood (FIML) method to give estimates for the two stages simultaneously. Particularly, we were interested in the treatment effect of mobile phone adoption i.e., the average treatment effect on the treated (ATT) and average treatment effect on the untreated (ATU), to better understand impact heterogeneity. Unbiased treatment effects (ATT and ATU) must control for unobserved and observed heterogeneity [66,69,70] and thus, are specified as:

$$ATT = E(\text{Income}_{\text{Adoption}} | MP_{\text{use}} = 1) - E(\text{Income}_{\text{Non-adoption}} | MP_{\text{use}} = 1) \quad (4)$$

$$ATT = E(\text{Income}_{\text{Adoption}} | MP_{\text{use}} = 0) - E(\text{Income}_{\text{Non-adoption}} | MP_{\text{use}} = 0), \quad (5)$$

where $\text{Income}_{\text{Adoption}} | MP_{\text{use}} = 1$ and $\text{Income}_{\text{Non-adoption}} | MP_{\text{use}} = 0$ are observed while $\text{Income}_{\text{Adoption}} | MP_{\text{use}} = 0$ and $\text{Income}_{\text{Non-adoption}} | MP_{\text{use}} = 1$ are counterfactual for households with and without adoption respectively.

2.4.3. Model Specification Tests

Some model specification tests were also conducted to ensure proper determination of parameters and relationships in the model as guided by Lomax and Schumacker [71]. Variance inflation factor (VIF) test was performed for multicollinearity diagnostic. The rule of thumb is that when VIF is higher than 10, efficiency of estimation may be affected [72–74]. Based on our estimation (Appendix A: Table A1), the highest VIF was 2.082 implying that multicollinearity was not a problem in our estimations.

We also used Pearson pairwise correlation coefficients to detect the presence of multicollinearity, and this was not significant considering the maximum coefficient was 0.627 (Appendix A: Table A2). According to Damodar [74] only when the pairwise correlation coefficient exceeds 0.80 can multicollinearity be regarded a problem in estimations.

3. Empirical Results and Discussion

3.1. Descriptive Statistics

This section presents a summary of the descriptive statistics. The mobile penetration rate in the area is 53.7% (Table 1) which is lower than the country's rate of 81.9% [39] but good for rural communities. The above average penetration rate is attributable to the fact that most farmers are fairly wealthier as seen from the value of their assets. However, there is still a potential of 28.2% to improve

mobile phone penetration in the area. Farmers have only owned the device for about three years which is sufficient for impact if adopted for use in agriculture but highly unlikely to influence attitudes which have been formed by long held beliefs and perceptions [57].

Also, similar to Quisumbing [75], there are more male household heads than female, and majority of households are members of cooperatives. Based on the discourse by Abate et al. [76], this is good as cooperatives serve as an alternative or complementary source of agricultural information for farmers.

Despite residing in areas that are about 8 kilometers from the market, majority of the farmers are on farmer inputs support program (FISP). By design, FISP demands subscription of farmers to MNOs so that they are informed about the progress of subsidized inputs to be received and other general information regarding the program [77,78]. However, since it is not mandatory, some farmers do not feel compelled to receive such information through the phone but rather make use of cooperative meetings or farmers who are mobile users. The observation by Simukanga, et al. [79] is that FISP beneficiaries who are also mobile phone users have access to wider information that is useful for agricultural activities.

Lastly, we find that a good number of farmers are married with their spouse having relatively the same level of education as the household head. This is essential to assess considering that mobile phone use requires attainment of basic education (can read and write in English and local language) to leverage benefits from its use [23]. Also, the family size is good enough to provide the farming labor required, and most farmers have an outstanding experience in farming. These household characteristics are useful when evaluating the role of farmers' attitudes towards mobile use especially that with more farming experience and family members, a household head may accurately discern their best platforms of information dissemination and access [15,47].

Table 1. Descriptive statistics.

Variable	Description	Mean (SD) N = 201
MP ownership	Whether at least one adult member in the household owns a mobile phone (1 = owns)	0.537 (0.5)
Gender	Gender of household head (1 = male)	0.856 (0.352)
Cooperative	Whether household is a member of a cooperative (1 = member)	0.93 (0.255)
Market	Distance in kilometers from the farm to the market	8.502 (3.704)
Govsubsidy	Whether household is a beneficiary of FISP (1 = beneficiary)	0.905 (0.293)
Family size	The number of people in a household	6.139 (3.318)
Farmexp	Years of farming experience of the household head	21.711 (12.243)
Education	Education of household head (1 = has basic education)	0.697 (0.461)
Marital	Marital status of household head (1 = married)	0.771 (0.421)
Seducation	Education of the household head's spouse (1 = has basic education)	0.522 (0.501)
MP duration	Length of mobile phone ownership (years)	3.83 (3.11)
Assets	Value of household assets in Zambian kwacha (ZMK)	13,807.25 (4079.04)

Notes: Figures in parentheses are standard deviations of the mean.

3.2. Determinants of Farmers' Behavioral Intention Towards Mobile Phone Use in Agriculture

Table 2 presents the results of the factors influencing farmers' behavioral intent. In an attempt to provide complete empirical results, we considered factors affecting attitude in general and also for each specific outcome (negative, undecided and positive). This approach permits policymakers to easily and accurately influence the desired farmers' attitudes, i.e., from negative to positive especially that the determinants are not the same. While mobile phone ownership, family size, wealth, government subsidy beneficiary status and spouse education influence both positive and negative attitudes significantly, membership to cooperatives and marital status only impact on those with negative attitude towards mobile phone use. In general farmers' attitudes are significantly influenced by marital status and five other factors cited above that impact on both negative and positive attitudes.

In the interest of clear policy implications as already indicated, we consider negative and positive attitude as less and high willingness to adopt mobile phone in agriculture respectively. Thus, among

all the determinants, mobile phone ownership is fundamental to the study and highly essential in explaining the attitude displayed. There is a sharp contrast between farmers with positive and negative attitudes. Ownership negatively impacts on farmers with a negative attitude, and this could be due to membership to cooperatives, which in most cases are perceived as reliable sources of agricultural information in rural areas. This also suggests that owning a phone would aid in bringing about positive attitudes towards mobile phone use in agriculture. This is in agreement with the finding of Baumüller [16] who recommends that mobile phone ownership is the first step in triggering innovation in the use of the device because it allows the user to explore and customize use according to their needs.

We also find that increase in family size positively influences positive attitude but negatively does so for negative attitude. One possible reason is that majority of rural households use one mobile phone per household [36] and this suggests that mobile phone ownership could be a household decision. Thus, it is plausible that for large households, mobile phone ownership decision could be made faster because of the desire to communicate as almost always the device facilitates the cheapest and quickest way to communicate [80]. Therefore, larger-resource poor households (typical of rural households) may have the immediate incentive to adopt mobile use in agriculture. However, in areas where village penetration of mobile phone holds as reported in Tadesse and Bahiigwa [23], family size would have little impact on farmers' attitudes because they would make use of other farmers' phone as if it were their own.

Consistent with common sense, attainment of basic education of the household head's spouse promotes positive attitude towards mobile phone use. Since education facilitates acquisition of knowledge and skills [81], it is reasonable to expect that it would also influence technology adoption. Particularly for mobile phones, technical ability (ability to read and write) is critical for effective usage as endorsed by Tadesse and Bahiigwa [23]. Thus, farmers with such abilities which are the aims for education in any setting, will have positive attitude towards use because it grants them a platform to put their education in practice. However, Boschen and Casey [82] caution that this is only true if the application packages are not intimidating for the users. Overall, in agreement with most literature [83–85], we hold the view that education stimulates positive attitude towards use of the device in agriculture.

We also find that being married and being members in a cooperative positively influence negative attitude. According to the TPB, people cannot perform a behavior if they have a negative attitude or other people do not expect them to act in that way or support them in doing so or they don't perceive themselves as being in a position to implement their intentions [86–88]. This suggests that either spouses are not supportive or household heads lack the confidence to use the mobile phone. More investigation is required to corroborate this finding.

As for cooperative, these are information machines for farmers and as Toluwase and Apata [89] observed, as long as farmers are satisfied with the information obtained from cooperatives, they hardly make any effort to access information from other sources. This poses a great threat to the sustainability of agriculture because if insufficient information is released by cooperatives, farmers may not be able to enhance their adaptive capacity to combat the changing environmental and socio-economic conditions. Eventually, this affects crop productivity because proactive information access is a prerequisite for contemporary agriculture [17,90].

Finally, we find that wealthy farmers and beneficiaries of agricultural inputs are likely to have negative attitudes towards mobile phones. Regarding beneficiaries, the reason behind this is the way the subsidy program is setup. Cooperatives are the critical farmer organizations through which selection of beneficiaries is done. While one of the goals of the program is to also ensure farmers subscribe to mobile operators in an attempt to achieving e-agriculture [91,92], most farmers still rely on cooperatives for information regarding subsidies. Thus, the objective is far from reach as long as mobile phone ownership is not explicitly emphasized.

For smallholder farmers with relatively greater assets, it appears like network challenges tend to stir up negative attitudes. Also, with the perception that network is poor in rural areas [93], they

would rather make physical contact with agricultural stakeholders. The fact is mobile phone services in rural areas in the past (though slightly better now) has been a complex challenge at both demand and supply ends—high level of capital requirements for mobile network operators and non-compliment of public services (especially electricity and local relevant content) to mobile phone adoption [94]. However, at present the Zambian government has adopted regulatory policies, though not based on localized empirical evidence, to rollout mobile phones in rural areas. The hope is that through e-agriculture services, the existing low demand will be addressed. Our result suggests that wealthy farmers' attitudes towards mobile phones have not yet been transformed from negative to positive.

Table 2. Factors affecting farmers' behavioral intention towards mobile phone use in agriculture.

Variables	Attitude in General	Specific Attitude Outcomes		
		Positive	Undecided	Negative
MP ownership	2.938 (0.342) ***	0.392(0.118) ***	0.522 (0.176) ***	−0.914(0.123) ***
Gender	−0.366 (0.593)	−0.059 (0.116)	−0.042 (0.039)	0.102 (0.147)
Govsubsidy	−1.582 (0.660) **	−0.440(0.244) *	0.178 (0.213)	0.262 (0.060) ***
Cooperative	−0.938 (0.667)	−0.210(0.213)	0.006 (0.136)	0.204 (0.090) **
Market	0.058 (0.037)	0.007(0.005)	0.010 (0.007)	−0.018 (0.012)
Family size	0.580 (0.087) ***	0.077(0.028) ***	0.103 (0.035) ***	−0.181 (0.030) ***
Farmexp	0.031 (0.019)	0.004(0.003)	0.006 (0.004)	−0.010 (0.006)
Education	0.319 (0.342)	0.039 (0.041)	0.065 (0.079)	−0.104 (0.116)
Seducation	1.405 (0.415) ***	0.205 (0.091) **	0.213 (0.078) ***	−0.418 (0.118) ***
Marital	−1.026 (0.542) *	−0.206 (0.157)	−0.042 (0.083)	0.248 (0.096) ***
Electricity access	0.695 (0.447)	0.078 (0.050)	0.155(0.120)	−0.232 (0.159)
MP duration	−0.077 (0.061)	−0.010 (0.009)	−0.014 (0.012)	0.024 (0.019)
Assets	−1.934 (0.344) ***	−0.258 (0.082) ***	−0.344(0.128) ***	0.601 (0.116) ***
Cut 1	−14.064 (2.831)			
Cut 2	−11.879 (2.722)			
Model Diagnostics				
Mean dependent var		1.819	SD dependent var	0.811
Pseudo r-squared		0.526	Number of obs	184.000
Chi-square		100.412	Prob > chi2	0.000
Akaike crit. (AIC)		159.208	Bayesian crit. (BIC)	201.871

Note: Figures in parentheses are standard errors of the coefficient, while *, **, and *** indicate statistical significance levels at 10%, 5%, and 1%, respectively.

3.3. Association of Mobile Phone Use and Farmers' Behavioral Intention

Understanding what prompts farmers to use mobile phones for information access is very pivotal because mobile phones have the potential to narrow the gap in the adoption of beneficial agricultural technology resulting in higher crop productivity [32]. In view of the theory of planned behavior (TPB), Table 3 presents the results of the association between attitude and adoption. For robust results, we estimated factors that influence mobile phone use in collecting agricultural information for the whole sample (where GR was incorporated) and mobile phone owners only (IMR was included as a predictor). As already stated, this is cardinal because TPB assumes that farmers have mobile phones and thus the model may need correction for selection bias. Therefore, the first model (whole sample) is employed to detect endogeneity, but our focus is on the second model (mobile owners only) which is consistent with the assumption of TPB. Both GR and IMR are insignificant, which implies that our estimation is exempt from endogeneity and selection bias.

Our result reveal that switching from negative to positive attitudes has positive and significant influence on adoption of mobile phones for agricultural information access. This aligns well with the finding of Arunrat et al. [40] who also found that farmers' attitude had a significant effect on adaptation to climate change. Mindful of the revelation from TPB that attitudes are formed from beliefs and perception, the identified association is plausible and consistent with the theory [51].

Other factors significantly influencing the adoption of mobile phone use are distance to the market, membership to a cooperative, education, farming experience and marital status. Attainment of higher levels of education for farmers facilitates adoption of improved technologies [81]. A myriad

of literatures agrees with this assertion which is now viewed as a fact. Our finding is similar to Arunrat et al. [40] and Akudugu, et al. [95].

On the other hand, experienced and married farmers have a lower probability to adopt mobile phone for information access. This is in agreement with the findings of Guliyev et al. [96] and Mwalupaso et al. [97] where experienced farmers in Azerbaijan and Mali are slow to adopt agricultural innovation. In addition, with more farming experience a farmer is likely to have negative attitude towards mobile phone use in agriculture. Considering that mobile phone use in agriculture is seen as new agricultural innovation to information access, on account of familiarity with old technologies, farmers with higher farming experience are reluctant to change their approach. This assertion is in line with the findings of Mwalupaso et al. [97] and Kebede et al. [98]. Therefore, more often than not, farmers with higher experience have negative attitude towards new technology. In our case, the possible reason could be due to low education considering that Aina [99] indicates that most farmers in rural Zambia are illiterate. Therefore, with attainment of more education, the situation is likely to be different. Regarding marriage affecting phone use, the mechanism and possible explanation need further investigation. This is because in our case, spouse education is competitive with that of household head and Kyun Choi et al. [100] and Wei and Lo [101] contend that females use the phones more than males. Thus, it is expected that married farmers would adopt mobile phones more than their counterparts except if culture is a barrier as pointed out by Potnis [102].

Likewise, longer distance from the market are likely to affect adoption negatively because as is a typical case with most rural African communities, there are mobile phone network challenges associated with areas further away from the markets. In some rural area of Zambia, farmers search for trees and hills to climb to access mobile networks on their phones. Thus, it could be irrational for farmers to own mobile phones in such area or, worse still, use them to access information. Also, membership to cooperatives suggests that farmers have an alternative source of information that mobile phones could compliment. However, most farmers may not view mobile phone in that way. Most cooperative members seem to be satisfied with the information accessed from cooperative and this affects their adoption decision. Unless, the benefits associated with membership and mobile phone use are emphasized, evidence presented here shows that membership will significantly and negatively affect adoption.

Table 3. Determinants of mobile phone use for agricultural information collection.

MP Use	Whole Sample	Mobile Owners Only
Attitude		
Undecided	0.172 (0.518)	−0.327 (0.651)
Positive	2.205 (0.539) ***	1.358 (0.609) **
Gender	0.864 (0.588)	0.290 (0.655)
Cooperative	−0.136 (0.497)	−1.169 (0.716) *
Market	−0.087 (0.055)	−0.133 (0.059) **
Family size	0.193 (0.136)	0.144 (0.179)
Farmexp	−0.076 (0.026) ***	−0.067 (0.031) **
Education	0.373 (0.113) ***	0.475 (0.115) ***
Marital	−1.660 (0.550) ***	−1.663 (0.495) ***
Assets	0.695 (0.406) *	0.386 (0.663)
GR/IMR	−0.206 (0.280)	0.847 (1.012)
Constant	−8.387 (3.755) **	−4.110 (5.851)
Model Diagnostics		
Pseudo r-squared	0.705	0.759
Chi-square	57.500 ***	46.698 ***
Log pseudolikelihood	−20.472	−17.010
Correctly classified	94.49%	93.46%

Note: IMR is calculated after estimation of the probability to own a mobile phone presented in Table A3.

Interestingly, we find that assets (a proxy for wealth) influences adoption positively and significantly for the whole sample but insignificant for mobile phone owners. Bearing in mind

that whole sample is comprised of owner and non-owners of mobile phone, the finding is plausible. Since wealth is a significant determinant of mobile ownership (Appendix A: Table A3), adoption may consequently be influenced by wealth especially where most farmers do not own the device. The result also suggests that mobile phone ownership is the most costly among the elements necessary for adoption of mobile phones to access agricultural information.

As a robust check, Chi-square test results are presented in Table 4. The cross-tabulation reveals that out of 100% of farmers with ‘negative attitude’, about 93% end up as non-users while 7% make use of mobile phones. Similarly, out of 100% of farmers with ‘positive attitude’, 67% end up as users and about 33% are not users. We observe one common trend in the two scenarios presented, i.e., a negative attitude is associated with non-usage of mobile phones and a positive attitude with usage. Vividly, a conclusion that an association exists would not be dismissed.

Consistent with the observation, both the Chi-square test and Fisher’s exact test confirm that a significant (at 1% significance level) association between attitudes and behavior (actual use). Informed by the empirical strategy in Section 2.4.1, Cramer’s V value of 0.64 validates that the association is strong. The results are consistent to those in Table 3, implying that no bias is introduced on account of omitting other explanatory variables. Therefore, we conclude that the use of the mobile phone is dependent upon farmers’ behavioral intention and this is in agreement with the TPH.

Table 4. Cross-tabulation of attitude and mobile phone use.

Attitude	Mobile Phone Use		Total (201)
	Non-User (159)	User (42)	
Negative	86 (93.48%)	6 (6.52%)	92 (100%)
Undecided	57 (95%)	3 (5%)	60 (100%)
Positive	16 (32.65%)	33 (67.35%)	49 (100%)
Key Statistics			
Pearson $\chi^2(2) = 84.6356$ ***			
Fisher’s exact ***			
Cramer’s V = 0.6489			

Note: Figures in parenthesis (percentages) are in relation to the row total of the number of farmers in each category, while *** indicate statistical significance levels at 1%.

3.4. Household Income Effects

Results of the average treatment effects are presented in Table 5. The ATT result indicates that adopters economically benefit from mobile phone adoption. In fact, farmers would have significantly lower income had they not adopted mobile phone (associated with positive behavioral intention). Hence, their decision of adoption seems to be rational. While the ATT result is specific to adopters in Mkushi and should not be generalized, it is not surprising that the total household income gains would amount to about 62% because it captures income from all the sources in their participation in agriculture. High income gains on account of mobile phone adoption were also reported by Kikulwe et al. [25], Sekabira and Qaim [26], and Mwalupaso et al. [38].

Likewise, non-adopting farmers would also economically benefit by about 14% if they switched to mobile phones for accessing agricultural information. Intuitively, we can acknowledge that the opportunity cost for having negative behavioral intention towards mobile phone is 1034.45 ZMK. This is because behavioral intentions are strongly associated with mobile phone use, which has household income effects. The positive and significant impact of mobile phones on household could be attributable to its ability to reduce transaction costs, increase access to resources and aid in making social networks stronger [20,23,24,47]. For instance, the device is used as a substitute for travelling as farmers frequently call someone at the market, thereby having more accurate and timely knowledge about market rates. Thus, farmers are able to sell their products more quickly, better and receive higher prices. Also, mobile phones are used to attract new and better knowledge which is a resource for moderately increasing labor and land productivity [19,103]. Lastly, mobile phones do not only

enhance farmers' social networks with friends and family but also with different agricultural players. Eventually this can result in additional economic and social benefits. Thus, the evidence of the impact of mobile phones suggests that farmers do not only use the device to communicate with family and friends but indeed also use it for collecting agricultural information.

Table 5. Average treatment effects of mobile phone adoption on household income.

Adoption Status	N	With Mobile Phone Adoption	Without Mobile Phone Adoption	Treatment Effect	% Change
Adopters	41	8999.78	5541.98	ATT: 3457.80 (538.669) ***	62.39
Non-adopters	156	8639.82	7605.37	ATU: 1034.45 (274.51) ***	13.60

Notes: The incomes (which are in ZMK) shown are predictions based on the coefficients estimated with the endogenous switching regression model. *** implies significance level at 1%.

3.5. Implication for Practice and Sustainability

Our results provide policy formulation and implementation insight in attaining favorable agricultural informatization. Also, implication for practice and sustainability can be deduced for communities in similar settings especially that the study area from Zambia provides a useful case and is comparable to most rural setups in developing countries.

The findings suggest that promotion of mobile phone ownership through mobile phone subsidy, good network coverage, lower prices of mobile phones, establishing information Centers with applications in local languages and abundant electricity access points will aid to transform negative into positive attitudes. Expressed differently, the realization of sustainable rural development is fundamental. Likewise, policy measures aimed at encouraging cooperatives to support varied forms of collecting agricultural information and sensitize on the role played by mobile phones in innovative agricultural information collection will significantly improve the flow of information in rural communities and narrow information asymmetry between urban and rural farmers. Considering the drastic and uncertain climate change bound to happen [50,104–106], timely and convenient access of highly customized information is indispensable [32,38]. Thus, efforts to realize desirable behavioral intention towards use of mobile phone use in agriculture may not be 'the one action fit it all' solution but is indeed well-timed, necessary, and comparably cost-effective [2,5,29]. Certainly, positive behavioral intention towards mobile phone use could foster sustainable development through influencing adoption which is useful in creating information rich farming societies and improving farmers' livelihoods. In fact, if appropriately deployed, mobile phones are likely to become powerful tools of economic empowerment.

Consequently, the aftermath is economic and social sustainability on account of the achievement of most if not all the effects of mobile phone use in agriculture—improved functioning of markets via reducing other types of transaction costs [5,24,55], farmers' marketing decision [23], input and output prices [107], agricultural production patterns [108,109], household income [25,26], gender equality and nutrition [59], market participation [31], agricultural productivity [38] and diversification to high-value crops [1]. These outcomes ultimately lead to agricultural sustainability.

4. Conclusions

Sub-Saharan Africa has the most significant and fastest-growing number of mobile users globally. Consistent with this fact, Zambia has made a significant investment in the telecommunications sector which has ensured rapid growth in subscribers yearly. However, despite the vital role played by mobile phone technology in facilitating the realization of benefits for farmers through access to useful agricultural information, the progress in rural agricultural communities has been slow. Given that behavior (mobile phone adoption) is a function of behavioral intention towards use, understanding and investigating this mechanism is essential. Up until now the topic has hardly been studied and so whether behavioral intention affects adoption of mobile phone for agricultural information access is still unclear.

The essence of this study, therefore, is to provide evidence of the link between farmers' behavioral intention towards mobile phone use in agriculture with its adoption and further establish whether adoption holds any economic benefits for the smallholder farmers. Our results indicate that a strong association exists consistent with TPH and the determinants of farmers' behavioral intention are mobile phone ownership, family size, farming experience, marital status and education of the household head's spouse. Results of the present study must not be over-interpreted in a causal sense because subjective norms (SN) and perceived behavioral control (PBC) have not been incorporated in the evaluation of behavioral intention. The former implies social pressure to adhere to a certain conduct, while the latter denotes a measure as to what extent the individual perceives they have control over engaging in the behavior. However, in view of the lack of empirical evidence on the subject, analysis of the association can add value to the existing literature for improved policy support and possibly stimulate follow-up research.

Bearing in mind that information is a critical input in agriculture enabling farmers to evaluate prospects that could improve their agricultural productivity promptly, we strongly recommend policy aimed at making it easier for farmers to own mobile phones. In addition, successful policies with a goal of enhancing farmers' perceptions and adaptive capacity (i.e., boosting of farmers' knowledge on how to apply mobile phones in agriculture through community awareness and campaigns; engaging multiple players from related sectors- researchers, local leaders and farmers to sponsor practical mobile-based application and intensify the quality of adoption strategies formulated; improve rural communication infrastructure) are likely to encourage both the actual and intended adoption of the mobile phone in agriculture.

Finally, this study was not without limitations. Study coverage area and data type were the key limitations—cross-sectional data from three agricultural camps. Use of panel data and extending the research area would provide more general conclusions. This presents an excellent opportunity for future research to corroborate our findings. In spite of these limitations, we cautiously conclude that farmers' behavioral intention towards mobile phone use for information access can accelerate adoption which augments farmer's income.

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Appendix A

Table A1. Variance inflation factor on determinants of mobile phone use.

Variable	VIF	1/VIF
Farmexp	2.082	0.48
Marital	2.006	0.499
Family size	1.897	0.527
Gender	1.693	0.591
Assets	1.479	0.676
Education	1.218	0.821
Behavioral intent	1.208	0.828
Market	1.141	0.876
Cooperative	1.114	0.898
Mean VIF	1.538	

Table A2. Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Behavioral intent	1.000								
(2) Gender	−0.080	1.000							
(3) Cooperative	−0.248	−0.059	1.000						
(4) Market	−0.076	−0.061	0.082	1.000					
(5) Family size	0.144	0.066	0.042	−0.174	1.000				
(6) Farmexp	−0.040	−0.100	0.142	0.038	0.574	1.000			
(7) Education	0.185	0.072	−0.155	−0.256	−0.031	−0.248	1.000		
(8) Marital	−0.136	0.627	0.038	−0.160	0.165	−0.155	0.193	1.000	
(9) Assets	0.120	−0.062	0.039	0.071	0.402	0.526	−0.091	−0.150	1.000

Table A3. Determinants of mobile phone ownership.

Explanatory Variable	Coef. (Std.Err)
Age	−0.052 (0.023) **
Gender	0.321 (0.384)
Cooperative	−0.084 (0.422)
Market	−0.009 (0.029)
Family size	−0.130 (0.049) ***
Farmexp	0.025 (0.024)
Education	0.015 (0.032)
Marital	0.033 (0.115)
Assets	1.003 (0.198) ***
Constant	−6.207 (1.718) ***

Notes: Figures in parentheses are standard errors of the coefficient, while ** and *** indicate statistical significance levels at 5%, and 1%, respectively.

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