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Mobile Money, Agricultural Intensification, and Household Welfare: Panel Evidence from Rural Uganda

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Abstract

We examine the impact of the rapidly expanding mobile banking service "mobile money" on rural households' decision to adopt modern agricultural inputs and its resultant effect on agricultural income using plot, household, and community-level panel data from rural Uganda. The main findings indicate that mobile money adoption increases per capita farm income by 13%. Pathway analyses show that mobile money adoption increases the likelihood of using chemical fertilizer on maize plots by 11 percentage points. Mobile money adoption increases the likelihood of high-yielding maize seeds adoption on maize plots by 8.2 percentage points. In the Ugandan context of rapid decline in soil fertility and very low adoption of fertilizer and modern seeds, mobile money provides an avenue to finance agricultural intensification.

1. Introduction

Over 80% of the extremely poor live in rural areas and are predominantly smallholder farmers. Agricultural development can play an important role in alleviating extreme poverty as growth in the agricultural sector is most beneficial to the extreme poor compared to growth in other sectors (Christiaensen, Demery, and Kuhl, 2011; Ravallion and Chen, 2007). However, when new technologies appear profitable to crop scientists and economists, small-scale farmers may not adopt them (Duflo, Kremer, and Robinson, 2008; Munshi, 2008). One major constraint for small-scale farmers to adopt agricultural technologies is limited access to credit (Gine and Klonner, 2006; Zerfu and Larson, 2010). Cash resources are generally insufficient to cover high-yielding variety (HYV) seeds and fertilizer purchased by small-scale farmers during the planting season (Awotide, Karimov, and Diagne, 2016).

This article examines the impact of the rapidly expanding mobile phone banking service dubbed "Mobile money" on the adoption of modern agricultural inputs such as chemical (inorganic) fertilizers and HYV seeds by smallholder farmers in rural Uganda. The article explores the impact of mobile money adoption on the welfare of smallholder households in rural Uganda by comparing households that have adopted mobile money to households that have not adopted mobile money. Mobile money is a financial service provided by mobile network operators. It enables its users to make peer-to-peer money transfers and pay bills using the mobile phone. The mobile network operators use retail points known as mobile money agents. These agents provide a range of mobile money services such as subscription, cash-in, and cash-out (cash transfer)

services. In 2015, there were over 16,000 mobile money agents operating across Uganda (Uganda Communication Council, 2017). In this study, mobile money adopter households are households in which at least one adult member has subscribed to the mobile money service.

This study is motivated by two important remarks. Firstly, Uganda's agriculture faces many challenges notably a sharp decline in soil fertility and limited access to irrigation and mechanization. Yet, the majority of Ugandan farmers do not use any chemical fertilizers or high-yielding seeds. Among other reasons, very limited access to credit to purchase input has been frequently mentioned (Sheahan and Barret, 2017). In this context of very low adoption of modern inputs due to limited access to credit, we examine the impact of mobile money as an alternative mode of financing the purchase of modern inputs and the ultimate impact on welfare.

Secondly, there is a small but growing literature on the impact of mobile money adoption on firm performance, notably in small businesses in Sub-Saharan Africa (SSA). In their study covering 16 SSA countries, Islam and Muzi (2021) find evidence that mobile money adoption increases access to credit and increases investments in female-headed small businesses. Other studies (Gosavi, 2018; Ahmad, Green, and Jiang, 2020) on firms have also documented increased access to credits and improvements in productivity induced by mobile money adoption. However, it remains unclear whether mobile money adoption can induce similar positive effects on investment in smallholder households. The extent to which mobile money can induce smallholder households to adopt chemical fertilizers and improved seeds in a context of very limited adoption remains an interesting empirical question.

Though it is well established that the financial inclusion of small scale farmers in developing countries induces significant productivity gains through greater input use and adoption of modern agricultural technologies (Deb and Suri, 2013; Narayanan, 2016), the banking sector in developing countries still lends a very small share of their loan portfolios to smallholder farmers. The introduction of mobile money and its rapid dissemination among rural households is expected to bridge the gap in financial inclusion and enhance access to financial resources needed for agricultural investment.

Though mobile money has the potential to significantly transform small-scale agriculture in Africa, empirical studies linking mobile money to small-scale agriculture are still nascent. Kenyan studies (Kirui, Okello, and Njiraini, 2013; Kikulwe, Fischer, and Qaim, 2014) reveal that mobile money adoption among smallholder farmers in Kenya leads to greater input use and commercialization of produce thereby increasing market access and household income.

Unlike Kirui, Okello, and Njiraini (2013) which uses cross-sectional data from 375 households in Kenya, our study makes use of a large panel data set of 781 households covering the period mobile money was introduced and adopted by a few households and a period of rapid expansion of mobile money adoption. Our data provides us with good variation in mobile money adoption which enables us to identify the impact of mobile money on welfare outcomes and agricultural input adoption. Also, our study adds value to a growing literature on how mobile money affects small businesses.

Recent studies have shown that mobile money adoption increases productivity and investment in small businesses (Gosavi, 2018; Ahmad, Green, and Jiang, 2020; Islam and Muzi, 2021). Our study extends this growing literature by examining the impact of mobile money adoption on short-term agricultural investments, i.e. fertilizer and improved seeds adoption.

The main findings indicate that mobile money adoption increases per capita farm income by 13%. Mobile money adoption is associated with an 11 percentage point increase in the likelihood of adopting chemical fertilizer on maize plots. It also increases the likelihood of HYV maize seeds adoption in maize plots by 8.2 percentage points. In the Ugandan context of very limited adoption

of modern agricultural inputs, mobile money provides a viable avenue to promote agricultural intensification.

The rest of the paper is organized as follows. Section 2 discusses the data and descriptive evidence, followed by empirical strategy in Section 3. Estimation results are discussed in Section 4 and Section 5 concludes the study.

2. Data and Descriptive Statistics

2.1. Data

This study uses household and community-level data collected in 2003, 2005, 2009, 2012, and 2015 by Makerere University, Foundation for Advanced Studies on International Development (FASID), and the National Graduate Institute for Policy Studies (GRIPS). The data collection was done under the Research on Poverty, Environment, and Agricultural Technology (RePEAT) project. The baseline survey conducted in 2003 covered 64 districts from which 94 local communities (LC1) were selected. From each local community, a random sample of 10 households was drawn.[1] In this study, we use balanced panel data of 781 households obtained from the 2012 and 2015 rounds of the RePEAT project.

The household-level component of the RePEAT survey captures information on demography, agriculture, income, health, education, financial services, land tenure, and migration among others. The community survey covers information on community characteristics such as; distance to market and district towns, conditions of roads, and availability of public services such as schools, hospitals, and telephone networks.

2.2. Descriptive Statistics

Table 1 stratifies households on mobile money adoption status. Adopter households are households with at least one household member having a mobile money account. In 2012, nonadopter households seem better off compared to adopter households. However, in 2015, adopter households seem better off compared to nonadopter households. In both survey years, nonadopters report higher farm income and lower remittances compared to adopter households. Also, adopter households have more assets compared to nonadopter households.[2]

In terms of agricultural input use, Table 1 reveals interesting differences between the two categories. Mobile money adopters are more likely to have adopted fertilizer in 2012. In 2015, nonadopters are more likely to have adopted fertilizer. In both survey years, mobile money adopters are more likely to have adopted HYV seeds.

All in all, Table 1 suggests that the households in our data are typical smallholder African households characterized by large family sizes, small land holding, and limited adoption of modern farming technologies such as chemical fertilizers. The fact that these households receive remittances suggests that rural–urban migration might be common in our sample.

3. Empirical Strategy

In this section, we are going to estimate (1) the determinants of mobile money adoption in rural Uganda; (2) the impact of mobile money adoption on per capita farm and nonfarm income, disaggregated components of farm income, notably crop income, livestock income, and farm wage

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[1]LC1 is the smallest administrative unit in Uganda.
[2]All monetary values have been deflated using CPI. USD values are PPP adjusted.

Table 1. Summary statistics (mean) by year and mobile money adoption status

Variables	2012			2015		
	Adopters	Nonadopters	All	Adopters	Nonadopters	All
Per capita income (1000 UGX)	1,053.91	1,116.01**	1,124.88	1,010.86	707.19*	926.04
Per capita non-farm income (1000 UGX)	345.32	188.11	233.19	268.9	203.68	238.46
Per capita farm income (1000 UGX)	468.41	860.79*	775.61	743.95	814.09*	772.33
Total remittance received (1000 UGX)	228.03	114.97**	140.81	191.84	165.7*	173.53
Landholding in hectares	3.99	2.34	2.87	2.81	2.52	2.69
Value of total assets (1000 UGX)	1,897.33	773.82	1,113.30	1,854.03	643.77**	1,452.37
Years of schooling of household head	7.17	4.88	5.58	6.03	4.32	5.46
Age in years of household Head	52.65	53.44	52.96	54.69	57.77	55.33
Household Size	12.35	10.64	11.27	14.47	12.23	13.78
1 if adopted chemical fertilizer	0.25	0.12*	0.16	0.14	0.22	0.16
Chemical fertilizer application (kg/hec)	2.76	2.11	2.2	2.73	2.93	2.73
1 if adopted HYV seed	0.46	0.32*	0.36	0.34	0.24**	0.3
Number of households	217	564	781	577	204	781

Note: Computed by author from RePEAT 2012 and 2015. 1$ = 2557UGX & 1$ = 2857UGX in 2012 and 2015, respectively (Bank of Uganda). *, **, and *** indicate statistical significance of the difference of means (*T*- test) at 10%, 5%, and 1% levels, respectively. UGX stands for Ugandan Shillings. HYV stands for high-yielding variety.

income; and (3) in examining pathways, we estimate the impact of mobile money adoption on the decision to adopt chemical fertilizers and modern seeds.[3]

Table 1 suggest that the adoption of mobile money is not random. Households that have adopted mobile money are potentially different from households that have not adopted mobile money. For example, households might adopt mobile money because they expect to receive remittances. In this case, remittances might induce mobile money adoption, thus leading to reverse causality. We resort to instrumental variable estimation to address the endogeneity of mobile money adoption.

We use the log of distance to the nearest mobile money agent as an instrument for mobile money adoption. The rationale for such an instrument is that the decision to adopt mobile money heavily depends on proximity to mobile money agents. We expect that households that are closer to a mobile money agent are more likely to adopt the service compared to distant households. We argue that agent placement does not have any direct impact on households' decisions to adopt modern input such as HYV seeds and fertilizer.

Firstly, the requirements to be a licensed agent are neither cumbersome nor rigorously implemented by the different mobile phone network operators.[4] This laxity is driven by the quest for market share. Consequently, the number of agents has increased astronomically in virtually all communities without any indication of selective placement. Given that the licensing of agents is exclusively the preserve of mobile phone companies, political influence, lobbying as well as strategic planning for placement in specific locations which may be correlated with other agricultural

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[3]The primary mechanism through which mobile money adoption affects welfare and investment is through remittances. It has been well established that mobile money provides a cost effective and quick platform for sending remittances (see for example Tabetando and Matsumoto, 2020; Munyegera and Matsumoto, 2016; Jack and Suri, 2014). We explore a secondary mechanism which is relevant for agriculture-modern inputs adoption.

[4]Requirements to be a licensed mobile money agent includes: completed agent agreement, deposit of atleast 384 USD per outlet in a specified bank account, certificate of registration, and memorandum of association.

policies are unlikely. Following Tabetando and Matsumoto (2020), we argue that most mobile money agents are traditional small shop owners who have expanded their business by providing mobile money services, consequently, a good number of the agents had already chosen their locations before the inception of mobile money.[5] As a caveat, it is possible that the adoption of mobile money services by shop owners is not random. Not all shop owners are mobile money agents. Shop owners who decided to serve as mobile money agents by providing mobile money services might be different from shop owners who do not serve as mobile money agents.

3.1. Determinants of Mobile Money Adoption

Given the potential endogenous nature of mobile money adoption, we adopt an instrumental variable approach. In the first stage estimation, we use the distance to the nearest mobile money agent as an exogenous determinant of mobile money adoption. The predicted probability of adopting mobile money obtained from the first stage estimation is used in estimating the impact of mobile money on welfare and modern input adoption. The decision to adopt mobile money services depends on observed characteristics of the household and community in the form:

$$\text{MM}_{ijdt} = 1\{\beta X_{ijdt} + \tau D_{ijdt} + \delta C_{jdt} + \gamma_{dt} + \varepsilon_{ijdt} > 0\}, \tag{1}$$

where MM_{ijdt} is a binary indicator of mobile money adoption which takes 1 if household i in community j of district d has adopted mobile money at time t and 0 otherwise; X_{ijdt} is a vector of controls of household i in community j of district d at time t. It includes household size, household head's age, gender, education, log of household assets holding and landholding. D_{ijdt} is the log of distance to the nearest mobile money agent of household i in community j of district d at time t. It is our main variable of interest providing an exogenous variation in mobile money adoption; C_{jdt} is a vector of community-level controls of community j in district d at time t. It includes population density, distance in km from the community to the nearest district town, and market. γ_{dt} is expected to capture the influence of district-time-specific factors including unobservable factors.

Equation (1) is estimated using a nonlinear estimator (Probit). We follow the literature in also estimating equation (1) using a linear probability model to rule out the effect of unobserved time-invariant household and village characteristics.[6]

3.2. Mobile Money, Farm, and Nonfarm Income

The impact of mobile money adoption on components of household income is estimated in the second stage of the instrumental variable estimation. The predicted probabilities of adopting mobile money from the first stage estimation are used in the second stage estimation.

The impact of mobile money adoption on different components of household income is specified as follows:

$$Y_{ijdt} = \alpha + \lambda_i + \delta_{\text{PM}}\text{PM}_{ijdt} + \delta_X X_{ijdt} + \delta_C C_{jdt} + \gamma_{dt} + \omega_{ijdt}, \tag{2}$$

where Y_{ijdt} is per capita income, per capita farm, per capita nonfarm income, or per capita remittance of household i in community j of district d at time t; λ_i is household fixed effects; α is the intercept. PM_{ijdt} is the predicted probability of mobile money adoption of household i in community j of district d at time t; The vector X_{ijdt} holds household-level characteristics of household i in

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[5]For a more elaborate discussion on distance to mobile money agent as an instrumental variable for mobile money adoption, see (Jack and Suri, 2014; Munyegera and Matsumoto, 2016; Riley, 2018)

[6]The linear estimation of equation (1) is the first stage estimation in the Instrumental variable approach which will be discussed in the next section. The exclusion variable(instrument) is the log of distance to the nearest mobile money agent. Its validity will be discussed in the next sections.

community j of district d at time t; C_{jdt} is a vector of community-level controls of community j in district d at time t. Community-level controls entail; log of distance measured in km from the community to the nearest market and district town and community population density. Community-level covariates strengthen the conditional independence of mobile money adoption from the random error term (ω_{ijdt}). γ_{dt} is expected to capture the influence of district-time-specific factors including unobserved factors. δ_{PM} is the parameter of our interest capturing the impact of mobile money adoption on components of household income conditional on other covariates.

3.3. Mechanism

3.3.1. Mobile Money and Input Use

In examining the mechanisms through which mobile money adoption induces welfare, we estimate the impact of mobile money adoption on a household's decision to adopt modern agricultural inputs such as chemical fertilizers and HYV seeds. As explained earlier, we instrument for mobile money adoption using the distance to mobile money agent. In the second stage estimation, we relate mobile money adoption (predicted from the first stage) at the household level to input use at the plot level as follows:

$$I_{psijdt} = \alpha + \lambda_i + \psi_{PM}PM_{ijdt} + \psi_X X_{ijdt} + \psi_P P_p + \psi_C C_{jdt} + \mu_{psijdt} \qquad (3)$$

where I is an indicator of fertilizer or HYV seeds adoption on plot p in season s of household i in community j of district d. PM_{ijdt} is the predicted probability of mobile money adoption of household i in community j of district d. X_{ijdt} is a vector of household levels controls of household i in community j of district d. The vector P holds plot-specific attributes such as a binary indicator of inter-cropped plots, time in minutes from homestead to plot p, and an indicator of maize plots. C_{jdt} is a vector of community-level controls of community j in district d. Community-level controls entail log of distance measured in km from the community to the nearest market and district town and community population density. psi_{PM} is our parameter of interest and is expected to enter the regression positively. λ_i is household fixed effects. μ_{pijdt} is a random error term with standard properties, and α is the intercept.

4. Results

4.1. Determinants of Mobile Money Adoption

The estimation results of equation (1) are presented in Table 2 alongside some instrumental variable diagnostic tests. The Cragg–Donald F *statistics* from the first stage estimation is 56.33, suggesting that the instrument has a strong impact on a household's decision to adopt mobile money. We test and report the LM underidentification test statistics. We reject the null hypothesis of underidentification. We also test for endogeneity and report the Durbin–Wu–Hausman test statistics (reported in Tables 3 and 4). Given that the test statistics range from 8.8 to 1.79 depending on the outcome variable of interest, we reject the null hypothesis that mobile money adoption is exogenous. This justifies the use of the instrumental variable approach.

The estimation results of equation (1) are qualitatively similar across columns. The key determinants of mobile money adoption are mobile phone ownership, distance to mobile money agent, and household characteristics such as household size, head's years of schooling, and head's age. Using previous waves of this same data set, Munyegera and Matsumoto (2016) report that mobile phone ownership increases the likelihood of adopting mobile money by 11 percentage points. Column 2 in Table 2 suggests that mobile phone ownership increases the likelihood of mobile money adoption by 13.8 percentage points. In Tanzania, Riley (2018) reports that mobile phone ownership increases the likelihood of adopting mobile money by 17.5 percentage points. Distance in km to the nearest mobile money agent is another significant determinant of mobile money adoption. A 1-km increase in the distance to a mobile money agent reduces the probability of

Table 2. Determinants of mobile money adoption (first-stage instrumental variable estimation)

Variables	Probit (Average Marginal Effects)	Household Fixed Effects
	Dep Variable: 1 If Adopted Mobile Money	
1 if own mobile phone	0.093***	0.138***
	(0.002)	(0.003)
Log of distance to mobile money agent	−0.023***	−0.018***
	(0.002)	(0.004)
1 if the head is female	−0.003	0.002
	(0.027)	(0.070)
Head's years of schooling	0.017***	0.017**
	(0.001)	(0.007)
Head's age in years	−0.002***	−0.003
	(0.00)	(0.004)
Log of household size	0.0105***	0.208**
	(0.003)	(0.095)
Log of distance to the district town	0.0277*	0.0392
	(0.014)	(0.056)
Log of distance to the market	−0.002	0.01
	(0.012)	(0.018)
Log of population density	−0.029**	−0.028
	(0.013)	(0.02)
Log value of asset holding	0.072***	0.065***
	(0.009)	(0.016)
Log of landholding	−0.022	−0.067**
	(0.015)	(0.033)
Constant		−0.771
		(0.415)
Observations	1,562	1,562
R-squared		0.411
Cragg-Donald *F-statistics*		56.33
LM Under identification Test statistics		7.29
LM Under identification χ^2 p-value		0.00
District by time	Yes	Yes
Number of households	781	781
Household FE		Yes

Community clustered standard errors in parenthesis.
Sample consists of panel households interviewed in 2012 and 2015.
Additional controls include: Number of men, women, and children and an indicator of improved cattle ownership.
*, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

Table 3. Mobile money, farm, and nonfarm income (main estimation)

	Fixed Effect-Instrumental Variable Estimation			
	Income	Farm Income	Nonfarm Income	Remittance
1 if adopted mobile money	0.361	0.133***	−0.330	0.210***
	(0.292)	(0.033)	(0.369)	(0.021)
1 if own mobile phone	0.162	−0.047	0.214	0.115**
	(0.119)	(0.121)	(0.153)	(0.046)
1 if Head is female	−0.099	−0.014	−0.08	0.221
	(0.168)	(0.161)	(0.154)	(0.271)
Head's years of schooling	−0.005	−0.0248	−0.032*	−0.016
	(0.014)	(0.015)	(0.017)	(0.026)
Head's age in years	0.005	0.005	0.001	0.333***
	(0.003)	(0.003)	(0.006)	(0.001)
Log value of total assets	0.114**	−0.016	−0.04	−0.125*
	(0.046)	(0.05)	(0.048)	(0.074)
Landholding	0.217**	0.472***	−0.119	−0.001
	(0.11)	(0.073)	(0.091)	(0.119)
Log of distance to the district town	0.049	−0.055	0.183*	−0.044
	(0.079)	(0.084)	(0.098)	(0.211)
Log of distance to the market	−0.03	0.009	0.155***	0.087
	(0.035)	(0.038)	(0.052)	(0.077)
Log of population density	0.027	0.011	−0.004	0.266***
	(0.027)	(0.031)	(0.034)	(0.041)
Observations	1,562	1,562	1,562	1,562
R-squared	0.253	0.087	0.224	0.221
Endogeneity (Durbin Wu Hausment) *test statistics*	8.82	8.62	1.71	7.73
Endogeneity *T*-test P-value	0.00	0.00	0.08	0.00
District by time	Yes	Yes	Yes	Yes
Number of Households	781	781	781	781
Household FE	Yes	Yes	Yes	Yes

First stage results are reported in Table 2. Log of distance to the nearest mobile money agent is used as an instrument for mobile money adoption.
Additional controls include: Number of Men, Women, and Children and indicators of improved cattle ownership.
Robust standard errors are reported in parenthesis.
*, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

mobile money adoption by at least 1.8 percentage points. Munyegera and Matsumoto (2016) report at least a 4.4 percentage points decrease in the likelihood of adopting mobile money if the distance to the agent increases by 1 km. Riley (2018) finds that the presence of a mobile money agent in a village in Tanzania increases the likelihood of mobile money adoption by 25 percentage points. On a whole, accessibility to mobile money agents remains an important determinant of household adoption of mobile money. Other important determinants of mobile money adoption are asset holding, age and years of schooling of household head, distance in km to the nearest district town, and population density.

Table 4. Impact of Mobile Money on Chemical fertilizer and Improved Seeds adoption

Variables	1 If Adopted Fertilizer	1 If Adopted HYV	1 If Adopted Fertilizer & HYV
1 if mobile money adopter	0.110***	0.082***	0.044***
	(0.022)	(0.03)	(0.015)
1 if own mobile phone	0.051**	0.0171	0.055**
	(0.020)	(0.055)	(0.022)
1 if maize plot	−0.01	0.251**	0.082***
	(0.007)	(0.113)	(0.009)
1 if the first season	0.000	0.061***	0.031***
	(0.008)	(0.020)	(0.008)
1 if the plot is intercropped	−0.012	−0.045***	−0.013*
	(0.009)	(0.014)	(0.007)
Time in minutes from homestead to plot	0.003	0.000	0.000
	(0.021)	(0.000)	(0.000)
Log of distance in km to the market	−0.009	−0.008	−0.010
	(0.006)	(0.010)	(0.011)
Log of distance in km to the district town	−0.021	−0.011	0.001
	(0.033)	(0.022)	(0.011)
Log of population density	−0.007*	0.00	−0.008*
	(0.004)	(0.007)	(0.004)
Observations (plots)	4920	4,920	1,450
R-squared	0.41	0.61	0.43
Endogeneity (Durbin Wu Hausment) *test statistics*	4.61	2.26	6.62
Endogeneity *T test* p-value	0.00	0.01	0.00
District by time	Yes	Yes	Yes
Household FE	Yes	Yes	Yes

First stage results are reported in Table 2. Log of distance to the nearest mobile money agent is used as an instrument for mobile money adoption.

Estimation sample comprises a pooled sample of maize and beans plots reported in RePEAT 2012 & 2015.

Additional controls include: Household size, Altitude and soil quality(nitrogen content).

The third column is estimated using a restricted sample of plots on which at least HYV and/or fertilizer is applied.

*, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

HYV stands for high-yielding variety.

Robust standard errors are in parenthesis.

4.2. Mobile Money, Farm, and Nonfarm Income: Instrumental Variable Results

Instrumental variable results are presented in Table 3. We use the log of distance to the nearest mobile money agent measured in kilometers at the community level as an instrument for mobile money adoption. In the first stage regression, we regress a binary indicator of mobile money adoption on the log of distance to the nearest mobile money agent and a vector of household and community level controls [equation (1)].

The dependent variables for columns 1–4 of Table 3 are per capita income, per capita farm income, per capita nonfarm income, and per capita remittances respectively. All outcome

variables are in logarithmic form. Mobile money adoption on average increases farm income by at least 13% as shown in column 2. In the context of Kenya, Kikulwe, Fischer, and Qaim (2014) report a 40% increase in farm income induced by the adoption of mobile money. Yao and Shanoyan (2018) show that the increase in farm income for farmers who have adopted mobile money is driven by increased participation in high earn markets. They report that mobile money adoption induces farmers in Ivory Coast and Tanzania to sell more of their products in urban markets compared to farm gate markets. The costs of these long-distance sales transactions are greatly reduced by payments through mobile phones.

We do not find any significant impact of mobile money on nonfarm income. This is unexpected given that some recent studies in SSA (Gosavi, 2018; Ahmad, Green, and Jiang, 2020; Islam and Muzi, 2021) have shown that mobile money adoption induces productivity and income gains in small businesses. One reason might be that the households in our sample are facing barriers to accessing productive off-farm opportunities. We find a significant impact on remittances in the last column.

We do not find any significant impact of mobile money adoption on total income (column 1). This is unexpected and we do not have any convincing explanation. Tentatively, it may suggest that mobile money adoption has a substitution effect on income portfolio. That is, mobile money might induce decreases(increases) in some sources of household income thereby having a zero net effect on total income. Also, it might suggest some weaknesses in the instrumental variable approach.

On a whole, the results presented in Table 3 suggest that mobile money adoption enhances farm income (Kikulwe, Fischer, and Qaim, 2014). We posit that increases in remittance receipts through mobile money may be partly used to finance short-term investment in agriculture.[7] As is the case with all instrumental variable estimations, our estimates are Local Average Treatment Effects (LATE). These estimates cannot be generalized. They are only valid for the complier subsample, i.e. households that adopted mobile money because of proximity to mobile money agents.

4.3. Mechanism

4.3.1. Mobile Money and Input use

The result from estimating equation (3) is presented in Table 4. The results suggest that mobile money adoption increases the likelihood of fertilizer and HYV seed adoption in maize plots by 11 and 8.2 percentage points, respectively. Most importantly it increases the likelihood of the joint adoption of fertilizer and HYV seeds by 4.4 percentage points conditional on the adoption of at least one of these modern inputs. Similar results have been reported in other studies. Kikulwe, Fischer, and Qaim (2014) find that Kenyan farmers who have adopted mobile money spend 30 USD and 15 USD more on chemical fertilizer and pesticides, respectively. In their study on smallholder rice farmers in Ghana, Rahaman and Abdulai (2022) show that adopters of mobile money applied 18% and 13% more fertilizers and herbicides, respectively, than nonadopters.

Closely related to mobile money, mobile phones also have a significant effect on modern input adoption albeit smaller than the effect of mobile money. The positive impact of mobile phones on smallholder agriculture has been well documented even before the advent of mobile money (Muto and Yamano, 2009; Ogutu, Okello, and Otieno 2014; Krell et al., 2021). Mobile phone enhances access to information such as weather and price information and reduces transaction costs among others.

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[7]The primary mechanism through which mobile money adoption affects welfare and investment is through remittances. See for example (Tabetando and Matsumoto, 2020; Munyegera and Matsumoto, 2016; Jack and Suri, 2014). Similar results for disaggregated farm income are shown in the appendix.

Table 5. Mobile money, farm, and nonfarm income (robustness check)

Variables	Household Fixed Effects Model			
	Income	Farm Income	Nonfarm Income	Remittance
1 if mobile money adopted	0.203***	0.229***	0.133	0.321***
	(0.044)	(0.028)	(0.110)	(0.011)
1 if own mobile phone	0.193*	0.134	0.121	0.221***
	(0.107)	(0.111)	(0.123)	(0.011)
1 if Head is female	−0.098	−0.004	−0.084	0.211
	(0.186)	(0.165)	(0.155)	(0.233)
Head's years of schooling	−0.002	−0.008	−0.040**	0.209*
	(0.013)	(0.011)	(0.017)	(0.121)
Head's age in years	0.004	0.003	0.002	0.00
	(0.002)	(0.003)	(0.004)	(0.001)
Log value of total assets	0.126***	0.053	−0.075*	−0.044
	(0.043)	(0.036)	(0.038)	(0.063)
Landholding	0.209*	0.422***	−0.093	−0.088
	(0.12)	(0.044)	(0.068)	(0.219)
Log of distance to the district town	0.055	−0.017	0.163	0.026
	(0.073)	(0.081)	(0.210)	(0.175)
Log of distance to the market	−0.03	0.005	0.157*	0.069
	(0.032)	(0.031)	(0.092)	(0.077)
Log of population density	0.026	0.006	−0.002	0.186***
	(0.018)	(0.019)	(0.061)	(0.054)
Constant	3.974***	4.835***	5.878***	4.002***
	(0.711)	(0.333)	(0.723)	(1.044)
Observations	1,562	1,562	1,562	1,562
R-squared	0.258	0.261	0.251	0.244
District by time	Yes	Yes	Yes	Yes
Number of Households	781	781	781	781
Household FE	Yes	Yes	Yes	Yes

Community clustered standard errors in parenthesis.
Additional controls include: Number of men, women, and children and an indicator of improved cattle ownership.
Sample consists of panel households interviewed in 2012 and 2015.
Outcome variables are in logarithmic form.
*, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

4.4. Mobile Money, Farm, and Nonfarm Income (Robustness Check)

For robustness purposes, we estimate and briefly discuss a basic variant of equation (2) estimated using only household fixed effects. These results are presented in Table 5. All outcome variables are in logarithmic form.[8] Mobile money adoption on average increases per capita income by at

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[8]Tobit and OLS estimates are qualitatively similar to FE estimates. They are available upon request.

least 20%. We do not find any significant impact of mobile money on nonfarm income. As expected, the impact of mobile money adoption on remittances is significant.

On a whole, the evidence presented in Tables 3 and 5 supports our claim that mobile money adoption induces larger farm income. Previous studies (Jack and Suri, 2014; Munyegera and Matsumoto, 2016) have linked mobile money adoption to greater per capita consumption via remittance receipt. Munyegera and Matsumoto (2016) find that households that have adopted mobile money receive twice as much remittances as households that have not adopted mobile money. In terms of the likelihood of receiving remittances, Riley (2018) reports a 15.4 percentage point increase associated with mobile money adoption in Tanzania. Though we do not provide direct evidence, Table 4 suggests that remittance receipt via mobile money may not only be used to smooth consumption but may also be used to finance short-term agricultural investment.[9]

5. Summary and Concluding Remarks

Recent studies have shown that mobile money adoption induces productivity and investment in small businesses in Sub-Saharan Africa (Gosavi, 2018; Ahmad, Green, and Jiang 2020; Islam and Muzi, 2021). In this article, we have examined the impact of mobile money adoption on short-term agricultural investment notably the adoption of improved seeds and chemical fertilizers. The main results of our analyses show that households that have adopted mobile money are more likely to adopt chemical fertilizers and improved seeds thereby inducing farm income.

These results imply that digital financial services such as mobile money can be effective in enhancing agricultural technology adoption and productivity. Unlike traditional financial services such as bank accounts, subscription to digital financial services such as mobile money is easier, faster, and cheaper. Mobile money provides an opportunity to enhance financial inclusion in rural Africa. In aggregate terms, mobile money induces significant economy-wide income gains. For example, a recent study in Kenya shows that the introduction of mobile money technology in 2007 can explain 10% of the per-capita income growth between 2007 and 2013 thus pointing to quantitatively significant macroeconomic effects of mobile money technology (Beck et al., 2018).

Fully harnessing the benefit of mobile money will require improvements in telephone network coverage. The effectiveness of mobile money depends on the availability and quality of the telephone network. In many parts of rural Uganda, the telephone network remains patchy. Also, further expansion of mobile money service points(agents) will enhance adoption in remote areas.

For further research, a disaggregated analysis of the distribution of the benefits of mobile money across income quintiles and gender would help identify the winners and losers of mobile money.

References

Ahmad, H., C. Green, and F. Jiang. "Mobile Money, Financial Inclusion and Development: A Review with Reference to African Experience." *Journal of Economic Surveys* **34**,4(2020):753–92.
Awotide, B., A. Karimov, and A. Diagne. "Agricultural Technology Adoption, Commercialization and Smallholder Rice Farmers' Welfare in Rural Nigeria." *Agricultural and Food Economics* **4**,3(2016):1–24. DOI 10.1186/s40100-016-0047-8.
Beck, T., H. Pamuk, R. Ramrattan, and B. Uras. "Payment Instruments, Finance and Development." *Journal of Development Economics* **133**,3(2018):162–86.

[9]Result for disaggregated farm income (crop income, livestock income, and farm wage income) are reported in the appendix. Mobile money adoption has a positive impact on crop income.

Christiaensen, L., L. Demery, and J. Kuhl. "The (Evolving) Role of Agriculture in Poverty Reduction—An Empirical Perspective." *Journal of Development Economics* **96**,2(2011):239–54.

Deb, R., and T. Suri. "Endogenous Emergence of Credit Markets: Contracting in Response to a New Technology in Ghana." *Journal of Development Economics* **101**,C(2013):268–83.

Duflo, E., M. Kremer, and J. Robinson. "How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya." *American Economic Review* **98**,2(2008):482–8.

Gine, X., and S. Klonner. "Credit Constraints as a Barrier to Technology Adoption by the Poor: Lessons from South Indian Small-scale Fishery." Policy Research Working Paper Series No. 3665. Washington, DC: World Bank, 2006.

Gosavi, A. "Can Mobile Money Help Firms Mitigate the Problem of Access to Finance in Eastern Sub-Saharan Africa." *Journal of African Business* **19**,3(2018):343–60.

Islam, A., and S. Muzi. "Does Mobile Money Enable Women-Owned Businesses to Invest? Firm-Level Evidence from Sub-Saharan Africa." *Small Business Economics* (2021). DOI 10.1007/s11187-021-00562-w.

Jack, W., and T. Suri. "Risk Sharing and Transactions Costs: Evidence from Kenya's Mobile Money Revolution." *American Economic Review* **104**,1(2014):183–223.

Kikulwe, E., E. Fischer., and M. Qaim. "Mobile Money, Smallholder Farmers, and Household Welfare in Kenya." *PLoS One* **9**,10(2014):e109804. DOI 10.1371/journal.pone.0109804.

Kirui, O.K., J.J. Okello, and G.W. Njiraini. "Impact of Mobile Phone-Based Money Transfer Services in Agriculture: Evidence from Kenya." *Quarterly Journal of International Agriculture* **52**,2(2013):141–62.

Krell, N., S. Giroux, Z. Guido, C. Hannah, S. Lopus, K. Caylor, and T. Evans. "Smallholder Farmers' Use of Mobile Phone Services in Central Kenya." *Climate and Development* **13**,3(2021):215–27.

Munshi, K. "Information Networks in namic Agrarian Economies." *Handbook of Development Economics*. Munshi, K., eds. Oxford: Elsevier Science, 2008.

Munyegera, G.K., and T. Matsumoto. "Mobile Money, Remittances, and Household Welfare: Panel Evidence from Rural Uganda." *World Development* **79**,C(2016):127–37.

Muto, M., and Yamano, T. 2009. "The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda." *World Development* **37**(12):1887–1896.

Narayanan, S. "The Productivity of Agricultural Credit in India." *Agricultural Economics* **47**,4(2016):399–409.

Ogutu, O., J. Okello, and D. Otieno. "Impact of Information and Communication Technology-Based Market Information Services on Smallholder Farm Input Use and Productivity: The Case of Kenya." *World Development* **64**,3(2014):311–21 DOI 10.1016/j.worlddev.2014.06.011.

Rahaman, A., and A. Abdulai. "Mobile Money Adoption, Input Use, and Farm Output Among Smallholder Rice Farmers in Ghana." *Agribusiness* **38**,1(2022):236–55.

Ravallion, M., and S. Chen. "China's (Uneven) Progress Against Poverty." *Journal of Development Economics* **82**,1(2007):1–42.

Riley, E. "Mobile Money and Risk Sharing Against Village Shocks." *Journal of Development Economics* **135**,C(2018):43–58.

Sheahan, M., and C. Barret. "Ten Striking Facts About Agricultural Input Use in Sub-Saharan Africa." *Food Policy* **67**,1(2017):12–25.

Tabetando, R., and T. Matsumoto. "Mobile Money, Risk Sharing, and Educational Investment: Panel Evidence from Rural Uganda." *Review of Development Economics* **24**,1(2020):84–105.

Uganda Communication Council. Annual Report, 2017.

Yao, B., and A. Shanoyan. "The Use of Mobile Money Application and Smallholder Farmer Market Participation: Evidence from Cote d'Ivoire and Tanzania." Paper presented at the International Association of Agricultural Economists (IAAE) 2018 Conference, Vancouver, British Columbia, July 28–August 2, 2018.

Zerfu, D., and D. Larson. "Incomplete Markets and Fertilizer Use: Evidence from Ethiopia." Policy Research Working Paper No. 5235. Washington DC: The World Bank, 2010.

Appendix A

Table A1. Mobile money and disaggregated farm income

Variables	Household Fixed (FE) Effects Model		
	Crop Income	Livestock Income	Farm Wage Income
1 if mobile money adopted	0.230***	−0.017	−0.074
	(0.061)	(0.117)	(0.050)
1 if own mobile phone	0.145	0.088	−0.0348
	(0.103)	(0.162)	(0.036)
1 if Head is female	−0.002	−0.161	−0.060*
	(0.168)	(0.291)	(0.031)
Head's years of schooling	−0.009	−0.050*	0.0124
	(0.011)	(0.026)	(0.009)
Head's age in years	0.003	0.000	−0.000
	(0.003)	(0.006)	(0.001)
Log value of total assets	0.047	−0.030	0.009
	(0.037)	(0.054)	(0.009)
Landholding	0.409***	0.147	−0.030
	(0.064)	(0.156)	(0.036)
Log of distance to the district town	−0.016	−0.348***	0.070*
	(0.096)	(0.127)	(0.036)
Log of distance to market	0.004	0.035	0.019
	(0.034)	(0.074)	(0.027)
Log of population density	0.010	0.063	−0.012
	(0.019)	(0.051)	(0.023)
Constant	4.924***	4.665***	3.682***
	(0.584)	(0.969)	(0.197)
Observations	1,562	1,562	1,562
R-squared	0.268	0.171	0.485
District by time	Yes	Yes	Yes
Number of Households	781	781	781
Household FE	Yes	Yes	Yes

Community clustered standard errors in parenthesis.
Additional controls include: number of men, women, and children and an indicator of improved cattle ownership.
Sample consists of panel households interviewed in 2012 and 2015.
*, **, and *** indicate statistical significance at 10%, 5%, and 1% level, respectively.

Table A2. Impact of mobile money on chemical fertilizer, hired labor, and improved seeds adoption

Variables	Household Fixed effects		
	Log of Expenditure on Chemical Fertilizer	Log of Expenditure on Hired Labor	Log of Expenditure on Seed
1 if mobile money adopted	0.141***	0.016	0.223*
	(0.015)	(0.332)	(0.122)
1 if own mobile phone	−0.0533	0.112*	0.411
	(0.331)	(0.05)	(0.45)
1 if Head is female	−0.410	−0.311	−0.366
	(0.313)	(0.461)	(0.677)
Head's years of schooling	−0.036*	0.082**	0.029
	(0.021)	(0.040)	(0.061)
Head's age in years	0.001	0.001	0.011
	(0.01)	(0.012)	(0.021)
Log value of total assets	0.089**	0.220**	0.233
	(0.043)	(0.109)	(0.181)
Landholding	0.041	0.448	0.215
	(0.137)	(0.247)	(0.35)
Log of distance to the district town	−0.022	0.033	0.412*
	(0.133)	(0.305)	(0.211)
Log of distance to market	0.066	−0.018	−0.081
	(0.055)	(0.090)	(0.106)
Log of population density	−0.069*	0.117*	0.066
	(0.041)	(0.06)	(0.071)
Constant	6.222***	3.881**	0.441
	(1.21)	(1.91)	(3.06)
Observations	1,562	1,562	1,562
R-squared	0.061	0.079	0.166
District by time	Yes	Yes	Yes
Number of Households	781	781	781
Household FE	Yes	Yes	Yes

Community clustered standard errors in parenthesis.
Additional controls include: Number of men, women, and children and an indicator of improved cattle ownership.
Sample consists of panel households interviewed in 2012 and 2015.
*, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

Sample of Questionnaire

Section 16-a. Input Use, Harvest, and Sales in First Crop Season 2015 (March – July 2015 Harvest)

HH8a Did this household engage in crop production in first crop season 2015? 1=Yes (Fill table), 2=No (go to Sec.8b)   HH8a_____
Make sure to ask all crops produced including feeding stuff (fodder leaves, elephant/Napier grass) and tree products (fruits).

Parcel ID same as Sec. 11	Plot ID	Crop Name	Crop Code See Code Sheet	Who is the main decision maker on this crop? Enter Person ID	Area under this crop in acres	Inter-cropped? 1=Yes 2=No	Seed type? 1=Local 2=Improved new 3=Improved recycled 4=Mixed Code below	For maize only, if C3=2 or 3, improved seed type? Code below	Qty	Unit	Price per unit (if purchased)	Type Code below	Qty	Unit	Type Code below	Qty	Unit	Type Code below	Qty	Unit	Expenditure on herbicides/pesticides/insecticides/fungicides	Expenditure for hired labour (land preparation/planting/weeding/harvesting)	Qty	Unit	Qty	Unit	Qty	Unit	Price per unit	Qty	Unit	Qty	Unit	Price per unit	Months stored before sale (Non-perishable Only)	To whom did you sell? Code below	Where did you sell? Code below	How did you contact with this sales outlet?
PID	LID	CName	CID	C0	C1	C2	C3	C3m	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31		

(Column group headers: Seed use | Chemical Fertilizer Use — 1st Chemical / 2nd Chemical | Organic Fertilizer Use | Harvest (-777 if not yet harvested) — Dry / Fresh | Sales [Skip to next row if not sold] — Dry / Fresh | For the largest sale)

Maize Seed Code:
1=DK Hybrid
2=Kenya Hybrid
3=Pannar Hybrid
4=Western Seed Hybrid
5=Longe 6 (Hybrid)
6=Longe 7H (Hybrid)
7=Longe 10H (Hybrid)
8=Longe 1-5 (OPV)
9=Other hybrid (Specify)
10=Other OPV (Specify)

Fertilizer Type Code:
1=Animal Manure (Dry form)
2=Green Manure
3=Compost
4=DAP
5=UREA
6=NPK
7=CAN
8=MAP
9=TSP
10=SSP
11=ASN (26:0:0)
12=household refuse crop residual
13=Other (Specify)

Unit codes:
1=KG
2=GRAM
3=LITER
4=NUMBER
5=TONNES
6=100 KG SACKS

11=100 KG SACKS
12=50 KG SACKS
13=25 KG SACKS
14=20L TIN
15=5L TIN
16=20L JERRYCAN
17=10L JERRYCAN
18=5L JERRYCAN
19=3L JERRYCAN
20=1L JERRYCAN
21=20L BASKET/BASIN
22=10L BASKET/BASIN
23=BIG BUNCH (12 CLUSTER)
24=MEDIUM BUNCH (8 CLUSTER)
25=SMALL BUNCH (5 CLUSTER)
26=2L JUG/MUG
27=1L JUG/MUG
28=WHEEL BURROW

Buyer code (C29):
1=Trader
2=Retail shop
3=Individual consumer
4=Cooperative association
5=Supermarket
6=Institution (e.g. school)
7=Company
8=Other (Specify)

Code for point of sale (C30):
1=Farm gate
2=Nearby trading centre
3=Local market
4=Other town (specify)

Code for contact (C31):
1=phone
2=send a person
3=by chance
4=other (specify)

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