Mobile Phone Technologies, Agricultural Production Patterns, and Market access in Uganda

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Abstract

Through various applications, the importance of mobile technologies has been more evident in developing economies since the late 1990s. One such application has been mobile money services, where mobile network subscribers transfer money electronically via a mobile phone, thus eliminating some of the developing countries' persistent barriers to financial services for instance financial market exclusion and remoteness. Despite mobile technologies' anticipated potential towards rural socio-economic development, there is however yet a very limited empirical focus on their welfare impacts. Using regression models and a panel data of 874 observations collected from predominantly coffee farmers in central Uganda, we argue that mobile money use has a positive impact on several income-enhancing mechanisms along the income pathway to smallholder household welfare. Compared to non-users, rural households using mobile money sell more of their coffee produce in a high-value form as shelled beans, receive higher prices for these shelled beans, and earn more off-farm income, with or without remittances. All these mechanisms enhance incomes, thus welfare.

1. Introduction

The use of mobile technologies has speedily increased in developing countries since the late 1990s; instigating social and economic transformations, that have led to rapid economic growth through reliable market information transfers and social linkages (Von Braun and Torero, 2005; Umeh, 2008; Aker, 2010; Sekabira et al., 2012; Muto, 2012; Blauw and Franses, 2016). These linkages have enhanced rural community networking (Scott et al., 2004) thus aiding the rural poor's economic participation through easing access to; education, health services, job opportunities, minimal transport costs, efficient markets, correct information updates and cashless mobile money transfers, that would otherwise be difficult or impossible (Jussawalla 1999; Blattman et al., 2002; Chowdhury et al., 2005; Jensen 2007 and 2010; Bhavnani et al., 2008; Muto and Yamano, 2009; Aker et al., 2012; Hoddinott et al., 2013; Tadesse and Bahiigwa, 2015). Through their various mobile applications, mobile technologies have potential for constructive economic and social rural development impacts (Von Braun, 2010). One of such applications is the mobile money (MM) services, (Aker and Mbiti, 2010; GSMA, 2014). MM-services enable electronic transfer of money via mobile phones, which the subscriber can collect in cash from nearest MM-service centers. MM-services enhance household welfare through remittances (money sent from distant relatives and family) transfers and savings, (Morawczynski, 2009; Mbiti and Weil, 2011; UCC, 2013). Globally, the World Bank (2014) estimates an increasing trend of remittances from 435 in 2014 to 667 US$ billions in 2017, and shows that in all developing countries except China, remittances surpass foreign direct investments. The importance of MM-services is widely predicted in developing countries where the banking infrastructure is less distributed, crippled, insufficient or even non-existent in certain localities, (Aker, 2011; Jack et al., 2013).

Despite the grossly anticipated potentials of MM-services towards uplifting livelihoods of rural populations, less is still known empirically about their welfare impacts (Aker, 2011; Aker and Ksoll, 2016; Nakasone et al., 2014). A scanty effort has yet only analyzed household income (Kikulwe et al., 2014), risk sharing (Jack and Suri, 2014), food security

(Murendo and Wollni, 2016), and per capita consumption, (Munyegera and Matsumoto 2016). Mechanisms along the income pathway via which MM impacts income have also been scantly investigated, with efforts limited to remittances and input use, (Kikulwe et al., 2014; Munyegera and Matsumoto, 2016). Studying such mechanisms individually can guide households' investment and policy.

We add to literature by assessing MM-use impacts on welfare-enhancing mechanisms; production patterns, market access and off-farm employment. We analyze these mechanisms respectively by studying MM-use impacts on; proportion of coffee produce sold in high-value form (shelled beans), prices of shelled beans in Uganda shillings (UGX) and off-farm incomes in UGX. Shelled beans are the highest value form possible for farmers to sell coffee in Uganda and fetch the highest price, whereas off-farm employment has increasingly become important to Ugandan households where 72% of working population still relies on agriculture that is predominantly rain fed and risky, (UBOS, 2015). We use a panel data collected from Uganda. Uganda is one of the largest exporters of coffee and coffee is her main cash-crop.

Next, we develop a conceptual framework identifying impact pathways, and then we explain the sample, data, and methods used. We then discuss results and conclude.

2. The conceptual framework

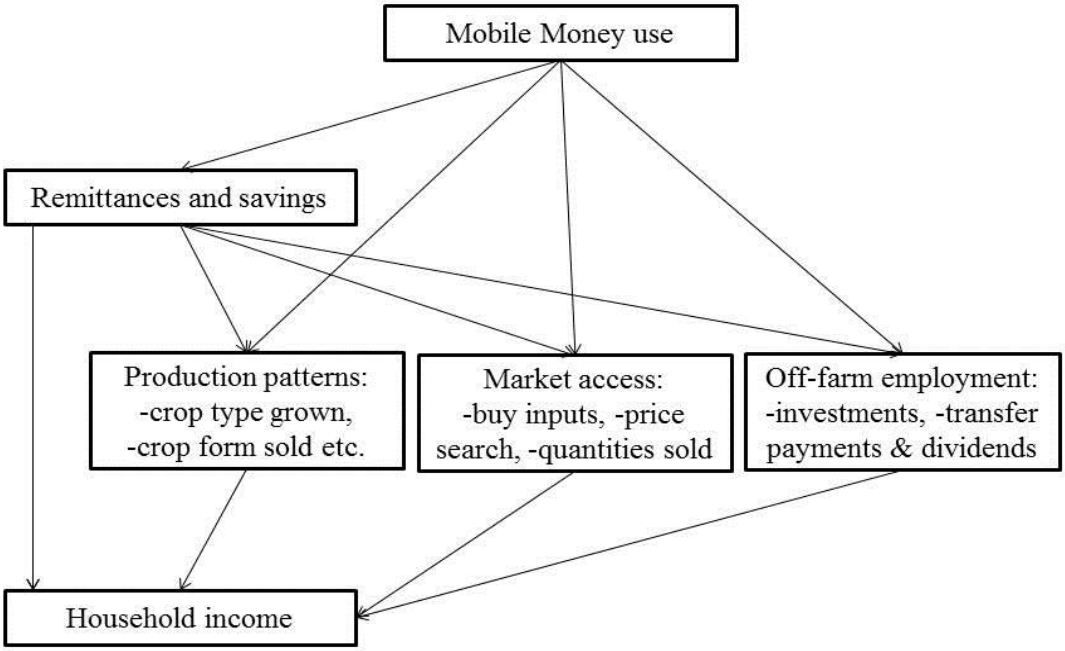

Figure 1: Impact pathways of MM on welfare

Along the income pathway there are several welfare-enhancing mechanisms upon which MM use impacts, hence impacting incomes and then welfare. For the purposes of this study we

identify production patterns, market access and off-farm employment as such mechanisms that are of importance to the study population.

MM-use enables households to access financial resources in remittances and savings that are used to procure inputs, (Kikulwe et al., 2014). Input use (chemicals, technologies or skills) increases productivity; for instance in the study area certification of coffee farming-systems was prevalent; under which farmers would be trained on various coffee management practices and receive market information. Remittances and savings also smooth consumption and avert risks (Jack and Suri, 2014), thus reducing pressure on saleable crops that would otherwise be harvested early or sold in raw forms to finance urgent consumption needs. Aker and Ksoll, (2016) also show that households using mobile technologies grow more marginal cash crops which cushions major cash crops. Such cushions allow households various choices for crops and form produced, consequently allowing farmers to venture into high-value crop forms. Thus we hypothesize that MM-users produce more shelled coffee beans.

MM-use also influences household market access through enabling monetary exchange and allowing households pay for inputs at reduced transactions cost. With lower transactions costs, households receive higher market prices (Kikulwe et al., 2014). Remittances and savings also finance search costs for better market prices. Therefore, we hypothesize that MM-users receive higher prices for shelled coffee beans.

MM-use also influences off-farm employment, through making payments to workers and remitting business incomes to owners possible, at reduced transactions costs. MM-users can also access remittances and savings that finance investment in rural job opportunities. Therefore, we hypothesize that MM-users receive more off-farm income. Although MM-users are known to earn more income (Kirui et al., 2013), disentangling off-farm income from farm income is important, since during bad cropping seasons households' consumption relies heavily on off-farm incomes.

3. Data and methods

3.1 Data

A multi-stage random sampling technique was used to identify respondents. Local government leaderships in Masaka and Luwero were approached for names of available coffee cooperatives that operated in sub-counties where they had participating farmers in various villages. All participating farmers' data were then provided at a village level, from which a random sample was drawn. Village local leaderships provided the data for the non-participating farmers from which a random sample was also drawn at a village level. The first wave of the data was collected in 2012 from 419 small-scale coffee farmers that constituted 163 and 108 participating farmers and, 48 and 100 non-participating farmers from Luwero and Masaka districts respectively. The second wave was collected in 2015 from 166 and 125 participants and 80 and 84 non-participants from Luwero and Masaka districts respectively, making 455 farmers. A total of 874 observations from 480 households were collected for an unbalanced panel.

Household heads were presented with a structured questionnaire and their responses were recorded to questions about; location details, household and farm characteristics like; household membership, age, education, consumption, production patterns, off-farm employment, mobile phone use, and other aspects.

3.2. *Statistical methods*

3.2.1. Probit model

Interested in understanding why farmers choose to use MM and others do not, we use a probit model in equation (1).

$$M_{jt} = \alpha + \beta \mathbf{X}_{jt} + \gamma T_t + \varepsilon_{jt} \quad (1)$$

Where M_{jt} is the dependent dummy variable of value 1 if household j used MM in year t, and 0 otherwise. $\mathbf{X}_{jt}$ is a vector capturing; household, farm and context specific characteristics that may sway households' decision on using MM. T_t is a year dummy controlling for time fixed effects, since a number of $\mathbf{X}$ characteristics are varying by time though some are invariant. ε_{jt} is the normally distributed random error term.

3.2.2. Panel regression models

Interested in analyzing panel data to establish treatment (causal) effects, regression panel models illustrated in equation (2) can be appropriate.

$$Y_{jt} = \theta + \phi M_{jt} + \chi \mathbf{V}_{jt} + \delta T_t + \mu_{jt} \quad (2)$$

Where Y_{jt} is the dependent continuous variable under investigation for instance; remittances, income, consumption, proportion of coffee produce sold as shelled beans, prices of shelled coffee beans and, off-farm income, of household j in year t. M_{jt} is the MM-use dummy, of value 1 if household uses MM and 0 otherwise. Hence ϕ is the treatment effect of MM-use we aim to estimate. $\mathbf{V}_{jt}$ is the vector of covariates. T_t is a year dummy of value 1 for 2015 and 0 for 2012. μ_{jt} is the randomly distributed error term.

Panel models however, can suffer from endogeneity due to; selection bias, covariates' measurement errors, and simultaneous biases, (Greene, 2002; Wooldridge, 2009). Endogeneity problems can be controlled for by specifying fixed effects (FE) for panel models, (Kennedy, 2003). However if we assume that unobserved heterogeneity does not bias estimates, then using random effects (RE) panel models becomes more feasible and both are indispensable approaches in estimating error components of panel models, (Cameron and Trivedi 2005; McManus, 2011). We therefore use both FE and RE that are statistically compared using Hausman tests.

3.2.3. Variables used

We majorly aimed at establishing the treatment effect of using MM on welfare-enhancing mechanisms. But for a complete understanding of the linkages between these mechanisms and welfare, we briefly investigate such impact on welfare using; remittances, income and consumption as proxies.

Remittances directly contribute to welfare via incomes. We measure remittances on an annual basis per household in UGX. On average between March-2012 and July-2015, 1 US$ was equal to 2,690 UGX. We calculate remittances from all moneys sent to the household from relatives and family.

Income reflects how much money is available to support households' basic needs. We measure income on an annual basis per household in UGX, calculated from both farm and off-farm activities.

Consumption reflects exactly how much of the available income is spent on basic needs. We measure consumption on a daily basis per capita in UGX, calculated from household expenditure on basic needs.

Shelled coffee beans are the highest value form under which coffee can be sold in Uganda. Ability to sell coffee in a high value form can be a good indicator of improving production patterns. Shelled coffee proportion is the measure of total coffee produce that is sold as shelled beans, calculated using conversion factors provided by the host Kibinge coffee cooperative in Masaka. One kilogram of fresh red coffee cherries yields 0.2 kilograms of shelled beans. We compute backwards the equivalent quantity of available shelled coffee beans in terms of red cherries per household per year, which we then divide by the total red cherries harvested. Empirically, other than labor and time invested, Fafchamps and Hill, (2005); Blandon et al., (2009); Weber, (2011) confirm that differences in prices that small-holder coffee farmers get depend on these farmers' marketing decisions (including form in which coffee is sold), and coffee quality (yield and humidity). Yield is the rate at which unshelled coffee produces shelled beans and humidity as how much of the coffee bean is water.

Shelled coffee beans' prices can reflect the high-value products markets` access, as this is the goal of improving production patterns. Prices are measured per kilogram of dried shelled coffee beans in UGX. However, for comparability, we use the 2012/13 Uganda consumer price index (CPI) of 200.2 UGX (UBOS, 2015) to weight 2012 prices.

For diversified sustainable rural livelihoods, off-farm employment whose benefit is measured by off-farm incomes is of importance especially where agriculture is dominantly rain fed and riskier. We measure off-farm income per household per year in UGX, computed from various non-farm income activities including; retail shops, forest harvests, transport services, remittances, formal jobs like teaching etc. Off-farm income without remittances is also used to estimate the impact of MM-use on purely rural based business or employment opportunities.

We use covariates including household characteristics like land size, household size, household heads'; age, formal education, and gender. These can define coffee quantities produced, marketable coffee form and prices as well as MM-use or otherwise. We also use context specific variables like distance to all weather roads as this can dictate market access. We also use a district dummy to capture district effects. Since social networks influence awareness and adoption of mobile technologies (Venkatesh and Morris, 2000; Lu et al., 2005; Dickinger et al., 2008), the probit model includes percentage of neighboring households using MM to capture neighborhood effects. We use certification and mobile phone dummies to control for these technologies that were prevalent in sample area. Inputs value, age of productive coffee trees and time taken to reach coffee plots are also used in studying determinants of shelled coffee proportions. We also use a migrant dummy to control for changing residence status since this can affect farm and off-farm activities.

4. Results and discussions

4.1 Descriptive results

4.1.1 Description of the sample and variables used in estimations

From table 1, significant differences are more visible in 2015 when MM-use had increased. Generally, remittances were insignificantly different between MM-users and non-users; however MM-users had higher incomes and consumption. In 2015, there were less proportions of coffee produce sold as shelled beans although households earned more off-farm incomes. Uganda received more rainfall in 2011 than in 2014, (UBOS, 2012; 2015) hence the lower 2015 farm production; thus the coffee quantities available for shelling. Households shell coffee after satisfying pressing consumption needs through selling coffee in lower value forms like; flower, unripe cherries, red cherries and or dried cherries. With diminishing farm out-put, off-farm activities thus incomes increased in 2015. In the pooled sample, MM-users had 31% of their coffee produce sold as shelled beans compared to only 23% sold by non-users. There were no significant differences in prices. MM-users also earned more annual off-farm income with or without remittances.

Majority mean values of covariates between users and non-users are significantly different within the pooled sample and this is informative in understanding MM-use determinants. MM-users were more formally educated. MM-use involves reading messages, currency figures and designing passwords. Better education enhances ease of such activities. MM-using households also had one person more, with larger endowments of land and assets. However, heads of MM-using households were younger and largely males. MM-users were more certified, and had more neighboring households using MM. On the other hand, the average age of productive coffee trees for MM-users was lower. Coffee trees are economically productive until 40 years (UCDA, 2015); hence MM-users had trees of better economic potential. MM-users also used more inputs. MM-users also spent more minutes to reach their coffee plots. About half of MM-using households were in Masaka and about 18% of the sample was immigrants.

Table 1: Descriptive statistics of variables used in estimations

	Mean values					
Year	2012		2015		Pooled sample	
Mobile money use status	Users (N=98)	Non-users (N=321)	Users (N=284)	Non-users (N=171)	Users (N=382)	Non-users (N=492)
Outcome Variables						
Remittances (000'000 UGX)	0.324 (0.499)	0.405 (0.766)	0.527 (0.596)	0.401 (0.467)	0.502 (0.623)	0.403 (0.622)
Income (000'000 UGX)	3.754** (3.737)	2.876 (3.173)	4.186*** (3.803)	2.040 (2.260)	4.075*** (3.786)	2.585 (2.913)
Consumption ('000 UGX)	3.136 (1.645)	3.332 (1.962)	4.161 (2.714)	3.759 (2.368)	3.898*** (2.522)	3.481 (2.119)
Shelled coffee proportion	0.427	0.295	0.273***	0.099	0.313*	0.227
Shelled coffee prices ('000 UGX)	4.478 (0.465)	4.446 (0.447)	4.288 (0.245)	4.217 (0.352)	4.350 (0.342)	4.401 (0.438)
Off-farm income ('000,000 UGX)	1.013 (1.533)	0.813 (1.409)	1.421*** (1.748)	0.600 (1.009)	1.316*** (1.703)	0.739 (1.287)
Off-farm income without remittances	0.960 (1.496)	0.750 (1.389)	1.209*** (1.694)	0.466 (0.932)	1.145*** (1.647)	0.651 (1.256)
Model Covariates						
Education of head (years)	5.945*** (2.946)	4.851 (3.388)	5.882*** (2.920)	4.469 (3.199)	5.898*** (2.923)	4.718 (3.325)
Household size (persons)	7.534*** (3.145)	6.373 (2.992)	7.145*** (2.907)	5.448 (2.923)	7.245*** (2.970)	6.051 (2.997)
Land owned (hectares)	1.268* (1.134)	1.007 (1.172)	1.131*** (1.388)	0.618 (1.394)	1.166*** (1.327)	0.872 (1.266)
Square of land owned	2.880 (4.175)	2.383 (3.209)	3.197* (5.532)	2.315 (3.169)	3.116*** (5.215)	2.359 (3.354)
Household assets ('000'000 UGX)	7.975*** (1.515)	7.258 (1.799)	8.028*** (1.598)	6.840 (1.747)	8.014*** (1.575)	7.113 (1.790)
Age of head (years)	54.118* (11.577)	57.210 (15.014)	56.745*** (13.018)	61.989 (14.417)	56.071*** (12.701)	58.871 (14.969)
Distance to tarmac road (KM)	17.888 (9.449)	18.322 (10.145)	17.900 (9.383)	17.282 (9.297)	17.897 (9.387)	17.961 (9.862)
Male head (dummy)	0.806	0.741	0.835***	0.684	0.827***	0.722
Masaka district (dummy)	0.500	0.495	0.493**	0.398	0.495	0.461
Migrant household (dummy)	0.224	0.215	0.158	0.129	0.175	0.185
Certified household (dummy)	0.745**	0.617	0.673*	0.591	0.691**	0.608
Households of ten neighbors using MM	2.745*** (2.542)	0.106 (0.686)	5.264*** (2.820)	0.111 (0.723)	4.618*** (2.961)	0.108 (0.698)
Age of productive coffee trees (years)	29.522** (11.319)	33.092 (13.443)	31.223 (11.992)	32.962 (12.793)	30.791*** (11.832)	33.047 (13.208)
Square of age of productive coffee trees	852.11** (363.16)	972.51 (433.63)	908.91 (379.53)	966.58 (411.36)	894.34*** (375.75)	970.45 (425.61)
Inputs per hectare ('000 UGX)	49.802 (31.652)	44.323 (34.533)	68.123*** (31.435)	52.795 (34.089)	63.423*** (32.454)	47.267 (34.581)
Average time to coffee plots (minutes)	1.899 (4.436)	1.349 (4.444)	3.377*** (2.423)	2.465 (2.104)	2.998*** (3.118)	1.737 (3.832)

Source: Survey data

Standard deviations in parentheses; *, **, *** significant differences at 10%, 5% and 1% levels between MM users and non-users; 1US$ = 2,690 UGX

4.1.1 Mobile money use and distribution

Mobile Telephone Network (MTN) and Airtel provide MM-services respectively to 71% and 28% of the sample. A local network, K2 serves only 1%. This trend is similar to that of Munyegera and Matsumoto, (2016). In table 2, we show MM-use distribution and it is evident

that MM-users more than doubled between 2012 and 2015, from 23% to 62%. The increment in MM-use was steeper than in mobile phone (MP), indicating an increasing importance of MM-use. MM-service centers in towns nearest to households had also more than doubled.

Table 2: Mobile money use and distribution

Variables	2012	2015	Pooled sample
	Mean	Mean	Mean
Proportion using MM	0.23	0.62***	0.44
MM-center available	0.17	0.54***	0.36
Proportion using MP	0.76	0.89***	0.83

Source: Panel survey data

*** implies mean proportions are significantly different at 1% level between years

4.1.1 Most important mobile money and Off-farm activities

From figure 2, about 72 percent of the sample used MM-services mostly for withdrawing money and then sending money, indicating a good prospect for remittances and off-farm income activities. Paying for goods and services for instance school fees, bills, buying inputs, bank transfers via MM-services, thus minimizing transport transactions costs, was third placed. About 24% of the sample was not involved in any off-farm income activity. However, 55% of those involved were most importantly active in businesses like retail shops, forest-harvests, transport services etc. Remittances were second most important to 31% of those involved, whereas salaried employment was least (14%) most important.

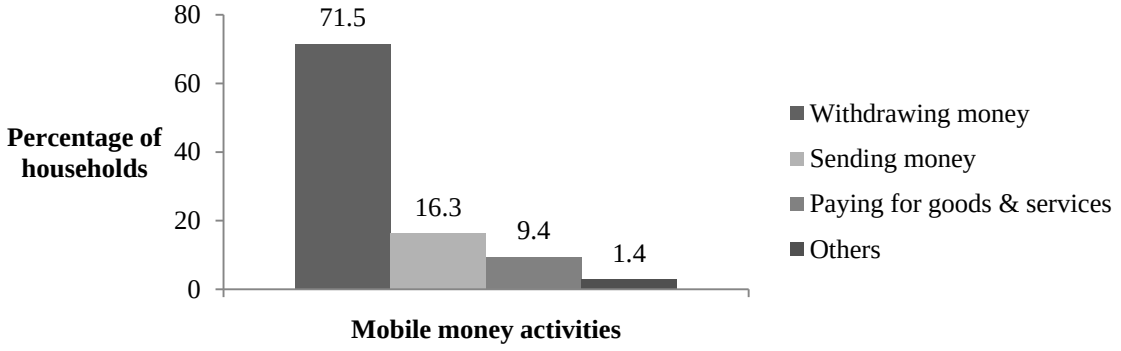

Figure 2: Most important activities executed using MM-services.

4.1.1 Equivalence in importance of shelled beans

We demonstrate the importance of selling coffee in a high value form (shelled beans) in table 3 by, presenting per unit equivalences of other forms of saleable coffee in terms of shelled beans by weight and price. We use a pooled sample for computations but weight 2012 prices with the CPI. With 1 kilogram of shelled beans generated from 2 and 5 kilograms of dried and red cherries respectively, if farmers sell coffee as dried or red cherries, they lose about 7% or 10% respectively of the price they would receive if sold shelled beans.

Table 3: Equivalences of other coffee forms per kilogram (Kg) of shelled beans

Coffee form	Flower	Red	Dried	Shelled
Farmers who at least sold form	27	277	680	182
Per Kg of shelled equivalent weight in Kgs	-	5.00	2.00	1.00
Average price per Kg of form in UGX	641	792	2,033	4,376
Per Kg of shelled equivalent price in UGX	-	3,960	4,066	4,376

Source: Survey data and Kibinge Coffee Cooperative

4.1 Regression results

4.1.1 Determinants of mobile money use

We present determinants of MM-use in table 4 using a pooled-probit model based on equation (1). From models (1 and 2); with an increasing household size, the probability of using MM increases significantly. With more persons within a household, links to a wider social network and information increases, thus increasing likelihoods of adoption, complementing Lu et al., (2005). The probability of MM-use also significantly increased in 2015, confirming a sharp increase in MM-use since 2012. Male-headed households were significantly less likely to use MM-services. Traditionally, male-heads' mobility is less-restricted. Male-heads move more frequently to even major town centers where other financial infrastructure is easily available. With an increasing number of MM-centers available in village towns, it increases the probability of using MM-services. When MM-subscribers want to withdraw cash or load money into their MM-accounts, they do so via MM-service centers hence are important. With more neighbors using MM-services, the probability to use MM-services also increases. Through using neighbors, non-users become aware of MM-services, hence positively influencing use of MM-services; agreeing with Kikulwe et al., (2014).

Context specific factors like distance to (tarmac) all weather roads and district dummy are not significant MM-use determinants. This indicates how wide MM-technologies have spread against the usual rural market access barriers like; distance and remoteness. Public and private sectors disseminating agriculture aiding technologies have usually sought out better income and easy to reach locations, (Aker, 2011), alienating the remote rural poor. We find that this is not the case with mobile network operators (MNOs).

Households can usually only use MM-services via a mobile phone (MP) especially in rural communities where MM-centers are much dispersed or unavailable. This positive influence is displayed in model (2), table 4. In model (2), we also control for certification; results reveal that there was no such important influence of certification on farmers' decision to use MM-services.

Table 4: Determinants of mobile money use

Dependent variable	Mobile Money use	
Model	(1)	(2)
Estimator	RE Probit	RE Probit
Covariates		
Education of head (years)	0.038	0.031
	(0.076)	(0.079)
Household size (persons)	0.247***	0.221**
	(0.087)	(0.093)
Land owned (hectares)	0.152	0.195
	(0.259)	(0.274)
Square of land owned	-0.077	-0.088
	(0.076)	(0.078)
Household assets (UGX)	1.4e-7	1.3e-7
	(1.5e-7)	(1.6e-7)
Age of head (years)	-0.020	-0.016
	(0.017)	(0.018)
Distance to tarmac road (KM)	0.012	0.017
	(0.025)	(0.027)
Year 2015	1.182***	1.055**
	(0.418)	(0.461)
Household uses MP (dummy)		1.832*
		(0.998)
Certified household (dummy)		-0.184
		(0.518)
Male head (dummy)	-1.117**	-1.195**
	(0.550)	(0.608)
Masaka district (dummy)	0.438	0.179
	(0.484)	(0.520)
Migrant household (dummy)	0.514	0.483
	(0.488)	(0.506)
MM-center available (dummy)	5.655***	5.549***
	(0.874)	(1.183)
Income (UGX)	-5.8e-8	-6.3e-8
	(7.3e-8)	(7.4e-8)
Households of ten neighbors using MM	1.314***	1.276***
	(0.203)	(0.273)
Constant	-5.873***	-7.116***
	(1.684)	(2.297)
Model Statistics		
Observations	874	874
No. of households	480	480
Wald χ^2	65.98***	28.31**
Likelihood-ratio test rho=0	17.18***	15.34***

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.1.1 Determinants of remittances, income, and per capita consumption

In table (5) we estimate the determinants of household remittances, income, and per capita consumption expenditure, including MM-use as a covariate. Generally both RE and FE estimations bear a positive coefficient for MM-use thus complementing Kirui et al., (2013);

Kikulwe et al., (2014); Munyegera and Matsumoto , (2016) that MM-use has a positive impact on household remittances, incomes and per capita consumption.

Table 5: Determinants of remittances, income, and consumption

Dependent variable	Remittances ('000 UGX)		Income ('000 UGX)		Consumption (UGX)	
Model	(1)	(2)	(3)	(4)	(5)	(6)
Estimator	RE	FE	RE	FE	RE	FE
Covariates						
Household uses MM (dummy)	34.8 (29.6)	26.8 (54.8)	502.9** (227.4)	391.4 (368.7)	227.1** (114.5)	61.8 (194.5)
Education of head (years)	2.5 (4.4)	-17.0 (11.7)	108.4 *** (34.9)	-2.5 (78.9)	32.4* (17.4)	39.4 (41.7)
Household size (persons)	4.3 (4.5)	-5.3 (11.3)	-55.4 (36.1)	-95.5 (76.2)	-308.0*** (18.0)	-283.7*** (40.2)
Land owned (hectares)	20.2* (10.4)		418.9*** (85.3)		78.6* (42.9)	
Household assets (UGX)			7.3e-4*** (6.9e-5)	5.6e-4*** (1.3e-4)	2.8e-4*** (3.5e-5)	2.6e-4*** (6.6e-5)
Age of head (years)	4.9 *** (0.9)	1.4 (3.6)	-19.1** (7.9)	-33.7 (24.6)	9.5** (3.9)	-10.4 (12.9)
Distance to tarmac road (KM)	-3.6*** (1.4)		6.8 (11.1)		9.0 (5.5)	
Year 2015	93.0*** (28.1)	104*** (37.4)	112.9 (198.7)	224.4 (250.0)	429.1*** (102.3)	524.7*** (131.9)
Household uses MP (dummy)	55.9 (38.3)	111.7* (64.0)	-75.5 (290.8)	182.1 (430.3)	124.8 (147.2)	342.0 (227.0)
Certifiedhousehold (dummy)			9.7 (225.3)	582.5 (573.8)	226.8** (112.2)	-11.6 (302.7)
Male head (dummy)	-39.1 (31.9)		212.3 (256.2)		183.9 (127.2)	
Masaka district (dummy)	19.6 (27.9)		788.6*** (232.6)		-37.0 (115.2)	
Migrant household (dummy)	18.2 (32.9)	-0.4 (52.6)				
Constant	-253*** (79.7)	5.9 (225.2)	-2.7e3*** (708.2)	779.2 (1.7e+3)	1.1e5*** (353.8)	1.1e5*** (897.0)
Model statistics						
Observations	874	874	874	874	874	874
No. of households	480	480	480	480	480	480
Wald $\chi 2$	74.8***		379.9***		415.1***	
F-value		4.19***		4.11***		15.14***
Hausman test $\chi 2$		7.01		9.66		7.63

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; 1US$ = 2,690 UGX

4.1.1 Determinants of proportion of coffee produce sold as shelled beans

From model (2), table 6; if a household uses MM-services, the proportion of coffee sold as shelled beans significantly increases by 19.2 percentage points annually. This treatment effect translates into a 46% annual increase for MM non-users who only sold about 23% of their coffee as shelled beans. MM-services allow farmers more access to inputs, and remittances

(Kikulwe et al., 2014). Increased input use enhances yield, and remittances smooth consumption which relieves pressure on coffee, thus allowing shelling. The negatively significant year effect indicates the low 2015 productions due to lower rains in 2014 relative to 2011; the years accounting for farm production recorded in survey years respectively. With low production, pressure to sell low value form coffee increases, thus reducing amounts available for shelling.

Table 6: Determinants for shelled coffee proportion sold as shelled beans

Dependent variable	Shelled coffee proportion	
Model	(1)	(2)
Estimator	RE	FE
Covariates		
Household uses MM (dummy)	0.092*	0.192**
	(0.050)	(0.085)
Education of head (years)	-0.007	-0.002
	(0.008)	(0.018)
Household size (persons)	-0.008	0.005
	(0.008)	(0.018)
Land owned (hectares)	-0.002	
	(0.019)	
Household assets (UGX)	1.9e-8	-2.6e-8
	(1.6e-8)	(2.9e-8)
Age of head (years)	-9.9e-5	0.002
	(0.002)	(0.006)
Distance to tarmac road (KM)	-0.007***	
	(0.002)	
Year 2015	-0.155***	-0.207***
	(0.048)	(0.060)
Household uses MP (dummy)	-0.028	0.102
	(0.065)	(0.101)
Certified household (dummy)	0.335***	0.097
	(0.048)	(0.133)
Male head (dummy)	0.068	
	(0.055)	
Masaka district (dummy)	0.513***	
	(0.050)	
Age of productive coffee trees (years)	-0.005	-0.012
	(0.022)	(0.037)
Square of age of productive coffee trees	2.6e-4	6.9e-4
	(6.8e-4)	(1.2e-3)
Inputs per hectare (UGX)	1.7e-6**	6.8e-7
	(6.9e-7)	(1.1e-6)
Average time to coffee plots (minutes)	-0.006	
	(0.006)	
Constant	-0.271	-0.066
	(0.166)	(0.432)
Model statistics		
Observations	874	874
No. of households	480	480
Wald $\chi 2$	224.84***	
F-value		2.47***
Hausman test $\chi 2$		18.68**

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The significant importance of MM-use along with other time-invariant covariates remains visible in model (1), table 6. Increase in distance to all-weather roads significantly reduces shelled coffee proportions. Longer distances to roads limit market access which entices farmers to sell coffee to village traders who usually buy coffee in low value forms. However, memberships in coffee certification schemes and input-use have a positive significant effect on these proportions. Certification schemes sensitize farmers on management practices that enhance high-value form production whereas input use improves productivity. The Masaka district dummy is also positive and significant. Masaka (currently Bukomansimbi) is where coffee is grown most in Uganda, (UBOS, 2015). Masaka has good red soils and a higher altitude, all favorable for coffee farming.

4.1.1 Determinants of price for shelled coffee beans

Table 7: Determinants of price for shelled coffee beans

Dependent variable	Shelled coffee prices (UGX)	
Model	(1)	(2)
Estimator	RE	FE
Covariates		
Household uses MM (dummy)	164.3	319.6*
	(111.6)	(179.7)
Education of head (years)	-16.4	-21.4
	(17.1)	(38.5)
Household size (persons)	-25.4	-17.6
	(17.7)	(37.2)
Land owned (hectares)	40.6	
	(41.9)	
Household assets (UGX)	7.8e-5**	1.0e-4*
	(3.4e-5)	(6.1e-5)
Age of head (years)	0.8	11.8
	(3.9)	(11.9)
Distance to tarmac road (KM)	-21.6***	
	(5.5)	
Year 2015	-511.9***	-673.4***
	(97.8)	(121.9)
Household uses MP (dummy)	-121.1	175.1
	(142.9)	(209.8)
Certified household (dummy)	1,094***	312.0
	(110.5)	(279.7)
Male head (dummy)	160.4	
	(125.6)	
Masaka district (dummy)	1,908***	
	(114.0)	
Constant	-492.5	-387.2
	(347.4)	(828.8)
Model statistics		
Observations	874	874
No. of households	480	480
Wald $\chi 2$	477.35***	
F-value		4.89***
Hausman test $\chi 2$		40.42***

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; 1US$ = 2,690 UGX

Basing on model (2), table 7, MM-use significantly increases shelled coffee prices paid to farmers by 320 UGX annually. This treatment effect translates into a 7% increase in prices paid to MM non-users, whose annual average is about 4,400 UGX per kilogram. MM-use increases input use thus farm productivity, coffee quality, and as well reduce transactions costs, translating into better coffee prices. Assets also have a significant positive influence on shelled coffee prices. Transport and communication assets assist farmers in reaching out to competitive markets offering competitive prices. Asset sales may also fund market searches for better prices. The year 2015 had a significant negative effect on prices. Low rains received in 2014, affected the general quantity and quality of coffee in 2015, hence also that of shelled beans. Low shelled coffee beans quality negatively affected prices.

Model (1), shows that longer distances to all-weather roads significantly reduce shelled coffee beans' prices. Longer distances to good roads increases transport costs, thus lowering prices offered for produce. However, certified households significantly received higher prices. Certified households receive trainings on better coffee management practices which enhance quality and thus prices, complementing Chiputwa et al., (2015); van Rijsbergen et al., (2016). Masaka was associated with higher prices, because the district has a better market infrastructure (organized cooperatives, coffee shelling stations, internet and, roads) that offers competitive prices.

4.1.1 Determinants of off-farm income

In table 8 we present estimations of the impact of MM-use on both off-farm income with remittances included and off-farm income without remittances. From model (2), MM-use significantly increases off-farm income by 330 thousand UGX annually. Such a treatment effect would mean a 31% increase for MM non-users whose annual average is 739 thousand UGX. Assets possessions also significantly increase off-farm incomes. Assets like hoes and machetes are used in forest products' harvesting, brick-laying etc. whereas motor-cycles are used in transport-services' provision as well as transporting retail-shops' merchandise, thus enhancing off-farm incomes.

From model (1), where we control for time-invariants, education and staying in Masaka were significant. Households with better educated heads significantly earned higher off-farm incomes. Key contributors to off-farm incomes were salaried employment that is usually dependent on education. However staying in Masaka reduced such incomes. Masaka has better agricultural land and organized cooperatives, hence skewing household income-earning activities more on the farm than off-farm.

When we exclude remittances, in models (3) and (4), we still observe a significantly positive impact of MM-use on off-farm incomes generated from exclusively rural based off-farm enterprises. From model (4), MM-users earn a significant increment of 307 thousand UGX, translating into a 32% increase in such incomes received by MM non-users, whose average is 651 thousand UGX. Therefore from model (3) and (4), we can argue that MM-use is no longer only a means of remittances' access but has also become a significant tool in aiding rural off-farm employment and business enterprises. With or without remittances incomes,

rural households use MM-services to better their off-farm employment and business opportunities. Assets also show a significant positive effect.

Table 8: Determinants of off-farm income

Dependent variable	Off-farm income ('000 UGX)		Off-farm income without remittances ('000 UGX)	
Model	(1)	(2)	(3)	(4)
Estimator	RE	FE	RE	FE
Covariates				
Household uses MM (dummy)	265.5**	330.2*	245.1**	307.1*
	(114.8)	(185.5)	(111.2)	(175.5)
Education of head (years)	71.3***	-8.6	69.9***	9.9
	(17.7)	(39.8)	(17.3)	(37.6)
Household size (persons)	-2.8	14.9	-2.9	22.2
	(18.2)	(38.7)	(17.8)	(36.6)
Land owned (hectares)	-22.8		-30.6	
	(43.1)		(41.8)	
Household assets (UGX)	2.2e-4***	1.8e-4***	1.9e-4***	1.5e-4**
	(3.5e-5)	(6.3e-5)	(3.4e-5)	(5.9e-5)
Age of head (years)	-2.8	-3.3	-7.3*	-4.2
	(4.0)	(12.4)	(3.9)	(11.7)
Distance to tarmac road (KM)	-8.9		-5.5	
	(5.6)		(5.5)	
Year 2015	103.4	204.8	12.9	104.6
	(100.4)	(126.9)	(95.5)	(120.1)
Household uses MP (dummy)	19.6	129.5	-28.5	20.9
	(146.6)	(216.6)	(141.5)	(205.0)
Certified household (dummy)	-155.6	-160.7	-184.6*	-215.3
	(113.9)	(289.9)	(111.7)	(274.4)
Male head (dummy)	155.5		217.9*	
	(129.9)		(127.7)	
Masaka district (dummy)	-201.1*		-213.4*	
	(117.9)		(116.2)	
Migrant household (dummy)	65.8	271.6	63.0	275.7
	(124.5)	(178.5)	(120.1)	(168.9)
Constant	-759.9**	-497.0	-410.9	-350.3
	(359.1)	(855.9)	(350.9)	(810.1)
Model statistics				
Observations	874	874	874	874
No. of households	480	480	480	480
Wald χ^2	129.57***		118.42***	
F-value		3.22***		2.21**
Hausman test χ^2		33.47***		28.78***

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; 1US$ = 2,690 UGX

From model (3), where we control for time-invariant factors, households with better educated and or male heads significantly earn higher incomes. However; with increasing age of the head, subscription to certification schemes and residing in Masaka, significantly reduce these incomes. Education enhances access to employment opportunities through a skilled labor force whereas the male gender enjoys more mobility away from the farm to sectors like transport services etc. that enhance off-farm income earning opportunities. On the other hand,

rural off-farm income activities are mainly based on physical well-being and health, which deteriorate with age, hence causing a reduction in off-farm work intensity hence the earnings. Certified households have more on-farm mandatory engagements like picking ripe cherries only, etc. hence limiting time available for off-farm income activities. More functional schemes were prevalent in Masaka.

4.1.1 Robustness checks

Results show that MM-use has a positive impact on welfare along the income pathway via mechanisms; production patterns, market access and, off-farm employment through increased; proportions of shelled beans, prices for shelled beans and, off-farm income respectively.

Table 9: RE-tobit model specifications for robustness checks

Dependent variable	Remittances ('000 UGX)	Shelled coffee proportion	Shelled coffee prices (UGX)	Off-farm income ('000 UGX)	Off-farm income without remittances
Model	(1)	(2)	(3)	(4)	(5)
Estimator	RE-tobit	RE-tobit	RE-tobit	RE-tobit	RE-tobit
Covariates					
Household uses MM (dummy)	179.0 **	0.523*	438.6**	301.5*	354.4**
	(90.3)	(0.306)	(212.7)	(155.4)	(176.8)
Education of head (years)	1.6	0.065	66.8**	104.1***	129.8***
	(12.4)	(0.049)	(31.6)	(23.4)	(27.1)
Household size (persons)	7.1	-0.112**	-90.3***	0.688	15.9
	(13.2)	(0.051)	(33.2)	(23.9)	(27.4)
Household assets (UGX)		4.0e-7***	3.3e-4***	2.6e-4***	2.8e-4***
		(9.9e-8)	(6.0e-5)	(4.4e-5)	(5.0e-5)
Age of head (years)	22.9***	0.009	11.4	-7.4	-20.5***
	(3.2)	(0.012)	(7.4)	(5.2)	(5.9)
Year 2015	438.1***	-1.585***	-2,827***	329.2**	152.8
	(89.2)	(0.309)	(199.6)	(138.1)	(155.6)
Household uses MP (dummy)	156.1	0.509	32.4	20.4	-33,165
	(120.9)	(0.450)	(256.3)	(201.6)	(231.8)
Certified household (dummy)		2.029***	1,231***	-210.8	-358.4**
		(0.410)	(211.2)	(147.9)	(168.9)
Age of productive coffee trees (years)		0.126			
		(0.178)			
Square of age of productive coffee trees		-0.003			
		(0.005)			
Inputs per hectare (UGX)		1.8e-5***			
		(4.9e-6)			
Migrant household (dummy)	43.3			56.6	78.6
	(102.6)			(169.4)	(191.5)
Constant	-2.5e3***	-9.069***	-2,550***	-1.7e3***	-1.6e3***
	(273.7)	(1.527)	(603.2)	(441.6)	(503.3)
Model statistics					
Observations	874	874	874	874	874
No. of households	480	480	480	480	480
Wald χ^2	91.72***	52.28***	266.41***	119.98***	124.39***
Log likelihood	-2045.38	-465.63	-4694.82	-9765.76	-8247.87

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; 1US$ = 2,690 UGX

The respective treatment effect of 46%, 7% and, 31% may seem high. Therefore, we conduct further analysis to ascertain robustness. Since FE-estimators control for time-invariant heterogeneity, we make preference for robustness checks using exact variables as used in FE-estimators. A key scare to robustness is the fact that some households received no remittances, sold nothing as shelled beans, and received no shelled beans prices and, others were never involved in off-farm employment. Therefore all key outcome variables had sizeable zero (0) value observations. Although RE-estimators controlled for time-invariant factors, they would less control for the 0 value observations. Therefore we check the robustness of FE-estimators by; re-estimating RE-tobit models with similar covariates as those used in respective FE-estimators. Results are in table 9.

From table 9, the positive and significant influence of MM-use remained intact and within range of original FE estimates. The magnitude and direction of other covariates also remains steadily intact. Hence we conclude that there is no significant bias caused by using FE and RE-estimators in assessing impacts of MM-use. More importantly, our FE and RE estimates used to interpret the treatment are generally more conservative. The effect of MM-use on off-farm income without remittances in model (5) as well as remittances individually in model (1) also remains robust.

5. Conclusions

In confirmation of our hypotheses, MM-using households sell more coffee produce as shelled beans, receive better shelled beans' prices and earn higher off-farm incomes with or without remittances included. Use of MM-services allows households receive more remittances that smooth consumption and relieve consumption-based pressure on coffee, enabling households to save and process coffee for sale in high value form for better prices. Better prices received boost investment in off-farm employment, thus higher off-farm incomes for MM-users. Although better educated household heads were more likely to use MM-services, by the end of 2015, 44% of the sample were using MM-services as opposed to only 23% in 2012, thus MM-use is rapidly increasing. Foreign companies provided MM-services to 99% of sample households; highlighting the importance of foreign investment in enabling rural households' access to new technologies. Therefore an economically and politically fair policy environment for foreign investment must prevail to improve welfare. Improvements in market infrastructure can also improve access to new technologies.

However, due to only a two-wave panel, we could not run reverse causality tests between MM-use and off-farm income or remittances. Nevertheless, we believe that it is more likely for MM-use to cause improvements in remittances and off-farm income since these fluctuate on everyday basis, than it is for the latter two to cause MM-use which is only installed once for a life-time on a mobile phone Subscriber Identity Module (SIM) card. We also base our findings on a data from dominantly coffee farmers in central Uganda; therefore results may have less universality. Although, we carry out robustness checks, we also accept that recall data usually bears biases that are impossible to avoid totally. However we believe that results

are empirically viable and informative. Wider research is needed on impacts of MM-services on non-monetary aspects of welfare like Nutrition and gender roles.

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