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Can mobile phones improve gender equality and nutrition? Panel data evidence from farm households in Uganda

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ABSTRACT

Since 2000, mobile phone technologies have been widely adopted in many developing countries. Existing research shows that use of mobile phones has improved smallholder farmers' market access and income. Beyond income, mobile phones can possibly affect other dimensions of social welfare, such as gender equality and nutrition. Such broader social welfare effects have hardly been analyzed up till now. Here, we address this research gap, using panel data from smallholder farm households in Uganda. Regression results show that mobile phone use is positively associated with household income, women empowerment, food security, and dietary quality. These results also hold after controlling for possible confounding factors. In addition to the household-level analysis, we also look at who within the household actually uses mobile phones. Gender-disaggregation suggests that female mobile phone use has stronger positive associations with social welfare than if males alone use mobile phones. We cautiously conclude that equal access to mobile phones cannot only foster economic development, but can also contribute to gender equality, food security, and broader social development. Further research is required to corroborate the findings and analyze the underlying causal mechanisms.

1. Introduction

Since 2000, mobile phone technologies have been widely adopted in developing countries. Mobile phones have significantly improved people's access to information, especially for the rural poor who were never connected to landline phones before. Mobile phones have also reduced other types of transaction costs, thus improving the functioning of markets (Jensen, 2007; Duncombe and Boateng, 2009; Aker and Mbiti, 2010; Aker, 2011; Aker and Ksoll, 2016; Blauw and Franses, 2016; Nakasone and Torero, 2016). Currently, about 4 billion people globally are using mobile phones. More than two-thirds of these people live in developing countries. With adoption rates around 90%, the highest penetration of mobile phones is found in sub-Saharan Africa (PRC, 2015).

In Africa, people generally use their mobile phones for a large number of activities and services, including communication with business partners and friends via calls and text messages, access to news and various other types of information, financial transactions, and entertainment (PRC, 2015; UCC, 2015). A growing body of literature has used micro-level data to analyze the effects of mobile phone use on market access, input and output prices, agricultural production patterns, and household income (Donner, 2007; Jensen, 2007; Aker, 2010, 2011; Aker and Mbiti, 2010; Kikulwe et al., 2014; Aker and Ksoll, 2016; Nakasone and Torero, 2016; Sekabira and Qaim, 2017). However, mobile phones can possibly also affect various other dimensions of social welfare, such as gender equality and nutrition. Understanding such broader effects is important especially against the background of the United Nations' Sustainable Development Goals, which go far beyond a narrow set of economic development indicators. While a few recent studies have conceptually discussed how mobile phones could influence food security and other welfare dimensions (e.g., Aker and Mbiti, 2010; Nakasone et al., 2014; Nakasone and Torero, 2016), empirical evidence is scarce.

Here, we address this research gap by using panel data from a farm household survey carried out in Uganda. In particular, beyond looking at income effects, we analyze possible effects of mobile phone use on gender equality and nutrition. As in other African countries, mobile phones were adopted very rapidly in Uganda during the last 10 years and are now widely used even by very poor households in remote rural locations (Muto and Yamano, 2009; UCC, 2015; Munyegera and Matsumoto, 2016). Due to self-selection, establishing clear causality between mobile phone use and social welfare is difficult. We use a pseudo fixed-effects panel estimator to control for time-invariant unobserved heterogeneity, but other potential issues of endogeneity may occur. Therefore, results should not be over-interpreted in a causal sense. Nevertheless, due to the dearth of quantitative evidence on the

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broader social implications of mobile phone use, even associational analysis can add to the literature and possibly stimulate follow-up research.

How can mobile phone use possibly influence gender equality and nutrition? A few early studies discussed potential effects on gender roles (Bayes, 2001; Nath, 2001), yet without evaluating them empirically. For farming households, improved market access through mobile phones will likely increase the degree of commercialization, which could reduce the decision-making power of women. Agricultural commercialization is often associated with men taking stronger control of agricultural production and income (Udry, 1996; Fischer and Qaim, 2012). On the other hand, women are often particularly constrained in their access to markets and information. Hence, if women themselves were able to use mobile phones, they could possibly benefit even more than men (Aker and Ksoll, 2016). This could contribute to women empowerment and improved gender equality within the household. Some of our data in Uganda were collected in gender-disaggregated form, so we are able to examine such aspects.

Possible nutrition effects of mobile phone use could occur through various pathways. Better market access and related income gains are typically associated with improved food security and dietary quality (Sibhatu et al., 2015). Changing gender roles within the household can also influence nutrition (Fischer and Qaim, 2012). As women tend to spend more on healthcare and dietary quality than men, women empowerment can improve nutrition even in the absence of income gains (Quisumbing and Maluccio, 2003; Hoddinott, 2012). Furthermore, easier access to all sorts of news services and information through mobile phones may raise people's nutrition knowledge and awareness, which could also contribute to improved dietary practices.

2. Materials and methods

2.1. Farm household survey

We use panel data collected in two survey rounds from randomly selected farm households in Masaka and Luwero Districts, Central Uganda. Farmers in these districts grow coffee as their major cash crop, in addition to banana, maize, sweet potato, and various other food crops. Within the two districts, we used a two-stage sampling procedure, first selecting three counties and then randomly selecting farmers in each of these counties. The first survey round was conducted in 2012 and covered 419 farm households (Chiputwa et al., 2015). The second survey round was conducted in 2015, targeting the same households. Out of the initial 419 households, 25 could not be re-surveyed in 2015, either due to migration or longer-term absence of the household head and other potential respondents. Hence, the sample includes 394 households for which we have two rounds of data, leading to a total of 788 observations. We use this balanced panel for the analysis. Comparing key socioeconomic variables for the 2012 sample with and without the 25 attrition households included shows no significant differences (Table A1 in the online appendix in the online appendix), so that we do not expect attrition bias.

In both survey rounds, we used a structured questionnaire for face-to-face interviews with the household head. Certain sections of the questionnaire were also answered separately by the spouse of the household head. The questionnaire focused on agricultural production and marketing, non-farm economic activities and income sources, household consumption, as well as other socio-demographic and contextual details. Household diets were assessed through a 7-day food consumption recall covering more than 100 different food items. We also asked for mobile phone ownership and use at the household level, as well as separately for different household members. In this study, we are particularly interested in the mobile phone use by male and female adults in each household. Similarly, ownership of assets was captured in a gender-disaggregated way.

As the small-farm households in Uganda do not keep written records of their economic activities, the data build on respondents' recalls and are therefore prone to measurement error. We tried to minimize such error by carefully designing the questionnaire using common formats for agricultural household surveys (Deaton, 1997), pre-testing the questionnaire in the local context, and thoroughly training the team of interviewers. Most of the questions related to mobile phone ownership and use were "yes" or "no" type of questions, which were easy to answer for respondents. For some of the continuous outcome variables, the data may be less precise. However, we do not expect systematic differences in the precision of the responses between users and non-users of mobile phones, so that measurement error should not lead to bias in the estimation results.

2.2. Measurement of key variables

The main explanatory variable of interest is mobile phone (MP) use. We consider a household to be a MP user if at least one adult household member owned and used a mobile phone during a particular survey year. MP use is captured through a dummy variable at the household level. Furthermore, we define a second dummy variable for female mobile phone (FMP) use. This second dummy – also measured at the household level – takes a value of one if at least one female adult in the household owned and used a mobile phone, and zero otherwise. Note that FMP-using households are a subset of the group of MP-using households: the remaining MP users are those where only male adults owned and used a mobile phone.

In terms of outcome variables, we are particularly interested in household income, gender equality within the household, and nutrition.[1] Household income is measured as the total income of the household from all sources over a period of 12 months. For farm income, this also includes the value of production not sold in the market. The cost of production was subtracted for all income derived from self-employed activities. Annual household income is expressed in Ugandan shillings (UGX) (1 US$ = 2690 UGX). To be able to compare incomes between the two survey rounds, income in 2012 was adjusted to 2015 using the official consumer price index (UBOS, 2015).

Gender equality within the household is measured in terms of the proportion of productive assets owned by women or jointly by male and female household members. The proportion refers to the monetary value of the assets. Looking at asset ownership is common in the literature when assessing the economic situation of women within households (Quisumbing and Maluccio, 2003; Alsop et al., 2006; Doss et al., 2014). We are interested in how mobile phone use may influence asset ownership. In order to reduce possible issues of reverse causality, we do not consider very durable assets such as land or buildings. We only include short- and medium-term productive assets such as agricultural equipment (hoes, saws, wheelbarrow, sprayers, etc.) and vehicles (bikes, motorbikes, trucks, etc.). In male-dominated households, such assets are predominantly owned by the male household head or other male members. A larger proportion of such assets owned by females or jointly owned by male and female household members can be interpreted as a higher degree of women empowerment.

Nutrition outcomes can be measured in different ways, including anthropometric indicators, food consumption based measures, and households' subjective assessments of food access (Ruel, 2003; Masset et al., 2012; Shiferaw et al., 2014; Kabunga et al., 2014; Chiputwa and Qaim, 2016). Here, we are particularly interested in how mobile phones affect household food consumption and dietary practices, which we measure through household dietary diversity scores. Dietary diversity

[1] In the descriptive analysis, we also look at agricultural yield, market access, and farm and off-farm income as intermediate outcomes. However, as effects of mobile phone technology on such intermediate outcomes were analyzed in a number of previous studies (Donner, 2007; Jensen, 2007; Aker, 2010; Kikulwe et al., 2014; Aker and Ksoll, 2016; Nakasone and Torero, 2016), we concentrate on household income, gender equality, and nutrition as broader indicators of social welfare in the econometric analysis.

scores count the number of different food groups consumed over a specified period of time and are a common tool to assess food security and dietary quality (Ruel, 2003; Jones et al., 2014; Koppmair et al., 2017).

We use the data from the 7-day food consumption recall to calculate the household dietary diversity score (HDDS) with 12 food groups, which is a common indicator of food security in the nutrition literature (Kennedy et al., 2011). The 12 food groups considered are: cereals; white roots and tubers; vegetables; fruits; meat and poultry; eggs; fish; pulses, legumes and nuts; milk and milk products; oils and fats; sugar and honey; and spices, condiments, and beverages. However, HDDS is not necessarily a good indicator of dietary quality. Especially the last three food groups (oils and fats; sugar and honey; spices, condiments, and beverages) are calorie-dense but contribute little to micronutrient consumption. Hence, in a robustness check we calculate an alternative dietary diversity score with only the 9 more healthy food groups considered. This alternative score with 9 food groups is generally considered a better indicator of dietary quality (Sibhatu et al., 2015).

2.3. Econometric strategy

We aim to estimate possible effects of mobile phone use on household income, gender equality, and nutrition, using the two-round panel data from farm households in Uganda. Given that these are observational data, where households self-selected into the group of mobile phone users, identifying causal effects is difficult. We try to reduce selection problems to the extent possible but admit that causal interpretation may still be subject to bias.

We start the econometric analysis by estimating the following panel data model:

$$Y_{it} = \beta_0 + \beta_1 MP_{it} + \beta_2' \mathbf{X}_{it} + \beta_3 T_t + \varepsilon_{it} \quad (1)$$

where Y_{it} is the outcome variable of interest referring to household i in year t. MP_{it} is a dummy variable that takes a value of one if any adult in the household owned and used a mobile phone in year t, and zero otherwise. $\mathbf{X}_{it}$ is a vector of farm, household, and contextual characteristics, T_t is a year dummy for 2015, and ε_{it} is a normally distributed random error term.

As mentioned above, we use three outcome variables (household income, gender equality, nutrition) and estimate a separate regression for each of them. We are particularly interested in the estimates for β_1. Positive and significant estimates would imply that mobile phone use is positively associated with household income, gender equality, and nutrition after controlling for other factors that are included in the vector $\mathbf{X}_{it}$.[2] For all three models, we use linear specifications and calculate standard errors that are cluster-corrected at the county level. In addition to the linear models, we also use Tobit specifications as a robustness check for the gender equality and nutrition models, as these have censored dependent variables.[3]

In a further step, we analyze more specifically who within the household uses mobile phones and related implications for household welfare. Women are often more constrained in terms of their access to markets and information. Against this background, we hypothesize that mobile phones used by women may have more positive effects than if men alone use this technology. To test this hypothesis, we estimate the following model:

[2] In a robustness check, we also include interaction terms between *MP* and **X** to see whether mobile phone effects depend on the level of other socioeconomic variables.

[3] As described above, gender equality is measured in terms of the proportion of productive assets owned by women or jointly by male and female household members. This variable is left- and right-censored at zero and one. Nutrition is measured in terms of the HDDS, which is censored at zero and twelve. As HDDS is a count variable, we also tested whether the data follow a Poisson distribution. Test results indicated that a Poisson model would not be appropriate in our case.

$$Y_{it} = \gamma_0 + \gamma_1 MP_{it} + \gamma_2 MP_{it} \times FMP_{it} + \gamma_3' \mathbf{X}_{it} + \gamma_4 T_t + \varepsilon_{it} \quad (2)$$

where MP_{it} is defined as above, and $MP_{it} \times FMP_{it}$ is an interaction term with the female mobile phone use (FMP) dummy (at least one female adult in the household owns and uses a mobile phone). In this specification, γ_1 alone measures the effect of mobile phones in households where only male adults use this technology, whereas the FMP effect is calculated as $\gamma_1 + \gamma_2$. Note that FMP use itself cannot be additionally included in Eq. (2), as this would lead to perfect collinearity. Our hypothesis of stronger effects of female mobile phone use on household welfare would suggest that γ_2 is positive and significant.

All models in Eqs. (1) and (2) are estimated with a random-effects (RE) panel estimator. The RE estimator assumes that MP and FMP are uncorrelated with any unobserved factors that may also influence the outcome variables. However, as households self-selected into using mobile phones, this assumption may be violated, which could lead to biased estimates. Therefore, in addition to the RE estimates, we also use a pseudo fixed-effects estimator, as proposed by Mundlak (1978). The Mundlak (MK) estimator includes covariate mean values as additional explanatory variables and thus controls for bias that may arise from time-invariant unobserved heterogeneity (Cameron and Trivedi, 2005). It should be noted that the efficiency of the MK estimator depends on the variation of key variables within households over time. In our sample, the variation in mobile phone use between 2012 and 2015 was relatively small, which should be kept in mind when interpreting the MK results.

2.4. Analyzing possible mechanisms

Possible effects of mobile phones on household income are fairly straightforward: mobile phone use reduces transaction costs, which improves access to information, technology, and markets and thus increases productivity and income. Positive effects of mobile phones on gender equality are also easy to explain: mobile phone use may empower women who are often more constrained in their access to markets and information. However, the effects of mobile phones on nutrition and dietary diversity are less straightforward. They may evolve through various mechanisms, possibly including income and gender equality. While we are not able to rigorously identify causal pathways, we estimate the following models to gain further insights into possible mechanisms:

$$HDDS_{it} = \delta_0 + \delta_1 INC_{it} + \delta_2 GE_{it} + \delta_3 MP_{it} + \delta_4' \mathbf{X}_{it} + \delta_5 T_t + \varepsilon_{it} \quad (3)$$

$$HDDS_{it} = \delta_0 + \delta_1 INC_{it} + \delta_2 GE_{it} + \delta_3 FMP_{it} + \delta_4' \mathbf{X}_{it} + \delta_5 T_t + \varepsilon_{it} \quad (4)$$

where $HDDS_{it}$ is the household dietary diversity score, INC_{it} is household income, and GE_{it} is gender equality. The other variables are as defined before. On the one hand, the coefficients δ_1 and δ_2 in each equation test whether income and gender equality are positively associated with nutrition, as we would hypothesize. On the other hand, the coefficient δ_3 tests whether mobile phone use (or female mobile phone use in Eq. (4)) is significantly associated with nutrition also after controlling for income and gender equality. If δ_3 is insignificant, we could cautiously conclude that the effects of mobile phones on nutrition are mainly channeled through income and gender equality. Yet, a positive and significant δ_3 could suggest that other mechanisms may also play a role. For instance, mobile phones could directly improve household diets through enabling better access to nutrition and health information that can influence food choices and dietary behavior.

3. Results and discussion

3.1. Descriptive statistics

Table 1 shows the patterns of mobile phone use by households in our sample and how these patterns developed between the two survey

Table 1
Number of households in the sample using and not using mobile phones.

	2012		2015		Pooled sample	
	Non-users	Users	Non-users	Users	Non-users	Users
Mobile phone use (MP)	90 (22.84)	304 (77.16)	38 (9.64)	356 (90.36)	128 (16.24)	660 (83.76)
Mobile phone used by female adults (FMP)	192 (48.73)	202 (51.27)	131 (33.25)	263 (66.75)	323 (40.99)	465 (59.01)

Percentage shares are shown in parentheses.

rounds. In 2012, 77% of the households owned and used mobile phones. By 2015, this share had increased to 90%. Table 1 also shows the gender patterns of mobile phone use. As can be seen, the share of households in which females owned and used mobile phones started from a lower base, but increased over-proportionally between 2012 and 2015.

While we did not capture quantitative details about the activities that mobile phones are used for, focus group discussions that we carried out prior to the actual survey revealed that households that own mobile phones are actively involved in making and receiving calls, exchanging text messages, receiving news and other types of information, and using mobile money services. Calls and text messages were exchanged with family, friends, and business partners, including farmer organizations. In Uganda's coffee-growing areas, farmer organizations are important sources of information about market prices, technical and institutional innovations, nutrition, health, and broader social services (Meemken et al., 2017). Such information spreads faster among households that own and use mobile phones, as was also highlighted in previous research carried out in rural Uganda (Muto and Yamano, 2009; Sekabira and Qaim, 2017).

Table 2 shows descriptive statistics for the socioeconomic characteristics that we use as explanatory variables in the econometric models, differentiating between mobile phone users and non-users. Some significant differences can be observed. Mobile phone users have larger farms, more family members, as well as younger and better educated household heads than non-users. In Table A2 in the online appendix we show the same variables, differentiating between households with and without female users of mobile phones.

Fig. 1 compares a few intermediate outcome variables – such as agricultural productivity, income, and market access – between users and non-users of mobile phones. MP users have higher farm incomes and also higher off-farm incomes than non-users. MP users also have higher coffee yields, resulting from better production technology and higher input intensity. As mentioned, coffee is the main cash crop for farmers in the study region. Finally, MP users sell a larger proportion of their coffee as shelled beans after drying and milling. Shelled beans are typically traded in higher-value markets, fetching significantly higher prices than unprocessed coffee cherries (Chiputwa et al., 2015). While we do not include such intermediate outcome variables in the econometric analysis, the observed differences provide an indication of how MP use may influence household welfare.

Table 3 shows descriptive statistics for the main outcome variables used in the econometric analysis. MP users have higher total household incomes and also higher levels of gender equality than non-users. In households without mobile phones, women own less than 50% of the productive assets alone or together with male household members. In mobile phone-using households, 63% of the assets are owned by women or jointly by male and female household members. Dietary diversity is also higher in households with mobile phones, and differences are statistically significant (comparisons for the dietary diversity score with 9 food groups are shown in Table A3 in the online appendix).

The lower part of Table 3 shows the main outcome variables differentiating between female mobile phone users and non-users. The differences are also statistically significant but somewhat smaller in magnitude. It should be noted that in this comparison the group of non-users includes households that do not use mobile phones at all, as well as households in which only male members use mobile phones. These groups are disentangled in the econometric analysis below.

3.2. Possible effects of mobile phone use

Table 4 shows the estimation results of the models in Eq. (1), using random-effects (RE) and Mundlak (MK) estimators. Results in column (1) suggest that mobile phone use is positively and significantly associated with household income. After controlling for other factors, mobile phone users have 0.53 million UGX higher incomes than non-users, which is equivalent to a 32% difference. Due to possible selection bias, this difference cannot be interpreted as the causal effect of mobile phone use. The MK estimator in column (2) also yields a positive coefficient for the MP use dummy, but this is not statistically significant. As mentioned above, the efficiency of the MK estimator depends on data variation within households over time. The relatively small variation in the MP use dummy leads to larger standard errors, so

Table 2
Socioeconomic characteristics by mobile phone use.

	2012		2015		Pooled sample	
	Non-users (N = 90)	Users (N = 304)	Non-users (N = 38)	Users (N = 356)	Non-users (N = 128)	Users (N = 660)
Age of household head (years)	58.411	51.243***	63.184	54.416***	59.828	52.955***
	(16.659)	(13.033)	(12.585)	(13.318)	(15.666)	(13.272)
Education of household head (years)	4.789	7.227***	5.184	7.045***	4.906	7.129***
	(3.558)	(3.486)	(3.384)	(3.669)	(3.499)	(3.584)
Male household head (dummy)	0.644	0.796***	0.500	0.798***	0.602	0.797***
Migrant household (dummy)	0.278	0.204	0.079	0.157	0.219	0.179
Household size (AE)	4.273	5.512***	3.263	5.381***	3.973	5.441***
	(2.204)	(2.916)	(2.340)	(2.562)	(2.283)	(2.729)
Land owned (ha)	1.836	2.408***	1.691	2.308*	1.793	2.354***
	(1.183)	(1.860)	(1.036)	(2.143)	(1.139)	(2.017)
Distance to tarmac road (km)	15.864	16.455	15.037	15.122	15.618	15.736
	(11.329)	(11.622)	(11.114)	(10.179)	(11.229)	(10.879)
Residence in Masaka	0.256	0.589***	0.316	0.534***	0.273	0.559***

Mean values are shown with standard deviations in parentheses. AE, adult equivalents. Differences in means between users and non-users are tested for statistical significance.
** $p < .05$.
*** $p < .01$.
* $p < .1$.

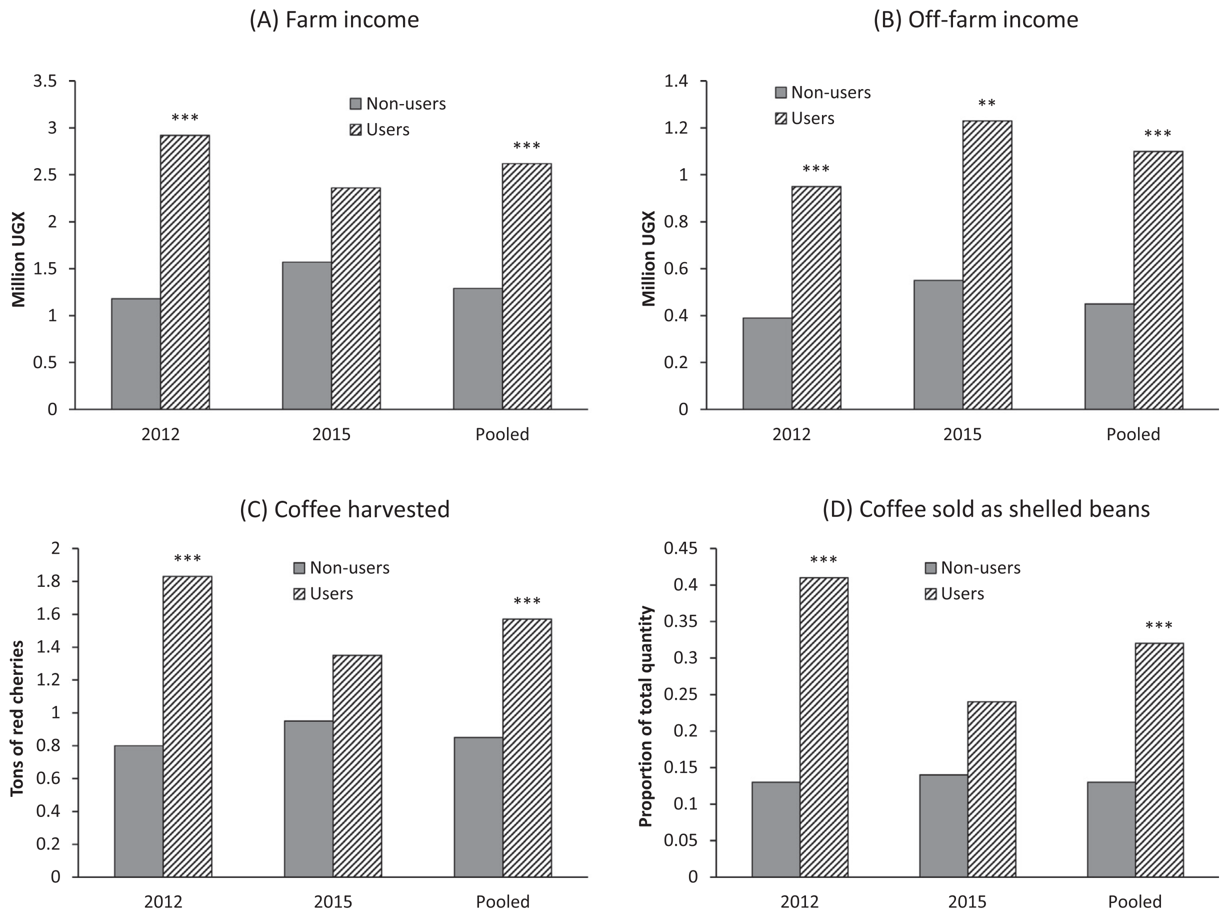

Fig. 1. Differences in income, agricultural production, and marketing between users and non-users of mobile phones. Differences in means between users and non-users are tested for statistical significance. ***p < .01, **p < .05.

Table 3
Household income, gender equality, and nutrition by mobile phone use.

	2012		2015		Pooled sample	
	Non-users	Users	Non-users	Users	Non-users	Users
Mobile phone use (MP)						
Income (million UGX)	1.471 (1.939)	3.515*** (3.477)	2.119 (3.374)	3.659** (3.575)	1.664 (2.173)	3.593*** (3.528)
Proportion of assets owned by women or jointly	0.469	0.555**	0.507	0.690***	0.479	0.628***
Household dietary diversity score (HDDS)	8.856 (1.969)	9.533*** (1.517)	8.342 (1.547)	9.244*** (1.445)	8.703 (1.863)	9.377*** (1.485)
Female mobile phone use (FMP)						
Income (million UGX)	2.510 (2.743)	3.559*** (3.695)	2.669 (2.851)	3.929*** (3.829)	2.575 (2.784)	3.769*** (3.772)
Proportion of assets owned by women or jointly	0.506	0.563*	0.615	0.701**	0.550	0.641***
Household dietary diversity score (HDDS)	9.135 (1.701)	9.609*** (1.577)	8.748 (1.624)	9.361*** (1.357)	8.978 (1.678)	9.469*** (1.461)

Mean values are shown with standard deviations in parentheses. Differences in means between users and non-users are tested for statistical significance.
*** p < .01.
** p < .05.
* p < .1.

it is possible that more variation or a larger sample would produce significant MK estimates. That mobile phones can have sizeable income effects was suggested in number of previous studies (Donner, 2007; Jensen, 2007; Muto and Yamano, 2009; Aker, 2010; Blauw and Franses, 2016).

Columns (3) and (4) of Table 4 show that mobile phone use is positively associated with gender equality. The RE and MK estimates for the MP use dummy are both statistically significant and almost identical in magnitude. Holding other factors constant, mobile phone use seems to increase the proportion of productive assets owned by women or jointly by women and men by 0.09, which is equivalent to a 19% increase over the mean female asset ownership in households without mobile phones. Such effects of mobile phones on gender equality were not analyzed before.

Results of the nutrition models with dietary diversity as dependent variable are shown in columns (5) and (6) of Table 4. The RE estimates

Table 4
Associations between mobile phone use, household income, gender equality, and nutrition.

	Income (million UGX)		Gender equality (proportion of assets)		Nutrition (HDDS)	
	(1)RE	(2)MK	(3)RE	(4)MK	(5)RE	(6)MK
MP use (dummy)	0.534***	0.388	0.089***	0.088***	0.314*	0.282
	(0.186)	(0.237)	(0.009)	(0.011)	(0.188)	(0.204)
Education of household head (years)	0.093***	−0.015	0.004	−0.003	0.068***	0.042
	(0.016)	(0.074)	(0.003)	(0.004)	(0.026)	(0.063)
Male household head (dummy)	0.741**	1.555***	−0.078***	−0.068	0.202***	1.495**
	(0.313)	(0.361)	(0.025)	(0.053)	(0.006)	(0.752)
Age of household head (years)	−0.015*	−0.022	−4.04E−5	0.001*	−0.009	−0.004
	(0.008)	(0.021)	(0.001)	(0.001)	(0.006)	(0.007)
Household size (AE)	0.044*	−0.071***	0.021***	0.019***	0.111***	0.068**
	(0.024)	(0.026)	(0.007)	(0.004)	(0.019)	(0.028)
Land owned (hectares)	0.546***	0.212**	−0.022**	−0.021***	0.033	0.101**
	(0.064)	(0.101)	(0.010)	(0.006)	(0.079)	(0.042)
Distance to tarmac road (km)	−0.009**	−0.004	−0.0003	−0.002	0.001	0.006
	(0.004)	(0.008)	(0.0004)	(0.003)	(0.003)	(0.021)
Migrant (dummy)	0.107	0.231	−0.059**	−0.031	−0.261***	−0.416**
	(0.317)	(0.415)	(0.030)	(0.051)	(0.081)	(0.185)
Masaka (dummy)	1.018***	1.057***	0.033***	0.023	−0.113**	−0.070*
	(0.063)	(0.087)	(0.010)	(0.015)	(0.054)	(0.036)
Year 2015 (dummy)	0.183	0.198	0.118***	0.117***	−0.267***	−0.277***
	(0.494)	(0.497)	(0.015)	(0.014)	(0.079)	(0.049)
Mundlak mean values						
Education of household head (years)		0.118		0.010		0.029
		(0.081)		(0.007)		(0.057)
Male household head (dummy)		−0.983***		−0.018		−1.499*
		(0.165)		(0.066)		(0.873)
Age of household head (years)		0.002		−0.002**		−0.007
		(0.029)		(0.001)		(0.012)
Household size (AE)		0.148***		0.002		0.067***
		(0.009)		(0.011)		(0.013)
Land owned (hectares)		0.501***		−0.005		−0.096
		(0.151)		(0.008)		(0.085)
Distance to tarmac road (km)		−0.012		0.002		−0.007
		(0.016)		(0.003)		(0.029)
Migrant (dummy)		−0.255		−0.069		0.343
		(0.314)		(0.055)		(0.250)
Constant	7.120***	7.328***	0.414***	0.415***	8.577***	8.735***
	(1.116)	(1.300)	(0.068)	(0.093)	(0.541)	(0.653)
Observations	788	788	788	788	788	788
No. of households	394	394	394	394	394	394

Notes: Coefficient estimates are shown with standard errors in parentheses. Standard errors are cluster-corrected at county level. RE, random-effects estimator; MK, Mundlak estimator; MP, mobile phone; UGX, Ugandan shillings; HDDS, household dietary diversity score; AE, adult equivalents.
*** $p < .01$.
** $p < .05$.
* $p < .1$.

show that mobile phone use is positively associated with HDDS, which is an indicator of household food security. The coefficient for the MP use dummy in the MK specification is similar in magnitude, but not statistically significant. Previous research hypothesized that mobile phone use may contribute to food security (Nakasone and Torero, 2016), although this hypothesis had not been tested before. Results with the 9 food group dietary diversity indicator are shown in Table A4 in the online appendix. With this alternative indicator, the RE and MK estimates are both statistically significant, suggesting that mobile phone use has positive effects on dietary quality.

As the gender equality and nutrition models have censored dependent variables, we re-estimated these models using a Tobit estimator as a robustness check (Table A5 in the online appendix). Results are very similar to those in Table 4, suggesting that variable censoring does not introduce any bias. In another robustness check, we re-estimated the models in Table 4 with additional interaction terms, to test whether the mobile phone effects depend on the level of other socioeconomic variables. Results are shown in Table A6 in the online appendix. Almost all of the interaction terms are statistically insignificant, suggesting that the specifications in Table 4 with a simple MP dummy included is appropriate.

3.3. Possible effects of female mobile phone use

So far, we have used household-level mobile phone use as the main explanatory variable in the models, regardless of who in the household actually owned and used mobile phones. Now we differentiate by the gender of mobile phone users and estimate the models described in Eq. (2). Results of these models are shown in Table 5. Columns (1) and (2) show that MP use alone has positive but insignificant effects on household income in these specifications. However, the interaction term with FMP produces large and significant coefficients, both in the RE and MK specifications. These results suggest that female mobile phone use has larger positive income effects than male mobile phone use, as hypothesized. Note that the additional effect of FMP use over male use alone is indicated by the interaction term itself, whereas the effect of FMP use over households that do not use MP at all is calculated as the sum of both dummy coefficients. For instance, the RE estimates in column (1) suggest that households in which at least one female adult owns and uses a mobile phone have close to 0.7 million UGX higher incomes than households where nobody owns and uses a mobile phone, implying a difference of 42%.

The effects on gender equality are shown in columns (3) and (4) of

Table 5
Associations between mobile phone use, household income, gender equality, and nutrition by gender of mobile phone users.

	Income (million UGX)		Gender equality (proportion of assets)		Nutrition (HDDS)	
	(1)RE	(2)MK	(3)RE	(4)MK	(5)RE	(6)MK
MP use (dummy)	0.306	0.192	0.073***	0.070***	0.082	0.075
	(0.272)	(0.305)	(0.015)	(0.019)	(0.304)	(0.319)
MP × FMP use (dummy)	0.389***	0.342***	0.029*	0.031	0.398**	0.362**
	(0.118)	(0.111)	(0.018)	(0.021)	(0.168)	(0.177)
Education of household head (years)	0.087***	−0.013	0.003	−0.003	0.061**	0.044
	(0.016)	(0.073)	(0.002)	(0.004)	(0.027)	(0.062)
Male household head (dummy)	0.822**	1.586***	−0.071***	−0.065	0.284***	1.528**
	(0.324)	(0.367)	(0.022)	(0.053)	(0.034)	(0.735)
Age of household head (years)	−0.015*	−0.022	−5.22E−5	0.001*	−0.009	−0.004
	(0.009)	(0.021)	(0.001)	(0.001)	(0.006)	(0.007)
Household size (AE)	0.039	−0.069***	0.020***	0.019***	0.105***	0.069**
	(0.024)	(0.026)	(0.007)	(0.004)	(0.018)	(0.029)
Land owned (hectares)	0.549***	0.212**	−0.022**	−0.021***	0.034	0.102***
	(0.065)	(0.095)	(0.010)	(0.005)	(0.077)	(0.038)
Distance to tarmac road (km)	−0.008	−0.006	−0.0002	−0.002	0.002	0.004
	(0.005)	(0.009)	(0.001)	(0.003)	(0.003)	(0.022)
Migrant (dummy)	0.093	0.239	−0.060*	−0.031	−0.271***	−0.408**
	(0.312)	(0.425)	(0.031)	(0.052)	(0.066)	(0.190)
Masaka (dummy)	1.001***	1.037***	0.031**	0.022	−0.130***	−0.092***
	(0.074)	(0.091)	(0.013)	(0.018)	(0.050)	(0.029)
Year 2015 (dummy)	0.133	0.151	0.114***	0.113***	−0.319***	−0.327***
	(0.494)	(0.493)	(0.017)	(0.017)	(0.078)	(0.058)
Mundlak mean values						
Education of household head (years)		0.109		0.009		0.020
		(0.079)		(0.007)		(0.052)
Male household head (dummy)		−0.933***		−0.014		−1.445*
		(0.135)		(0.063)		(0.817)
Age of household head (years)		0.002		−0.002**		−0.007
		(0.029)		(0.001)		(0.012)
Household size (AE)		0.138***		0.001		0.057***
		(0.010)		(0.011)		(0.019)
Land owned (hectares)		0.502***		−0.005		−0.095
		(0.146)		(0.008)		(0.079)
Distance to tarmac road (km)		−0.008		0.003		−0.003
		(0.017)		(0.004)		(0.029)
Migrant (dummy)		−0.293		−0.073		0.303
		(0.326)		(0.055)		(0.286)
Constant	7.126***	7.344***	0.415***	0.416***	8.586***	8.751***
	(1.120)	(1.295)	(0.067)	(0.093)	(0.556)	(0.671)
Observations	788	788	788	788	788	788
No. of households	394	394	394	394	394	394

Coefficient estimates are shown with standard errors in parentheses. Standard errors are cluster-corrected at county level. RE, random-effects estimator; MK, Mundlak estimator; MP, mobile phone; FMP, female mobile phone use; UGX, Ugandan shillings; HDDS, household dietary diversity score; AE, adult equivalents.

*** $p < .01$.

** $p < .05$.

* $p < .1$.

Table 5. Interestingly, mobile phones seem to improve gender equality even in households where only male members use this technology. This is plausible, as women's status within the household depends to a large extent on the attitudes of male household members. It is possible that better access to information and more social exchange through mobile phones gradually contributes to changes in men's attitudes towards gender roles. However, the effect on gender equality increases when female household members also own and use mobile phones. At least in the RE estimates in column (3) this additional effect is statistically significant. The combined effect suggests that in households where at least one female adult uses a mobile phone the proportion of assets owned or co-owned by women is 0.1 (21%) higher than in households where nobody uses a mobile phone.

The results in columns (5) and (6) of Table 5 suggest that male mobile phone use alone has insignificant effects on household nutrition, but female mobile phone use affects food security and nutrition in a positive way. These results also hold when looking more specifically at dietary quality with the 9 food group indicator (Table A4 in the online appendix).

That the effects of male mobile phone use on household income and nutrition are not statistically significant should not be over-interpreted. First, many male adults had already adopted MP prior to the first survey round in 2012, so the observed variation over time was smaller than for FMP use. Possibly the effects of male MP use would have been larger if the first-round data had been collected a few years earlier. Second, in many households male and female members both use mobile phones, and these cases are captured by the FMP dummy. Nevertheless, that female mobile phone use seems to matter more for household welfare than male mobile phone use is a remarkable finding and in line with our hypothesis on gendered implications. Women benefit over-proportionally from the use of mobile phone technologies, and larger economic gains are also reflected in enhanced gender equality within the household and better household nutrition.

3.4. Towards explaining possible mechanisms

We now estimate the models explained in Eqs. (3) and (4) to gain further insights into possible mechanisms underlying the mobile phone effects on household nutrition. Results are shown in Table 6. All models shown have the household dietary diversity score (HDDS) as dependent

Table 6
Possible mechanisms underlying the effects of mobile phone use on nutrition.

	Household dietary diversity score (HDDS)					
	(1)	(2)	(3)	(4)	(5)	(6)
MP use (dummy)	0.314*			0.207		0.108
	(0.188)			(0.153)		(0.219)
FMP use (dummy)		0.397***			0.321**	0.301*
		(0.133)			(0.138)	(0.179)
Household income (million UGX)			0.172***	0.168***	0.164***	0.163***
			(0.053)	(0.051)	(0.053)	(0.052)
Gender equality (proportion of assets)			0.236***	0.215**	0.207**	0.197*
			(0.092)	(0.104)	(0.100)	(0.112)
Education of household head (years)	0.068***	0.063**	0.054***	0.052***	0.047**	0.047**
	(0.026)	(0.029)	(0.019)	(0.019)	(0.021)	(0.021)
Male household head (dummy)	0.202***	0.300***	0.096	0.089	0.170*	0.162
	(0.006)	(0.009)	(0.082)	(0.085)	(0.093)	(0.100)
Age of household head (years)	−0.009	−0.010**	−0.007*	−0.006	−0.007*	−0.007
	(0.006)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Household size (AE)	0.111***	0.107***	0.104***	0.099***	0.095***	0.093***
	(0.019)	(0.020)	(0.027)	(0.026)	(0.027)	(0.025)
Land owned (hectares)	0.033	0.038	−0.051	−0.055	−0.050	−0.053
	(0.079)	(0.079)	(0.067)	(0.065)	(0.064)	(0.064)
Distance to tarmac road (km)	0.001	0.001	0.002	0.002	0.003	0.003
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Migrant (dummy)	−0.261***	−0.274***	−0.262***	−0.262***	−0.274***	−0.273***
	(0.081)	(0.068)	(0.078)	(0.077)	(0.061)	(0.060)
Masaka (dummy)	−0.113**	−0.110**	−0.267***	−0.291***	−0.290***	−0.301***
	(0.054)	(0.045)	(0.099)	(0.100)	(0.092)	(0.095)
Year 2015 (dummy)	−0.267***	−0.284***	−0.298***	−0.323***	−0.342***	−0.352***
	(0.079)	(0.096)	(0.040)	(0.067)	(0.017)	(0.042)
Constant	8.577***	8.619***	7.401***	7.292***	7.329***	7.277***
	(0.541)	(0.332)	(0.532)	(0.581)	(0.485)	(0.567)
Observations	788	788	788	788	788	788
No. of households	394	394	394	394	394	394

Coefficient estimates are shown with standard errors in parentheses. Standard errors are cluster-corrected at county level. All models estimated with a random-effects estimator. MP, mobile phone; FMP, female mobile phone use; UGX, Ugandan shillings; AE, adult equivalents.

*** $p < .01$.

** $p < .05$.

* $p < .1$.

variable. In columns (1) and (2), we include MP and FMP as separate dummies together with the other socioeconomic control variables. These results are mainly shown for comparison and as a reminder that mobile phone use – and especially mobile phone use by females – is positively and significantly associated with household dietary diversity. The model in column (3) excludes MP and FMP but includes household income and gender equality instead. Both these variables have significantly positive effects on dietary diversity, suggesting that income gains and women empowerment contribute to food security in smallholder households. We showed previously that MP use and FMP use have positive effects on income and gender equality, implying that some of the effects of mobile phones on nutrition are channeled through these two pathways.

In columns (4), (5), and (6) of Table 6, we include the mobile phone dummies together with income and gender equality to test the existence of other possible mechanisms. The coefficients of income and gender equality remain significant, but they decrease in comparison to column (3), as one would expect given that we now control for mobile phone use. The coefficients for the MP and FMP dummies are also smaller than those in columns (1) and (2), as one would expect as well. The MP use dummy in columns (4) and (6) turns insignificant, which could be an indication that the nutrition effects of mobile phones are primarily channeled through the income and gender equality pathways. However, the FMP dummy remains significant in columns (5) and (6), suggesting that other pathways also play a role. As discussed above, better access to nutrition and health information through mobile phones may influence dietary choices directly. And this information pathway seems to be stronger when female household members use mobile phones, as females are often the ones making dietary choices for the household.

4. Conclusion

Mobile phone technologies have spread very rapidly in rural Africa and other parts of the developing world. While previous studies had analyzed effects of mobile phone use on economic indicators – such as input and output prices, profits, and income – research on implications for broader social development is scarce. Better understanding social welfare effects is of particular importance against the background of the United Nations' Sustainable Development Goals. In this article, we have used data from farm households in Uganda to analyze associations between mobile phone use, household income, gender equality, and nutrition. Gender equality was measured in terms of the proportion of household productive assets owned by females or jointly by female and male household members, as opposed to ownership by male members alone. Nutrition was measured in terms of two dietary diversity scores that portray food security and dietary quality.

Results showed that mobile phone use is positively and significantly associated with household income, gender equality, and nutrition, also after controlling for possible confounding factors. Gender disaggregation further revealed that female mobile phone use is more strongly associated with household income and social welfare than male mobile phone use alone. Women seem to benefit over-proportionally from mobile phone technologies, which is plausible given that women are often particularly constrained in their access to markets and information. Hence, a new technology that helps reduce transaction costs and allows new forms of communication can be particularly advantageous for women. Higher incomes and better access to information for women positively influence their bargaining position within the household, thus also improving gender equality and nutrition.

The identified associations are plausible and consistent with economic theory. Nevertheless, some caution is warranted not to over-interpret in a causal sense, because the identification strategy is imperfect. We used observational survey data, so that selection bias cannot be ruled out completely. The panel structure of the data helped to reduce bias to some extent. In particular, we tried to control for unobserved heterogeneity through using the Mundlak estimator with pseudo fixed effects. However, this approach can only control for time-invariant heterogeneity, meaning that possible problems with time-variant unobserved factors remain. Another limitation is that the variation in the mobile phone use data was somewhat limited. Our panel data only included two survey rounds, covering a time span in which many of the rural households in Uganda had already adopted mobile phones. Adoption rates further increased between the first and the second survey round, but an earlier baseline survey with lower adoption rates would have led to larger data variation and possibly different and more efficient results. Unfortunately, such baseline data were not available.

In spite of these limitations, we cautiously conclude that mobile phone technologies can improve household living standards, gender equality, and nutrition in rural areas, especially when women have access to mobile phones. Of course, results from one specific setting should not be widely generalized, but the smallholder households surveyed in Central Uganda are quite typical for the African small-farm sector in terms of farm sizes, access to infrastructure and markets, gender roles, mobile phone adoption, and other social parameters. Hence, some broader lessons can be learned. Follow-up studies in other settings and with better data and methodologies will certainly be useful to corroborate the findings and further extend the research direction.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodpol.2017.10.004.

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