携帯電話がアフリカの農家の市場参加に与える影響：ウガンダのパネルデータより
The impact of mobile phone coverage expansion on market participation：panel data evidence from Uganda[＊1]

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要　旨

ウガンダでは近年、携帯電話の電波が届くエリアが急速に拡大した。携帯電話の電波が届くようになると、その地域で交わされる情報の量が増える。具体的には、携帯電話を所有する仲買人が農産物をより活発に集荷するようになり、バナナ（主食の１つ）のように鮮度が重要な農産物に関し、農家がより市場に参加するようになる。この効果は、市場から距離的に遠く、携帯電話なしでは情報量の小さい地域で大きいと期待される。この論文では、94村856家計から収集したパネルデータを用いる。データが収集された２時点、つまり、2003年と2005年の間に携帯電話の電波が届くエリアはサンプル94村中の41村から87村へと急拡大した。新たに電波が届いた地域でかつ市場から20マイル以上離れたところでは、バナナを販売した生産農家は50％から69％に上昇した。メイズ生産農家ではこのような変化は見られなかった。メイズはバナナに比べて、鮮度が重要ではないからである。以上により、携帯電話の電波が届くエリアの拡大は、鮮度が重要な農産物を生産し、かつ、市場から遠い地域にいる農家の市場参加を促進すると推察される。

ABSTRACT

Uganda has recently experienced a rapid increase in the areas covered by mobile phone networks. As the information flow increases due to the mobile phone coverage expansion, the cost of crop marketing is expected to decrease, particularly more so for perishable crops, such as banana, in remote areas because the increased information allows traders to collect perishable products more efficiently. We use panel data of 856 households in 94 communities, where the number of communities covered by mobile phone networks increased from 41 to 87 over a two-year period between the first and second surveys in 2003 and 2005, respectively. We find that the proportion of banana farmers who sold banana increased from 50 to 69 percent in the communities more than 20 miles away from district centers after the expansion of the mobile phone coverage. For maize, which is another staple but less perishable crop, we find that the increased mobile phone coverage did not affect market participation. These results suggest that mobile phone coverage expansion induces market participation of farmers who are located in remote areas and produce perishable crops.

＊1　This is a working level paper for discussion purpose.

1. Introduction

One important route to reduce poverty in rural areas is to enhance the market participation of rural farmers, as this can increase the net returns to agricultural production (World Bank, 2007). Many farmers in Sub-Saharan Africa, however, remain subsistence farmers whose production activities are conducted mainly for home consumption (Verheye, 2000). In the case of Uganda, one-third of farmers surveyed in 1992/93 were subsistence or autarky farmers, and the rest marketed less than 10 percent of their output (Larson and Deininger, 2001). One reason for remaining at the subsistence farming level is the high cost of marketing. Better access to information is expected to reduce such costs and to encourage farmers to participate in markets by increasing the returns to their products. For instance, a study of fishermen in India finds that mobile phones help fishermen choose a fish market where they can sell their fish for the highest price (Jensen, 2007).

In recent years, mobile phone networks have been expanding in many African countries, including Uganda. In 2004, the average number of mobile phone units per 100 inhabitants in Africa reached 9.1, with an annual growth rate during 1999 to 2004 of 59.7% (ITU, 2006). Although increased access to information via mobile phones can potentially increase farmers' market participation in remote areas, no study thus far has investigated on the impacts of mobile phone network expansion on the market participation of farmers.

The purpose of this study, therefore, is to estimate the impact of mobile phone network expansion on farmers' market participation in Uganda. In Uganda, the mobile phone network coverage expanded from 46.0% of the population in 2003 to 70.0% in 2005 (ITU, 2006). In this study, we use panel data of 856 households in 94 communities across the country, except north regions. During the two-year period between the first survey in 2003 and the second survey in 2005, we find that the mobile phone network expanded from 41 to 87 communities out of the 94 sample communities. The mobile phone network was not yet available in the remaining nine communities even in 2005. We expect that the increased flow of information has a larger impact on the marketing of perishable products than cereals because the prices of perishable products depend highly on freshness at the time of exchange. The mobile phone network can help both producers and traders transport and market perishable products quickly to avoid spoilage. In Uganda, banana (matooke) is an important staple crop and is highly perishable (Smale and Tushemereiruwe, 2007). Thus, we expect to find a larger impact of improved information flow on the crop marketing of banana than maize, which is another important staple crop but is much less perishable than banana. In terms of farm-gate prices, the mobile phone coverage by itself may not increase the farm-gate prices of perishable crops fully if there is information asymmetry between traders and farmers. Traders may keep a large marketing margin if farmers are not aware of the market price. Thus, we estimate the impacts of the mobile phone network expansion on the farm-gate prices of banana and maize.

In the next section, we review previous studies linking market access to poverty, as well as impact assessments of telecommunications. Section 3 presents the conceptual framework. Section 4 presents the data, descriptive statistics, and the estimation method. The estimation results are reported in Section 5, followed by and the conclusion and discussion in Section 6.

2. Literature Review

Previous empirical studies on the geographical concentration of poverty show a positive relationship between remoteness and poverty. Stifel et al. (2003) find that the incidence of poverty in rural Madagascar increases with remoteness. Minot (2005) indicates that poverty is positively associated with the distance to regional urban centers in Tanzania. These studies, however, only identify an association between remoteness and poverty in cross-sectional data, not a causal relationship between the two.

Regarding the impact of mobile phone networks on poverty reduction, there are some anecdotal articles. Jensen (2007), however, is the only study, as far as we are aware of, that rigorously identifies the impact of the introduction of mobile phones on marketing in developing countries. He shows that fishermen in India increase arbitrage among local fish markets after the introduction of mobile phones, leading to a decrease in the variation in fish prices and a reduction of spoilage.

Existing studies with similar attention to telecommunications (mostly landline) include Chong et al. (2006) reporting that public telephone usage is positively linked with income by using quasi-natural experiment data from Peru, and Tolero et al. (2006) showing that household's willingness to pay for public telephone service is higher than the tariff rate in the cases of Peru and Bangladesh. Bayes (2001) reports that agricultural output prices are higher in the Bangladesh villages with pay phones than those without them. Building on a trader survey, Overa (2006) reports that traders reduce food spoilage by marketing them efficiently by using telephones.

In Uganda, some 2.5 million smallholder households produce 94% of the total agricultural production and constitute 80% of the employed population. Using cross section household/community data collected in 1992/93 in Uganda, Larson and Deininger (2001) show that (landline) telephone variables have significant impacts on the difference between district and local prices. Fan et al. (2004) find that the Ugandan government's expenditure on rural roads has a substantial impact on rural poverty reduction. Pender et al. (2004), however, find little evidence between access to markets and output value in rural Uganda. No studies have yet estimated the impacts of mobile phone network expansion on the market participation of farmers in Uganda.

In addition, most previous studies are in reduced form, linking the telephone network expansion with welfare indicators such as income or expenditure, but do not explicitly consider pathways in which better access to information increases income through farmgate price or through increases in production. The purpose of this study, therefore, is to estimate the impact of the mobile phone network expansion on market participation and income in Uganda, by using panel data. We compare the changes in price and market participation over the two surveys in 2003 and 2005 between areas that were covered already by the mobile phone network at the time of the first survey and areas that were covered by the network in between the first and second surveys.

3. Conceptual framework

Suppose that the farm gate price of farmer i at time t of commodity j is defined as $p_{itj}^{FG} = p_{tj}^{M} - \gamma_j(I_t)\tau_i$ (Figure 2). p_{tj}^{M} is the market price of commodity j at the district center at time t. τ_i is a measure of the transportation related cost, which is proportional to the distance between the market and farmer i. We assume that $\gamma_j(I_t)$

is the sensitivity of the output price of commodity j with regard to the distance to market. As the information, I_t, increases by one unit, $\gamma_j(I_t)$ decreases: $\frac{\partial \gamma_j(I_t)}{\partial I_t} < 0$. The mobile phone coverage increases the flow of information and thus the efficiency in marketing, leading to a lower level of $\gamma_j(I_t)$. The marginal change in $\gamma_j(I_t)$ due to a one unit increase in information, I_t, is expected to be larger for perishable crops, such as banana, than for cereals, such as maize. Thus,

$$\left|\frac{\partial \gamma_B(I_t)}{\partial I_t}\right| > \left|\frac{\partial \gamma_M(I_t)}{\partial I_t}\right|,$$

where γ_B is for banana and γ_M is for maize. The potential gain for farmers when the information flow increases and the market price remains the same can be derived as follows:

$$\begin{aligned}\Delta p_{itj}^{FG} &= p_{i1j}^{FG} - p_{i0j}^{FG} \\ &= p_{1j}^{M} - \gamma_j(I_1)\tau - p_{0j}^{M} + \gamma_j(I_0)\tau \\ &= -\{\gamma_j(I_1)\tau - \gamma_j(I_0)\}\tau\end{aligned}$$

where $I_1 > I_0$ and $\{(\gamma(I_1) - \gamma(I_0))\} < 0$ so that $\Delta p_{itj}^{FG} > 0$.

In practice, traders use mobile phones to set up a time and a place to trade banana, according to our field surveys. When the mobile phone network is not available, traders usually visit banana producing areas without any prior announcement and spend several days to fill up their trucks with banana. When the area is covered by a mobile phone network, however, the traders can contact banana producing communities in advance to set up a time and a place to collect banana and fill up their trucks quickly. Fresh bananas collected this way can fetch higher prices at urban markets and have less spoilage. In addition, traders can increase the frequency of their collecting activities.

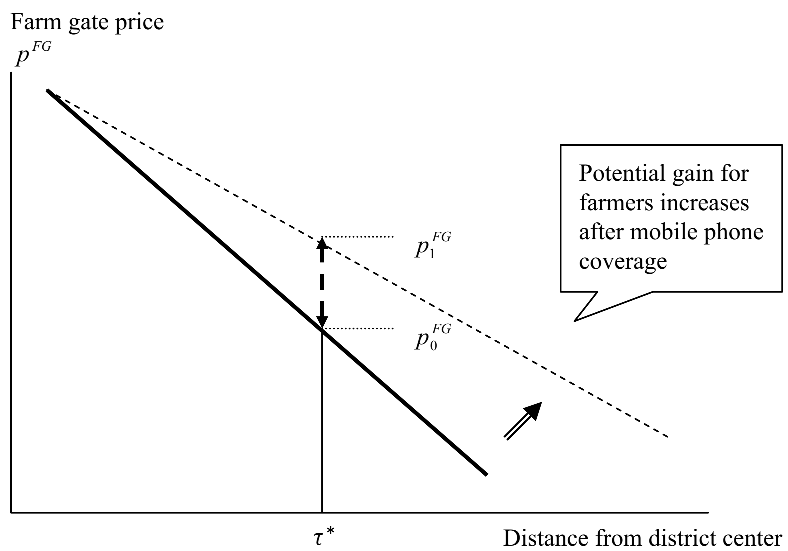
The potential gain, Δp_{itj}^{FG}, is expected to be captured by farmers if there is competition among traders. The competition among traders to whom the farmers sell their products will increase the actual farm-gate price, which would exceed the reservation price of farmers. In contrast, if a trader has monopoly power in an area and has more market information than farmers, the trader may keep the actual farm-gate price just a little above the reservation price of the farmers, so that the farmers sell their products but with little gain. This is more likely to occur in remote areas, where price information is less diffused.

Therefore, when information asymmetry between traders and farmers remains in favor of the traders, actual farm gate prices are not expected to increase significantly although the market participation of farmers is expected to increase. This is different from the case of the fishermen in India discussed in Jensen (2007), where both producing and marketing activities are conducted by the same fishermen.

Since mobile phones can provide price and other market information regardless of the distance from the market centers, it seems reasonable to hypothesize that the expansion of the mobile phone network has a larger impact on farmers' marketing in areas farther away from the district center than those in areas near the district center, where local markets are usually located and market information flows even without mobile phones. This hypothesis is depicted in Figure 2. The impact is expected to be large in the case of perishable crops, such as banana, for which freshness at time of exchange determines the sales value to a significant extent. As we have discussed, this does not guarantee that the actual farm-gate price approaches fully to its potential level if traders are not competitive and there exists information asymmetry between the farmers and the traders.

Figure 1：Mobile phone network coverage expansion in Uganda

Figure 2：Conceptual Banana Price Schedule and Impact of Mobile Phone Coverage Expansion



4. Data, descriptive analysis and estimation method

4.1 Data and descriptive analysis

This paper uses data from household and community surveys in Uganda collected as part of the Research on Poverty, Environment, and Agricultural Technology (R*e*PEAT) project. The surveys were jointly conducted by Makerere University, the Foundation for Advanced Studies on International Development (FASID), and the National Graduate Institute for Policy Studies (GRIPS) in 2003 and 2005. The surveys cover 29 districts in the West, Central, and East regions of Uganda, representing the major farming systems of the country. In 2003, the baseline survey collected information from 94 Local Counsel (LC1)s[*2] and ten households from each LC1, making a total of 940 households. In 2005, a follow-up survey of the 940 households was conducted, and 856 households were interviwed successfully. In both surveys, household and community surveys were conducted. The dataset is unique in including data on spatial location and infrastructure such as distance to district centers/market, information on the mobile phone network availability as well as mobile phone possession by the sample households.

We stratify our samples by the mobile network coverage in Table 1. We find that about 42 percent of the sample households were covered already by the mobile phone network by the time of the 2003 survey. By the time of the second survey in 2005, 92 percent of the total households were covered by the mobile phone network. As for the household mobile phone ownership, only 4.3 percent of the households possessed at least one unit in 2003, while in 2005 the percentage increased to 11.5 percent.

We further stratify our sample of banana farmers in Table 2 into two groups according to the timing of the mobile phone coverage and present the ratio of households who have sold crops and the ratio of sales out of production. The first group is the households who were covered by the network at the time of the 2003 survey, and the second group is the households who attained covererage by the network between the 2003 and 2005 surveys. We exclude 68 households who have never been covered by the network to simplify our analysis in Table 2. Then, we further stratify our samples by the distance to the district center, where markets are usually located, because we think that the impacts of the mobile phone network on crop sales would depend on the distance to markets.

In the case of banana, we find a large increase in the ratio of households selling banana in locations more than 20 miles away from the district centers. The proportion of households who sold banana increased from 50 percent in 2003 to 68.8 percent in 2005 in locations where the mobile phone network became available after the 2003 survey. We also find that the proportion of banana sales out of production increased by 11.7 percentage points among the same group. In contrast, the proportion of households who sold banana increased only by 3.8 percent in locations where the mobile phone network was already available in 2003. Thus, we conjecture that the mobile phone network increased banana sales in these locations.

Table 3 is the case of maize. For areas newly covered by the mobile phone network sometime between 2003 and 2005, we find an increase in the ratio of sellers among producers

＊2 LC1 is the smallest administrative unit in Uganda.

Table 1：Mobile Phone Network Coverage and Ownership

Region	Number (%) of households	Number (%) of sample households by mobile phone network coverage			Proportion (%) of households who own mobile phone units	
		2003 and 2005	Only in 2005	Never covered	2003	2005
Eastern	383 (44.7)	133 (34.7)	221 (57.7)	29 (7.5)	2.6	8.6
Central	250 (29.2)	123 (49.2)	127 (50.8)	0 (0)	8.0	17.6
Western	223 (26.0)	107 (47.9)	77 (34.5)	39 (17.4)	3.1	9.8
Total	856 (100)	363 (42.4)	425 (49.6)	68 (7.9)	4.3	11.5

Table 2：Ratio of Banana Sellers and Sales by Mobile Phone Coverage

Mobile coverage		Ratio of sellers among producers (%)			Ratio of sales among production (%)		
		2003	2005	Dif. (t-value)	2003	2005	Dif. (t-value)
All locations	N/Y	48.3	53.4	5.1 (−1.19)	20.1	24.6	4.5^{**} (−2.14)
	Y/Y	54.0	50.7	−3.3 (0.12)	19.6	22.8	3.2^{**} (−2.06)
More than 20 miles	N/Y	50.0	68.8	18.8^{**} (−2.13)	18.4	30.1	11.7^{***} (−2.66)
	Y/Y	67.3	71.1	3.8 (0.00)	24.5	30.5	6.0 (0.19)
Less than 20 miles	N/Y	47.6	46.1	−1.5 (−0.13)	20.8	22.0	1.2 (−1.01)
	Y/Y	50.9	46.5	−4.4 (0.12)	18.5	21.2	2.7^{**} (−2.26)

Note: N/Y indicates the group of households that were not covered by the mobile phone network in 2003 but covered in 2005. Y/Y indicates the group of households that were covered by the mobile phone network both in 2003 and 2005. *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively.

by 4.8 percentage points from 47.5% to 52.3% in locations closer than 20 miles from the district center, rather than an increase in remote locations. The proportion of maize sales out of production does not show any significant difference regardless of the mobile phone coverage expansion.

4.2 Estimation Method

In the following sections, we estimate the determinants of (1) the possession of mobile phones at the household level, (2) the 2005/2003 price ratio of banana and maize, (3) the banana and maize market participation, (4) the proportions of sales out of the total production of ba-

Table 3：Ratio of Maize Sellers and Sales by Mobile Phone Coverage

Mobile coverage		Ratio of sellers among producers (%) 2003	2005	Dif. (t-value)	Ratio of sales among production (%) 2003	2005	Dif. (t-value)
All locations	N/Y	48.5	52.0	4.5* (−1.73)	25.2	24.4	−0.8 (−0.47)
	Y/Y	51.8	50.9	−0.9 (0.38)	24.7	24.2	−0.5 (0.91)
More than 20 miles	N/Y	51.1	51.3	0.2 (−0.53)	28.0	24.7	3.3 (−0.64)
	Y/Y	69.7	65.8	−3.9 (0.43)	38.2	37.1	−1.1 (1.17)
Less than 20 miles	N/Y	47.5	52.3	4.8* (−1.67)	24.2	24.3	0.1 (−0.19)
	Y/Y	48.4	48.2	−0.2 (0.26)	22.1	22.0	−0.1 (0.38)

Note: N/Y indicates the group of households that were not covered by the mobile phone network in 2003 but covered in 2005. Y/Y indicates the group of households that were covered by the mobile phone network both in 2003 and 2005. *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively.

nana and maize, and (5) income. As explanatory variables, we include the 2005 survey year dummy, *yr05*, the dummy for the community level mobile phone network coverage, *LC1mob*, and the distance from the community to the nearest district center, *miles*. The interaction term between the community level mobile phone coverage and the community level distance to the district center, *LC1mob**miles*, is also included to examine the combined effect of mobile coverage and distance to market.

First, we estimate the determinants of the household level possession of mobile phones:

$$\mathrm{pr}(HHmob=1)_{it}=\beta_0+\beta_1 yr05_t+\beta_2 LC1mob_{jt}+X_{it}\beta_k+Z_{jt}\beta_l+\alpha_i+\varepsilon_{it},$$

where t = 2003 and 2005, X_{it} is a set of household characteristics, Z_{jt} is a set of community characteristics, and α_i is time-invariant unobserved household and community characteristics. First, we estimate this model with the Probit model because the dependent variable is a dummy variable, which takes one if the household possesses at least one mobile phone unit. Then, to estimate a more precise estimator of the impact of the mobile phone coverage at the community level, we estimate the same model with the household level fixed effects (FE) model. By estimating the FE model, we eliminate any biases caused by the time-invariant unobserved household and community characteristics.

In the following models, we estimate the impacts of the mobile phone coverage at the community level and the mobile phone possession at the household level on crop marketing. Because the mobile phone possession at the household level is endogenous, we treat it as an endogenous variable by applying the fixed effects instrumental variables (FE-IV) model. We use interaction terms between the dummy variable for the mobile phone coverage at the community level, which is time-variant, and the initial household characteristics, which are time-invariant, as instrumental variables. Because we apply the household level FE models, the initial household characteristics are excluded from the FE models. Thus, we can use them as IVs when they are interacted with the community level mobile phone network coverage. We use the following four household characteristics: the farm asset value in log, the age of household head, the education level of male adults, and the education level of female adults. These household characteristics are strongly correlated with the mobile phone possessions as we show later in this study.

Second, the farm-gate price is expected to increase as the mobile phone network helps farmers and traders to reduce marketing costs. To confirm this hypothesis, we estimate the following model:

$$p_{i05}^{FG} / p_{i03}^{FG} = \beta_0 + \beta_1 LC1mob_j + \beta_2 LC1mob_j{}^{*} miles_j + \beta_3 miles_j + \varepsilon_{it}$$

The coefficient of the mobile phone network is positive. The sign of the coefficient of the interaction term between the mobile phone coverage and the distance to the district center is not clear a priori. It depends on who gains from the reduced marketing cost. If the information asymmetry between farmers and traders allows the traders to retain the majority of the efficiency gain, the farm-gate price may not increase in remote areas where such information asymmetry exists without mobile phones.

Third, on the determinants of the market participation, we estimate the following model with the household FE-IV model:

$$\begin{aligned} \mathrm{pr}(S_i > 0)_{it} = \beta_0 + \beta_1 HHmob_{it} + \beta_2 LC1mob_{jt} \\ + \beta_3 LC1mob_{jt}{}^{*} miles_j + \beta_4 yr05_t \\ + X_{it}\beta_k + Z_{jx}\beta_l + \alpha_i + \varepsilon_{it} \end{aligned}$$

Our hypotheses suggest that the estimated coefficients of the mobile phone variables would be larger on banana marketing than maize marketing because banana is more perishable than maize, and that there are larger margins to be reduced in banana than maize. Further, we hypothesize that the impact is larger in areas farther away from the district center and, hence, the estimated coefficient of the interaction term between the mobile phone coverage and the distance from the district center is expected to be positive. Note that because producers decide whether they sell their products by comparing their reservation price and the actual farm gate price, household characteristics are important determinants of the market participation. Because we estimate the household level fixed effects model, however, the fixed household characteristics are excluded from the fixed effects models. Following the same estimation strategy, we estimate the same model for the decision on the rate of the sales out of the production for banana and maize. Finally, we estimate the same model on the banana income by replacing the dependent variable with the banana production income, which is the difference between the banana production value and the paid-out costs, which do not include unpaid family labor.

Regarding the independent variables, we use mostly community level variables. First, we use the community level mobile phone network coverage variable, *LC1mob*. The mobile telephone network in Uganda rapidly expanded between the survey years. As we discussed earlier, in 2003, around 42% of the communities responded that they had mobile phone coverage, while in 2005 about 92% of the communities did. The earliest coverage by the mobile network among our sample communities was in 1995. Regarding the household level mobile phone possession, *HHmob*, 11.5% of the households possess handsets in 2005, while it is about 4.3% in 2003.

As many as 88% of the communities surveyed in 2005 responded that they are connected to the nearest district town by all season tarmac or dirt roads. In 2003, the corresponding number was 84%. When asked if it is possible to drive there, 97% of the communities responded that it was possible both in 2005 and 2003. This suggests that the road condition in the surveyed communities did not change much between 2003 and 2005. Thus, we use the 2003 distance from the community center to the district center in the analyses.

5. Results

We first present the estimation results on the determinants of household mobile phone possession in Table 4. The Probit result suggests that the probability of possessing mobile phones increases by 2.5 percentage points if the community is covered by the mobile phone network. The magnitude of the impact increases to 5.4 points when the household FE model is used. This suggests that the Probit coefficient is under-biased due to unobserved fixed effects. The year dummy for 2005 is also under-biased in the Probit model. According to the FE model, the probability of possessing mobile phones increases by 4.2 points in 2005.

Among household characteristics, the total value of farm related assets and the education level of both male and female household members increase the possession significantly. The age of the household head has a negative impact, suggesting that households with young heads have mobile phones. We do not include these household characteristics in the FE model because these variables are initial household characteristics and fixed over time. Because these initial household characteristics do not belong to the FE models, they can be used as instrumental variables when they are multiplied by the mobile phone coverage dummy which is time-variant. When the network covers a community, we expect that households with more assets and higher education levels are more

Table 4：Determinants of Household Mobile Possession

	Household mobile possession with mobile coverage dummy	
	Probit	Household Fixed Effects
Year 05 (=1)	0.024 (3.33)***	0.042 (4.08)***
Mobile coverage dummy	0.025 (3.51)***	0.054 (3.80)***
Household Characteristics		
Size of household	0.010 (1.13)	
Number of male adults	−0.013 (−1.38)	
Number of female adults	−0.013 (−1.36)	
Number of boys	−0.003 (−1.07)	
Number of girls	0.001 (0.55)	
Age of household head	−0.001 (−4.06)***	
Gender of head (fem=1)	−0.001 (−1.05)	
Widowed household (yes=1)	0.022 (1.12)	
Education of male adults	0.004 (4.21)***	
Education of female adults	0.005 (5.65)***	
ln (land size)	−0.001 (−0.51)	
ln (farm assets value)	0.014 (6.50)***	
# of observations	1,755	1,755

Note: Coefficients are marginal changes in the probability. Numbers in parentheses are t-values. *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively.

likely to possess mobile phones than others with fewer assets and lower education levels. Thus, in the following analyses, we use four interaction terms between the mobile phone coverage and four household characteristic variables, farm assets, age of household head, male education, and female education, as instrumental variables.

In Table 5, we present the OLS results on the price ratio (2005/2003) of banana and maize. We include only those households who have sold banana (or maize) in both 2003 and 2005 in the analyses. By using the price ratio of the same household over time, we can estimate the impacts of the mobile phone coverage on the farm-gate price, while controlling for household and community characteristics and also the quality of banana.

The mobile phone network expansion by itself has a positive and significant impact on the price ratio of banana. This suggests that farmers gain from efficient marketing after the expansion of the mobile phone coverage. The interaction term between the distance to the district center and the mobile phone coverage, however, has a negative coefficient for banana. This suggests that the price gain for farmers is larger in areas close to the district center. Farmers in remote areas may not be informed about the banana price as much as farmers close to the district centers even after being covered by the mobile phone network. Thus, traders may be able to keep the banana price just higher than the reservation price so that farmers sell banana but not obtain the full potential gain. In contrast to the banana results, we do not find any significant impacts of the mobile phone network on the maize price ratio. The mobile phone network may not have a significant impact on maize marketing because maize is not so perishable.

The results on the mobile phone possession at the household level suggest that the possession increases the probability of banana sales by 20 percentage points (columns 1 and 2). Although this result is based on the fixed effects models and not biased by unobserved time-invariant household characteristics, it is still possible that it is biased by the unobserved time-varying household characteristics. When we apply the fixed effects instrumental variables model in column 3, we find that the coefficient of the household mobile phone possession shrinks in magnitude to 0.15 and is no longer

Table 5：2005/2003 Price Ratio at Household Level: Banana and Maize[*1]

Variables	Price ratio of Banana (05/03)	Price ratio of Maize (05/03)
Mobile Coverage dummy	2.015**	−0.258
	(2.42)	(−1.15)
Distance to district center (miles) x Mobile Coverage	−0.918**	0.011
	(−2.36)	(1.08)
Distance to district center (miles)	0.083**	−0.010
	(2.53)	(−1.30)
Constant	0.074	1.185***
	(0.12)	(8.13)
# of observations	107	98

Note: Samples include only those households who sold banana (or maize) in both 2003 and 2005. By using the price ratio of the same household, we can estimate the impacts of the mobile phone coverage on the farm-gate price, while controlling for household and community characteristics. Numbers in parentheses are t-values. *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively.

statistically significant. Thus, although the results in Table 6 suggest that there is a positive association between the household mobile phone possession and the banana sales, the causal impact is not clear.

Regarding the community level impact, the result in Table 6 indicates that the mobile phone network increases the probability of the banana sales in remote areas: the interaction term of the distance to the district center and the mobile phone coverage has a positive coefficient. The mobile phone network itself, however, has a negative coefficient and thus decreases the probability of the banana market participation by 9.5 percentage points. As a result, the combined impact is negative near the district center and positive in remote areas. According to the results, the combined impact turns to positive at 12 miles away from the district center because the estimated coefficient of the interaction term indicates that the banana sales participation increases by 0.8 percentage points as the distance from the district center increases by one mile (the 0.8 percent increase multiplied by 12 miles is about 9.6 percent). The results, therefore, suggest that, as indicated by Figure 2, the farther away the farmer is located from the district center, the larger the impact on the market participation is induced by the mobile phone coverage. Because banana farmers in remote areas have lower costs of banana production in general, the mobile phone network may have favored the banana producers in remote areas over the banana farmers near the district centers. The result does not change much even after applying the instrumental variables (FE-IV), supporting the same hypothesis. The results on the ratio of banana sales quantity out of the production are very similar to the results on the market participation.

In summary, according to the results from the instrumental variables model in Table 6, the household level mobile phone possession does not have a significant impact on the banana sales participation, but the community level mobile phone network coverage has a signifi-

Table 6：Market Participation and Mobile Coverage/Possession: Banana

Variables	Pr (Selling Banana)			Ratio of sales quantity out of production		
	FE	FE	FE-IV	FE	FE	FE-IV
Household Mobile Phone	0.203**	0.209**	0.151	0.118**	0.121**	−0.062
Possession dummy[(A)]	(2.35)	(2.44)	(0.19)	(2.39)	(2.45)	(−0.14)
Community Mobile Phone	0.055	−0.095	−0.094	0.054***	−0.011	0.000
Coverage dummy	(1.57)	(−1.41)	(−1.11)	(2.68)	(−0.29)	(0.02)
Distance to district center		0.008***	0.007***		0.003**	0.003**
(miles) x Mobile Coverage		(2.62)	(2.53)		(1.99)	(1.81)
Year 2005 (=1)	0.481***	0.502***	0.505***	0.174***	0.183***	0.191***
	(17.73)	(17.84)	(10.85)	(11.18)	(11.31)	(7.04)
F-stat on IVs			2.58			2.58
# of observations	1161	1161	1151	1161	1161	1151

Note: Numbers in parentheses are t-values. *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. The distance to the district center itself is not included in the models because it is fixed over time.

[(A)] Instrumental variables: In the case of the mobile coverage dummy, Household mobile possession (HHmobile) is instrumented by (mobile coverage dummy *lnfarmassets), (mobile coverage dummy) *(age of household head), (mobile coverage dummy) *(education of male adult), (mobile coverage dummy) *(education of female adult). These IVs together passed the overidentification test at the 1% significance level.

cant impact in remote areas. The results, therefore, suggest that even those households who do not possess mobile phones benefit from the mobile phone network, possibly because traders use mobile phones to reduce marketing costs. Indeed, according to the surveys used in this study, most of the farmers in Uganda sell banana and maize to traders at the farm gate (Annex table 1).

In contrast, the results of the same analyses on maize in Table 7 do not show any significant impacts of the mobile phone network on maize marketing. Neither the mobile phone network coverage nor the interaction term between the distance and the coverage show significant effects on the market participation and the sales ratio of maize. This may be due to the fact that maize is a less perishable cereal where marketing efficiency through mobile phone usage does not significantly decrease transaction cost.

Lastly, Table 8 shows the analysis regarding the production income per household of banana, where we can confirm a significant positive impact of the mobile phone network in remote areas. The results suggest that the network expansion increases the banana income in remote areas. Similar to the results in Table 6, the mobile phone network itself has a negative impact but the interaction term with the distance from the district center has a positive coefficient. According to the results, the combined impact turns to positive at about 18.2 miles: 7,394 Shilling times 18.2 miles is about 135,310, which is just larger than the estimated coefficient of the mobile phone network. To further investigate who have benefited from the mobile phone network beyond the distance, we have included an interaction term between the mobile phone network and the household land size in the third column. The negative coefficient for the interaction term between mobile phone coverage and land owned suggests that the income increase was experienced by smaller land holders.

Table 7：Market Participation and Mobile Coverage/Possession: Maize

Variables	Pr (Selling Maize)			Ratio of sales quantity out of production		
	FE	FE	FE-IV	FE	FE	FE-IV
Household Mobile Phone	−0.084	−0.083	−2.19	−0.031	−0.031	−0.172
Possession dummy[(A)]	(−1.10)	(−1.09)	(−2.04)	(−0.71)	(−0.71)	(−0.42)
Community Mobile Phone	0.075**	0.033	0.165	0.010	0.004	0.012
Coverage dummy	(2.39)	(0.58)	(1.47)	(0.55)	(0.13)	(0.29)
Distance to district center		0.002	0.000		0.000	0.000
(miles) x Mobile Coverage		(0.86)	(0.18)		(0.20)	(0.06)
Year 2005 (=1)	0.463***	0.468***	0.561***	0.242***	0.243***	0.251***
	(19.06)	(18.79)	(9.31)	(17.10)	(16.73)	(10.99)
F-stat on IVs			2.58			2.58
# of observations	1291	1291	1283	1291	1291	1283

Note: Numbers in parentheses are t-values. *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. The distance to the district center itself is not included in the models because it is fixed over time.

(A) Instrumental variables: In the case of the mobile coverage dummy, Household mobile possession (HHmobile) is instrumented by (mobile coverage dummy *lnfarmassets), (mobile coverage dummy) *(age of household head), (mobile coverage dummy) *(education of male adult), (mobile coverage dummy) *(education of female adult). These IVs together passed the overidentification test at the 1% significance level.

Table 8：Production Income and Mobile Coverage/Possession: Banana

Variables	Production income (Shs)			
	FE	FE	FE	FE-IV
Household Mobile Phone	−86,385	−93,333	−82,829	234,283
Possession dummy(A)	(−1.04)	(−1.11)	(−0.97)	(0.49)
Community Mobile Phone	−134,851**	−2,775	−42,664	−159,937**
Coverage dummy	(−2.09)	(−0.08)	(−0.57)	(−2.16)
Distance to district center	7,397**		7,543**	7,861**
(miles) x Mobile Coverage	(2.45)		(2.48)	(2.49)
Land Owned x			−84,316***	
Mobile Coverage			(−2.65)	
Year 2005 (=1)	199,122***	182,141***	198,461***	187,251***
	(7.07)	(6.65)	(6.34)	(5.25)
F-stat on IVs				9.52
#of observations	1503	1503	1482	1482

Note: Numbers in parentheses are t-values. *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. The distance to the district center it self is not included in the models because it is fixed over time.
(A) Instrumental variables: In the case of the mobile coverage dummy, Household mobile possession (HHmobile) is instrumented by (mobile coverage dummy *lnfarmassets), (mobile coverage dummy) *(age of household head), (mobile coverage dummy) *(education of male adult), (mobile coverage dummy) *(education of female adult). These IVs together passed the overidentification test at the 1% significance level.

6. Conclusion and discussion

Enhancing farmers' participation in markets is considered as an important strategy to reduce rural poverty in Africa. This paper uses panel data from Uganda to test the hypothesis that mobile phone coverage expansion induces the market participation of farmers in remote areas producing perishable crops such as banana. Uganda recently has experienced a rapid increase in areas covered by the mobile phone network. As information flow increases due to the mobile phone coverage expansion, the cost of crop marketing is expected to decrease, particularly in remote areas where potential marketing gains from the increased information flow is large. We indeed find that the mobile phone network expansion has a larger impact on the market participation in areas farther from district centers. For maize, which is another staple but less perishable crop, we did not find any impacts from the mobile phone network expansion on maize marketing. The results, therefore, suggest that mobile phone coverage expansions in Uganda, as well as in other developing countries, encourage the market participation of farmers who are located in remote areas and produce perishable crops.

It is not clear, however, whether farmers obtain the full efficiency gain due to the mobile phone expansion. To allow farmers to obtain the full potential efficiency gain, the information asymmetry between traders and farmers needs to be eliminated. One route to eliminate the information asymmetry is to strengthen the public dissemination of price information. For instance, one possible mechanism is to enhance the capacity of the community to obtain and share timely price information through producers' associations so that farmers who do not have mobile phones can obtain the market information. Nevertheless, the evidence in this paper suggests that in remote areas in rural

Uganda, the mobile phone coverage expansion itself, not necessarily the mobile phone possession at the household level, has benefited farmers who produce perishable product.

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Annex 1：Ratio of Sellers Who Sell to Traders/ Individuals: Banana and Maize combined

Mobile coverage		Ratio of sellers who sell to traders (%)			Ratio of sellers who sell to individuals (%)		
		2003	2005	Dif.	2003	2005	Dif.
All locations	N/Y	50.0	56.2	6.2	9.3	8.8	−0.5
	Y/Y	45.1	50.6	5.5	13.5	11.7	−1.8
More than 20 miles	N/Y	57.0	62.5	5.5	11.6	8.3	−3.3
	Y/Y	58.3	61.1	2.8	11.1	11.1	0.0
Less than 20 miles	N/Y	46.7	53.2	6.5	8.2	9.0	0.8
	Y/Y	42.5	48.5	6.0	13.1	11.8	−1.3

N/Y: No mobile phone coverage in 2003; covered in 2005
Y/Y: Covered in both 2003 and 2005

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