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## **Impact of ICT-based Market Information Service Projects on Smallholder Farm Input Use and Productivity in Kenya**

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### **Abstract**

Information asymmetry has traditionally constrained smallholder farmers' access to markets. Past studies indicate that it contributes to low adoption of modern agricultural technologies that have the capacity to enhance the productivity of smallholder farms. Low use of inputs results in low farm productivity, which curtails the transformation from subsistence to commercial agriculture, hence perpetuating the detention of smallholder farmers in the low equilibrium poverty trap. The desire to improve farmers' access to markets has seen the emergence of a number of projects that employ Information and Communication Technology (ICT) tools in the provision of market information. However, little is known about the effects of such projects on smallholder agriculture, particularly in developing countries. The present study evaluates the impact of participation in an ICT-based market information service (MIS) project on farm input use (e.g. fertilizer, purchased seed, purchased manure, pesticides, labour etc.), labour and land productivity in Kenya. It employs propensity score-matching technique on cross-sectional data of 375 farmers from Bungoma, Kirinyaga and Migori counties in Kenya. The study finds that participation in an ICT-based MIS project has a positive and significant impact on the quantity of seeds and fertilizers used and improves land and labour productivity. Specifically, participants in an ICT-based project spent between Kshs 282.45 and 359.21 and Kshs 952.67 and 1035.10 more than non-participants on purchased seed and fertilizer per acre, respectively. Additionally, participants in the ICT-based MIS project have relatively higher land productivity (between Kshs 7,007.14 and 8,605.84) per acre than non-participants. Participation in an ICT-based MIS project also increases labour productivity by



between Kshs 367.46 and Kshs 406.95 per acre. However, participation in an ICT-based MIS project has a negative and significant impact on the use hired, family and total labour. Participants in the ICT-based project use less labour by between 6.10 and 6.46, 7.95 and 13.49, and 15.68 and 21.96 man-days per acre for hired, family and total labour, respectively. The study discusses the implications of these findings for policy.

**Key words:** *Impact evaluation, Market information, propensity-score matching, smallholder farmers, productivity.*

## Introduction

The importance of information for adequate functioning of markets has been a prominent concern in economic theory, tracing back to the seminal work of Stigler (1961) on the economics of information. Moreover, in the late 1980s to early 1990s, many developing countries assisted by donors, invested in Market Information Services (MIS) and other reforms to improve market linkage and subsequently, rural household incomes (Kizito, 2009). MIS mainly emerged as accompanying measures to the Structural Adjustment Programs (SAPs) that targeted the liberalization of agricultural markets. Such interventions eliminated some of the barriers that curtailed the private sector from providing agricultural services. Private sector participation in the agricultural markets was expected to address smallholder farmers' problems of access to input and output markets (Okello and Ndirangu, 2010).

Nevertheless, situations of information asymmetry still prevail in most developing countries (Svensson and Yanagizawa, 2008). As a result, there have been information related problems such as moral hazard and adverse selection that in turn increases transaction costs and hence limit market participation by some farmers (Okello *et al.*, 2012). Although smallholder farmers play a vital role in the economies of most developing countries, they face significant challenges in accessing agricultural markets. In Kenya for instance, smallholder farmers account for about 75 percent of the total agricultural output and provide virtually all the domestic food requirements of the nation (Kuyiah *et al.*, 2006). However, these farmers are resource poor and face substantial constraints in accessing inputs and high-end markets for their products (Okello, 2010).

Some of the factors highlighted to have contributed to the failure of input and output markets comprise: high transactions costs by the farmers in



the input markets, illiteracy, distance to information sources and absence of the type of information the farmers need to produce their choice crop (Okello and Ndirangu, 2010). Consequently, these dampens farmers' incentives to use better production techniques such as yield augmenting inputs that have the potential to increase the productivity of their land holdings and enhance their access to high value markets. The low use of inputs in turn results in lower farm productivity, and curtails the transition from subsistence to commercial agriculture, hence perpetuating the detention of smallholder farmers in the low-equilibrium poverty trap (Barrett, 2008). Such is the case in Kenya where productivity levels for most crops are below optimal due to poor market access, extension services and low application of modern agricultural technologies (Kenya Vision 2030).

Consequently, the enhancement of agricultural productivity has drawn the attention of policy makers in Kenya due to the significant role of the agricultural sector in the country's economic development (Odhambo and Nyangito, 2003). Thus, Information and Communication Technology (ICT) based projects have been recently introduced as part of the strategies to overcome the low farm productivity among smallholder farm households. Such projects include: DrumNet (Gine, 2005), Kenya Agricultural Commodity Exchange (KACE) (Mukhebi *et al.*, 2007) Regional Agricultural Trade Intelligence Network (RATIN), National Livestock Market Information System (NLMIS) (Dyke and Kaitho, 2007) and M-farm (M-farm Kenya, 2012). Theoretically, these projects are expected to improve the performance of the targeted farmers. Specifically, it is expected that farmers who participate in such projects will have used the technical information acquired through them to adopt superior techniques of production, hence realize higher outputs.

In spite of the expected gains from ICT-based MIS projects in theory, few studies have provided empirical evidence of the impact of such projects, particularly in the developing country context. Notable exceptions include: Jensen (2007), Aker (2008), Svensson and Yanagizawa (2008), Houghton (2009) and Okello (2010). Specifically, there is a dearth of empirical evidence of the impact of such projects on farm input use and productivity. The few studies that have attempted to provide empirical evidence of the impact of ICT-based MIS on agricultural productivity are limited and comprise: Lio and Liu (2006), the study was conducted at a macro-level using applied Ordinary Least Squares (OLS) approach, that does not control for selection bias. Houghton (2009) assessed the impact of mobile phones on agricultural productivity by employing micro-level data using Heckman two-stage regression. The study used cattle



ownership as the proxy for measuring productivity gains. Finally, Kiiza *et al.*, (2011) evaluated the impact of ICT-based market information on prices received by farmers and the intensity of adoption of improved maize seed in rural Uganda. This study is similar, in some aspects, to that of Kiiza *et al.*, (2011), but extends it by evaluating the impact of ICT-based MIS projects on the use of fertilizer, pesticides, farm manure, besides improved seed. It also examines the impact of ICT-based MIS projects on land and labour productivity.

This study focuses primarily on smallholder farmers. It uses data collected from smallholder farmers stratified by participation in ICT-based MIS project. The rest of this paper is organized as follows: Section 2 presents the theoretical framework of the study. Section 3 presents the study results, while section 4 concludes.

## Theoretical framework

### Participation decision and household welfare

Following Ali and Abdulai (2010), it can be assumed that the decision to participate in an ICT-based MIS project is dichotomous, where participation only occurs when the expected utility from participation  $U_{ip}$  is greater than non-participation ( $U_{in}$ ) i.e.  $U_{ip} > U_{in}$ . The difference between the utility from participation and non-participation may be denoted as a latent variable  $R_i^*$ , such that  $R_i^* = (U_{ip}) - (U_{in}) > 0$  indicates that the utility from participation exceeds that of nonparticipation. The decision by a farmer to participate or not to participate in a new ICT-based MIS project is dependent on the farm, as well as farmer characteristics; hence, it relies on each farmer's self-selection rather than random assignment. Assuming a risk neutral farmer, the index function to assess participation in an ICT-based MIS project can be expressed as:

$$R_i^* = yX_i + e_i \quad (1)$$

where  $R_i^*$  is a latent variable signifying the difference between the utility derived from participation in an ICT-based MIS project and the utility from failure to participate in an ICT-based MIS project. The term  $yX_i$  represents an estimate of the difference in utility derived from participating in an ICT-based MIS project by employing the household and farm-level characteristics ( $X_i$ ) as explanatory variables, whereas  $e_i$  is an error term. Theoretically, participation in ICT-based MIS projects is expected to affect the demand for agricultural inputs such as fertilizer, purchased seed, manure, pesticides, herbicides, labour, as well as yields and net returns ( $\pi$ ). To link the participation decision with these potential



outcomes of participation in an ICT-based MIS project, we still consider a risk neutral farmer that maximizes profits  $\pi$  subject to a competitive output and input market and a single output technology that is quasi-concave in the vector of variable inputs,  $W$ . This may be expressed as:

$$M a x \pi = P Q W X - V W \quad (2)$$

where  $P$  is output price,  $Q$  is the quantity of output,  $V$  is a vector of factor prices, while  $W$  is a vector of input quantities.  $X$  is a vector of farm level and household characteristics. The farmer's net returns or profits can be expressed as a function of participation ( $R$ ), variable inputs ( $V$ ), output price ( $P$ ) and household characteristics ( $X$ ) as follows:

$$\pi = \pi (R V P X) \quad (3)$$

Application of Hotelling's Lemma to equation (2) with respect to factor price and output price yields reduced form equations for negative input demand and output supply, respectively;

$$\frac{\partial \pi}{\partial v} = -W = W (R V P X) \quad (4)$$

$$\frac{\partial \pi}{\partial v} = Q = Q (R V P X) \quad (5)$$

The specifications in equations (4) and (5) show that the decision to participate, input and output prices, as well as farm and household characteristics tend to affect a farm household's net returns, demand for inputs and output level.

### Impact evaluation

The fundamental approach to consider when evaluating the impact of participation in an ICT-based MIS project on smallholder farm productivity would be to include a dummy variable equal to one in the outcome equation if the household participated in ICT-based MIS project and zero otherwise, and then apply an Ordinary Least Squares (OLS) regression. That basic relationship is a linear function of vector explanatory variables ( $X_i$ ) and a participation dummy variable ( $D_i$ ) specified as follows:



$$Y_i = \alpha X_i + \beta D_i + \mu_i \quad (6)$$

where  $Y_i$  is the mean outcome of the target variable for household  $i$ ,  $D_i$  is a dummy variable,  $D_i = 1$  for participation in an ICT-based MIS project and  $D_i = 0$  otherwise.  $X_i$  is a vector representing household and farm level characteristics.  $\mu_i$  is the normal stochastic term reflecting unobserved characteristics that also affect  $Y$ .

Equation (6) reflects an approach commonly used in impact evaluations (e.g. in Lio and Liu, 2006), which is to measure the direct effect of the program  $D$  on outcomes  $Y$ . This approach, however, is likely to generate biased estimates because it assumes that participation in an ICT-based MIS project is exogenously determined while it is potentially endogenous. The treatment assignment is not often random due to either purposive program placement or self-selection into the program. That is, programs being placed according to the need of the communities or individuals who in turn self-select based on program design and placement. Self-selection could be based on observed characteristics, unobserved factors, or both (Khandker *et al.*, 2010).

Selection bias specifically occurs if unobservable factors influence both error terms of the participation equation (1)  $e_i$  and the outcome equation (6)  $\mu_i$ , resulting in the correlation of the error terms of the participation decision and the outcome specification. In other words, the correlation between the two stochastic terms is greater than zero. In this case, ordinary least squares (OLS) will lead to biased estimates, including estimates of the program effect (Becerril and Abdulai, 2010). This may lead to over estimation of the project's effect.

To address the problem of selection bias, most empirical studies employ Heckman two-step estimation. This method has the advantage of controlling for the differences in both the observed, besides the unobserved attributes between the treated and control groups by the inclusion of the inverse of mills ratio as an extra regressor in the outcome equation. However, the main drawback with this method is that selection estimators are dependent on a strong assumption that the hidden variables are normally distributed. This has resulted to the questioning of the robustness of their results in literature employing both actual and simulated data (Ali and Abdulai, 2010; Kiiza *et al.*, 2011).

Selection bias can also be controlled by Instrumental Variable (IV) method. This technique yields unbiased and consistent estimates in the presence of hidden bias. The main drawback of the IV method, however, is that it will often be difficult to find at least one variable in the selection model to serve as a suitable 'instrument' that should influence the probability





of treatment, without itself being determined by any confounding factors affecting outcome, i.e. without being correlated to the error term (Wooldridge, 2002). Since this last condition is difficult to test, the choice of a valid instrument largely depends on intuition and economic reasoning. In addition, the IV approach typically reduces the precision of the causal estimates and introduces new uncertainty, besides the difficult to test assumptions (DiPrete and Gangl, 2004; Kiiza *et al.*, 2011).

Double Difference (DD) methods can also be used. They are advantageous in the sense that they relax the assumption of conditional exogeneity or self selection on observed characteristics. Moreover, they provide an appealing and intuitive way to account for selection based on unobserved characteristics. Their main shortcoming, however, rests precisely with this assumption: the concept of time-invariant selection bias is unlikely for many target programs in developing countries (Khandker *et al.*, 2010). Furthermore, DD methods are limited to studies with baseline survey data. To overcome the drawbacks of the mentioned methods, this study employs Propensity Score-Matching (PSM) technique to control for selection bias. The method does not depend on the functional form and distribution assumptions and is intuitively attractive since it compares the observed outcomes of adopters (participants) and non-adopters (non-participants) of technology (Asfaw, 2010). The matching technique has heavy data requirement. However, in the absence of such data, experimental treatment effect results can still be obtained.

### Impact evaluation problem and the propensity score matching method

The main challenge of impact evaluation in this study is to determine the outcome of the ICT-based MIS project participants if the project had not existed. A participant's outcome in the absence of the intervention would be its counterfactual. The PSM approach provides unbiased estimation of treatment effects and can be used to draw causal-effect inference and control for simple selection bias in non-experimental settings. It does this by attempting to construct a proper counterfactual of the outcome of participants conditional on nonparticipation. According to Rosenbaum and Rubin (1983), the average treatment effect  $\Delta_i$  in a counterfactual framework can be specified as:

$$\Delta_i = Y_{i1} - Y_{i0} \quad (7)$$

where  $Y_{i1}$  and  $Y_{i0}$  denotes the outcomes of household  $i$  that participates in an ICT-based MIS project and one that does not participate, respectively. Estimating the impact of project participation on the  $i^{\text{th}}$  household from



equation (7) would be misleading due to the problem of missing data. Normally either outcome  $Y_i$  is observed for household  $i$  at a time, but not both. That observed outcome can be expressed as:

$$Y_i = D_i Y_1 + (1 - D_i) Y_0 \quad (8)$$

where  $D$  denotes a dummy = 1 or 0 for participant and nonparticipant, respectively. The average treatment effect on the treated (ATT) households which is the parameter of interest in empirical research, as noted by Rosenbaum and Rubin (1983), Caliendo and Kopeinig (2008) and Kiiza *et al.*, (2011) is written as follows:

$$ATT = E(Y_1 - Y_0 | D=1) = E(Y_1 | D=1) - E(Y_0 | D=1) \quad (9)$$

As argued earlier,  $E(Y_0 | D=1)$  which is the counterfactual outcome is not observed for a given household, implying that although ATT may be estimated, it is likely to be biased. The central focus of impact evaluation lies in estimating  $E(Y_0 | D=1)$  and not  $E(Y_0 | D=0)$ . The problem of using  $E(Y_0 | D=0)$  is that the participating and non-participating households may not be similar before the intervention; hence the expected difference between these households may not be entirely due to program intervention. The PSM technique attempts to capture the effects of various observed covariates  $X$  on participation in a single propensity score. The propensity score in this study's context can be defined as the conditional probability that a household will participate in an ICT-based MIS project, given its pre-participation characteristics. Consequently, the program effects can be obtained by comparing the outcomes of participating and non-participating households with similar propensity scores.

According to Ali and Abdulai (2010), the PSM technique creates conditions of a randomized experiment by employing two assumptions namely, unconfoundedness assumption also referred to as conditional independence assumption (CIA) and common support assumption (CSA). The CIA implies that once  $X$ , vector of pre-participation characteristics is controlled for, participation in an ICT-based MIS project will be random and uncorrelated with the outcome variables. In other words, selection into group will be solely based or explained by the observable characteristics. The propensity score under the CIA is given by:

$$P(X) = Pr(D=1 | X) = E(D | X) \quad (10)$$



where  $D = 1$  or  $0$  is the indicator for participation and  $X$  is the vector of pre-participation characteristics. The conditional distribution of  $X$ , given  $p(X)$  is similar in both groups of participants and non-participants. The core objective of estimating the propensity score is to balance the observed distribution of covariates across groups of participants in ICT-based MIS projects and non-participants.

On the other hand, the CSA helps in ensuring that every individual has a positive probability of being either a participant or a non-participant in an ICT-based MIS project, hence ruling out perfect predictability. The CSA is expressed as:

$$0 < \Pr(D=1 | X) < 1 \quad (11)$$

Under the assumptions (10) and (11), the ATT be expressed as follows:

$$ATT = E(Y_1 - Y_0 | D=1)$$

$$ATT = E[E(Y_1 - Y_0 | D=1, p(X))]$$

$$ATT = E[E\{Y_1 | D=1, p(X)\} - E\{Y_0 | D=0, p(X)\} | D=1] \quad (12)$$

The propensity scores can be generated using either a binary probit or logit model. The probit model assumes a normal distribution of the stochastic term, whereas the logit assumes a logistic distribution. Since we cannot determine that the random term has a normal distribution a priori, a logit model is estimated to generate the propensity scores for participation in an ICT-based MIS project. This is then succeeded by matching. Various matching methods have been employed in literature, however, this study uses the most commonly used nearest neighbour matching (NNM), Radius matching (RM) and Kernel-based matching (KBM). The three matching methods are used to check the robustness of the results.

### Test for robustness and unobserved heterogeneity

Since matching is not conditioned on all covariates, but on the estimated propensity score, it is essential after matching to check if all the relevant covariates are balanced in both treatment and control groups (Caliendo and Kopeinig 2008, Becceril and Abdulai, 2010). The quality of the resulting matches are inherently tested by examining the situation before and after matching to check if there remains any difference after conditioning on



the propensity score (Caliendo and Kopeinig 2008). Furthermore, Sianesi (2004), Caliendo and Kopeinig (2008) and Becceril and Abdulai (2010) suggest the re-estimation of propensity score on the matched sample, i.e. on participants and matched non-participants, and subsequent comparison of pseudo- $R^2$  before and after matching. Pseudo- $R^2$  indicates how well the predictors  $X$  predict the probability of participation. The pseudo- $R^2$  after matching should be fairly low, indicating that there are no systematic differences in the distribution of observed covariates between treatment and control groups. In addition, one can also perform a likelihood ratio test on the joint significance of all predictors in the probit or logit models. The test should not be rejected before, but should be rejected after matching.

Given that with PSM 'hidden bias' may arise if there are unobserved covariates that simultaneously influence participation and the welfare outcomes of households, it is essential to check for the presence of hidden bias after matching. In order to test the extent to which an assignment on unobserved covariates may bias the results or inferences, this study employs Rosenbaum bounds sensitivity analysis to ascertain how strongly an unmeasured variable must influence the selection process so that it could undermine the findings of the matching analysis. Rosenbaum bounds take the difference in the response variable between treatment and control cases, and give the critical levels of gamma at which the causal inference of a significant impact of treatment may be questioned. By considering the lowest critical value of sensitivity analysis, we can conclude the level at which unobserved heterogeneity would alter the inference about the estimated effects of treatment (Kiiza *et al.*, 2011).

### **Sampling procedure and data**

This study used data collected from smallholder farmers located in Kirinyaga, Bungoma and Migori counties. The counties were selected for the survey because they hosted an ICT-based MIS project, namely the DrumNet project, between 2004 and 2007. They were therefore likely to have benefited from the demonstration effects of the project. The counties were also selected to capture diverse social and economic backgrounds. Kirinyaga County has export-oriented agriculture with several export crops (French beans, various Asian vegetables and baby corn) being produced by the farmers that were targeted by the project. Smallholder farmers in Bungoma County mainly planted maize (a lower value crop) and some sugarcane, while in Migori County; the main crops were maize and tobacco (for some famers). The study targeted smallholder farmers including those who participated in ICT-based projects that used ICT-based tools and those who did not. The respondents in this study were



therefore stratified by participation in such an ICT-based MIS agricultural project.

The sampling procedure entailed three stages. First, in each county, an area with an ICT-based MIS project was identified. Second, for each such area, a list of all farmers registered to participate in the ICT-based MIS project was drawn with the help of project staff and farmers' leaders. A second list of farmers that did not participate in the ICT-based projects was also obtained with the help of local administration (village elders and area agricultural extension officers) and verified by project staff and farmers' leaders as non-project members. Third, the respondents were sampled from the two lists using probability proportionate to size sampling method. That is, more farmers were sampled from the list with more names. This procedure resulted in 144 farmers who had participated in ICT-based MIS projects and 231 nonparticipants, giving a total sample of 375 farmers comprising 130, 127 and 118 respondents from Bungoma, Kirinyaga and Migori counties, respectively. The data were collected through personal interviews using a pre-tested questionnaire. Important information collected included farmer-specific characteristics, farm-specific characteristics, household capital/asset endowments, and location characteristics. The household survey was conducted in April and May 2010.

Definition of the variables collected during the study and applied in the econometric models is given in Table 1, while Table 2 presents the test of mean differences in some characteristics of participants and non-participants in ICT-based MIS projects.

## **Results and discussion**

The descriptive statistics reveal that 35 percent of the farmers interviewed in Kirinyaga participated in ICT-based MIS projects, compared to 55 percent and 25 percent in Bungoma and Migori counties, respectively. Contrary to expectation (Okello et al., (2012) argues that farmers in Kirinyaga County have a higher likelihood of using ICT tools for agricultural transaction due to their production of market-oriented export vegetables), the proportion of participants in the ICT-based MIS project is highest in Bungoma relative to other counties. This may have been due to awareness created by the active existence of an ICT-based MIS provider, KACE, in the region. Overall, the sample mean indicates that only 38 percent of the all the farmers interviewed participated in ICT-based projects, probably due to lack of awareness of the existence of the projects and or their possible benefits.

Table 1: Definition of variables and descriptive statistics						
County	Kirinyaga – n = 127		Bungoma – n = 130		Migori – n = 118	
Dependent Variables	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
ICT-based MIS project (1 = participant 0 = Non-participant)	0.35	0.47	0.55	0.50	0.25	0.43
Value of purchased seed per acre (Kshs)	1,660.05	1,470.66	984.82	603.22	599.39	599.31
Value of purchased fertilizer per acre (Kshs)	3,672.28	2,994.03	3,613.99	2,660.78	914.41	1,706.85
Value of purchased manure per acre (Kshs)	104.35	471.21	18.27	146.93	0.28	3.07
Value of purchased herb <sup>a</sup> or pesticides per acre	454.83	747.98	9.86	69.45	1.59	17.26
Total value of purchased inputs per acre (Kshs)	6,290.65	5,131.50	4,626.93	2,930.68	1,515.67	1,932.27
Value of household output per acre (Kshs)	29,952.63	23,062.32	25,826.00	16,818.12	16,151.62	11,398.74
Value of household output per man-day (Kshs)	709.61	748.75	546.44	482.24	469.60	474.94
Hired labour man-days per acre	30.14	35.1	10.82	16.3	10.68	16.01
Family labour man-days per acre	29.98	32.15	46.21	31.87	33.63	26.7
Total labour man-days per acre	57.30	38.5	57.41	31.58	45.45	25.7
<b>Independent Variables</b>						
Age	43.78	12.46	43.7	13.12	42.75	16.04
Gender (1=Male 0=Female)	0.54	0.50	0.49	0.50	0.48	0.50
Education (years)	8.96	3.44	8.85	3.49	7.34	3.84
Farming experience (years of farming)	18.09	10.49	16.22	11.01	18.87	13.19
Distance to the local market (km)	3.07	1.93	2.12	1.45	1.81	1.58
Distance to the nearest local market for inputs	4.04	3.1	4.13	2.59	4.69	5.39
Household size (number)	4.41	1.28	6.87	2.23	5.93	2.11
Household adult equivalent (number)	2.42	0.62	3.27	0.92	2.97	0.94
Cultivated land area in 2009 (acre)	2.32	1.8	1.53	1.25	1.53	1.25
Number of crop enterprises	3.11	1.43	3.08	1.74	3.08	1.74
Market participation (1=yes 0=No)	0.77	0.42	0.58	0.49	0.58	0.49
Group membership (1=Member 0=Non-member)	0.63	0.49	0.72	0.45	0.25	0.43
County of Survey: Kirinyaga 1=Kirinyaga, 0=Otherwise						
Bungoma						
Migori						
Pooled – n = 375						
					Mean	Std. Dev
					0.38	0.49
					1,092	1,075.51
					2,784.26	2,825.52
					41.76	290.38
					157.95	485.29
					4,155.37	3,913.28
					24,179.35	18,707.94
					577.52	591.26
					17.32	25.91
					36.76	31.16
					53.61	32.88
					43.43	13.87
					0.50	0.50
					8.41	3.66
					17.69	11.6
					2.89	0.91
					4.27	3.84
					5.74	2.17
					2.89	0.91
					2.2	1.91
					2.91	1.52
					0.65	0.48
					0.62	0.49
					0.34	0.47
					0.33	0.48
					0.31	0.47

The exchange rate at the time of the survey was 1 US dollar = Kshs 78



The results in Table 2 indicate that there are significant differences between participants and nonparticipants in an ICT-based MIS project with respect to use (or value) of farm inputs. In particular, participants have higher values of purchased seed per acre, fertilizer per acre and aggregate non-labour inputs per than non-participants. However, the results indicate that participants use less of hired labour per acre and total labour per acre than non-participants. The  $t$  values suggest that there are significant differences in some of the variables used in the empirical analysis namely farm, farmer and asset endowment variables. Specifically, participants have higher average figures for age, household size adult equivalent, distance to nearest local market, number of crop enterprises, market participation and membership to farmer organization than non-participants.

Table 2: Differences in means of participants and non-participants

Characteristic	participants n = 144	non-participants n = 231	mean difference	t values	p values
<b>Dependent variables</b>					
Value of purchased seed per acre (Kshs)	1,297.25	964.4	332.85***	2.73	0.007
Value of purchased fertilizer per acre (Kshs)	3,582.90	2286.41	1296.48***	4.13	0.000
Value of purchased manure per acre (Kshs)	52.37	35.15	17.22	0.53	0.600
Value of purchased herbicide or pesticide per acre	140.66	168.73	-28.08	-0.57	0.568
Total value of purchased inputs per acre (Kshs)	5,073.16	3583.23	1489.93***	3.52	0.001
Family labour man-days per acre	34.32	38.28	-3.96	-1.22	0.225
Hired labour man-days per acre	14.25	19.23	-4.98*	-1.91	0.057
Total labour man-days per acre	46.38	58.11	-11.73***	-3.59	0.000
Value of household output per man-day (Kshs)	793.82	442.69	351.13***	5.12	0.000
Value of household output per acre (Kshs)	28,905.47	21,233.20	7,672.28***	3.83	0.000
<b>Farmer specific variables</b>					
Age (years)	46.68	41.4	5.28***	3.74	0.000
Gender (1= Male, 0= female)	0.54	0.48	0.06	1.15	0.251
Farming experience (years of farming)	19.52	16.55	2.98	2.47	0.014
Household size (number)	6.1	5.52	0.59**	2.52	0.012
Household size (adult equivalent)	3.1	2.76	0.33***	3.46	0.001
<b>Farm specific variables</b>					
Distance to the nearest local market (Km)	2.56	2.21	0.35*	1.86	0.064
Market participation (1=yes, 0= No)	0.74	0.59	0.15***	3.16	0.002
Number of crop enterprises	3.31	2.67	0.64***	3.89	0.000
<b>Asset endowment variables</b>					
Education (years of formal education)	8.75	8.2	0.55	1.41	0.160
Cultivated land area in 2009 (acre)	2.17	2.22	-0.05	-0.27	0.787
Membership to farmer organization (1=yes, 0=No)	1	0.39	0.61***	18.98	0.001

Note: Significance level of mean difference is at \* 10 percent, \*\* 5 percent and \*\*\* 1 percent





### **Impact of ICT-based MIS projects on farm input use and productivity**

The impact analysis is preceded by the estimation of propensity scores for the treatment variables using the logit model presented in Table 3. The propensity scores, as noted by Lee (2008), are useful for balancing the observed distribution of covariates across the treated and the untreated groups. Generally, most of the variables in the model have the expected signs.

**Table 3: Logistic regression estimates of propensity scores for participation in ICT-based market information service projects**

Variable definition	coefficient	p-value
Dependent variable = Participation in ICT-based MIS project		
Farmer specific variables		
Age	0.12**	0.035
Age-squared	- 0.00*	0.096
Gender	- 0.01	0.984
Farming experience	0.00	0.957
Farm specific variables		
Household size	- 0.03	0.690
Distance to the local market	0.10	0.184
Number of Crops	0.22***	0.007
Asset endowment variables		
Mobile phone user (ICT tool user)	1.01***	0.008
Education	0.01	0.760
Group Membership prior to project	0.58**	0.041
Land size owned prior to project	0.12**	0.034
Regional variables		
Bungoma	1.27***	0.000
Migori	- 0.14	0.696
Constant	- 6.30***	0.000
No. of observations: 375		
Pseudo R <sup>2</sup> : 0.15		
p-value : 0.000		
Log Likelihood: -211.07		
Hosmer-Lemeshow $\chi^2$ (8) = 5.77		
Prob > $\chi^2$ = 0.6729		

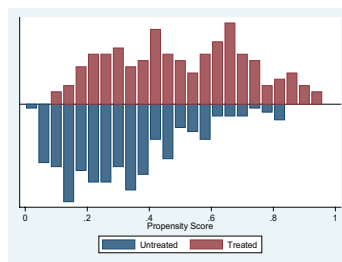
Note: Significance level is at \*10 percent, \*\*5 percent and \*\*\*1 percent

\*Kirinyaga County was automatically dropped from the model due to high multicollinearity

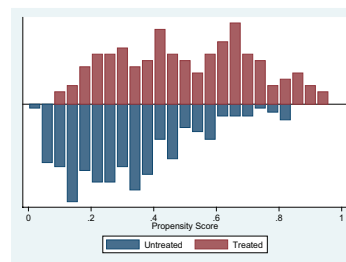


Figure 1 presents the distribution of the estimated propensity scores and the region of common support. The common support condition is imposed in the estimation of impact by matching in the region of common support. The results show a bias in the distribution of the propensity scores between the groups of participants and non-participants, and clearly reveal that all the treated and the untreated households were within the region of common support. This implies that the CSA, which requires each treated household to have a corresponding untreated household as a match, was satisfied.

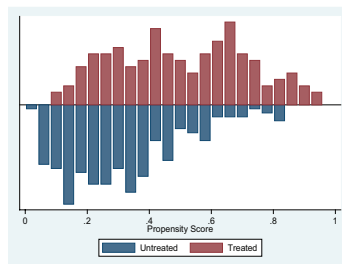
**Figure 1: Distribution of the estimated propensity scores and the region of common support.**



Nearest Neighbour Matching



Radius Matching



Kernel Based Matching

*Source: Authors' calculation*



The empirical results of the impact of ICT-based MIS projects on farm inputs use and productivity estimated with NNM, RM and KBM are presented in Table 4.

**Table 4: Impact of participation in ICT-based market information services on input use and productivity**

Matching Algorithm	Nearest Neighbour Matching		Radius Matching		Kernel Based Matching	
	ATT	T-stat	ATT	T-stat	ATT	T-stat
Value of purchased seed per acre	359.21**	2.35	285.41**	2.25	285.45**	2.17
Value of purchased fertilizer per acre	1,035.10***	2.61	1,009.86**	3.08	952.67***	2.84
Value of purchased manure per acre	33.79	1.01	20.12	0.59	19.92	0.57
Value of purchased Herbicides per acre	-9.85	-0.14	-58.68	-1.10	-50.83	-0.91
Value of total purchased non-labour inputs per acre	1,363.59***	2.61	1,171.82***	2.62	1,129.33**	2.45
Hired labour man-days per acre	-6.10*	-1.68	-6.11**	-2.16	-6.46**	-2.19
Family labour man-days per acre	-13.49***	-2.99	-6.99**	-2.00	-7.95**	-2.19
Total labour man-days per acre	-21.96***	-4.62	-15.68***	-4.43	-16.94***	-4.58
Value of output per man-day	406.95***	5.25	367.46***	5.22	374.85***	5.24
Value of output per acre	8,605.84***	3.30	7,007.14***	3.31	7,160.28***	3.28

Note: Significance level is at \*\*\*1 percent, \*\* 5 percent and \*10 percent

As shown, the three matching methods indicate that participation in ICT-based MIS projects has a positive and significant impact on the use (or value) of purchased seed per acre, purchased fertilizer per acre and total purchased non-labour inputs per acre. The average treatment effect on the treated (ATT) for the value of purchased seed per acre ranges from Kshs 282. 45 to Kshs 359.21 and is significantly different from zero at 5 percent in all the matching methods. The ATT for the value of purchased



fertilizer per acre also ranges from Kshs 952.67 to Kshs 1,035.10 and is significantly different from zero at 5 percent with KBM, but at 1 percent for both NNM and RM. This result is consistent with the finding by Kiiza *et al.*, (2011) that revealed that access to ICT-based MIS improves the intensity of adoption of improved maize seed. Additionally, the ATT for the total value of purchased non-labour inputs per acre, ranges from Kshs 1,129.33 to Kshs 1,363.59, and is significantly different at 1 percent in all the matching methods, except with KBM that is significant at 5 percent level. These results suggest that participation in an ICT-based MIS project increases the use of purchased seed per acre, fertilizer per acre and aggregate purchased non-labour inputs per acre.

Conversely, participation in an ICT-based MIS project has a negative and significant impact on the use of hired, family and total labour man-days per acre. The ATT for hired labour varies from - 6.10 to - 6.46 man-days per acre and is significantly different from zero at 5 percent level in all the matching methods, except with NNM where it is significant at 10 percent. The ATT for family labour and total labour vary from - 6.99 to - 7.95 and - 15.68 to - 21.96 man-days per acre, respectively. The ATT for family labour is significantly different from zero at 5 percent level in all the methods, except with NNM where it is 1 percent, while the ATT for total labour is significantly different from zero at 1 percent level in all the matching methods. These results imply that participation in an ICT-based MIS project reduces the use of hired, family and total labour by between 6.10 and 6.46, 6.99 and 7.95 and 15.68 and 21.96 man-days per acre, respectively.

Following the results in Table 4, it can be argued that access to ICT-based MIS projects enhances the use of non-labour improved inputs, but conversely, reduces the use of labour in farm households. Improved access to the right information on inputs via an ICT-based MIS project reduces information asymmetries and transaction costs, hence facilitating increased smallholder farmers' participation in input markets. Households with sufficient information are likely to use less labour in negotiating for contracts and searching for information on production inputs e.g. certified seeds, fertilizer, hired labour etc, hence use less labour. Additionally, the negative but significant impact of ICT-based MIS projects on labour use could be due to the "induced innovation hypothesis" (Hayami and Ruttan, 1971) which postulates that as resources become scarcer or expensive, individuals invest in technologies that facilitate the substitution of the less expensive factors for the more expensive factors of production. Thus, better access and use of improved inputs is argued to be substituting for less-skilled labour use among ICT-based MIS project participants.



Table 4 further shows that participation in the ICT-based MIS project increased the value of output per man-day by between Kshs 367.46 and Kshs 406.95, this increment is significant at 1 percent in all the matching methods. This suggests that participation in an ICT-based MIS projects has a positive and significant effect on labour productivity. Finally, participation in an ICT-based MIS project also increases the value of output per acre (land productivity). As shown in Table 4, the ATT for the value of output per acre is between Kshs 7,007.14 and Kshs 8,605.84, and is significantly different from zero at 1 percent in all the matching methods. Participation in the ICT-based MIS project, therefore, increases land productivity by between Kshs 7,007.14 and 8,605.84. These findings possibly suggest that the higher levels of labour and land productivity among participants are stimulated by the expanded use of improved agricultural inputs (i.e., seed and fertilizer) due to better access to agricultural information. This is particularly noteworthy because increased use of non-labour inputs spurs productivity and subsequently leads to increased commercialization as farm households participate more in the market economy.

#### **Test for robustness of results**

Table 5 presents results of covariate balancing tests and sensitivity analysis for assessing the quality of the matches and robustness of the results.

**Table 5: Covariate balancing tests, PSM quality indicators before and after matching with NNM, RM & KBM, and sensitivity analysis**

Matching algorithm	Mean bias before matching	Mean std bias after matching	%  bias  reduction	Pseudo R <sup>2</sup> unmatched	Pseudo R <sup>2</sup> matched	P-value of LRChi2 unmatched	P-value of LRChi2 matched	Outcome	Critical level of hidden bias ( $\gamma$ )
Nearest Neighbour Matching	29.60	5.11	82.7	0.156	0.011	0.000	0.978	Value of purchased seed per acre	1.15 – 1.20
								Value of fertilizer per acre	1.35 – 1.40
								Value of total non-labour inputs/acre	1.30 – 1.35
								Hired labour man-days per acre	1.70 – 1.75
								Family labour man-days per acre	2.45 – 2.50
								Total labour man-days per acre	4.20 – 4.25
Radius Matching	29.60	12.93	56.31	0.156	0.038	0.000	0.287	Value of output per man-day	3.65 – 3.70
								Value of output per acre	1.95 – 2.00
								Value of purchased seed per acre	1.15 – 1.20
								Value of fertilizer per acre	1.30 – 1.35
								Value of total non-labour inputs/acre	1.15 – 1.20
								Hired labour man-days per acre	2.75 – 2.80
Kernel Based Matching	29.60	9.33	64.48	0.156	0.022	0.000	0.803	Family labour man-days per acre	2.25 – 2.30
								Total labour man-days per acre	3.85 – 3.90
								Value of output per man-day	5.95 – 6.00
								Value of output per acre	1.35 – 1.40
								Value of purchased seed per acre	1.15 – 1.20
								Value of fertilizer per acre	1.25 – 1.30
								Value of total non-labour inputs/acre	1.15 – 1.20
								Hired labour man-days per acre	2.85 – 2.90
								Family labour man-days per acre	2.35 – 2.40
								Total labour man-days per acre	4.20 – 4.25
								Value of output per man-day	2.95 – 3.00
								Value of output per acre	1.40 – 1.45



As shown in Table 5, there is a substantial reduction in bias as a consequence of matching. The estimates show that the standardized mean bias before matching is 29.60 percent, while the standardized mean bias after matching is reduced to between 5.11 percent and 12.93 percent. The percentage reduction in the absolute bias is 82.7, 56.31 and 64.48, with NNM, RM and KBM matching methods, respectively. Since the percentage reduction in bias by all the three matching methods is greater than 20 percent, a value suggested by Rosenbaum and Rubin (1985) as sufficiently large enough reduction in standardized bias, it is deduced that matching substantially reduced selection bias.

The second diagnostic statistic employed is the pseudo- $R^2$  from the logit estimation of the conditional probabilities of participation. The results in Table 5 indicate that the pseudo- $R^2$  after matching is lower than before matching for all matching algorithms. This implies that after matching there are no systematic differences in the distribution of covariates between the participants and non-participants in ICT-based MIS projects. After matching, the predictors in the vector  $\chi$  have extremely low or no explanatory power for assignment into treatment. The  $p$ -values of the likelihood ratio tests indicate that the joint significance of the regressors could not be rejected at any level of significance before matching. However, after matching the joint significance of the regressors is rejected. This suggests that there was no systematic difference in the distribution of covariates between participants and nonparticipants in ICT-based MIS projects after matching.

The results of the sensitivity analysis of hidden bias, which show the critical levels of gamma at which the causal inference of a significant impact of participation in an ICT-based MIS project may be questioned, are also presented in the last column of Table 5. Since sensitivity analysis for insignificant effects is not meaningful, Rosenbaum bounds (rbounds) are calculated only for treatment effects that are significantly different from zero (Hujer *et al.*, 2004). The results show that robustness to hidden bias varies across different outcomes. Specifically, the value of gamma vary from 1.15 to 1.35, 3.65 to 4.25, 1.35 to 2.00 and 2.95 to 6.00 for values of total non-labour inputs per acre, total labour man-days per acre, value of output per acre and value of output per man-day, respectively. For instance, for the impact of participation in ICT-based MIS project on the value of output per acre (land productivity), the critical value of gamma with NNM is between 1.95 and 2.00. This suggests that the unobserved variable would have to increase the odds ratio of participation by 95 to 100 percent before it would bias the estimated impact.





The lowest critical value of gamma is 1.15 to 1.20, whereas the largest critical value is 5.95 to 6.00. Some of the empirical studies that have reported critical values of gamma close to this study's (in the lower range of 1.15 to 1.20) comprise: Becceril and Abdulai (2010), Ali and Abdulai (2010) and Kiiza et al., (2011), while in the upper range, Kiiza et al., (2011) and Clement (2011). This study therefore concludes that the estimated average treatment effects of participation in the ICT-based MIS project on input use, labour and land productivity remain robust even in the presence of substantial amounts of unobserved heterogeneity. Thus, the CIA requirement for the PSM was satisfied.

### **Summary, conclusion and recommendations**

This study evaluates the impact of participation in ICT-based MIS projects on farm inputs use, labour and land productivity among smallholder farmers in Kenya. It uses descriptive analysis to compare the mean differences in some of the observed covariates between participants and non-participants. A logit model is also specified to estimate the probabilities conditioning participation, succeeded by propensity score matching in order to evaluate impact. PSM is used to reduce selection bias, for precise estimation of the project's effects.

The study finds that participation in an ICT-based market information services projects has a positive and significant effect on the level of use of farm inputs (i.e., seed and fertilizer). However, participation in the ICT-based MIS project has a negative and significant impact on the use hired, family and total labour. Additionally, participation in ICT-based projects also increases labour productivity land productivity.

This study concludes that access to ICT-based market information services improves the use of non-labour inputs, i.e. seed and fertilizer, but reduces the use of hired, family and total labour. Furthermore, ICT-based MIS projects increase both labour and land productivity. The implication of these findings is that there is need to expand the coverage of ICT-based MIS projects in rural areas, since they enhance smallholder farmers' participation in agricultural input markets, subsequently improving their labour and land productivity. In addition, programs aiming to improve food security and farm incomes should consider both the promotion of yield-augmenting agricultural technologies as well as improved access to ICT-based market information. The study findings also suggest the importance of improving the infrastructure for ICT usage (especially mobile phones) in rural areas. It also highlights the need for expansion of the rural electrification program to allow access to power (electricity)



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for charging mobile phone batteries and powering other ICT devices. The need for expansion of mobile phone network coverage in farming areas where mobile phone network is still poor is also brought to the fore.



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