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Technology Adoption and Dissemination in Agriculture: Evidence from Sequential Intervention in Maize Production in Uganda

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We use a randomized control trial to measure how the free distribution of modern inputs for maize production affects their adoption in the subsequent season. Information collected through sales meetings where modern inputs were sold revealed that the average purchase quantity of free-input recipients was much higher than that of non-recipients; that of the neighbors of recipients fell in-between. Also, credit sales had a large impact on purchase quantity, and the yield performance of plots where the free inputs had been applied positively affected the purchase quantities of both recipients and the neighbors with whom they shared information on farming. (*JEL* O13, O33, O55)

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Why are the adoption rates of modern agricultural inputs such as hybrid seed and chemical fertilizers so low in developing countries? This is an empirical puzzle that relates to technology adoption in agriculture. In Sub-Sahara Africa in particular, the adoption rate and application level of agricultural modern inputs have been very low. Despite the presence of large-scale public interventions that encourage farmers to use such technologies and boost agricultural productivity, their proliferation has been slow and incomplete; hence, agricultural productivity in this region has been stagnant for several decades.[1]

This study examines technology adoption and dissemination in terms of maize production in Uganda, where the dissemination of technologies relating to intensive farming methods is in its nascent stage. Technologies for maize production, more concretely, modern inputs such as chemical fertilizers and hybrid seeds have been rarely used in Uganda by small-scale farmers. However,

[1] Morris, Kelly, Kopicki, and Byerlee (2007) provide a comprehensive review of public interventions geared toward the promotion of fertilizer use in Sub-Sahara Africa, as well as the consequences thereof.

observing recent drastic changes in market and production environment, for instance, land scarcity due to population pressure, hike in crop prices, improvement of access to commodity markets and market information; it seems that Ugandan farmers are facing the onset of transition from traditional to modern farming system.

A situation in which there is potential demand for inputs but those inputs are not well-known to farmers is ideal for us in examining farmers' adoption behavior of new agricultural technologies and their diffusion. To investigate the impact of a proposed policy intervention on technology adoption among small-scale farmers, in 2009, we conducted an experimental intervention in maize production in Uganda. The intervention involved a sequential randomized–controlled trial. The first exercise therein was a village-level randomized control trial, implemented prior to the first cropping season. We distributed free maize inputs and gave 2 hours of instruction on the use of those inputs. We targeted households located in 46 treatment villages, randomly selected from 69 target villages; we asked each household to allocate a quarter-acre of land as a trial plot where the inputs would be applied, while we did not do so in the other 23 control villages. The second exercise of the trial occurred in the intermediate period between the first and subsequent cropping seasons of 2009, when we revisited the 69 target villages to sell the same inputs previously provided for free to the sample farmers. We held a sales meeting in each of the target villages, inviting both the original target households and the neighbors of the free-input recipients in the treatment villages. The purpose of the workshop was to gather information on input demand for the participating households and make comparisons among the three groups—the non-recipients, recipients, and neighbors of the recipients—by actually selling the modern inputs. In addition to the experimental interventions (i.e., the free-input distribution and the sales meeting), we conducted the survey in October–December 2009 to collect information, particularly on the performance of the trial plots and details of social networking among the participants in the interventions. Data from both the experimental interventions and the later survey were used in this study.

The information from the sales meeting showed that (i) the distribution of modern agricultural inputs has a positive effect on the purchases of farmers with little experience in the use of inputs; (ii) the intervention had a spillover effect on the neighbors' adoption; and (iii) the credit sale option also had a large impact, as it allowed deferred payment of the input cost after the harvest. The impact of the credit sales was largest among recipients of the free trial packages.

Moreover, the survey data revealed that there was a high level of heterogeneity across the recipients, in terms of yield performance of the trial plots where the distributed inputs were applied. There were some individuals for whom the yield gain from the use of modern inputs was not sufficiently large to cover the cost of inputs, although the inputs did help many farmers realize a positive profit. The heterogeneity in the return of inputs in the trial plots enabled us to examine the intensity of own learning as well as social learning related to the performance of the modern inputs.

Among the recipients, the yield gain from the modern inputs, measured by the difference between the actual yield of the trial plot and the hypothetical yield of traditional farming methods predicted by the farmers themselves, positively affected their purchase quantities. Not surprisingly, a successful experience tended to increase the farmers' purchase quantities of modern inputs for the subsequent season more than an unsuccessful one.

The performance of the trial plots of the recipients of the free inputs also positively affected the purchase quantities of the neighbors with whom the recipients shared information on the farming business; on the other hand, it did not affect the purchase quantities of neighbor households who merely lived in proximity but did not exchange farming information with the recipients. These findings suggest that farmers learn new agricultural technologies through social networking rather than through geographic peers, and that they will adopt such technologies in cases where they recognize the benefits thereof.

The rest of this paper is organized as follows. Section I reviews the related literature and background information on the current farming system in Uganda. Section II discusses a series of interventions that we have conducted in Uganda since January 2009. Section III discusses the village-level and household-level data comprising the same, by type of household. Section IV reports the key results of the sales experiment and yield predictions based on the quantities of modern agricultural inputs purchased at the sales experiment. Finally, Section V concludes the paper.

I. Background

A. Related literature

There has been a growing body of empirical literature on technology adoption in agriculture in Africa.[2] There is little doubt that there are profitable agricultural technologies suitable to conditions in Africa. Many studies confirm the high average return of agricultural inputs or methods, for example, fertilizers for maize production in Kenya (Duflo, Kremer, and Robinson (2008)) and hybid seeds in Kenya (Suri (2011)), fertilizers for cocoa production in Ghana (Zeitlin, Caria, Dzene, Janský, Opoku, and Teal (2011)), and the system of rice intensification (SRI) method for rice production in Madagascar (Moser and Barret (2006)). Nonetheless, such technologies tend to diffuse slowly and incompletely. This

[2] The literature on technology adoption in agriculture is reviewed comprehensively by Sunding and Zilberman (2001) and Feder, Just, and Zilberman (1985). Foster and Rosenzweig (2010) review more recent literature in technology adoption in general, and Munshi (2008) reviews literature on social learning.

observation constitutes a puzzle in Africa, if one considers the low rate of adoption of technologies that offer the promise of high returns.

In the case of Uganda, evidence of the profitability of modern agricultural inputs is sporadic, and some of the available estimates are conflicting. The results of trial plots for experimental purposes indicate the very high physical returns of modern inputs. For instance, based on a report by the National Agricultural Research Organization (NARO) in Uganda, the difference in average crop yields between NARO trial stations that use modern inputs and the plots of local farmers who typically use no modern inputs shows a considerable physical yield response to the inputs, indicating large potential profits (Bayite-Kasule (2009)). Namazzi (2008) reports the results of fertilizer response trials on maize that were carried out in 2003 across different districts by Sasakawa Global 2000, an international nongovernmental organization that promotes agricultural technologies in several African countries; that study shows that fertilizer application was generally high and profitable, although the level of profitability varied by region.

Unlike the reports from the trial plots, the results of local farmer surveys tend to be quite varied. Matsumoto and Yamano (2009) estimate the maize yield function, using plot-level panel data from 2003 and 2005; they compare the marginal physical product of inorganic fertilizer with its relative price to maize grain, and conclude that the relative price is too high for the average farmer to turn a profit from the use of fertilizer. Nkonya, Pender, Kaizzi, Kato, and Mugarura (2005) also report that the use of inorganic fertilizer appears not to be profitable for most farmers, based on the results of their farm household survey.

The inputs' low average economic return on the ground does not necessarily mean that such technologies are not profitable to all farmers who face different weather, soil, and market-access conditions, given the high performance of modern inputs in demonstration plots. Returns could vary among regions and even individuals, depending not only on their environment and conditions but also on their knowledge of how to use the technologies. Several recent studies point out the importance of heterogeneous returns to agricultural technologies, to understand the reasons of low adoption rate of technologies that have high average expected returns. Suri (2011) argues, in her study of maize production that covers most of the maize-growing areas in Kenya, that the low adoption rate of modern inputs can be accounted for by the heterogeneity of returns to modern inputs.[3] That is, although the average return is high, the return differs largely across regions, individuals, and time, and hence, some farmers do not use them persistently. Zeitlin, Caria, Dzene, Janský, Opoku, and Teal (2011) also report that the high average effect of modern inputs on cocoa production among Ghanian farmers were found to be consistent with negative economic profits, for a

[3] Duflo, Kremer, and Robinson (2008) also found that the returns of inorganic fertilizer in maize production varied across farmers in western Kenya.

substantial fraction of the farmers who were provided a package of fertilizer and other inputs on credit.

In our experimental setting, the modern inputs distributed to farmers for the purpose of their trial were not tailored, and instruction on usage delivered to farmers in the training workshop was uniform across all villages and participants. Given heterogeneous agricultural and market conditions, we expected that the non-tailored inputs would create variations in return across villages and even individuals within a village. Thus, in addition to the average effect of an intervention that involves the introduction of new inputs, we also focus in the following section on measuring the effect of heterogeneous returns on adoption and assess whether differences in returns are related to the adoption of the inputs in the subsequent season.

Our study also looks to measure the effect of social learning. Recent literature on technology adoption often uses experiments to measure social-learning effects (Kremer and Miguel (2007), Duflo, Kremer, and Robinson (2011), Dupas (2010)). Experimental approaches can overcome the reflection problem that arises when inferring that the adoption behavior of individuals is due to other reference group members' adoption—behavior that could be due, in turn, to the presence of common unobservable characteristics that also affect all member adoption (Manski (1993)). Using an experimental approach, researchers can create an exogenous variation in distribution that determines whether or not experiment participants are exposed to a new technology in the initial period, whereupon the researchers can then observe their neighbors' adoption in subsequent periods. Our study is within this domain.

The social-learning effect was measured by comparing the purchase quantities of the modern inputs between the neighbors of the recipients of free inputs and those who lived in the control villages. We found large positive effects, which is not consistent with the findings of Duflo, Kremer, and Robinson (2011) or Suri (2011), each of who found little evidence of social learning in modern inputs for maize production among Kenyan farmers. An important difference between these studies and ours is that the technologies addressed (i.e., hybrid seed and chemical fertilizers) are not new to Kenyan farmers, but are new to Ugandan farmers. In Kenya, these technologies have been known to most farmers for many years (Suri (2011)); in our sample in Uganda, however, only 10 percent of households had reported experience in the use of hybrid seed before our intervention, and a negligible number of households had used chemical fertilizers in crop production. Unlike Uganda, there might be nothing new or easy to learn from others at this stage of the diffusion process in Kenya. Thus, once we consider the difference in the degree of dissemination between these two countries, the difference in impact as a result of social learning, with respect to these technologies, will be more readily comprehended.

In addition to the experiment, during the first intervention, we collected detailed information regarding social networks from the neighbors of the recipients of the free inputs. Using this information, we distinguished learning from “geographic peers” who live in geographical proximity from that of “information peers” who exchange farming business information. We found that the performance of the trial plots of the recipients also positively affected the purchase quantities of the information peers, but that it did not affect the purchase quantities of the geographic peers. This finding is consistent with that of a recent study by Conley and Udry (2010), who argue that it is not geographical proximity but rather information networks that significantly enhance social learning.

B. Maize production in Uganda

In Africa, the application level of chemical fertilizers and the adoption rate of high-yielding varieties are generally much lower than in other parts of the world. However, there are also large variations across African countries. One example can be seen in the interesting contrast in the use of modern inputs for maize production between two neighboring countries, Kenya and Uganda (Matsumoto and Yamano (2009)). Only a few farmers in Uganda have used modern inputs in maize production while most farmers in Kenya have used them for long.

Table 1 compares input use for maize production between Kenya and Uganda, using data from the RePEAT surveys in Kenya and Uganda.[4] In the survey years, only 5 percent of farmers in Uganda planted hybrid maize seed, and they applied negligible amounts of chemical and organic fertilizers on the maize plots. In contrast, about 60 percent of Kenyan farmers planted hybrid seed and used 94 kg/ha of chemical fertilizers; in addition, they used more than 1 ton/ha of organic fertilizers on maize plots. Some of the farmers in Kenya have been using such inputs for a decade or longer, and most of them have at least some experience with them.[5] As a consequence, the average maize yield is higher in Kenya than in Uganda.

[Insert Table 1 Here]

Owing to the high transportation costs associated with the import of modern inputs, particularly in Uganda, the market price of those inputs is high, and hence their profitability is low (Omamo (2003)). As standard neoclassical models of

[4] RePEAT (Research on Poverty, Environment, and Agricultural Technologies) is a research project headed by a research team of the National Graduate Institute for Policy Studies (GRIPS) and the Foundation for Advanced Studies on International Development (FASID, Japan). It aims to identify constraints and effective technologies that reduce poverty in east African countries—especially Kenya, Uganda, and Ethiopia—through empirical analyses based on field data vis-à-vis agricultural production, collected from farm households. RePEAT also indicates their intention to repeat data collection, in order to construct panel data over a longer period. (See Yamano, et al. (2004) for more details.)

[5] The RePEAT surveys in Kenya mainly covered areas in the Central, Rift Valley, Nyaza, and Western provinces, where population density is higher and the environment is better suited to crop production than other areas.

technology adoption predict,[6] the low profitability of modern inputs has been one of the major reasons for low adoption rates and application levels among Ugandan farmers. In addition, in the past, the issue of land scarcity was not a prominent one in Uganda, owing to favorable climate conditions for crop production relative to the population densities of the country. Thus, Ugandan farmers have had little incentive to use modern inputs for intensive farming. Moreover, because of the low potential demand for these inputs, the supply network in Uganda has not been adequately developed to make their use financially feasible.

However, conditions for farming have been changing drastically in Uganda. First, because of high population pressures[7] and limitations for the expansion of arable land through land-clearing, land is becoming increasingly scarce; as a result, the average amount of land per household has been decreasing rapidly (National Environment Management Authority (2007)). Second, recent hikes in crop prices are prompting farmers to change their perceptions with regard to crop production. Some farmers have started to consider crop production a business enterprise rather than purely for subsistence. Third, owing to infrastructure

[6] See, for instance, Besley and Case (1993) and Munshi (2004) with regard to the model for learning about the profitability of new technologies, and Foster and Rosenzweig (1995) and Conley and Udry (2010) with regard to the model for learning about the management of new technologies.

[7] Estimates of annual population growth rate in 2005 placed Uganda in 11th place worldwide (3.58%) and Kenya in 42nd place (2.36%).

improvements such as roads and mobile networks, farmers have had better access to commodity markets and market information than before.[8] These factors have created high potential demand for intensive farming methods among crop farmers in Uganda. Since these modern inputs are experience goods, a lack of knowledge on their usage and profitability might be a large deterrent to their adoption by farmers who have little experience. Thus, we expected that small interventions involving one-time material support and training on the usage of such modern agricultural inputs would have a large impact on their adoption among Ugandan farmers in the long term.

II. Experimental Design and Survey Data

To investigate the impact of a possible policy intervention on technology adoption by small-scale Ugandan farmers, we conducted an experimental intervention there in maize production, in 2009.[9] The intervention was a

[8] Muto and Yamano (2009) show that the expansion of mobile networks has induced farmers' market participation in Uganda.

[9] The experimental intervention was carried out as part of the Global Center of Excellence (GCOE) Project of GRIPS, Japan, in collaboration with Makerere University, Uganda. It was financially supported by Ministry of Education, Culture, Sports, Science, and Technology, Japan.

sequential randomized–controlled trial.[10] The target sites and individuals were the sample villages and households in the Eastern and Central regions surveyed for the RePEAT panel study.[11]

[Insert Figure 1 Here]

A. Free-input distribution

In the first exercise, which took place in February and March 2009, prior to the first cropping season, we distributed free maize inputs to 377 RePEAT households and asked them to allocate a quarter-acre of land (approximately 0.1 ha) as a trial plot where the inputs would be applied. These households are located within 46 villages (26 and 20 in the Eastern and Central regions, respectively) that were randomly chosen from the RePEAT villages.[12] For convenience, we refer to

[10] Figure 1 shows the timeline for and the number of sample households involved in each project within the RePEAT study. In the initial RePEAT household survey in 2003, 10 households were surveyed in each village. Because of attrition, 106 households dropped out from the 61 treatment villages.

[11] Three of the 94 RePEAT survey villages are excluded from this experimental intervention. Two of them are located in Kapchowa district, close to the Kenyan border. Their application rates of chemical fertilizers and their adoption rates of hybrid maize seed, according to the 2005 RePEAT survey, were exceptionally high. The other village has been involved in the United Nations' Millennium Village Project since 2008. These villages are very different from others in terms of their experience with modern inputs, and they were thus excluded as unrepresentative outliers.

[12] The smallest local administrative unit in Uganda is LC1. In this paper, we refer to the LC1 as a "village." We included in the free-input distribution 22 villages (15 treatment and seven control villages) in the Western region. However,

the households in the 46 villages as the "treatment households"[13]; this distinguishes them from the remaining households located in the other 23 villages (13 and 10 in the Eastern and Central regions, respectively) that are referred to as the "control households."[14] The geographic distribution of those villages is shown in Figure 2. The randomization for the selection of the treatment villages was implemented based on a computer-generated random number after the stratification by region.

[Insert Figure 2 Here]

The free inputs distributed to the treatment households were uniform (i.e., non-tailored) across the treatment villages. They comprised 2.5 kg of hybrid seed, 12.5 kg of base fertilizer, and 10 kg of top-dressing fertilizer.[15] In addition, a 2-hour

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they were excluded from the second exercise because of time and budget constraints. Thus, in this study, we focus on samples only from the Eastern and Central regions.

[13] There were a small number of households who were part of the original RePEAT sample and invited to the workshop where free inputs were distributed but did not attend and hence did not obtain them. We also call these households "treatment households." Thus, the treatment households can be considered part of an "intent to treat" sample.

[14] We included in the free-input distribution 22 villages (15 treatment and seven control villages) in the Western region. However, they were excluded from the second exercise because of time and budget constraints. Thus, in this study, we focus on samples only from the Eastern and Central regions.

[15] These are the recommended input levels for growing a quarter-acre of maize by an agronomist in National Agricultural Research Organization, Namulonge, Uganda just for a research purpose for us to implement an uniform

training session on the use of these modern inputs was delivered by an extension worker to the members of the treatment households.

B. Sales experiment

The second exercise occurred in August and September 2009—the intermediate period between the first and subsequent cropping seasons—during which we revisited 46 treatment and 23 control villages in the Eastern and Central regions to sell the same inputs that had previously been provided for free to the sample farmers. We held a sales meeting in each of the target villages and invited members of all the RePEAT households, as well as randomly selected neighbors of the treatment households (called "neighbor households," hereafter). To select the neighbor households, we visited each of the treatment households prior to the sales experiment, asked the household head to list five to 10 households as neighbors, and then randomly selected one household from the list as the "neighbor household." We expected this neighbor-household selection procedure to mitigate the selection bias that would occur if the treatment households were to invite households with special interests or relationships (e.g., friends or relatives),

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intervention. The composition may not be optimal under some circumstances because it does not consider heterogeneity of agroclimatic environments as well as input-output price ratio. The market value of these inputs was 52,500 Ugandan Shillings (Ush) (US$26.80, at the exchange rate of February 2009).

especially, in cases where the treatment households perceived our first intervention to be beneficial.

We held the sales meeting and provided the supplies procured from a whole seller in Kampala by ourselves, rather than working with local input suppliers. This was because the supply network of agricultural inputs had not been well developed and hence there were places in our target areas where we could not procure the reliable quality inputs from local retailers.

The purpose of the sales experiment was to gather information on input demand for the participating households and to make comparisons among the three groups—the control, treatment, and neighbor households. To obtain information on their demand in response to a change in price, we used a “price contingent order form” that asked farmers how much of each input they would buy at different discount levels (Appendix). Three discount rates from the market price were offered, namely, 0, 10, and 20 percent.[16] Which discount rate would be used for the actual sales was not determined until they filled out the order form, although the participants were informed at the beginning of the sales experiment that one of the discount rates would be randomly chosen and that they would need to pay for the amounts indicated on the form at the chosen discounted price.

[16] We were interested in collecting information on the purchase quantities at a wider range of discount rates. However, given the possibility that the participants could profit from reselling inputs to other residents or even input dealers, we could not offer higher discount rates.

We used a similar order form for credit purchases, on which participants indicated how much of each input they would buy if credit were available. In the proposed credit scheme, the participants were allowed to pay the balance—that is, the total payment with interest, minus the initial payment—at the end of the subsequent season after the harvest, as long as the initial payment exceeded the minimum down-payment agreed upon at the meeting. The interest rate and the minimum down-payment rate were randomly assigned at the village level, according to the project. The interest rates offered were 5, 10, or 15 percent per cropping season. The minimum down payments offered were 20, 30, or 40 percent.

After the participants filled out the forms, one of them—typically a village leader—drew a ball from a bingo cage to randomly determine the discount rate; a second ball was then drawn, to determine whether the credit option was actually available to the group. The chance of winning the credit option was one in 10.[17] Finally, at the end of the sales experiment, the participants did, in fact, purchase inputs as indicated on the order forms at the discount level, and with or without the credit option as determined by the bingo game.

Using the price contingent order form at the sales meeting, we obtained information on the participants' purchase quantity levels at three different

[17] The participants in all the 69 villages where the sales experiment was held had a chance to buy inputs on credit.

discount rates, with and without the credit option—that is, six quantity levels in total, for each input from each participant.

C. Survey data

In addition to the experimental intervention, we conducted a survey (called "RePEAT 2009," hereafter) in October–December of 2009 and collected information from the target households. In particular, we collected detailed information on maize production in the years 2008 and 2009, including that on input use on the experimental plots and other plots. In addition, we gathered information on social networks from neighbor households, by using a preprinted list of the names of the treatment households in the same village, together with the questionnaire, which asked the neighbor households about their relationship with each of the treatment households.[18] For this study, we used both the data from the experimental intervention and the survey data conducted later. Table 2 shows the number of sample villages and households for each event, by region and type of household.

[Insert Table 2 Here]

[18] This is useful information in learning about social networks, not only for the neighbor households but also for the other types of households. However, we were able to collect information only from the neighbor households, given time and budget constraints regarding the field survey, as data collection had been time-consuming.

D. Village and household characteristics in 2009

Table 3 shows the characteristics of villages involved in the RePEAT 2009 survey, by village type. Owing to the nature of the random assignment of free-input distribution, there were presumably no systematic differences in terms of pre-intervention characteristics, between these types of villages. The test statistics of the difference in mean of the key variables shown in Column 4 confirmed this presumption. Similarly, Table 3 shows household characteristics, by household type. As expected, there were no systematic differences between the treatment and control households except the past use of chemical fertilizers on maize plots. (The test statistics of the mean difference are given in Column 4.) The past use of chemical fertilizers was higher for the control households than the treatment households. If it had a positive effect on the adoption of modern inputs, we would underestimate the treatment effect of our intervention without controlling for this variable. We may need careful investigation on this.

Our sample households comprised small-scale farmers; on average, each cultivated 1.2 ha of land, contained slightly fewer than eight family members, and had a head who was 50 years old and had six years of schooling.

[Insert Table 3 Here]

Compared to the treatment and control households, the neighbor households were smaller in family size and in the land size cultivated; their heads were both younger and more educated. These differences between neighbor households and others, despite the sampling scheme (see the explanation of the sales experiment in the previous section), are probably because the treatment and control households were already older than the average residents were, because the original RePEAT samples had been sampled since 2003. At the same time, it may imply that they are different in their potential demand for intensive farming methods, owing to differences in land availability and education level. We controlled for these factors in regressions, to mitigate potential sampling biases between neighbor households and other types of households.

E. Sample Attritions

In the following analyses, we mainly use the information obtained from the sales experiment in 2009 and combined with RePEAT 2009 Survey data. There is an issue to be considered. The sample attritions in the sales experiment are not negligible, which are indicated in the parentheses in Table 2. When we held the sales experiment, we announced village leaders (who were supposed not to be the subject households) about our visit and its purpose two to three weeks prior to the scheduled date via mobile phone and asked them to circulate the information to the target households. Then, we also asked the leaders to mention to the target households about the compensation for the participation. However, some of the target sample households did not show up at the sales experiment because some might not have been interested in the experiment or other may not have been correctly informed about the purpose and venue of the sales experiment. As a consequence, the sample attrition in the sales experiment was large and may cause a serious selection bias when we estimate the demand curves in the following analyses. Especially, if those who were not interested in the modern inputs did not participate in the event, the estimates of the demand for the modern inputs based only on the participants' information would be upwardly biased.

One simple compromise may be to consider those absentees as those who would not purchase any input even when they had participated in and to incorporate them into the samples for the estimation of the demand. In that case, the purchase quantity of the absentees is set at zero and hence the estimates of the demand can be considered as the lower bound. We confirmed that the inclusion of the absentees by setting their purchase quantity at zero did not affect results much compared with the ones presented in the tables for the following analyses.[19]

[19] Those results will be presented by the author upon request.

III. Empirical Strategies

A. Demand for inputs, by household type

The simplest approach to observing the impact of free-input distribution on adoption behavior on modern inputs in the subsequent season is to compare the mean values of the purchase quantities at the sales experiment among the different household types. For convenience, let us denote x_i as the purchase quantity of the *i*-th household. Let I_T, I_C, and I_N be the sets of households that belong to the treatment, control, and neighbor household groups, respectively. Since the assignment of the treatment status was random, the average effect of the free-input distribution on the purchase quantity is given simply by $E[x_i|i \in I_T] - E[x_i|i \in I_C]$. Also, its effect on the purchase quantity of the neighbor households is given as $E[x_i|i \in I_N] - E[x_i|i \in I_C]$.

Since we collected purchase-quantity data with and without the credit option, we were also able to determine the effect of the credit option on the purchase quantity by household type, i.e., $E[x_i|i \in I_O, CR = 1] - E[x_i|i \in I_O, CR = 0]$ for $O = \{T, N, C\}$, where CR is a binary variable that takes the value of 1 if the credit option is available, and 0 otherwise.

B. Regressions

In addition to the average intervention effect, depending on the household's treatment status, we were also interested in the influence of other factors; which we examined by using simple regression models. This might also be important in estimating the impact of the intervention—especially on the neighbors' adoption, given the difference in some characteristics of the neighbor households, compared to other household types.

First, we considered a model that identified the factors that affect the purchase quantity of input *x* of household *i* located in community *j* at price level *P*, as well as the availability of the credit option, denoted by the dummy variable *CR*:

(1) $$x_{ij}(P, CR) = \alpha + \beta_T T_i + \beta_N N_i + \gamma P + \gamma_T T_i \cdot P + \gamma_N N_i \cdot P$$

$$+ \delta CR + \delta_T T_i \cdot CR + \delta_N N_i \cdot CR + \phi X_{ij} + \varepsilon_{ij}(P, CR),$$

where *T* is a dummy variable for the treatment households, *N* is a dummy variable for the neighbor households, and *X* is a vector of other exogenous variables associated with the household and the community. The following variables are considered the exogenous *X*: the down-payment rate that determined the level of minimum payment for the credit sales, the interest rate charged for the credit sales, and their interactions with the credit-sales dummy; the household variables involving the number of family members; the dependency rate (i.e., the ratio of family members aged below 15 or over 65 to those aged between 15 and 65 inclusively); a dummy variable for female-headed households; the household head's age and years of schooling; the size of land owned in ha; assets-holding level, in millions of Ush; past use of maize hybrid seed; and past use of chemical fertilizers on maize production.

C. Heterogeneity in yield and profitability across regions and individuals

The performance of modern inputs used in the trial plots of the treatment households varied across communities, as well as across households within a given community. According to the simple learning model, it is expected that successful experiences from the use of a new technology will enhance the likelihood of its use in subsequent periods, while unsuccessful experiences will reduce it. In addition to learning from one's own experiences, the model also predicts learning from peers—especially among those who share information (Conley and Udry (2010)). Using survey data collected after the sales experiment, we examined the effect of the difference in performance of the trial plots on adoption in the subsequent season.

Figure 3 shows the distribution of the yield difference between the actual yield of the trial plot and the hypothetical yield predicted by the farmers themselves among the treatment households, had the traditional method been applied to the same plot.[20] The two vertical lines indicate the level of yield gain from the use of modern inputs that would be required to recover the input costs for the trial plot (approximately US$25) at two different prices of the output. The dotted line corresponds to the required level at the output price of 500 Ush which is equivalent to the median producer price in 2008/2009, while the dashed line corresponds to the level at 250 Ush equivalent to the 5th percentile level.[21] Yield gains varied across individuals, and not all the farmers saw positive profit-gains from the use of modern inputs. One of the reasons would be the fact that the modern inputs that we distributed for free had not been tailored to specific regions or individuals: they may not be suitable for certain soil or climate conditions. Also, differences in yield gain could be caused by differences in crop management, as some individuals might have managed them properly, while others did not.

[Insert Figure 3 Here]

[20] There are 203 households which reported both the hypothetical yield and the actual yield of a plot where local seeds and no fertilizers were applied in the first cropping season in 2009. Comparing the hypothetical yield with the actual yield, their distributions appeared to be similar; the p-value of the t-test for the difference in mean is 0.895, which cannot reject the null hypothesis that the difference is equal to zero.

[21] Typically, almost no purchased inputs are applied when local seed is planted.

D. Learning from one's own experience: effect among treatment households

Given the large heterogeneity in performance of the modern inputs on the trial plots, we were able to see its effect on the purchase of the modern inputs during the sales meeting among the treatment households. We incorporated the yield gain from the modern input use denoted, $\Delta Y_i (\equiv Y_i^H - \hat{Y}_i^L)$, where Y_i^H represents the actual yield from the trial plot (the subscript *i* corresponds to household *i* and the superscript *H* indicates the use of hybrid seed and chemical fertilizers); $\hat{Y}_i^L$, meanwhile, is the hypothetical yield reported by household *i*, had a local seed variety and no fertilizers been applied in the same plot. We used this variable as a covariate in the regression of the purchase of modern inputs. In this analysis, we focused on within-community variations in yield gain as a determinant of the purchase quantities, by controlling for household-level characteristics *X* and community-level specific factors by the community fixed effect α_j.

(2) $$x_{ij}(P, CR) = \alpha_j + \beta \Delta Y_i + \gamma P + \delta CR + \phi X_{ij} + \varepsilon_{ij}(P, CR).$$

The coefficient β captures the magnitude of the impact of the yield gain (in kg) of the trial plot from the use of modern inputs on the purchase quantity (in kg). We estimated the parameters of this model by applying a community-level fixed-effect regression.

E. Learning from peers: effect among neighbor households

Through social networking, the performance of the trial plots would affect adoption behavior, not only to treatment households themselves but also to their neighbor households. As Conley and Udry (2010) suggest, the flow of useful information may not necessarily be restricted to neighbors in close geographic proximity. Rather, social networks based on friendship or kinship may play critical roles in diffusing information. In this study, we look to distinguish the influence of geographic versus information peers.

In the survey following the sales experiment, we collected from neighbor households data indicating their relationship with each of the treatment households. Particularly, we used information pertaining to whether or not they exchanged information on the farming business with each of the treatment households; we did so, to construct a measure that represents the effect of the performance of treatment peers' experimental plots on the decision-making of neighbor households. We created a variable representing the average of the yield gain ΔY of the treatment households with which the *i*-th neighbor household exchanged information on the farming business, denoted by $\Delta\bar{Y}_{info}$ and referred to as "mean yield gain of information peers" in the results table (Table 7). For the purpose of comparison, we also constructed the mean yield gain of geographic peers, $\Delta\bar{Y}_{geo}$, which is defined as the weighted average of ΔY of geographic peers.[22]

(3) $x_{ij}(P, CR) = \alpha_j + \beta\Delta\bar{Y}_{n,ij} + \gamma P + \delta CR + \phi X_{ij} + \varepsilon_{ij}(P, CR)$, ($n$ = *info* or *geo*)

The coefficient β captures the magnitude of the impact of the mean yield gain of peers (in kg) on the purchase quantity (in kg) of the neighbor households. We estimated the parameters of this model by applying a community-level fixed-effect regression.

IV. Results

A. Average purchase quantity by household type

Table 4 shows the results of the average quantity purchased of each input at different discount rates, by household type.[23] Panel A corresponds to the results

[22] As the weight, we use the Gaussian kernel, $K(x) = \frac{1}{\sqrt{2\pi}}e^{-x^2/2}$, based on the distance in km between the households. Thus, the mean yield gain of geographic peers for the i-th neighbor household is given by $\Delta\bar{Y}_{geo,i} = \sum_m K\left(\frac{Distance_{im}}{h}\right) \cdot \Delta Y_m / \sum_n K\left(\frac{Distance_{in}}{h}\right)$ where h is a bandwidth. We use h=1.

[23] Their graphical representations are give in Figure 4-1 to 4-3, by input type.

for cash purchases, and Panel B corresponds to those for credit purchases. Column 4 in Table 4 reports the difference in mean of purchased quantities between the control and treatment households and the standard errors of the test statistics (in parentheses) corresponding to the null hypothesis, in which the difference in mean is equal to 0. Similarly, Column 5 and 6 show the difference between the control and neighbor households and the difference between the treatment and control households, respectively.

[Insert Table 4 Here]

[Insert Figure 4-1 Here]

[Insert Figure 4-2 Here]

[Insert Figure 4-3 Here]

The difference in purchased quantities between the control and treatment households was statistically significant at the 1 percent level for all inputs and at all discount levels. This observation confirmed the significant impact of free-input distribution on the adoption and purchased quantity of modern inputs in the subsequent cropping season, following free-input distribution. The difference becomes larger with the availability of credit.

The purchased quantity of modern inputs by neighbor households was larger than that of control households, in all cases. The difference was statistically significant for chemical fertilizers at all discount levels, but it was not significant for hybrid seed, as shown in Table 4. The level of purchased quantities lay between that of control and treatment households, in all cases.

Panel C reports the differences in purchase quantities between the cash and credit purchase. The effect of credit was very large for all types of households, especially with regard to fertilizer purchases. The credit option boosted the purchased quantities of fertilizers more than threefold. The impact of credit was largest among treatment households, possibly because they had acquired, through the intervention, knowledge on the usage and profitability of modern inputs.

B. Regression results

We considered the four dependent variables for the regressions specified in the previous section. The first three variables were simply the weight of each of the three modern inputs—hybrid seed, base fertilizer, and top-dressing fertilizer, in kilograms—purchased at the sales experiment; the last variable, meanwhile, was the aggregate quantity index, which is defined as the total cost of those three inputs at the market price, divided by 1,000.

Table 5 shows the results of the regressions, in which all household types were used as the sample, corresponding to Eq.(1). The estimates of the coefficients of the dummy for the treatment households, the neighbor households, and their interactions with the dummy for the credit option further supported the results of

Table 4. The purchase quantity of all the inputs was largest for the treatment households, and smallest for the control households (reference group); in the middle were the neighbor households, although the difference between the neighbor and control households was not significant. The credit option has the largest impact on all types of inputs. We also confirmed that the credit option had a differential impact, depending on the household type: it was largest for the treatment households (which can be seen as the coefficient of the interaction term of the credit-option dummy with the dummy for the treatment households) and smallest for the control households. These estimates were consistent with the results in Table 4, in which only the mean effect of the treatment status was considered and the other factors ignored; this implies that our randomization had been successfully implemented.

[Insert Table 5 Here]

The minimum down-payment rate—which determines the amount of cash payment required to be paid during the sales experiment for a credit purchase, and is randomly assigned at the community level—had a negative impact on the purchase quantity, but only for credit purchases. This result was consistent with the fact that the down payment rate was effective only for credit sales. Also, the significant effect implied that the immediate cash constraint was binding for the average participant in the sales experiment. A 10 percentage-point increase in the minimum down-payment rate would result in a 6,374 Ush decrease in the total input purchase.

The interest rate—charged for the cost of credit purchases and randomly assigned at the community level—was also effective for credit purchases only. Although we expected it to have a negative impact on the input purchase only for credit purchases, we obtained a somewhat odd result: the coefficient of the interest rate was positive and significant for the cash purchase of hybrid seed. This finding may require further investigation.

Household size had a positive and significant effect on the purchase quantities of seed and base fertilizer, and on the quantity index. This may suggest that labor requirements for intensive farming methods that use modern inputs are higher than those for traditional farming. The coefficients of the household head's age were negative and significant, meaning that younger farmers were more active in the use of new inputs than older ones. The head's years of schooling had a positive effect on the purchase of modern inputs, indicating that more educated persons were more willing to buy modern inputs, although the magnitude was relatively small. The coefficients of size of land owned showed inconsistent signs, depending on the type of inputs. The coefficients of level of asset holdings were negative for all inputs, although their magnitude, too, was very small.

The coefficients of past use of hybrid seed and chemical fertilizers were positive for all and significant, except for the purchase quantity of hybrid seed.

Although only a few farmers used maize hybrid seed and chemical fertilizers on maize prior to our experimental intervention (as shown in Table 1), it seems that they had known of the value of modern inputs and hence purchased more at the sales experiment.

C. Learning from own experience

We focused on the effect, among the treatment households, of the differential performance of the experimental plots that used modern inputs on purchase quantities in the subsequent season. Table 6 shows the results of regressions corresponding to Eq.(2), which helped determine the effects of the performance of the experimental plots among treatment households.

Yield gains in the experimental plots, which were measured as the difference between the actual yield of the experiment plot and the farmer's prediction of the yield with the use of traditional inputs in the same plot, were found to significantly increase the purchase of inputs during the sales experiment. For example, on average, a 100-kg gain—the approximately median gain—increased the purchase of inputs by 4,510 Ush at the market price during the sales experiment (Table 6, regression 4). For other covariates, the results were more or less similar to the previous regressions in Table 5.

[Insert Table 6 Here]

D. Learning from peers

We estimated the impact of the yield gain of the treatment households on the neighbor households' input purchases. We used two variables defined in the previous section: the mean yield gain of information peers and the mean yield gain of geographic peers, in their respective experimental plots. The results are provided in Table 7. The coefficients of the mean yield gain of the information peers were all positive and significant, except for that of the top-dressing fertilizer; those of geographic peers showed different signs, depending on the types of input measures, and they were not significant for any of the inputs. This observation suggests that information on the usefulness or profitability of technology, or modern inputs, flows through an information network more efficiently than among neighbors with geographic proximity, and hence boosts the adoption of such technology.

[Insert Table 7 Here]

IV. Conclusions

Maize productivity in Uganda remains very low; one obvious reason for this is the limited use of modern maize inputs. In the early stages of technology dissemination, a lack of knowledge is a crucial explanation for the low adoption rate of profitable technologies. Our study results showed that once farmers recognize the benefits of new inputs in crop production, many of them will invest in the inputs for the subsequent season. It is also important to note that farmers learn from their own and others' successful experiences, through social networking. These observations point to the importance of agricultural extension services in diffusing new and profitable technologies. Emphasizing the role of extension services, it is obviously important to note that because the profitability of a technology can vary to a great extent across regions and with time, an untailored technology will not bestow benefits upon every farmer in every place. Technologies may need to be chosen by those with on-the-ground knowledge of suitable technologies and their profitability. For this reason, it might often be the case that local private stakeholders such as input suppliers who can both deal with tailored agricultural-input technologies and have knowledge of the commodity market might well be more competent providers of extension services than public providers. We believe that there is ample opportunity for the private sector to play a significant role in this service area.

Finally, this study also showed that Ugandan farmers face severe credit constraints; this was underscored by the fact that their demand for inputs increased significantly when they were given a credit option. This observation suggests that the provision of affordable financial services in rural areas could prompt Ugandan farmers to change their farming methods, boost productivity, and improve their quality of life. Owing to the development of mobile technologies and drastic reductions in the transaction costs associated with communication and financial services via mobile phones, financial services that target small-scale farmers in remote areas can become more feasible, at least on a technical level. The provision of such services promises the potential of great advances among the farmers in Uganda.

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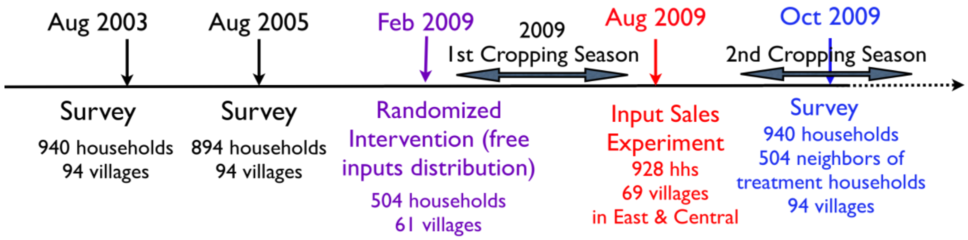

FIGURE 1. TIMELINE OF SURVEYS AND FIELD EXPERIMENTS

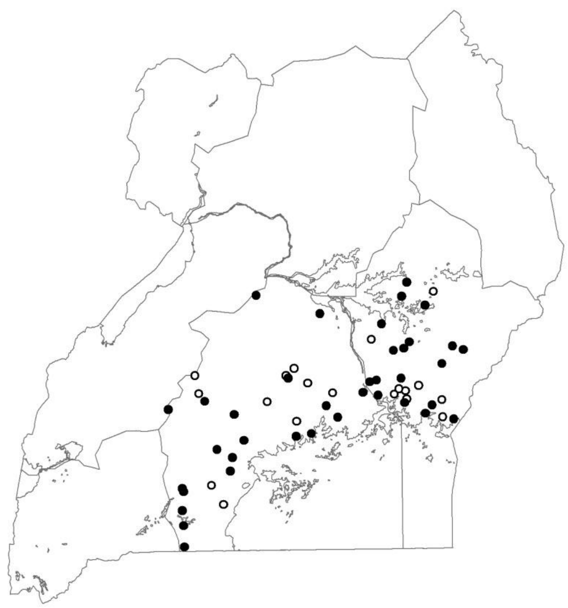

FIGURE 2. SURVEY VILLAGES

Notes: Black circles indicate treatment villages; white circles indicate control villages.

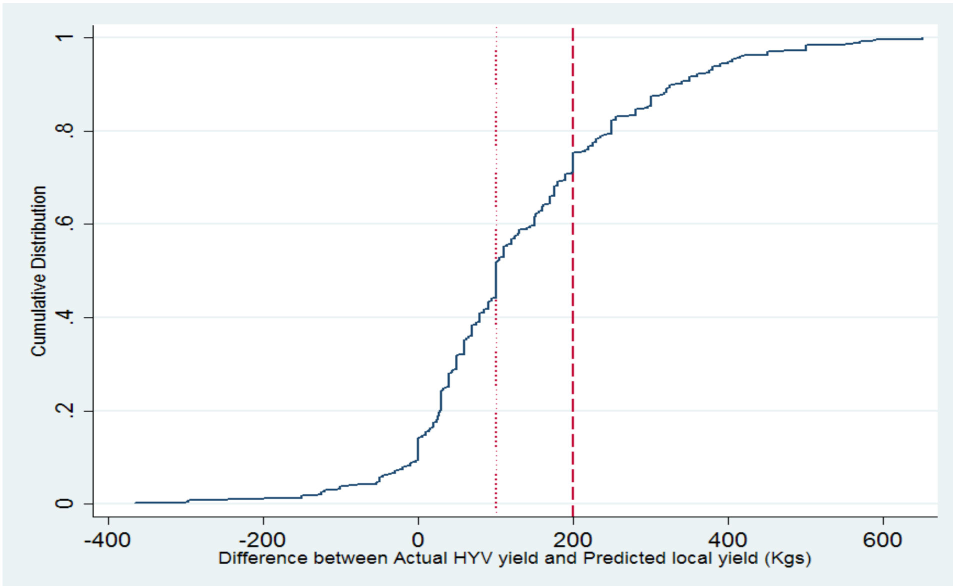

FIGURE 3. DIFFERENCE (IN KG) BETWEEN THE HYBRID YIELD (ACTUAL) IN THE EXPERIMENTAL PLOT (0.1 HA) AND THE LOCAL YIELD (PREDICTED), AMONG THE TREATMENT HOUSEHOLDS

Notes: two vertical reference lines—the dotted line on the left and the dashed line on the right—correspond to the yield levels at which the farmer recovers the cost used in the experimental plot at different output price levels, 500 Ush/kg (equivalent to the median level of the producer price in 2008/2009) and 250 Ush/kg (equivalent to the 5th percentile level), respectively. Most farmers who planted local seed applied no purchased inputs.

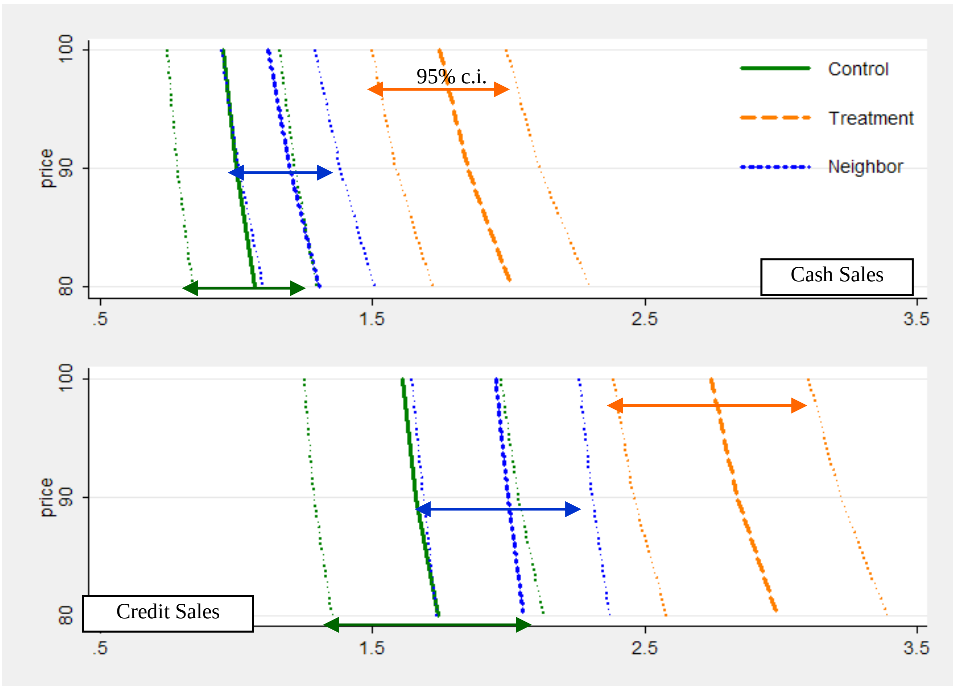

FIGURE 4-1. HYBRID SEED: ESTIMATED DEMAND CURVES

Note: The arrows indicate 95 percent confidence intervals.

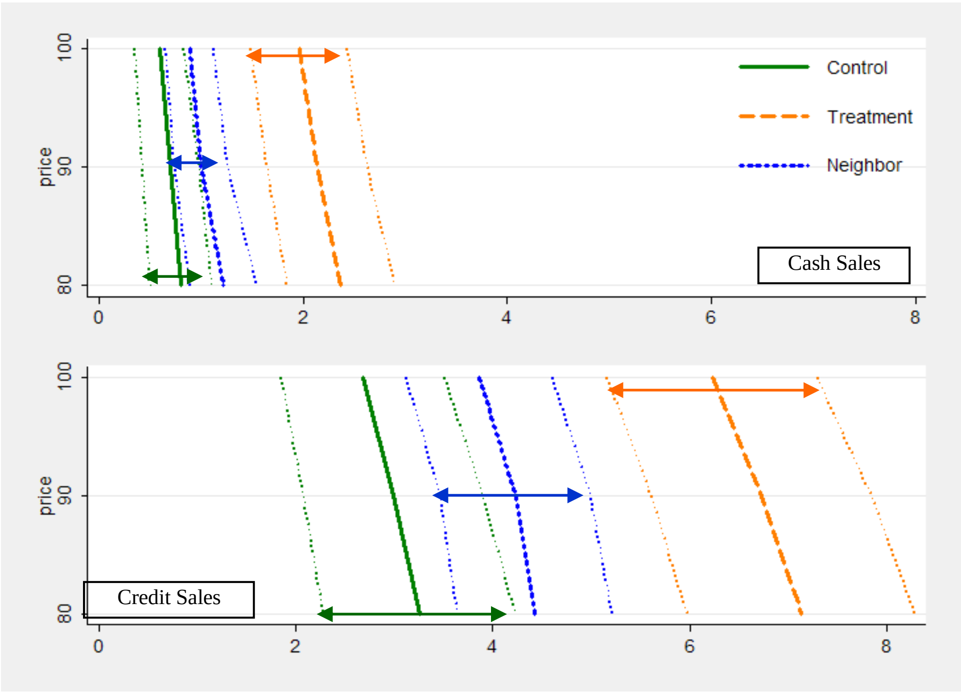

FIGURE 4-2. BASE FERTILIZER: ESTIMATED DEMAND CURVES

Note: The arrows indicate 95 percent confidence intervals.

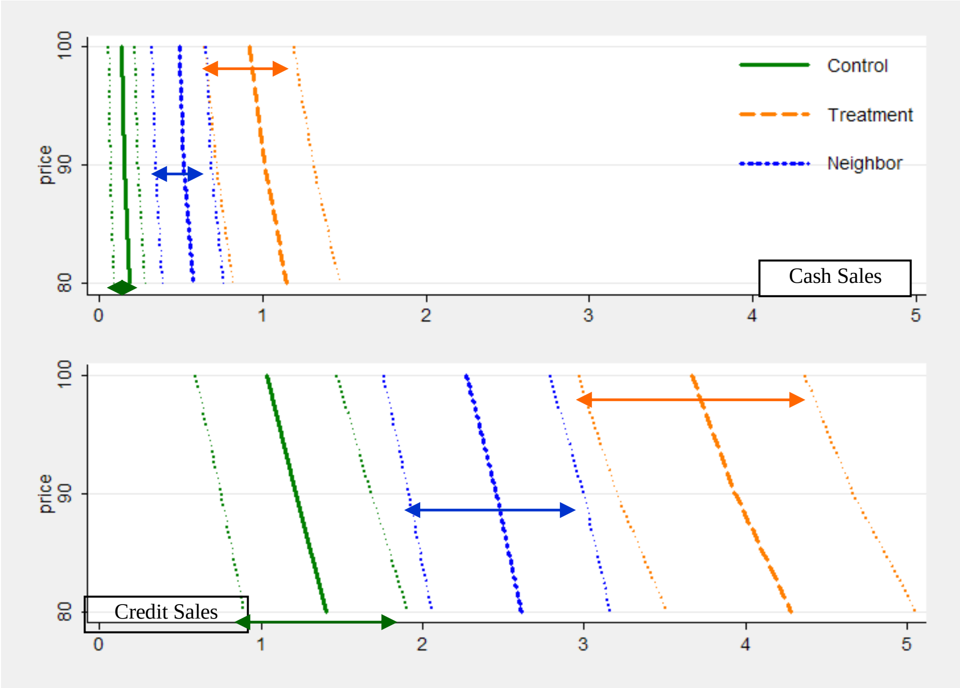

FIGURE 4-3. TOP-DRESSING FERTILIZER: ESTIMATED DEMAND CURVES

Note: The arrows indicate 95 percent confidence intervals.

TABLE 1. COMPARISON OF INPUT USE IN MAIZE PRODUCTION, BETWEEN KENYA AND UGANDA

	Kenya 2004/2007 (1)	Uganda 2003/2005 (2)
Hybrid seed use (percent)	59.0	4.9 [a]
	(49.2)	(21.6)
Average inorganic fertilizer application (kg/ha)	94.7	2.4
	(124.5)	(18.9)
Average organic fertilizer application (kg/ha)	1,935	86
	(4,835)	(768)

Notes: Standard deviations are given in parentheses. The difference in mean for each of the three variables above is significantly different from zero at the 1 percent level.

Sources: RePEAT 2004/2007 in Kenya, RePEAT 2003/2005 in Uganda.

[a] Because there is no information on the type details of maize seed in the questionnaire used in the Uganda surveys, the percentage of hybrid seed use was obtained as the proportion of maize plots with seed whose price was more than or equal to 3,000 Ush/kg.

TABLE 2. NUMBER OF HOUSEHOLDS PARTICIPATING IN EACH EVENT IN EASTERN AND CENTRAL REGIONS

Panel A *Number of villages, by type*	Village type by status of free input distribution, 2009 Total	 Control	 Treatment
	(1)	(2)	(3)
Eastern	39	13	26
Central	30	10	20

Panel B *Number of households, by event and type*	Household type by status of free input distribution, 2009 Total	 Control	 Treatment	 Neighbor
	(1)	(2)	(3)	(4)
Free input distribution, Feb.–Mar. 2009				
Eastern	242	0	242	
	(8)		(8)	
Central	135	0	135	
	(37)		(37)	
Sales experiment, Aug.–Sept. 2009				
Eastern	512	109	210	193
	(93)	(13)	(40)	(43)
Central	297	78	124	95
	(112)	(17)	(48)	(47)
RePEAT 2009 Survey, Oct.–Dec. 2009				
Eastern	575	118	235	222
	(33)	(4)	(15)	(14)
Central	372	90	155	127
	(37)	(5)	(17)	(15)

Note: The size of sample attrition (those targeted minus those who participated) is shown in parentheses. For the free-input distribution, the sales experiment, and the RePEAT 2009 survey, we did not target the households who were migrated out of LC1 (the smallest administrative unit in Uganda) after the RePEAT 2005 survey.

TABLE 3. SUMMARY STATISTICS OF KEY VARIABLES IN THE REPEAT 2009 SURVEY

Panel A. *Village Characteristics*	Mean by village type: Control	Treatment		Mean difference: Control vs. Treatment		
	(1)	(2)	(3)	(4)	(5)	(6)
Longitude (degree)	33.03	32.97		0.06		
	(0.98)	(1.06)		(0.26)		
Latitude (degree)	0.6	0.59		0.01		
	(0.45)	(0.63)		(0.14)		
Altitude (meter)	1,251.1	1,204.7		46.39		
	(181.8)	(140.4)		(43.20)		
1{Public electricity is available}	0.32	0.14		0.18		
	(0.48)	(0.35)		(0.11)		
1{Mobile network is available}	1	1		0		
	(0.00)	(0.00)		(.)		
1{Any primary school}	0.68	0.61		0.07		
	(0.48)	(0.49)		(0.13)		
1{Any secondary school}	0.09	0.11		–0.02		
	(0.29)	(0.32)		(0.08)		
1{Any health facility}	0.82	0.8		0.02		
	(0.39)	(0.41)		(0.10)		

Panel B. *Household Characteristics*	Mean by household type: Control	Treatment	Neighbor	Mean difference: Control vs. Treatment	Control vs. Neighbor	Treatment vs. Neighbor
	(1)	(2)	(3)	(4)	(5)	(6)
1{used maize HYV seed in past}	0.15	0.15	0.12	-0.001	0.03	0.03
	(0.36)	(0.36)	(0.34)	(0.03)	(0.03)	(0.03)
1{used chem. fertilizers on maize in past}	0.16	0.10	0.12	-0.07***	0.05	-0.02
	(0.37)	(0.30)	(0.33)	(0.03)	(0.03)	(0.02)
Household size	7.75	7.97	7.12	–0.22	0.63***	0.85****
	(3.45)	(3.82)	(3.31)	(0.31)	(0.30)	(0.26)
1{head is female}	0.18	0.13	0.11	0.05	0.07***	0.02
	(0.38)	(0.34)	(0.32)	(0.03)	(0.03)	(0.02)
Head's Age	50.4	49.7	43.4	0.76	7.01****	6.25****
	(14.2)	(13.1)	(13.7)	(1.20)	(1.24)	(1.0)
Head's years of schooling	5.68	6.05	6.60	–0.37	–0.91***	–0.54*
	(4.03)	(4.19)	(4.30)	(0.35)	(0.36)	(0.31)
Cultivated land (ha) [a]	1.21	1.18	1.03	0.03	0.18***	0.16***
	(0.93)	(0.95)	(0.96)	(0.08)	(0.08)	(0.07)
Assets (millions of Ush)	0.64	1.08	0.50	–0.44	0.15	0.58*
	(2.0)	(5.79)	(0.98)	(0.33)	(0.15)	(0.30)

Assets except vehicle (millions of Ush)	0.45	0.55	0.45	–0.10	0.00	0.10*
	(0.66)	(0.80)	(0.68)	(0.06)	(0.06)	(0.06)
1{owns mobile phone}	0.51	0.56	0.55	–0.06	–0.04	0.01
	(0.50)	(0.50)	(0.50)	(0.04)	(0.04)	(0.04)

Note: Standard deviations are given in parenthese in Column (1)-(3). Standard errors are given in parentheses in Column (4)-(6).

[a] Amount of land cultivated (ha) in main cropping season.

*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

TABLE 4. PURCHASE QUANTITY OF MODERN INPUTS AT THE SALES EXPERIMENT

Panel A. *Cash purchase*	Mean by household type			Mean difference		
	Control	Treatment	Neighbor	Control vs. Treatment	Control vs. Neighbor	Treatment vs. Neighbor
	(1)	(2)	(3)	(4)	(5)	(6)
			Hybrid seed (kg)			
Discount rate						
0 percent	0.95	1.75	1.12	-0.79***	-0.16	0.63***
	(1.51)	(2.48)	(1.58)	(0.16)	(0.14)	(0.15)
10 percent	1.00	1.85	1.20	-0.86***	-0.2	0.65***
	(1.58)	(2.64)	(1.72)	(0.17)	(0.15)	(0.16)
20 percent	1.07	2.01	1.30	-0.94***	-0.24	0.71***
	(1.67)	(2.90)	(1.88)	(0.19)	(0.16)	(0.18)
			Base fertilizer (kg)			
0 percent	0.59	1.96	0.89	–1.37***	–0.3*	1.07***
	(1.76)	(4.73)	(2.18)	(0.27)	(0.17)	(0.27)
10 percent	0.70	2.14	1.00	–1.44***	–0.3	1.14***
	(2.04)	(4.93)	(2.40)	(0.29)	(0.19)	(0.28)
20 percent	0.80	2.37	1.22	–1.57***	–0.42*	1.15***
	(2.21)	(5.29)	(3.03)	(0.31)	(0.23)	(0.32)
			Top-dressing fertilizer			
0 percent	0.14	0.92	0.49	–0.78***	–0.35***	0.43***
	(0.58)	(2.74)	(1.53)	(0.15)	(0.09)	(0.16)
10 percent	0.15	1.02	0.52	–0.86***	–0.36***	0.5***
	(0.61)	(2.98)	(1.57)	(0.16)	(0.10)	(0.17)
20 percent	0.19	1.15	0.58	–0.96***	–0.39***	0.57***
	(0.69)	(3.27)	(1.72)	(0.17)	(0.11)	(0.19)

Panel B. *Credit purchase*	Mean by household type			Mean difference		
	Control	Treatment	Neighbor	Control vs. Treatment	Control vs. Neighbor	Treatment vs. Neighbor
	(1)	(2)	(3)	(4)	(5)	(6)
			Hybrid seed (kg)			
Discount rate						
0 percent	1.61	2.75	1.95	–1.14***	–0.34	0.79***
	(2.65)	(3.61)	(2.84)	(0.26)	(0.24)	(0.24)
10 percent	1.66	2.84	2.00	–1.18***	–0.34	0.84***
	(2.75)	(3.81)	(2.87)	(0.27)	(0.25)	(0.25)
20 percent	1.74	2.99	2.05	–1.25***	–0.31	0.93***
	(2.85)	(4.08)	(2.94)	(0.29)	(0.26)	(0.26)
			Base fertilizer (kg)			
0 percent	2.68	6.23	3.86	–3.55***	–1.18**	2.37***
	(6.07)	(10.71)	(6.86)	(0.69)	(0.57)	(0.66)
10 percent	2.99	6.73	4.23	–3.74***	–1.24**	2.5***
	(6.67)	(11.21)	(7.05)	(0.73)	(0.60)	(0.69)
20 percent	3.25	7.14	4.43	–3.88***	–1.17*	2.71***

	(7.14)	(11.70)	(7.31)	(0.77)	(0.64)	(0.71)
			Top-dressing fertilizer			
0 percent	1.03	3.67	2.27	–2.63**	–1.24**	1.39**
	(3.17)	(7.02)	(4.75)	(0.42)	(0.34)	(0.44)
10 percent	1.22	3.93	2.46	–2.72**	–1.24**	1.48**
	(3.40)	(7.34)	(4.99)	(0.44)	(0.36)	(0.46)
20 percent	1.41	4.28	2.61	–2.88**	–1.21**	1.67**
	(3.72)	(7.77)	(5.13)	(0.47)	(0.38)	(0.48)

Note: Standard deviations are given in parenthese in Column (1)-(3). Standard errors are given in parentheses in Column (4)-(6).

*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

TABLE 4 (CONTINUED). PURCHASE QUANTITY OF MODERN INPUTS AT THE SALES EXPERIMENT

Panel C. *Difference between cash and credit purchase*	Mean by household type			Mean difference		
	Control	Treatment	Neighbor	Control vs. Treatment	Control vs. Neighbor	Treatment vs. Neighbor
	(1)	(2)	(3)	(4)	(5)	(6)
			Hybrid seed (kg)			
Discount rate						
0 percent	0.66***	1.00***	0.84***	–0.34**	–0.18	0.16
	(0.11)	(0.09)	(0.10)	(0.15)	(0.15)	(0.14)
10 percent	0.66***	0.99***	0.8***	–0.33**	–0.14	0.19
	(0.11)	(0.10)	(0.09)	(0.15)	(0.15)	(0.13)
20 percent	0.67***	0.99***	0.77***	–0.32**	–0.10	0.22
	(0.12)	(0.10)	(0.09)	(0.16)	(0.15)	(0.14)
			Base fertilizer (kg)			
0 percent	2.09***	4.27***	2.98***	–2.18***	–0.88*	1.29**
	(0.35)	(0.40)	(0.32)	(0.54)	(0.48)	(0.52)
10 percent	2.29***	4.59***	3.23***	–2.31***	–0.95*	1.36***
	(0.39)	(0.42)	(0.32)	(0.57)	(0.50)	(0.53)
20 percent	2.45***	4.83***	3.28***	–2.38***	–0.82	1.55***
	(0.41)	(0.43)	(0.31)	(0.60)	(0.52)	(0.54)
			Top-dressing fertilizer (kg)			
0 percent	0.89***	2.75***	1.78***	–1.85***	–0.89***	0.96***
	(0.21)	(0.29)	(0.22)	(0.36)	(0.30)	(0.37)
10 percent	1.07***	2.92***	1.94***	–1.85***	–0.88***	0.98**
	(0.22)	(0.30)	(0.23)	(0.38)	(0.32)	(0.38)
20 percent	1.22***	3.2***	2.06***	–1.98***	–0.84**	1.14***
	(0.24)	(0.32)	(0.24)	(0.40)	(0.34)	(0.40)

Note: Standard errors for the t-test (H0: the mean value of the difference between credit purchase and cash purchase is equal to 0) are given in parentheses in Column (1)-(3). Standard errors are given in parentheses in Column (4)-(6).

*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

TABLE 5. DETERMINANTS OF INPUT PURCHASE: OLS REGRESSION

Dependent variables / Control variables	Hybrid seed (kg)	Base fertilizer (kg)	Top-dressing fertilizer (kg)	Aggregate quantity index (1,000 Ush)
	(1)	(2)	(3)	(4)
1{Treatment HH}	1.851***	3.339***	2.459***	16.71***
	(0.688)	(1.112)	(0.619)	(4.773)
1{Neighbor HH}	0.227	0.702	0.538	2.522
	(0.506)	(0.890)	(0.410)	(3.517)
Price	-0.785***	-2.380***	-1.176***	-10.29***
	(0.219)	(0.555)	(0.287)	(2.095)
Price * 1{Treatment HH}	-0.848**	-1.829**	-1.524***	-8.458**
	(0.417)	(0.870)	(0.568)	(3.239)
Price * 1{Neighbor HH}	-0.104	-0.497	-0.067	-0.828
	(0.264)	(0.710)	(0.362)	(2.414)
1{Credit sales}	1.250***	9.505***	4.164**	30.65***
	(0.426)	(2.934)	(1.698)	(8.627)
1{Treatment HH} * 1{Credit sales}	0.414	2.880***	2.244***	10.85***
	(0.338)	(1.030)	(0.684)	(3.591)
1{Neighbor HH} * 1{Credit sales}	0.137	0.829	0.933*	3.647
	(0.326)	(0.830)	(0.512)	(2.951)
Down-payment rate	-0.341	-1.208	-1.328	-5.95
	(1.641)	(2.676)	(1.957)	(10.85)
Down-payment rate * 1{Credit sales}	-2.330*	-20.34**	-8.088**	-63.74***
	(1.265)	(7.976)	(3.734)	(22.13)
Interest rate	3.287	-2.517	-2.619	3.949
	(3.213)	(6.833)	(5.348)	(26.34)
Interest rate * 1{Credit sales}	2.051	-8.693	-4.532	-15.08
	(3.229)	(11.94)	(8.769)	(40.81)
Household size	0.095*	0.160*	0.0685	0.800**
	(0.054)	(0.082)	(0.045)	(0.344)
Dependency rate	-0.100	-0.344**	-0.105	-1.226*
	(0.093)	(0.150)	(0.107)	(0.629)
1{Female headed HH}	-0.321	-0.501	-0.691**	-3.250*
	(0.215)	(0.493)	(0.288)	(1.851)
Head’s age	-0.017**	-0.032*	-0.004	-0.131*
	(0.008)	(0.018)	(0.011)	(0.071)
Head’s years of schooling	0.036	0.133**	0.060	0.499**
	(0.028)	(0.062)	(0.038)	(0.219)
Land size owned (ha)	-0.004	-0.029***	0.044**	0.005
	(0.007)	(0.010)	(0.022)	(0.064)
Asset holdings (millions of Ush)	-0.014	-0.014	-0.029***	-0.122
	(0.009)	(0.018)	(0.009)	(0.073)
1{past use of maize HYV seed}	0.612*	2.180**	1.269	8.178**
	(0.316)	(1.026)	(0.826)	(3.787)
1{past use chem. fertilizers on maize}	0.489	1.509**	1.120**	6.712**

	(0.391)	(0.720)	(0.491)	(2.960)
Constant	1.537*	3.095*	0.936	13.83*
	(0.870)	(1.789)	(1.418)	(7.345)
Number of observations	3,966	3,966	3,962	3,962
Number of households	661	661	661	661
Number of communities	68	68	68	68
R-sq	0.101	0.166	0.151	0.187

Note: Robust standard errors (clustered by community) are given in parentheses.

*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

TABLE 6. DETERMINANTS OF INPUT PURCHASE AMONG TREATMENT HOUSEHOLDS: COMMUNITY-FIXED EFFECT REGRESSION

Control variables / Dependent variables	Hybrid seed (kg)	Base fertilizer (kg)	Top-dressing fertilizer (kg)	Aggregate quantity index (1,000 Ush)
	(1)	(2)	(3)	(4)
Yield gain of experimental plot (kg)	0.002	0.012**	0.008**	0.045**
	(0.002)	(0.005)	(0.003)	(0.022)
Price	–1.433***	–4.664***	–2.640***	–18.82***
	(0.339)	(0.745)	(0.557)	(2.689)
1{Credit sales}	1.690***	17.00***	5.858*	50.38***
	(0.488)	(5.161)	(2.934)	(12.98)
Down-payment rate * 1{Credit sales}	–1.71	–31.74**	–4.609	–79.77**
	(1.441)	(15.27)	(6.753)	(35.11)
Interest rate * 1{Credit sales}	0.223	–18.1	–7.91	–47.61
	(3.981)	(18.60)	(15.85)	(64.74)
Household size	0.0987*	0.466***	0.258***	1.725***
	(0.058)	(0.135)	(0.095)	(0.579)
Dependency rate	–0.034	0.0197	0.256	0.356
	(0.207)	(0.397)	(0.213)	(1.504)
1{Female-headed HH}	–0.193	–0.467	–0.784	–2.952
	(0.370)	(0.932)	(0.824)	(3.764)
Head's age	–0.0007	–0.013	–0.014	–0.048
	(0.012)	(0.030)	(0.025)	(0.116)
Head's years of schooling	0.094	0.181	–0.115	0.526
	(0.066)	(0.153)	(0.072)	(0.479)
Amount of land owned (ha)	–0.004	–0.070***	0.039**	–0.091
	(0.006)	(0.013)	(0.016)	(0.059)
Asset holdings (millions of Ush)	0.089***	0.200***	0.009	0.756***
	(0.026)	(0.051)	(0.025)	(0.203)
1{past use of maize Hybrid seed}	1.582**	1.585	0.59	9.812*
	(0.773)	(1.104)	(1.020)	(5.442)
1{past use chem. fertilizers on maize}	–0.362	0.231	0.331	–0.258
	(0.446)	(0.875)	(0.667)	(3.824)
Constant	1.767*	0.267	1.146	8.364
	(0.909)	(2.589)	(1.894)	(8.985)
Number of observations	1,500	1,500	1,499	1,499
Number of communities	44	44	44	44
R-sq	0.109	0.226	0.194	0.233

Note: Robust standard errors (clustered by community) are given in parentheses.
*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

TABLE 7. DETERMINANTS OF INPUT PURCHASE AMONG NEIGHBOR HOUSEHOLDS: COMMUNITY-FIXED EFFECT REGRESSION

Dependent variables / Control variables	Hybrid seed (kg)		Base fertilizer (kg)	
	(1)	(2)	(3)	(4)
Mean yield gain of information peers (kg)	0.0046**		0.0080**	
	(0.002)		(0.004)	
Mean yield gain of geographic peers (kg)		0.0053		–0.0090
		(0.005)		(0.020)
Price	–0.880***	–0.880***	–2.903***	–2.903***
	(0.149)	(0.149)	(0.448)	(0.448)
1{Credit sales}	1.822***	1.822***	11.43***	11.43***
	(0.441)	(0.441)	(2.673)	(2.673)
Down-payment rate * 1{Credit sales}	–5.176***	–5.176***	–19.42***	–19.42***
	(1.429)	(1.429)	(5.499)	(5.499)
Interest rate * 1{Credit sales}	5.765*	5.765*	–22.09*	–22.09*
	(3.329)	(3.329)	(12.22)	(12.22)
Household size	0.0415	0.0756	0.00335	0.0471
	(0.046)	(0.049)	(0.093)	(0.093)
Dependency rate	–0.222**	–0.316***	–0.560**	–0.674**
	(0.096)	(0.101)	(0.273)	(0.259)
1{Female-headed HH}	–0.136	0.136	–1.716**	–1.247*
	(0.515)	(0.580)	(0.709)	(0.620)
Head's age	–0.00385	–0.00797	–0.0224	–0.0259
	(0.010)	(0.010)	(0.034)	(0.035)
Head's years of schooling	0.0671**	0.0725**	0.145*	0.158*
	(0.029)	(0.029)	(0.081)	(0.082)
Amount of land owned (ha)	0.0595	0.0823	0.145	0.153
	(0.068)	(0.071)	(0.205)	(0.227)
Asset holdings (millions of Ush)	0.324**	0.299**	0.832*	0.847*
	(0.150)	(0.138)	(0.413)	(0.458)
1{past use of maize Hybrid seed}	–0.00694	0.0772	2.12	2.182
	(0.393)	(0.402)	(1.283)	(1.304)
1{past use chem. fertilizers on maize}	0.915*	0.918*	0.754	0.828
	(0.479)	(0.510)	(1.168)	(1.207)
Constant	0.859	0.856	2.555	4.631
	(0.702)	(1.073)	(1.632)	(2.858)
Number of observations	1,332	1,332	1,332	1,332
Number of communities	44	44	44	44
R-sq	0.212	0.19	0.243	0.235

Note: Robust standard errors (clustered by community) are given in parentheses.
*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

TABLE 7 (CONTINUED). DETERMINANTS OF INPUT PURCHASE AMONG NEIGHBOR HOUSEHOLDS: COMMUNITY-FIXED EFFECT REGRESSION

Dependent variables / Control variables	Top-dressing fertilizer (kg)		Aggregated quantity index (1,000 Ush)	
	(5)	(6)	(7)	(8)
Mean yield gain of information peers (kg)	0.0022		0.037**	
	(0.002)		(0.016)	
Mean yield gain of geographic peers (kg)		–0.011		–0.018
		(0.012)		(0.067)
Price	–1.253***	–1.253***	–11.16***	–11.16***
	(0.220)	(0.220)	(1.173)	(1.173)
1{Credit sales}	7.514***	7.514***	41.61***	41.61***
	(1.932)	(1.932)	(8.812)	(8.812)
Down-payment rate * 1{Credit sales}	–15.28***	–15.28***	–82.91***	–82.91***
	(4.368)	(4.368)	(19.54)	(19.54)
Interest rate * 1{Credit sales}	–8.046	–8.046	–33.03	–33.03
	(7.962)	(7.962)	(39.09)	(39.09)
Household size	0.00893	0.0142	0.167	0.391
	(0.065)	(0.063)	(0.297)	(0.291)
Dependency rate	–0.325	–0.334	–2.416**	–3.009***
	(0.199)	(0.209)	(1.003)	(0.918)
1{Female-headed HH}	–0.63	–0.501	–4.998**	–2.824
	(0.496)	(0.462)	(2.304)	(2.388)
Head's age	–0.0080	–0.0073	–0.075	–0.096
	(0.020)	(0.021)	(0.122)	(0.126)
Head's years of schooling	0.109*	0.114*	0.725**	0.782**
	(0.058)	(0.059)	(0.337)	(0.339)
Amount of land owned (ha)	0.077	0.065	0.683	0.760
	(0.150)	(0.156)	(0.790)	(0.857)
Asset holdings (millions of Ush)	0.453	0.484*	3.518***	3.509**
	(0.274)	(0.281)	(1.270)	(1.409)
1{past use of maize HYV seed}	0.503	0.483	4.892	5.29
	(0.801)	(0.807)	(3.829)	(3.935)
1{past use chem. fertilizers on maize}	1.031	1.083	6.352	6.607
	(0.838)	(0.804)	(4.316)	(4.531)
Constant	0.928	2.442	9.777	16.65
	(1.001)	(1.796)	(6.327)	(10.420)
Number of observations	1,332	1,332	1,332	1,332
Number of communities	44	44	44	44
R-sq	0.197	0.199	0.297	0.282

Note: Robust standard errors (clustered by community) are given in parentheses.
*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Appendix. Price-contingent order form used in the sales experiment

Q1a. Do you know the purpose of us coming is to sell the agricultural inputs? 1. Yes 2. No
Q1b. How many days ago did you know of this sales experiment being held today?
Q2. In the case of cash sales, how many kilograms of inputs do you buy? Fill out the following table.

Discount rate	Hybrid seed	Base fertilizer	Top-dressing fertilizer	(Coordinators help to calculate; round-down the last two digits) **Total amount** you would pay **today**
0 percent	(3,600) kg	(2,100) kg	(1,700) kg	Ush
10 percent	(3,240) kg	(1,890) kg	(1,530) kg	Ush
20 percent	(2,880) kg	(1,680) kg	(1,360) kg	Ush

Note: Discount prices per kg (Ush) are given in parentheses.

Q3. In the case of credit sales, how many kilograms of inputs do you buy? Fill-out the following table.

Discount rate	Hybrid seed	Base fertilizer	Top-dressing fertilizer	(Coordinators help to calculate; round down the last two digits in Total amount)				
				Sub-total	**Down-payment** (above **xx** percent of Subtotal)*	**Balance** (Subtotal minus Down-payment)	**Interest** (**zz** percent of Balance)*	**Total amount** you pay **after harvest**
0 percent	(3,600) kg	(2,100) kg	(1,700) kg	Ush	Ush	Ush	Ush	Ush
10 percent	(3,240) kg	(1,890) kg	(1,530) kg	Ush	Ush	Ush	Ush	Ush
20 percent	(2,880) kg	(1,680) kg	(1,360) kg	Ush	Ush	Ush	Ush	Ush

***** The numbers for **xx** and **zz** are preprinted and differ from village to village.

Q4. If you decide to buy inputs, how do you finance the cost?

1. Own savings 2. Borrowing from relatives 3. Borrowing from friends 4. Other ( )