Disseminating New Farming Practice among Small Scale Farmers: Experimental Intervention in Uganda*

Tomoya Matsumoto†

March 2013

Abstract

We used a randomized control trial to measure how the free distribution of modern inputs for maize production affected small-scale farmers' adoption in the subsequent seasons by collecting the information on their demand for the same inputs through the sales workshops we organized in 2009 and 2011 where the inputs were actually sold. It revealed that the demand for the inputs of the free-input recipients was significantly higher in both 2009 and 2011 than that of non-recipients; that of neighbors of the recipients fell in-between. The initial treatment assignment has a persistent influence in the farmers' adoption over two years whereas the difference across the treatment status, particularly, between the free-input recipients and their neighbors has been reduced. The reduction of the gap in the adoption is partly driven by learning through social networks. (JEL O13, O33, O55)

*VERY PRELIMINARY. Please do not cite. I thank George Sentumbwe, Geoffrey Kiguli, and other research team members from Makerere University who contributed to the project. I am also grateful for funding from the Global COE project, sponsored by the Ministry of Education, Culture, Sports, Science, and Technology, Japan.

†Matsumoto: National Graduate Institute for Policy Studies, 7-22-1 Roppongi, Minato-ku, Tokyo 106-8677, Japan (email: tmatsumo@grips.ac.jp).

1 Introduction

Technology adoption is the key to realize drastic improvement of agricultural productivity as proved in the Asia's Green Revolution occurred since the late 1960s, which was nothing but the outcome of new technologies (or new seed varieties) invented through scientific researches and their dissemination. Given the current low application of technologies, there seems to be ample room for small-scale farmers in Sub-Saharan Africa to drastically enhance their productivity by adopting technologies which have been used in the other part of world. However, many of productivity enhancing technologies have not been widely adopted in this area.

This paper presents the second episode of the experimental interventions on maize production targeting small-scale farmers in Uganda conducted since 2009 in order to examine the technology adoption of productivity-enhancing inputs and their dissemination process. For the purpose, we implemented a series of interventions. It started from a randomized control trial in 2009 in which modern agricultural inputs for maize production were distributed for free to the target households living in the randomly sleeted 46 out of 69 target villages for this study. The agricultural inputs given for free were maize hybrid seeds and chemical fertilizers, which had been used by only few farmers in Uganda before our intervention. The second and third exercise were the workshop that we organized in each target village for sales of the same inputs to the target households.

Our previous study (Matsumoto, Yamano, and Sserunkuuma, 2012) presents the first episode of a series of the interventions and examines the outcomes of the first sales workshop held in 2009 just after the cropping season in which the free agricultural inputs were used by the recipients. It observed the farmers' purchasing behaviors on the same inputs and found the following empirical results. 1) The free input recipients purchase significantly more of the same inputs in the subsequent season. The input demand of their neighbors (who live in the treatment villages but were not given free inputs) falls in between the free input recipients and the control households (who live in the control villages where no free inputs were given). 2) The input demand is much higher when credit is available, and there is a positive interaction between the free input treatment and credit availability. 3) The free input recipients' demand in the subsequent season is correlated with the yield performance of the free inputs given to them. 4) The neighbors of the free input recipients purchased more inputs if their "information peers" (whom they communicate with) have a higher yield with the use of the inputs compared to local maize yield.

Another round of the sales workshop held in 2011 gives us an opportunity to observe the change in adoption behaviors and the dissemination process of a new technology. Also it enables us to examine farmers' adjustment process of application level or input composition of multiple inputs. This study pays a special attention to those factors. We obtained the following empirical results. The input demand of the free-input recipients in the treatment villages was significantly higher in 2011 than that of non-recipients living in the control villages; that of the recipient's neighbors who live in the treatment villages. The initial treatment status has a persistent influence in the farmers' adoption over two years whereas the difference across the treatment status has been reduced significantly, particularly, between the free-input recipients and their neighbors for fertilizers. The reduction of the gap in the application level of fertilizers is mainly driven by learning through social networks.

The rest of this paper is organized as follows. Section 2 reviews the related literature and gives background information on the current farming system in Uganda. Section 3 discusses a series of interventions that we have conducted in Uganda since January 2009. Section 4 discusses the empirical framework which describes the research questions and hypotheses to be addressed. Section 5 reports the key results of the sales experiment. Finally, Section 6 concludes the paper.

2 Literature

There has been a growing body of empirical literature on technology adoption in agriculture in Africa. 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 hybrid 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 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. 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 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.

Owing to the high transportation costs associated with the import of modern inputs, particularly in land locked countries like Uganda, the market price of those inputs is high, and hence their profitability is low (Omamo (2003)). As standard neoclassical models of technology adoption predict, 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 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 improvements such as roads and mobile networks, farmers have had better access to commodity markets and market information than before. 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.

3 Experimental Design and Survey Data

To investigate the impact of a possible policy intervention on technology adoption by small-scale farmers and its dissemination process, we conducted a series of experimental interventions in maize production since 2009. The interventions was a sequential randomized–controlled trial. The target sites and individuals were the sample villages and households surveyed for the RePEAT panel study.[1] Table 1 shows timings of and sample sizes involved in the interventions that we have conducted. The reason why we chose maize as the target crop of this study is simply because maize is one of major crops in this area and nearly 85 percent of target farmers planted maize in the first cropping season in 2008. Dissemination of modern inputs for maize production has been very slow and incomplete at all.

[Insert Table 1 Here]

3.1 Free input distribution (a randomized intervention)

The first exercise was a randomized control trial at the village level, which took place in February and March 2009, prior to the first cropping season of the year. 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. 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

[1] The RePEAT panel study is a longitudinal rural household survey project executed in East Africa; making use of a GRIPS research team, it targeted Kenya, Uganda, and Ethiopia. There are 94 RePEAT villages in Uganda which have been often visited for surveys since 2003. There were originally 10 target households in each sample village. Due to migration and dissolution of some of the initial survey households, about 8 percent of the households could not be trucked by year 2009. In this study, we target the original 639 households who still resided in year 2009 in 69 out of 71 RePEAT villages in Eastern and Central regions. These regions are known as maize growing areas and most farmers plant maize once or twice a year. Two villages excluded from this study are located in Kapchowa district, close to the Kenyan border. Their application rates of chemical fertilizers and their adoption rates of hybrid maize seeds, according to the 2005 RePEAT survey, were exceptionally high. These two villages are very different from others in terms of their experience with modern inputs, and they were thus excluded as unrepresentative outliers.

of top-dressing fertilizer.[2] In addition, a 2-hour training session on the use of these modern inputs was delivered by an extension worker to the members of the treatment households.

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. For convenience, we refer to the households in the 46 villages as the "treatment households"; 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." The geographic distribution of those villages is shown in Figure 1. The randomization for the selection of the treatment villages was implemented based on a computer-generated random number after the stratification by region (Eastern or Central region).

[Insert Figure 1 Here]

Table 2 shows the summary statistics of the target sample villages and households obtained from the RePEAT 2005 survey.

[Insert Table 2 Here]

All the community and household variables in 2005 are independent from the treatment status, which verifies the success of the randomization of the status.

3.2 Sales experiments

After the free input distribution, we visited the target villages three times to sell the same inputs given for free in the first intervention.

Sales workshop 2009

The second intervention was the first sales workshop that we held in each of the target villages in August and September 2009—the intermediate period between the first and second cropping seasons—during which we revisited both 46 treatment and 23 control villages in the

[2] 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 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.

Eastern and Central regions to sell the same inputs that had previously been provided for free to the treatment households.[3] In the sales workshop held in each of the target villages, we 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 5 to 10 households living nearby, and then our enumerators randomly selected one household from the list as a "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), especially, in cases where the treatment households perceived our first intervention to be beneficial. 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.

Price contingent order form 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. Three discount rates from the market price were offered, namely, 0, 10, and 20 percent. 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 workshop 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. 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

[3] We held the sales workshop 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.

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 by the project at the village level in advance, based on a computer-generating random number after the stratification by region. 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 ten. 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 workshop, we obtained information on the participants' purchase quantity levels at three different discount rates, with and without the credit option—that is, six quantity levels in total, for each input from each participant.

Sales workshop 2011[4]

We conducted the similar exercise to the sales workshop 2009 in January and February in 2011, in which we sold the modern inputs for maize production again to observe the change in the farmers' adoption behaviors. We used a modified version of the price-contingent order form and also added some minor changes in the arrangement of the workshop.

Firstly, we offered a wider variation of discounted prices, or 5 different discount rates, -10, 0, 10, 20, and 40 percent. Secondly, by considering the high inflation rate and market interest rates in the field, we raised by 5 percent point the interest rate which was randomly

[4]In February and March in 2010, we visited randomly selected 57 villages out of 69 target villages (38 treatment villages and 19 control villages) to sell the same inputs. We did not use the price contingent order form and sold the inputs at a randomly-selected single discount price assigned to each village. Because the period for the project was limited, we could implement only a simpler version of the sales workshops unlike the workshop 2009 and 2011 to the limited number of villages. Because the choice of the sites visited was randomly selected and so is the price offered in the sales workshop, it would not contaminate our estimations in this study as long as they are properly controlled for.

assigned as the interest rate by the project at the village level. Lastly, we paid a random compensation to each participant in the beginning of the sales workshop so that they could use the compensation to buy inputs. The amount of compensation was determined by a bingo game played by each participant. We gave them a 50 percent chance of getting 4,000Ush, a 30 percent chance of getting 6,000, a 10 percent chance of getting 8,000, and a 10 percent chance of 10,000 Ush. Using the compensation, participants could buy at least 1 kg of hybrid seeds if they wanted. This random compensation helped us to analyze purchasing behaviors of those who came to the workshop without money.[5]

While visiting the villages for the Sales Workshop 2011, we collected the information on maize production in year 2009 and 2010 from the participants. Also, we gathered information on social networks by using a preprinted list of the names of the target households in the same village, together with the questionnaire, which asked them about their relationship with each of the target households in the same village.[6]

3.3 RePEAT Survey 2009

We also use the household survey data from the RePEAT Survey 2009 held in October - December in 2009.[7]

[5]There was another modification in the arrangement of the sales workshop. In addition to the same three maize inputs (a variety of hybrid seed, a base fertilizer, and a top-dressing fertilizer) sold in the sales workshop 2009, we added another option for the seed variety for the participants of the sales workshop 2011. Considering agroclimatic conditions of the villages, we picked up two varieties: one is a type of maize seeds for villages with high-elevation while the other is for villages with low-elevation. One of these two varieties was added in the list for the sales commodities according to the elevation level of the villages. In this study, we combine the demand for these two varieties into one and do not distinguish the difference in this paper although it is interesting to see the switching behaviors of the farmers from the variety used since the beginning of the project to the one newly introduced in the sales workshop 2011. This remains as a future research topic.

[6]We collected the similar social network data also in the RePEAT Survey 2009 mentioned in the following subsection but only from the neighbor households about their relationships with each of the treatment households, given time and budget constraints regarding the field survey, as the network data collection had been time-consuming. In this time, however, we collected the social network information from all the participants in the sales workshop 2011. We admit the fact that the social network data is not ideal since we collected the information after the free input distribution was held and also some experienced the inputs. If the network formation is endogenous and evolves over time, our interventions might have a large influence on the formation of social network.

[7]We missed one of the treatment villages in Central region to be visited for the survey due to heavy rains during the scheduled dates. When we use variables from the RePEAT Survey 2009, we have to drop the

[Insert Table 3 Here]

Table 3 shows household characteristics obtained from the RePEAT 2009 survey by household type. As expected, there are 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. 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.

3.4 Sample attritions

We mainly use the information obtained from the sales workshops in 2009 and 2011 combined with RePEAT Survey 2009 data in the following analyses. There is an issue to be considered. The sample attritions are not negligible, which are indicated by the gap between the number of target households and households participating in each workshop in Table 1. When we

samples from the village.

held the workshops, we usually 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.[8]

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.

Table 4 shows the results of the regressions of the participation in the sales workshop 2011. It shows that the treatment households, those who participated in the past sales workshops, and those who purchased inputs in the past sales workshops are more likely to participate in, which implies that those who show more interests are more likely to come to the workshop.

[Insert Table 4 Here]

One simple compromise may be to consider those absentees as those who would not purchase any input even if 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. Since the attrition rate is different across the household type, the extent of underestimation also depends on the household type. Because higher attrition causes greater underestimation, the demand estimates for the neighbor households would suffer from the bias more seriously

[8] The amount of compensation was equivalent to a rural daily wage in the sales workshop 2009 and randomized and worth at least a daily wage in the sales workshop 2011.

(see the attrition rate by household type in Table 1) than for other types of households. We present the results of the following analyses both with and without the absentees in order to mitigate the issue on the attrition bias whenever possible.

4 Empirical framework

This study mainly addresses four issues. i) Does the treatment status in the free-input distribution in 2009 have still an influence on the farmers' adoption and application level of the productivity-enhancing inputs in 2011? ii) How did the adoption and application level change over 2 years? Is there any difference in the changing pattern depending on the treatment status? iii) Which factors cause the difference in pattern if any? iv) Does own experience matter or neighbor's experience or both?

The first two are related to the average effect of the initial treatment status on input demand and its change over time for fact-finding purpose while the last two are related to a mechanism which explains the differential impact of the household types. We firstly describe simple empirical specifications to estimate the average effect of the free input distribution in 2009 on the demand in 2011 and the change in demand over two years. Secondly, we describe a simple model which explores the adoption decision of a new technology and its dissemination by learning in its nascent stage and then derive some testable empirical hypotheses from the model. Lastly, empirical specifications corresponding to the hypotheses are described.

4.1 Demand for inputs by household type

We use a following empirical specification identifying the average effect of the household types on the input demand in the sales workshop in 2011 and its change over 2 years since 2009 while controlling for some other exogenous variables. We use a following specification of the input demand, denoted by z, of a household i located in a community j given a price level p and the availability of the credit option $Cr \in \{0, 1\}$ in a sales workshop:

$$\begin{aligned} z_{ij}(p, Cr) &= \alpha + \alpha_T T_i + \alpha_N N_i + \gamma p + \gamma_T T_i \cdot p + \gamma_N N_i \cdot p \\ &\quad + \delta Cr + \delta_T T_i \cdot Cr + \delta_N N_i \cdot Cr + \phi X_{ij} + \varepsilon_{ij}(p, Cr) \end{aligned} \tag{1}$$

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 as exogenous variables X: 1) community level experimental variables chosen by the project based on a computer generating random number, namely, 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; 2) a household level experimental variable that is a random compensation which was given to each participant and could be used to purchase inputs and whose level was determined by a bingo game played by each participant; 3) the household variables from the RePEAT 2009 survey as controls, including 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; use of maize hybrid seed before the free input distribution, or 2009; and use of chemical fertilizers on maize production before 2009.

We use a modified version for the specification above for regressions of the change in input demand between 2009 and 2011:

$$\begin{aligned} dz_{ij}(p, Cr) &= \beta + \beta_T T_i + \beta_N N_i + \gamma p + \gamma_T T_i \cdot p + \gamma_N N_i \cdot p \\ &\quad + \delta Cr + \delta_T T_i \cdot Cr + \delta'_N N_i \cdot Cr + \phi' dX_{ij} + u_{ij}(p, Cr) \end{aligned} \tag{2}$$

where the prefix d is an operator to take the first order time difference of the following variable over the two years, 2009 and 2011.[9] It is worth noting that the coefficients in this specification capture the change in the coefficients in Eq. [1] between 2009 to 2011. These regressions above are expected to measure the average effect of household types on the input demand and its change. In the following subsection, I want to explore more on the mechanism of evolution of the adoption decision of a new technology through learning.

4.2 Decision on adoption of a technology at the early stage of its dissemination

When farmers do not face a credit constraint and have good information on an productivity-enhancing input for a particular crop, farmers decide to buy it if it yields profit gain.[10] We consider a simple model in which farmers decide whether to use hybrid or local seeds and application level of chemical fertilizer. The optimal application level of seeds for a certain size of land does not vary depending on seed types. Thus, we do not consider the application level of seeds. The hybrid seeds are more responsive to chemical fertilizers than local seeds. Thus, hybrid maize yield (kg/ha), y^H, is higher than local maize yield, y^L, given the same level of fertilizer application (kg/ha), q. The i-th farmer's profit gain from the adoption of the hybrid seeds, $\Delta\pi_i$, can be expressed as follows:

$$\Delta\pi_i = p_y(y_i^H - y_i^L) - p_q(q_i^H - q_i^L) - \left(C_s^H - C_s^L\right) - \left(C(l_i^H) - C(l_i^L)\right) \tag{3}$$

where the superscripts, H and L, represent seed types, namely, hybrid and local respectively, p_y and p_q are unit prices of maize and fertilizer, C_s is the cost for seeds planted for 1 ha, and

[9]Since, in the sales workshop 2009, we offered only 3 price-discount levels while we offered 5 levels in 2011, the difference in the input demand over time is obtained at the 3 price discount level, namely, 0,10, and 20. It is also noticed that household characteristics included in X are taken from the RePEAT 2009 survey only and hence dropped from the regression.

[10]We may have to think of farmers crop choice as well, that is, the possibility of choosing not to plant the particular crop (which is maize in this case) even when it produces positive profit because its profit gain smaller than that of other crops. Since most farmers in the target areas in this study plant maize once or twice a year, it is reasonable to exclude such a case.

$C(l)$ is the cost of labor inputs used for 1 ha of maize production.[11] We assume that the labor input is a linear function of fertilizer application level and yield, that is, $l = \tau + \tau_q q + \tau_y y$ where τ_q and τ_y are positive constants.[12] Let ω denote the unit price of labor. The equation can be rewritten as

$$\begin{aligned} \Delta\pi_i &= (p_y - \omega \cdot \tau_y)\Delta y_i - (p_q + \omega \cdot \tau_q)\Delta q_i - \Delta C_s \\ &= \rho_y \Delta y_i - \rho_q \Delta q_i - \Delta C_s \end{aligned} \tag{5}$$

where $\Delta x \equiv x^H - x^L$ for $x \in \{y, q, C_s\}$, $\rho_y \equiv p_y - \omega \cdot \tau_y$ and $\rho_q \equiv p_q - \omega \cdot \tau_q$.

As the Appendix Table 1 shows that almost no fertilizer is used for maize production with local seeds, that may be due to low response rate of chemical fertilizers of local seeds and also high relative price of fertilizer to maize. The optimal fertilizer application for local maize is given at the corner solution ($q^{L*} = 0$) for the relevant range of ρ_y/ρ_q. Thus, we assume that the optimal fertilizer application level for the local maize production is zero, $q_i^L = 0$, meaning that the local maize is always planted without fertilizer. We assume that there is an underlying function g such that $\Delta y = g(q^H) + \varepsilon$, $g' > 0$ and $g'' < 0$ due to the diminishing marginal product of the chemical fertilizer application, where ε is a stochastic disturbance term. Farmers do not know the exact shape of this function but can infer it through his own experience and information from social networks. Learning of a new technology embedded in a productivity-enhancing input is a process of formulation of the unknown function g by

[11] There is an issue to be considered to calculate profit using our data because our maize production data has only limited number of observations with labor input. We collected maize production information from the RePEAT 2009 survey and also from a supplementary survey focusing on maize production and social network during the sales workshop in 2011. But the labor input information is collected only from one or at most two maize plots in the RePEAT 2009 survey. Thus, many observations on maize production do not have labor input information. We use the imputed profit because of lack of information on labor input. In order to impute their profit level without labor input, we make a following assumption in the main text.

[12] We estimated the per hectare labor input (hour) equation using labor input data of the experimental plot (where the free inputs were applied) and non-experimental plot in 2009 with the household fixed effect regression. The following result is obtained:

$$\hat{l} = 769.7 + 2.37 q_{base} + 2.32 q_{top} + 0.099 y \tag{4}$$

, where q_{base} is the quantity of the base fertilizer applied (kg/ha) and q_{top} is the quantity of the top-dressing fertilizer applied (kg/ha), y is the yield (kg/ha).

farmers.

Formulation of the expected profit gain ($\Delta\pi$)

If the expected profit gain from the adoption of hybrid seeds is positive for the coming cropping season, a risk-neutral farmer will plant the hybrid seeds. The likelihood becomes higher as the expected profit gain increases even if farmers are risk-averse. How do they formulate the expectation? Firstly, let us consider a situation where there is no information available on the new inputs. Since they are new, farmers do not know the response of hybrid maize yield to the application of the chemical fertilizer. In other words, farmers do not know the shape of the production function.

A farmer i starts using the inputs for his own experiment, just out of curiosity, or by attending an extension service workshop in the beginning of the period 0. After the harvest, he may keep a pair of records on $(y^H_{i,0}, q^H_{i,0})$ or $(\Delta y_{i,0}, q^H_{i,0})$, where the second subscript represents the period, in his memory or farmer's diary. He also collects the information of others' maize production through his social network, $\left\{(\Delta y_{j,0}, q^H_{j,0})\right\}_{j\in N_i}$ where N_i is a set of i's "information peers" with whom i exchanges information of hybrid maize production. When the time for land preparation (which is the beginning of the period 1) comes, the farmer i visits an agricultural input shop to decide whether he buys hybrid seeds or not and how much chemical fertilizer to be purchased. Given the expected maize price of the next season and the input prices at the shop, he evaluates profits predicted by pairs of records on yield gains and fertilizer application levels at the period 0 in his reference list, i.e. , $\{(\Delta y_{k,0}, q^H_{k,0})\}_{k\in\{i,N_i\}}$. We assume that the farmer's expected maize price at the end of the period 1 is equal to the price at the period 0, that is, $E[p_{y,1}|I_0] = p_{y,0}$, where I_0 is information set available at the period 0. Similarly, the expected labor wage at the period 1 is equal to the wage rate at the period 0, that is, $E[\omega_1|I_0] = \omega_0$. Then, the farmer i can construct a set of the predicted profit gains based on the records of his information peers and himself in the beginning of the period 1, given by $\{\Delta\hat{\pi}_{k,1}\}_{k\in\{i,N_i\}}$, where $\Delta\hat{\pi}_{k,1} = \rho_{y,1}\Delta y_{k,0} - \rho_{q,1}q^H_{k,0} - \Delta C_{s,1}$

(, where $\hat{\rho}_{y,1} = p_{y,0} - \omega_0 \cdot \tau_y$ and $\hat{\rho}_{q,1} = p_{q,1} + \omega_0 \cdot \tau_q$).

Choice of fertilizer application level and adoption decision on hybrid seed

Because of noises on a series of the predicted profits, farmers may need to use a simple statistical inference to find the better fertilizer application level at the period 1. For the farmer i, the most reliable information is the record of his own experience, that is, $(\Delta y_{i,0}, q^H_{i,0})$. Since the records from his information peers include errors, each individual record may not be reliable. One possible way for him to utilize the information from his information peers is to average out the yield gain and fertilizer application level and then to use them as a reference, $(\overline{\Delta y}_{Ni,0}, \overline{q^H}_{Ni,0})$ where $\overline{\Delta x}_{Ni,0}$ for $x \in \{y, q^H\}$ is the average among i' s information peers. Then, the farmer i will predict the profit gain of his information peers as $\hat{\overline{\Delta \pi}}_{Ni,1} = \rho_{y,1}\overline{\Delta y}_{Ni,0} - \rho_{q,1}\overline{q^H}_{Ni,0} - \Delta C_{s,1}$ and compare it with his own predicted gain.[13] If it is greater than his own, he will update his fertilizer application level toward the average application level of his information peers and will maintain his current application level for the period 1 otherwise.

Hypothesis 1 *If a farmer's predicted profit gain from adoption of hybrid seeds is smaller than the average gain of information peers ($\Delta\hat{\pi}_{i,1} < \hat{\overline{\Delta \pi}}_{Ni,1}$), he updates the fertilizer application level for the subsequent season toward that of information peers and does not do so otherwise.*

To what extent will he update his fertilizer application level toward the average level of his information peers? We are not able to predict the extent without assuming any particular updating mechanism. But, in any case, his target application level for the next period can be represented by a convex combination of his own and the average of information peers, that is, $q^H_{i,1} = (1-\phi)q^H_{i,0} + \phi\overline{q^H}_{Ni,0}$ for $\phi \in (1, 0)$. If he uses the Baysian inference, ϕ becomes larger as the variance of $\overline{q^H}_{Ni,0}$ becomes smaller (or as the information from the peers becomes more

[13]His predicted profit gain for the period 1, given the same fertilizer application level as that in the period 0, is given by $\Delta\hat{\pi}_{i,1} = \rho_{y,1}\Delta y_{i,0} - \rho_{q,1}q^H_{i,0} - \Delta C_{s,1}$.

reliable). Also, it is natural to think that if a small change in fertilizer quantity generates a big change in profit, the speed of adjustment in the fertilizer quantity can be fast. If it is the case, ϕ may also increase in the gap between the profit gain of information peers and his own, that is, $\overline{\hat{\Delta\pi}}_{Ni,1} - \Delta\hat{\pi}_{i,1}$.

The update rule can be rewritten as

$$q^H_{i,1} - q^H_{i,0} = \phi\left(\overline{q^H}_{Ni,0} - q^H_{i,0}\right), \tag{6}$$

which implies that the growth of the fertilizer application level is larger as the gap in the application level between the average of information peers and his own is larger and also as the information from the peers is more reliable.

Hypothesis 2 *Given the condition that $\Delta\hat{\pi}_{i,1} < \overline{\hat{\Delta\pi}}_{Ni,1}$, growth of the fertilizer application of a farmer becomes larger i) as the gap between the average application level of peers and his own becomes larger, ii) as the gap between the profit gain of information peers and his own becomes larger and also iii) as the information from the peers is more reliable.*

Adoption decision on hybrid seeds

When the farmer i's predicted profit gain ($\Delta\hat{\pi}_{i,1}$) is positive, i always decides to use hybrid seeds for the period 1. Even when it is negative, farmer i may decide to use hybrid seeds for the period 1 if his expected profit gain (evaluated at the target fertilizer level, that is, $(1-\phi)q^H_{i,0} + \phi\overline{q^H}_{Ni,0}$) for the period 1 conditional on that $\Delta\hat{\pi}_{i,1} < \overline{\hat{\Delta\pi}}_{Ni,1}$ is positive. A problem is that farmer i is not able to know his expected profit gain for the period 1 exactly because g-function is unknown to him and so is $g((1-\phi)q^H_{i,0} + \phi\overline{q^H}_{Ni,0})$. But he knows that it is larger than the convex combination of i's predicted profit gain and the average of the information peers, that is, $E\Delta\pi_{i,1} > (1-\phi)\Delta\hat{\pi}_{i,1} + \phi\overline{\hat{\Delta\pi}}_{Ni,1}$ because of the concavity of the unknown g-function. The condition that $(1-\phi)\Delta\hat{\pi}_{i,1} + \phi\overline{\hat{\Delta\pi}}_{Ni,1} \geq 0$ or equivalently $\Delta\hat{\pi}_{i,1} + \phi\left(\overline{\hat{\Delta\pi}}_{Ni,1} - \Delta\hat{\pi}_{i,1}\right) \geq 0$ is sufficient for the farmer i to adopt hybrid seeds. Then the likelihood of using hybrid seeds for the period 1 increases in i's predicted profit gain ($\Delta\hat{\pi}_{i,1}$). Also it increases in i's information peers' average profit gain, $\overline{\hat{\Delta\pi}}_{Ni,1}$, under the condition that $\Delta\hat{\pi}_{i,1} \leq \overline{\hat{\Delta\pi}}_{Ni,1}$.

Hypothesis 3 *The larger a farmer's profit gain from adoption of hybrid seeds is, the higher his likelihood of adopting hybrid seeds for subsequent seasons is. Moreover, under the condition that* $\Delta\hat{\pi}_{i,1} \leq \overline{\hat{\Delta\pi}}_{Ni,1}$*, the larger his information peers' average profit gain is, the higher his likelihood of adopting hybrid seeds is.*

Experiences on the production

This simple model can describe farmers' adoption decision of hybrid seeds and update rules of chemical fertilizer application only at the early stage of dissemination of a new technology. As farmers have more experiences on the new production, their reference list for the records on (Δy, q^H) becomes richer and hence provides him better knowledge on the unknown g-function or the production function under the new technology. Thus, he would not need to rely on the information from his peers in order to find the optimal application level of the inputs as his reference list becomes richer.

Hypothesis 4 *A farmer's past experience weakens the influence of their information peers on the production decision.*

4.3 Empirical specifications

We examine the determinants of input purchase in the sales workshop 2011 and its change from the workshop 2009 with consideration of hypotheses stated above. Since the hypotheses mention about the decision on the input use for the subsequent season rather than input purchase, we have to translate them into the input purchase decision in the sales workshop in 2011. Firstly, we consider a following regression model for fertilizers so as to address the hypotheses:

$$
\begin{aligned}
Q_{ij,1}(p,Cr) - Q_{ij,0}(p,Cr) &= \beta_j + \beta_I I_{i,1}(p) + \beta_{Dq} Dq_{i,0} + \beta_{Iq} I_{i,1}(p)\cdot Dq_{i,0} \\
&\quad + \beta_{D\pi} D\hat{\pi}_{i,1}(p) + \beta_{\pi q} D\hat{\pi}_{i,1}(p)\cdot Dq_{i,0} + \beta_{\pi Iq} D\hat{\pi}_{i,1}(p)\cdot I_{i,1}(p)\cdot Dq_{i,0} \qquad (7)\\
&\quad + \gamma_q \cdot p + \delta_q \cdot Cr + \phi_q' dX_{ij} + e_{ij}(p,Cr)
\end{aligned}
$$

The dependent variable is the growth of $Q_{ij,t}(p,Cr)$ ($Q \in$\{Base fertilizer, Top-dressing fertilizer\}, $t \in \{0,1\}$), which is the fertilizer quantity that the farmer i intended to purchase in the price contingent order form at the sales workshop held at year 2009 + $2t$, given discounted price level p and credit availability Cr. As the right hand side variables, the following new variables are added: the difference in the predicted profit gain between information peers' average and i's own, denoted by $D\hat{\pi}_{i,1}(p) \equiv \overline{\hat{\Delta\pi}}_{Ni,1}(p) - \Delta\hat{\pi}_{i,1}(p)$; a dummy variable indicating that information peers' average profit gain is larger than i's own, denoted by $I_{i,1}(p) = 1\{D\hat{\pi}_{i,1}(p) \geq 0\}$; a difference in fertilizer application level at period 0 between information peer's average and i's own, denoted by $Dq_{i,0} = \overline{q^H}_{Ni,0} - q^H_{i,0}$.

Similarly, we consider the following model for hybrid seed:

$$
\begin{aligned}
S_{ij,1}(p,Cr) - S_{ij,0}(p,Cr) &= \alpha_j + \alpha_\pi \Delta\hat{\pi}_{i,1}(p) + \alpha_I I_{i,1}(p) + \alpha_{D\pi} D\hat{\pi}_{i,1}(p) + \alpha_{ID} I_{i,1}(p)\cdot D\hat{\pi}_{i,1}(p) \\
&\quad + \gamma_s \cdot p + \delta_s \cdot Cr + \phi_s' dX_{ij} + e_{ij}(p,Cr). \qquad (8)
\end{aligned}
$$

If there exists learning effect through own experience or information from social networks, the hypotheses expect following results.

- Hypothesis 1 predicts that $\beta_{Iq} > 0$.
- Hypothesis 2 predicts that i) β_{Iq} is lowest for the control households because they are

less exposed to information peers who use the hybrid seeds. Thus, ϕ in Eq.[6] is low for the control households.

- Hypothesis 3 predicts that $\alpha_\pi > 0$, $\alpha_I > 0$ and $\alpha_{ID} > 0$.
- Hypothesis 4 predicts that if we run a regression for hybrid seed with the sample households who had no experience of the use of hybrid seed before the sales workshop 2009, the estimate of α_{ID} could be larger than the regression with full samples. Similarly, if we run a regression for chemical fertilizer with the sample households who had no experience of the use of hybrid seed before the sales workshop 2009, the estimate of β_{Iq} could be larger than one obtained the regression with full samples.

5 Results

5.1 Effect of the initial treatment status on input demand

Sample means of purchase quantities by input type and by household type

Figure 2, 3, and 4 are the graphical representations of the average effect of the initial treatment status on input demand in the sales workshop 2011. The average purchase quantities among the participants (including those purchased no input) are calculated conditional on household type, price, credit availability and plotted on the price-quantity plane. Each table has four panels, two upper panels from the sales workshop 2009 which are presented for the comparison purpose, and two bottom panels from the workshop 2011. The first one of the two panels shows the mean quantities in the sales without credit (captioned as "cash sales") while the second one shows those in the sales with credit (captioned as "credit sales"). Colors of the graphs correspond to the household types, the treatment household in orange, neighbor household in blue, control household in green. Two dotted lines along with a solid line indicates 95 percent confidence interval.

The two panels for the sales workshops in 2009 and 2011 show a very similar pattern. The treatment households purchase the largest amount of the inputs while the control household buy the least amount and the neighbor households buy the amount in-between. The credit option has a large impact on the purchase quantity of any type of inputs. These observations indicate that the influence of the first intervention, that is, the free input distribution conducted in the beginning of 2009, remains persistently. The difference in the purchased quantity between the household types, however, seems to become smaller in 2011 than 2009 particularly between the treatment and neighbor households. If there exist spillover effects, the demand of the new adopters may converge to that of the early adopters who have used the inputs for longer period. This rationale is consistent with the fact that the difference between the neighbor households and the treatment households became smaller over time.

Results of regressions of the household type on the input purchase

In order to statistically test the difference in the demand for the inputs across the household types, we run simple regressions specified in Eq.[1] in the previous section for three types of inputs—hybrid seed, base fertilizer, and top-dressing fertilizer—and the aggregate index which is the total value of the three inputs at the market price, divided by 1,000. Two types of regressions, probit and tobit, were applied for each input. The dependent variable of the fist type of the regression is a binary indicator representing whether a household purchases a particular input or not while that of the second type is quantity that a household intended to be purchased using the price contingent order form in the sales workshop 2011. Table 5 presents the regression results using the information collected from the participants of the workshop 2011 whereas Table 5A shows the results of the same regressions but using information not only from the participants of the sales workshop 2011 but also from the non-participants by assuming that those who did not participate in are considered as households who buy no input and by setting their purchase quantities and their random compensation at zero. Table 5 and 5A are very similar although in some cases the significance levels are different. I report mainly the results of Table 5 but also those of 5A if necessary.

[Insert Table 5 Here]

[Insert Table 5A Here]

Both the likelihood of purchase and the purchase quantity without credit option are the largest for the treatment households (β_T), and the smallest for the control households (reference group); in the middle were the neighbor households (β_N) in most cases except the likelihood of purchase of the top-dressing fertilizer in which the estimate for the neighbor households is slightly higher than that for the treatment households but not significant. The difference between the treatment and the control households was significant for the hybrid seed and the aggregate index but not for fertilizers. The similar pattern can be seen in the difference between the neighbor and control households.

The credit option has the large impact on the demand for all types of inputs, which can be observed in the estimates of coefficient of the credit option dummy. We also confirmed that the credit option had a differential impact, depending on the household type and also the input type: the estimates of fertilizers were significantly larger for the treatment and neighbor households for the two types of fertilizers than the control households while the difference between the treatment and neighbor households, which can be seen as the estimate of $(\beta_T+\beta_{TC})-(\beta_N+\beta_{NC})$ in the bottom part of Table 5, is not significant except the aggregate index.

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 positive impact on the purchase quantity of the top-dressing fertilizer, contrary to our expectation. Firstly, the down payment rate was effective only for credit sales but the results show that the coefficient of the downpayment rate itself is significant. Secondly, it is supposed to have a negative impact on the credit purchase if any but the results show the positive effect on the top-dressing fertilizers. This finding may require us further investigation. The interest rate—charged for the cost of credit purchases and randomly assigned at the community level—was also effective for credit purchases only.

As we expected, it has a negative impact on the input purchase only for credit purchases. For instance, a 10 percent point reduction of the interest rate increases the purchase of the base fertilizer by 1 kg. The random compensation—which was given to the participants of the sales workshop 2011 in the beginning of the event so that they were able to use it to buy inputs if they wanted—was significantly positive for all inputs in both types of regressions. It suggests that some participants face immediate cash constraints and would not be able to buy the inputs if the compensation had not been given to them.

In the regressions presented in Table 5, other exogenous variables such as household characteristics are not included. We confirmed, however, that the inclusion of household characteristics did not affect the results presented in these tables much.[14]

Results of regressions of the household type on the change in input purchase over 2 years

Table 6 presents the results of regressions of the growth or change in input purchase quantity between the sales workshop 2009 and 2011.

[Insert Table 6 Here]

In this analysis, I added two variables which are the ratio of fertilizer quantity (of the base and top-dressing fertilizer, respectively) to seed quantity intended to be purchased in the sales workshops. The column 3 and 5 are corresponding to the results of regressions of these newly introduced variables. These variables are expected to represent the intensity level of fertilizer application on the maize plot.[15] We assume that the weight of seeds indicates the size of land allocated for maize, that the plant density (or seed quantity used for a certain size of land) chosen by each individual would be constant over time, and that all the inputs purchased in the workshop will be used for maize production. If so, these two variables represent the intensity level of fertilizer application.

[14]Those results will be presented by the authour upon your request.

[15]In the workshop for the free input distribution conducted in 2009, the extension service worker worked for the project recommended the participants to use 5 kg of the base fertilizer and 4 kg of the top-dressing fertilizer for 1 kg of the hybrid seed.

Table 6 shows that the coefficient of the treatment household dummy (which represents the change in input purchase or fertilizer application level of the treatment households relative to that of the control households) is negative but insignificant while that of the neighbor household dummy is positive but insignificant in most cases. It implies that the direction of the change in the input purchase was opposite during the two year period between the treatment and neighbor households and, hence, their level of the input purchase level gets closer over time although it is not statistically significant, which can be seen as the difference in their coefficients ($\beta_T - \beta_N$) in the bottom part of Table 6. The difference becomes significant for all the input purchase quantities when the credit option is available, which can be confirmed as the difference in their coefficients $(\beta_T + \beta_{TC}) - (\beta_N + \beta_{NC})$ in Table 6. However, the difference was not significant in the ratio of fertilizer to seed quantity. It implies that the neighbor households increased input purchase more than the treatment households corresponding to the credit being available but they did not change the composition (or the application level of fertilizers to hybrid seed) enough to make the coefficient significant. It is worth noting that the constant term indicates the average change in the input purchase (Column 1, 2, 4 and 6) and the change in the application level of each fertilizer (Column 2, 4) among the control households. Hence, the constant term plus the coefficient of the treatment household dummy represents the average change in the input purchase and the fertilizer application level among the treatment households. For instance, the treatment households increase the hybrid seed purchase by 0.25 kg and the top-dressing fertilizer by 0.3 kg and decrease the base fertilizer by 1.07 kg on average in the sales workshop 2011 compared to the purchase in the sales workshop 2009.

The coefficient of input price can be interpreted as the change in the slope of demand curve over 2 years. The negative (or positive) sign indicates that the demand became more elastic (or inelastic) than 2 years ago. The coefficient is negative and significant for the hybrid seeds and positive for both types of fertilizers but significant only for the top-dressing fertilizer, implying that when the input prices decline, the participants buy more seeds than fertilizers compared to the purchase pattern in 2009. The interaction term of the price with the dummy for the neighbor households is significant for all types of inputs but significant only for the top-dressing fertilizer. Their demand becomes elastic in 2011 than 2009 relative to the control households. The increase in the minimum down payment rate has a negative impact on the seed and base fertilizer purchase significantly with the credit option being available.

In sum, we observed that the influence of the treatment status assigned at the initial intervention remains persistently. Thus, we still see the difference in demand for modern inputs depending on the household types. As time passed, however, the difference between household types has been reduced, especially, in the difference between the treatment and neighbor households. These observations allude the existence of spillover effect across households. In the following subsection, we pay a careful attention on the mechanism of the dissemination of the new modern inputs.

5.2 Effect of own experience and spillover from information neighbors

Demand change in the hybrid seed

Table 7 shows the results of regressions of the change in the hybrid seed quantity intended to be purchased using the price contingent order form in the sales workshop 2009 and 2011. The difference from analyses in the previous subsection is that the indicators representing the farmer's his own as well as his neighbors' experiences in terms of the profitability of modern inputs are incorporated in the regressions.

[Insert Table 7 here]

In the first specification, the change in the quantity of hybrid seed over 2 years is regressed on the profit gain from the use of the hybrid seed in 2010 by the sample farmer himself, his information peers, and his geographic peers.[16] The information peers of farmer i are

[16] The profit gain from the use of the hybrid seed is the difference in the per hectare profit between hybrid

defined as the persons among our target sample households whom the farmer i exchanges farming business information while the i's geographic peers are defined as the persons among our target sample households who live within 0.5 km radius from the i' residential point. We calculated the average profit gain of information and geographic peers respectively and added these two variables as regressors. We applied the community fixed effect regressions considering unobservables at the community level such as distance to market, land scarcity, weather conditions, etc. In addition to the profit gain of farmers themselves, the average of the profit gain of their information peers, and that of their geographic peers, the following variables are added as control variables; discounted price level, a dummy representing credit availability, its interaction term with the change in down payment rate and interest rate, the random compensation given in the sales workshop 2011, and its interaction with the credit dummy.

The first regression in Column 1 shows that the three indicators representing the performance of maize hybrid seed are all positive and significant. It suggests that both own experience and information from neighbors have a influence on the demand for the new inputs. Moreover, we found that farmers' own profit gain has the biggest impact on the increase in the demand for the hybrid seed. It may imply that farmers use the information from his own experience primarily and update it according to others' experiences.

The second specification is a bit more flexible than the first one. It allows to change the impact of profit gain depending on its level. When a farmer's own profit gain is negative, he would stop using the hybrid seed rather than reducing the use of hybrid seed a bit. By introducing the interaction term of farmers' own profit gain with a dummy variable taking

and local maize. It is calculated as follows. When a farmer planted both local and hybrid maize in 2010, we obtain harvest, plot size, fertilizer quantities for base and top-dressing fertilizer separately for local and hybrid maize plot. Then we calculate the sales value per hectare by evaluating the yield at the average market price of the community and per hectare fertilizer cost at the market price. For labor input, we used the formula (Eq. [4] on the foot note in the previous section) to impute labor input and evaluated it at the marget wage rate in the community to obtain the labor cost. Then, the profit is calculated as the sales value - (fertilizer cost + labor cost + seed cost) for hybrid and local maize respectively. If he planted only hybrid maize, the community average of local maize profit is used as his reference. The profit gain is the difference in the per-hectare profit between hybrid and local maize calculated as described above.

1 if the profit gain is positive and 0 otherwise, we can capture the differential impact of the own profit gain depending on whether it is positive or not. Similarly, we introduced the interaction terms of the information and geographic peers' profit gain with a dummy variable indicating that the peers' average gain is greater than the farmer's own profit gain. It also enables us to capture the differential impact of the peers' profit gain depending on whether it is beyond the farm's own gain or not. We obtained the interesting results. Firstly, the coefficient of the interaction term of the farmer's own profit gain with the dummy for the positive own profit gain is positive and significant. The farmer's own profit gain has a bigger impact on the demand for the hybrid seed when the profit gain is positive. Secondly, the coefficient of the interaction term of the profit gain of the information peers is also positive while the coefficient of their profit gain is small and not significant. It suggests that when the information peers' profit gain is smaller than the farmer's his own, the peers' profit gain does not affect his demand for the hybrid seed whereas when it is greater, their profit gain does affect his demand. In contrast, the geographic peers' profit gain has a positive impact of the farmer's demand no matter whether it is greater than his own profit gain. This may imply that farmers tend to follow what their neighbors do no matter whether it brings about benefits. Among information peers, however, this would not happen because of closer interactions in which they exchange information on their farming business.

In the last specification, we introduced the interaction terms of those three profit gain variables with the treatment status dummies so that we can explore whether there is a differential impact of the gain variables depending on the treatment status. Looking at the interaction terms of the treatment household dummy with the profit gain variables, the interaction with the own profit gain is positive, and that with the information peers' gain is negative, that with the geographic peers's gain is positive and all significant. Because the coefficients of the profit gain variables without interaction represent the impacts of the profit gains on the demand of the control households, the profit gain by the control households themselves has no impact on their change in demand while that of information peers have a positive and significant impact. That of geographic peers is negative and significant. Compared with the control households, the treatment households have a bigger impact of his own experience on their demand compared to the information peers' influence and the geographic peers'. The similar description above fits the case of the neighbor households, too. It may suggest that when the exposure to the new technology is low as in the control villages, the information peers' adoption is very influential. As more people start using the inputs, however, the relative importance is being replaced with farmers' their own experiences.

6 Conclusions

At the early stage of technology dissemination, lack of knowledge is a crucial determinant of the low adoption rate of profitable technologies. Our experimental intervention shows that once farmers recognize the benefit of new inputs for crop production, many of them invest in the inputs in the subsequent seasons. It is also important to note that farmers learn from the successful experience of others though social networks. These observations underscore the importance of agricultural extension services for successful diffusion of new profitable technologies. While emphasizing the role of extension services, it is obviously important to note that because profitability of technologies varies across regions and time to large extent, an untailored technology may not be profitable to all farmers in different places. Hence, suitable technologies have to be selected by extension service providers. In this respect, it may often be the case that local private dealers dealing with tailored technologies in the form of agricultural inputs may be more suitable as extension service providers than the public sector. We believe that there is room for the private sector to play a significant role in this area of agricultural services. This study also shows that Ugandan farmers face severe credit constraints because 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 welfare. Because of the development of mobile technologies and drastic reduction of the transaction cost for communication and financial services via mobile phones, financial services targeting small scale farmers in remote areas became plausible at least technically. The provision of such services has a large potential for enhancing the welfare of farmers in Uganda.

References

[1] Bayite-Kasule, S., 2009. "Inorganic Fertilizer in Uganda—Knowledge Gaps, Profitability, Subsidy, and Implications of a National Policy," Uganda Strategy Support Program (USSP) Brief No. 8, International Food Policy Research Institute, Washington, DC, USA.

[2] Besley, T., Case, A., 1993. "Modeling Technology Adoption in Developing Countries," American Economic Review Papers and Proceedings, 83(2), 396–402.

[3] Conley T., Udry, C., 2010. "Learning About a New Technology: Pineapple in Ghana," American Economic Review, 100(1), 35-69.

[4] Duflo, E., Kremer, M., Robinson, J., 2008. "How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya," American Economic Review, 98(2): 482–8.

[5] Duflo, E., Kremer, M., Robinson, J., 2011."Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya," American Economic Review, 101(6), 2350-90.

[6] Dupas, P., 2010. "Short-Run Subsidies and Long-Run Adoption of New Health Products: Evidence from a Field Experiment," NBER Working Papers, 16298. Feder, G., Just, R., Zilberman, D., 1985. "Adoption of Agricultural Innovations in Developing Countries: A Survey," Economic Development and Cultural Change, 33(2), 255–98.

[7] Foster, A., Rosenzweig, M., 1995. "Learning by Doing and Learning from Others: Human Capital and Technological Change in Agriculture," Journal of Political Economy, 103, 1176–209.

[8] Foster, A., Rosenzweig, M., 2010. "Microeconomics of Technology Adoption," Annual Review of Economics, 2(1), 395–424.

[9] Kremer, M., Miguel, E., 2007. "The Illusion of Sustainability," Quarterly Journal of Economics, 122(3): 1007–65.

[10] Manski, C., 1993. "Identification of Endogenous Social Effects: The Reflection Problem," Review of Economic Studies, 60(3): 531–42.

[11] Matsumoto, T., Yamano, T., Serunkuuma, D. 2012. "Technology Adoption and Dissemination in Agriculture: Evidence from Sequential Intervention in Maize Production in Uganda", mimeo.

[12] Matsumoto, T., Yamano, T., 2009. "Soil Fertility, Fertilizer, and the Maize Green Revolution in East Africa," World Bank Policy Research Working Paper, no. WPS 5158.

[13] Morris, M., Kelly, V.A., Kopicki, R., and Byerlee, D., 2007. Promoting Increased Fertilizer Use in Africa: Lessons Learned and Good Practice Guidelines. Washington, DC: World Bank.

[14] Moser, Barret C. 2006. "The Complex Dynamics of Smallholder Technology Adoption: The Case of SRI in Madagascar," Agricultural Economics, 35, 373–88.

[15] Munshi, K., 2004. "Social Learning in a Heterogeneous Population: Technology Diffusion in the Indian Green Revolution," Journal of Development Economics 73(1): 185–213.

[16] Munshi, K., 2008. "Information Networks in Dynamic Agrarian Economies," in Handbook of Development Economics, Vol. 4. ed. by T.P. Schultz and J. Strauss. Oxfort: Elsevier Science.

[17] Namazzi, J., 2008. "Use of Inorganic Fertilizer in Uganda," IFPRI-Kampala Policy Brief. National Environment Management Authority (NEMA), 2008. State of Environment Report for Uganda. Kampala: NEMA.

[18] Nkonya, E., Pender, J., Kaizzi, C., Kato, E., Mugarura, S., 2005. "Policy Options for Increasing Productivity and Reducing Soil Nutrient Depletion and Poverty in Uganda," Environment and Production Technology Division Discussion Paper, no. 132. International Food Policy Research Institute, Washington, DC, USA.

[19] Omamo, S.W., 2003. "Fertilizer Trade and Pricing in Uganda," Agrecon, 42(4), 310–24.

[20] Sunding, D., Zilberman, D., 2001. "The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector," in Handbook of Agricultural Economics, Vol. 1, ed. by B. Gardner and G. Rausser. Amsterdam: North Holland.

[21] Suri, T., 2011. "Selection and Comparative Advantage in Technology Adoption," Econometrica, 79(1), 159–209.

[22] Yamano, T., Sserunkuuma, D., Otsuka, K., Omiat, G., Ainembabazi, J.H., Shimamura, Y., 2004. "The 2003 RePEAT Survey in Uganda: Results," http://www3.grips.ac.jp/~globalcoe/j/data/repeat/REPEATinUgandaReport.pdf, accessed September 19, 2011.

[23] Yamano, T., Muto, M., 2009. "The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda," World Development, 37(12), 1887–96.

[24] Zeitlin, A., Caria, A.S., Dzene, R., Janský, P., Opoku, R., Teal, F., 2011. "Heterogeneous Returns and the Persistence of Agricultural Technology Adoption," Centre for the Study of African Economies Working Paper, WPS/2010-37, November 2010. Ahn, H., Powell, J. L. 1993. Semiparametric estimation of censored selection models with a nonparametric selection mechanism. *Journal of Econometrics* 57, 3-29.

Table 1. Timing and Sample Sizes of Interventions and Surveys

Mon/Year	Event	Total		Treatment Community				Control Community	
	Number of target communities by type	69		46				23	
				Treatment Household		Neighbor Household		Control Household	
	Number of target households by type	1017		422		378		217	
Feb/2009	Free input distribution								
	Number of households receiving free inputs	378		378		0		0	
Aug/2009	Sales workshop 2009								
	Number of households participating	809		334		288		187	
	Number of households purchasing HYB maize seed*	539	(0.67)	239	(0.72)	196	(0.68)	104	(0.56)
	Number of households purchasing fertilizers*	441	(0.55)	195	(0.58)	165	(0.57)	81	(0.43)
Oct/2009	RePEAT 3 survey								
	Number of communities visited	68		45				23	
	Number of households interviewed	947		390		349		208	
Feb/2010	Sales workshop 2010								
	Number of communities visited	57		38				19	
	Number of households participating	535		236		188		111	
	Number of households purchasing HYB maize seed*	177	(0.33)	86	(0.36)	52	(0.28)	39	(0.35)
	Number of households purchasing fertilizers*	67	(0.13)	39	(0.17)	17	(0.09)	11	(0.10)
Feb/2011	Sales workshop 2011								
	Number of communities visited	69		46				23	
	Number of households participating	779		347		269		163	
	Number of households purchasing HYB maize seed*	646	(0.83)	304	(0.88)	227	(0.84)	115	(0.71)
	Number of households purchasing fertilizers*	220	(0.28)	108	(0.31)	75	(0.28)	37	(0.23)

* The number of households which exhibit positive quantity at the non-discount price in the price contingent order form in the sales experiment. Ratio of those who purchase inputs to participants in the sales experiment is given in parentheses.

Table 2. Summary statistics in RepEAT 2005 survey

	Village Type					
	Control		Treatment			
RePEAT Survey in Aug-Sep 2005	(1)		(2)		(3)	
Num. of Villages	23		46			
Village Characteristics	Mean a		Mean a		Difference b	
1 if Public Electricity is Available	0.17	(0.39)	0.2	(0.40)	-0.02	(0.10)
1 if Mobile Network is Available	0.91	(0.29)	0.89	(0.31)	0.02	(0.08)
1 if any Primary School	0.65	(0.49)	0.67	(0.47)	-0.02	(0.13)
1 if any Secondary School	0.13	(0.34)	0.11	(0.31)	0.02	(0.09)
1 if any Health Facility	0.83	(0.39)	0.67	(0.47)	0.15	(0.11)
Longitude (degree)	33.03	(0.98)	32.97	(1.06)	0.06	(0.26)
Latitude (degree)	0.6	(0.45)	0.59	(0.63)	0.01	(0.14)
Altitude (meter)	1251.07	(181.80)	1204.68	(140.40)	46.39	(43.20)
Household Characteristics						
Household Size	7.94	(3.86)	7.8	(4.16)	0.14	(0.33)
1 if Head is Female	0.16	(0.37)	0.12	(0.32)	0.05	(0.03)
Head's Age	46.86	(14.50)	46.27	(14.00)	0.59	(1.20)
Head's Years of Schooling	6.71	(3.42)	6.62	(3.16)	0.09	(0.30)
1 if having Mobile Phone	0.1	(0.29)	0.14	(0.34)	-0.04	(0.03)
Income (1000sh)	1700.43	(116.50)	1691.6	(92.10)	8.83	(153.10)
Nonfarm Income Share	0.24	(0.29)	0.26	(0.29)	-0.02	(0.02)
Assets (1000sh)	348.73	(1117.0)	320.45	(763.6)	28.29	(83.9)
Cultivated Land (ha) c	1.28	(1.03)	1.22	(1.12)	0.06	(0.09)
1 if Planted Maize	0.82	(0.38)	0.85	(0.35)	-0.03	(0.03)
Maize Production among Maize Growers						
Yield (kg/ha)	1664.86	(1460.0)	1436.13	(1796.0)	228.73	(153.9)
Chemical fertilizer Use (kg/ha)	2.77	(12.21)	1.29	(10.28)	1.48	(1.00)
1 if used Hybrid Seed d	0.06	(0.24)	0.06	(0.24)	0	(0.02)

a. Standard deviation in parentheses

b. Standard error in parentheses

**, *, + indicate 1%, 5%, 10% significance level, respectively

c. Size of land cultivated (ha) in main cropping season.

d. Because of no direct information in the RePEAT survey on whether the purchased seed was hybrid or other type, we assumed that the seed whose price was more than 3000 Ush was hybrid.

Table 3. Summary statistics in RePEAT 2009 survey by household type

Household Characteristics	Mean by household type			Mean difference		
	Control	Treatment	Neighbor	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****
	(14.20)	(13.10)	(13.70)	(1.20)	(1.24)	(1.00)
Head's years of schooling	5.68	6.05	6.6	–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	0.5	–0.44	0.15	0.58*
	(2.00)	(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	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 parentheses 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. Determinants of the participation in the Sales Workshop 2011. Dependent variable: 1 if participating in Sales Workshop 2011 and 0 otherwise

	Probit			FE Logit	
	(1)	(2)	(3)	(4)	(5)
1 if Treatment HH	0.307**	0.328**	0.539***		
	(0.15)	(0.16)	(0.16)		
1 if Neighbor HH	-0.12	-0.0675	0.225		
	(0.15)	(0.16)	(0.15)		
1 if purchasing inputs in Sales Workshop 1		0.21	0.218	0.0811	0.21
		(0.13)	(0.14)	(0.22)	(0.26)
1 if purchasing inputs in Sales Workshop 2		0.283**	0.21	0.827***	0.614*
		(0.14)	(0.14)	(0.29)	(0.32)
1 if participating in Sales Workshop 1		0.358**	0.295*	0.682***	0.258
		(0.18)	(0.18)	(0.26)	(0.32)
1 if participating in Sales Workshop 2		0.309**	0.237*	0.928***	0.795***
		(0.13)	(0.14)	(0.21)	(0.26)
Household size			0.0277		0.0820**
			(0.02)		(0.03)
Dependency rate			-0.0948*		-0.262**
			(0.05)		(0.10)
1 if female-headed household			0.122		0.163
			(0.17)		(0.33)
Household head's age			0.00587		0.0123
			(0.004)		(0.008)
Household head's years of schooling			0.00258		-0.0154
			(0.013)		(0.028)
Land size owned (Ha)			0.00419		0.0203
			(0.008)		(0.024)
Value of asset (millions of Ush)			-0.0463***		-0.0691**
			(0.015)		(0.034)
Constant	0.678***	0.0503	-0.349		
	(0.122)	(0.19)	(0.317)		
Community Fixed effects				Yes	Yes
Number of households	1008	1008	794	900	682
Number of communities				62	57

Standard errors in second row
* p<0.10, ** p<0.05, *** p<0.01

Table 5. Determinants of demand for 3 inputs and aggregate index

	Hybrid seed		Base fertilizer (DAP)		Top-dressing fertilizer (UREA)		Aggregate index	
	1 if purchased any	Purchased quantity (Kg)	1 if purchased any	Purchased quantity (Kg)	1 if purchased any	Purchased quantity (Kg)	1 if purchased any	Total value at market price (1000Ush)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1{Treatment HH}: β_T	0.603***	1.252**	0.29	3.797	0.395	5.953	0.661***	9.090***
	(0.21)	(0.54)	(0.21)	(2.47)	(0.27)	(3.94)	(0.21)	(3.48)
1{Neighbor HH}: β_N	0.423*	0.743	0.167	1.974	0.415	5.768	0.558**	6.057*
	(0.23)	(0.50)	(0.21)	(2.44)	(0.27)	(3.76)	(0.23)	(3.35)
Price (=discounted price/market price - 1)	-0.124	-2.017***	-0.187**	-3.748***	-0.216	-3.843*	-0.127	-10.83***
	(0.13)	(0.35)	(0.07)	(0.87)	(0.16)	(2.15)	(0.13)	(1.77)
Price * 1{Treatment HH}	-0.019	-0.282	-0.001	-0.652	-0.117	-1.936	-0.007	-3.343
	(0.15)	(0.48)	(0.09)	(0.98)	(0.18)	(2.42)	(0.15)	(2.41)
Price * 1{Neighbor HH}	0.017	-0.140	-0.075	-0.869	-0.045	-1.664	-0.030	-2.588
	(0.15)	(0.45)	(0.10)	(1.00)	(0.18)	(2.49)	(0.16)	(2.57)
1{Credit sales}	0.0490*	1.097***	0.264***	3.662***	0.503***	7.657***	0.0514*	6.847***
	(0.03)	(0.21)	(0.08)	(1.08)	(0.16)	(2.54)	(0.03)	(1.49)
1{Credit sales} * 1{Treatment HH} : β_{TC}	-0.012	0.298	0.161*	3.197**	0.102	1.900	0.002	6.752***
	(0.03)	(0.27)	(0.10)	(1.32)	(0.17)	(2.39)	(0.04)	(2.47)
1{Credit sales} * 1{Neighbor HH} : β_{NC}	-0.001	0.312	0.287***	3.592***	0.130	1.861	-0.040	5.178**
	(0.05)	(0.26)	(0.10)	(1.33)	(0.18)	(2.46)	(0.03)	(2.17)
Down-payment rate (demeaned)	0.30	5.62	3.29	41.75	7.807***	107.5***	1.11	58.45*
	(2.36)	(4.71)	(2.46)	(27.90)	(3.00)	(38.32)	(2.45)	(31.15)
Down-payment rate * 1{Credit sales}	0.05	-0.14	-0.76	-9.57	-2.06	-25.02	0.25	23.72
	(0.29)	(2.19)	(1.10)	(13.93)	(1.61)	(20.39)	(0.32)	(23.51)
Interest rate (demeaned)	-2.790**	-4.64	0.224	0.392	-0.906	-15.3	-3.307**	-32.06*
	(1.22)	(3.23)	(1.08)	(11.49)	(1.22)	(15.84)	(1.29)	(16.53)
Interest rate * 1{Credit sales}	-0.305	-3.563**	-0.711	-10.36*	-0.821	-15.23	0.0417	-29.78**
	(0.30)	(1.73)	(0.49)	(6.11)	(0.71)	(10.47)	(0.18)	(13.94)
Random compensation (1000Ush) (demeaned)	0.0531*	0.126**	0.0859***	0.950***	0.0568**	0.724**	0.0698**	1.089***
	(0.03)	(0.05)	(0.02)	(0.25)	(0.02)	(0.29)	(0.03)	(0.31)
Random compensation * 1{Credit sales}	0.0058	-0.0182	-0.0336*	-0.340*	-0.0427**	-0.533**	-0.0070	-0.0508
	(0.01)	(0.05)	(0.02)	(0.20)	(0.02)	(0.26)	(0.00)	(0.28)

Constant	0.564***	0.701	-0.925***	-13.08***	-1.701***	-25.61***	0.573***	0.206
	(0.19)	(0.45)	(0.17)	(2.58)	(0.25)	(5.26)	(0.19)	(2.89)
Number of observations	6993	6993	6993	6993	6993	6993	6993	6993
Number of households	777	777	777	777	777	777	777	777
Number of communities	69	69	69	69	69	69	69	69
$\beta_T - \beta_N$	0.179*	0.509*	0.123	1.823	-0.020	0.185	0.103	3.033*
(p-value)	(0.000)	(0.001)	(0.027)	(0.035)	(0.593)	(0.486)	(0.000)	(0.001)
$\beta_T + \beta_{TC}$	0.590***	1.550**	0.452**	6.994***	0.497**	7.853**	0.663***	15.842***
(p-value)	(0.000)	(0.001)	(0.027)	(0.035)	(0.593)	(0.486)	(0.000)	(0.001)
$\beta_N + \beta_{NC}$	0.423*	1.054*	0.454**	5.566**	0.545**	7.630**	0.518**	11.235**
(p-value)	(0.000)	(0.001)	(0.027)	(0.035)	(0.593)	(0.486)	(0.000)	(0.001)
$(\beta_T+\beta_{TC})- (\beta_N+\beta_{NC})$	0.168	0.496	-0.002	1.427	-0.048	0.223	0.145	4.607*
(p-value)	(0.000)	(0.001)	(0.027)	(0.035)	(0.593)	(0.486)	(0.000)	(0.001)

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.

Observations are taken from the price-contingent order forms of the sales workshop 2011 participants.

Table 5A. Determinants of demand for 3 inputs and aggregate index

	Hybrid seed		Base fertilizer (DAP)		Top-dressing fertilizer (UREA)		Aggregate index	
	1 if purchased any	Purchased quantity (Kg)	1 if purchased any	Purchased quantity (Kg)	1 if purchased any	Purchased quantity (Kg)	1 if purchased any	Total value at market price (1000Ush)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1{Treatment HH}: β_T	0.577***	1.722***	0.336*	4.559*	0.411	6.512	0.603***	11.80***
	(0.16)	(0.55)	(0.18)	(2.36)	(0.25)	(3.97)	(0.16)	(3.62)
1{Neighbor HH}: β_N	0.213	0.589	0.115	1.538	0.352	5.291	0.266*	4.906
	(0.16)	(0.50)	(0.18)	(2.28)	(0.25)	(3.74)	(0.16)	(3.29)
Price (=discounted price/market price - 1)	-0.0785	-1.704***	-0.170**	-3.543***	-0.204	-3.775*	-0.0789	-9.235***
	(0.08)	(0.31)	(0.07)	(0.86)	(0.15)	(2.15)	(0.08)	(1.59)
Price * 1{Treatment HH}	0.001	-0.339	-0.002	-0.649	-0.111	-1.956	0.010	-3.369
	(0.09)	(0.43)	(0.08)	(0.97)	(0.17)	(2.42)	(0.09)	(2.18)
Price * 1{Neighbor HH}	0.031	-0.028	-0.054	-0.681	-0.029	-1.337	0.020	-1.604
	(0.08)	(0.39)	(0.09)	(0.99)	(0.16)	(2.43)	(0.09)	(2.24)
1{Credit sales}	0.027	0.873***	0.224***	3.357***	0.457***	7.355***	0.0308*	5.428***
	(0.02)	(0.18)	(0.07)	(1.06)	(0.15)	(2.50)	(0.02)	(1.26)
1{Credit sales} * 1{Treatment HH} : β_{TC}	-0.011	0.331	0.156*	3.193**	0.108	2.069	-0.006	6.334***
	(0.02)	(0.24)	(0.09)	(1.30)	(0.16)	(2.38)	(0.02)	(2.22)
1{Credit sales} * 1{Neighbor HH} : β_{NC}	-0.008	0.241	0.240***	3.385***	0.108	1.740	-0.0276*	4.033**
	(0.02)	(0.23)	(0.09)	(1.31)	(0.16)	(2.44)	(0.02)	(1.85)
Down-payment rate (demeaned)	-0.20	3.87	2.83	38.93	7.103**	104.0***	0.16	44.34
	(1.77)	(4.77)	(2.27)	(28.01)	(2.87)	(39.56)	(1.79)	(33.34)
Down-payment rate * 1{Credit sales}	0.04	-0.32	-0.93	-11.70	-2.21	-28.44	0.12	16.91
	(0.14)	(1.89)	(0.94)	(13.08)	(1.48)	(20.14)	(0.15)	(19.81)
Interest rate (demeaned)	-1.518*	-4.587	0.147	-0.162	-0.898	-15.73	-1.678*	-31.61*
	(0.90)	(3.37)	(0.98)	(11.43)	(1.18)	(16.36)	(0.94)	(18.64)
Interest rate * 1{Credit sales}	-0.11	-2.965*	-0.659	-10.06*	-0.726	-14.29	0.0538	-24.71**
	(0.13)	(1.52)	(0.42)	(5.78)	(0.66)	(10.30)	(0.08)	(12.15)
Random compensation (1000Ush) (demeaned)	0.158***	0.380***	0.127***	1.466***	0.0879***	1.198***	0.175***	2.667***
	(0.03)	(0.07)	(0.02)	(0.30)	(0.02)	(0.33)	(0.02)	(0.42)
Random compensation * 1{Credit sales}	(0.01)	(0.02)	-(0.02)	-(0.27)	-0.0353**	-0.465*	(0.00)	(0.28)
	(0.01)	(0.05)	(0.02)	(0.20)	(0.02)	(0.28)	(0.00)	(0.27)

Constant	-0.0149	-0.870*	-1.139***	-16.42***	-1.844***	-29.13***	-0.0128	-9.287***
	(0.13)	(0.47)	(0.14)	(2.68)	(0.23)	(5.59)	(0.13)	(3.16)
Number of observations	9072	9072	9072	9072	9072	9072	9072	9072
Number of households	1008	1008	1008	1008	1008	1008	1008	1008
Number of communities	69	69	69	69	69	69	69	69
$\beta_T - \beta_N$	0.364***	1.133***	0.221**	3.020**	0.059	1.222	0.337***	6.893***
(p-value)	(0.000)	(0.001)	(0.027)	(0.035)	(0.593)	(0.486)	(0.000)	(0.001)
$\beta_T + \beta_{TC}$	0.566***	2.053***	0.493***	7.752***	0.519**	8.581**	0.597***	18.133***
(p-value)	(0.000)	(0.004)	(0.003)	(0.001)	(0.013)	(0.019)	(0.000)	(0.001)
$\beta_N + \beta_{Nc}$	0.205	0.829	0.355**	4.923**	0.460**	7.031**	0.238	8.939**
(p-value)	(0.198)	(0.191)	(0.032)	(0.027)	(0.033)	(0.039)	(0.135)	(0.047)
$(\beta_T+\beta_{TC})- (\beta_N+\beta_{NC})$	0.361***	1.224***	0.138*	2.829**	0.060	1.550	0.359***	9.194***
(p-value)	(0.000)	(0.003)	(0.093)	(0.018)	(0.388)	(0.188)	(0.000)	(0.004)

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.

Observations are taken from the price-contingent order forms of the sales workshop 2011 participants and also include non-participants, whose purchase quantities are set at zero.

Probit method is used to obtain the results of the ODD columns. Tobit method is used to obtain the results of the ODD columns.

Table 6. Determinants of the growth of purchase quantity between the 2009 and 2011 sales workshop.
OLS regression results

	d(Hybrid seed) (Kg)	d(Base fertilizer) (DAP in Kg)	d(Base fertilizer/ hybrid seed)	d(Top-dressing) fertilizer (UREA in Kg)	d(Top-dressing fertilizer/ hybrid seed)	d(Aggregate index) (Total value of inputs at market price in 1000Ush)
	(1)	(2)	(3)	(4)	(5)	(6)
1{Treatment HH} (β_T)	-0.108	-0.626	-0.132	-0.339	-0.188	-2.307
	(0.38)	(0.64)	(0.19)	(0.39)	(0.14)	(2.71)
1{Neighbor HH} (β_N)	0.235	0.193	0.0156	0.00759	-0.0994	1.243
	(0.34)	(0.47)	(0.16)	(0.23)	(0.10)	(2.07)
Price (market price = 0)	-1.271***	0.666	0.509***	0.851**	0.429***	-0.857
	(0.36)	(0.68)	(0.17)	(0.33)	(0.11)	(2.77)
Price * 1{Treatment HH}	0.454	0.727	0.283	0.409	-0.027	3.398
	(0.51)	(0.92)	(0.44)	(0.57)	(0.19)	(3.68)
Price * 1{Neighbor HH}	-0.509	-0.114	-0.132	-1.470**	-0.259	-4.841
	(0.65)	(0.84)	(0.23)	(0.68)	(0.16)	(3.83)
1{Credit sales}	0.785*	-5.054***	-0.990***	-1.425*	-0.523**	-10.04**
	(0.47)	(1.38)	(0.28)	(0.80)	(0.22)	(4.57)
1{Credit sales} * 1{Treatment HH} (β_{TC})	0.015	-0.357	0.150	-0.712	0.034	-1.872
	(0.34)	(0.90)	(0.20)	(0.56)	(0.13)	(3.05)
1{Credit sales} * 1{Neighbor HH} (β_{NC})	0.361	1.090	0.224	0.410	0.085	4.140
	(0.30)	(0.81)	(0.19)	(0.56)	(0.15)	(2.85)
d(Down-payment rate)	-0.94	3.63	1.15	3.42	1.491*	8.98
	(1.49)	(2.94)	(0.98)	(2.22)	(0.84)	(12.91)
d(Down-payment rate) * 1{Credit sales}	-2.465*	-18.57***	-3.596***	-1.84	-0.72	-49.81***
	(1.30)	(5.98)	(1.15)	(2.63)	(0.81)	(17.85)
d(Interest rate)	-0.0456	3.847	0.797	-0.674	-0.16	6.634
	(2.20)	(3.67)	(1.01)	(1.29)	(0.56)	(15.33)
d(Interest rate) * 1{Credit sales}	-4.179**	3.219	-0.591	2.7	0.377	-4.304
	(1.76)	(3.84)	(0.82)	(2.78)	(0.64)	(13.08)
Random compensation (1000Ush) (demeaned)	0.107*	0.295***	0.0698**	0.061	0.008	1.076***
	(0.06)	(0.07)	(0.03)	(0.04)	(0.02)	(0.30)
Random compensation * 1{Credit sales}	0.012	0.103	0.006	-0.033	-0.004	0.232
	(0.06)	(0.12)	(0.03)	(0.10)	(0.02)	(0.40)

Constant	0.354	-0.449	-0.133	0.636	0.221	0.993
	(0.63)	(0.96)	(0.33)	(0.43)	(0.18)	(4.22)
Number of observations	4282	4281	4281	4278	4278	4278
Number of households	476	476	476	476	476	476
Number of communities	69	69	69	69	69	69
R-sq	0.019	0.043	0.035	0.018	0.023	0.029
$\beta_T - \beta_N$	-0.343	-0.819	-0.147	-0.347	-0.089	-3.550
(p-value)	(0.217)	(0.134)	(0.421)	(0.369)	(0.389)	(0.106)
$\beta_T + \beta_{TC}$	-0.093	-0.983	0.018	-1.051	-0.154	-4.178
(p-value)	(0.877)	(0.420)	(0.936)	(0.182)	(0.302)	(0.407)
$\beta_N + \beta_{NC}$	0.597	1.283	0.240	0.417	-0.014	5.383
(p-value)	(0.249)	(0.213)	(0.313)	(0.545)	(0.938)	(0.216)
$(\beta_T+\beta_{TC})- (\beta_N+\beta_{NC})$	-0.690*	-2.266**	-0.222	-1.468**	-0.140	-9.562***
(p-value)	(0.051)	(0.017)	(0.220)	(0.027)	(0.248)	(0.007)

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.

Observations are taken from the price-contingent order forms of the participants of both the 2009 and 2011 sales workshop.

Table 6A. Determinants of the growth of purchase quantity between the 2009 and 2011 sales workshop. OLS regression results

	d(Hybrid seed) (Kg)	d(Base fertilizer) (DAP in Kg)	d(Base fertilizer/hybrid seed)	d(Top-dressing) fertilizer (UREA in Kg)	d(Top-dressing fertilizer/hybrid seed)	d(Aggregate index) (Total value of inputs at market price in 1000Ush)
	(1)	(2)	(3)	(4)	(5)	(6)
1{Treatment HH} (β_T)	0.0378	-0.39	-0.0414	-0.268	-0.165	-1.197
	(0.27)	(0.43)	(0.15)	(0.28)	(0.11)	(1.82)
1{Neighbor HH} (β_N)	0.0966	0.068	0.0193	-0.0856	-0.141*	0.329
	(0.24)	(0.30)	(0.12)	(0.17)	(0.08)	(1.37)
Price (market price = 0)	-0.722**	1.517***	0.750***	0.725**	0.441***	2.32
	(0.33)	(0.56)	(0.17)	(0.29)	(0.11)	(2.43)
Price * 1{Treatment HH}	0.143	0.413	-0.065	0.412	-0.097	1.739
	(0.42)	(0.72)	(0.24)	(0.47)	(0.14)	(3.00)
Price * 1{Neighbor HH}	-0.471	-0.173	-0.166	-0.659*	-0.134	-3.459
	(0.43)	(0.54)	(0.19)	(0.36)	(0.13)	(2.56)
1{Credit sales}	0.313	-2.280***	-0.846***	-0.470	-0.353**	-4.495
	(0.29)	(0.80)	(0.20)	(0.47)	(0.15)	(2.91)
1{Credit sales} * 1{Treatment HH} (β_{TC})	0.127	-0.068	0.301*	-0.721	0.043	-0.902
	(0.26)	(0.65)	(0.18)	(0.44)	(0.12)	(2.31)
1{Credit sales} * 1{Neighbor HH} (β_{NC})	0.228	0.571	0.314*	0.151	0.095	2.217
	(0.23)	(0.55)	(0.17)	(0.36)	(0.12)	(2.01)
d(Down-payment rate)	0.80	3.726**	1.293*	2.406*	1.308**	14.15**
	(0.85)	(1.66)	(0.66)	(1.33)	(0.61)	(6.96)
d(Down-payment rate) * 1{Credit sales}	-1.22	-6.829***	-2.168**	0.21	-0.10	-18.03**
	(0.97)	(2.45)	(0.95)	(1.69)	(0.64)	(8.17)
d(Interest rate)	-0.891	0.788	-0.304	-0.612	-0.253	-2.973
	(1.05)	(1.69)	(0.57)	(0.96)	(0.42)	(7.43)
d(Interest rate) * 1{Credit sales}	-2.296*	-1.233	-0.828	-0.106	-0.0703	-10.89
	(1.15)	(2.49)	(0.62)	(1.80)	(0.48)	(9.21)
Random compensation (1000Ush) (demeaned)	0.175***	0.304***	0.0897***	0.0723*	0.019	1.333***
	(0.05)	(0.07)	(0.02)	(0.04)	(0.02)	(0.28)

Random compensation * 1{Credit sales}	0.047	0.121	0.011	0.012	0.003	0.458
	(0.05)	(0.10)	(0.03)	(0.09)	(0.02)	(0.37)
Constant	0.522*	0.244	0.0362	0.469**	0.202**	2.973*
	(0.28)	(0.32)	(0.16)	(0.21)	(0.08)	(1.64)
Number of observations	6636	6636	5977	6631	5972	6631
Number of households	722	722	655	721	654	721
Number of communities	69	69	69	69	69	69
R-sq	0.015	0.027	0.036	0.018	0.028	0.022
$\beta_T - \beta_N$	-0.059	-0.458	-0.061	-0.182	-0.023	-1.526
(p-value)	(0.748)	(0.184)	(0.613)	(0.452)	(0.752)	(0.266)
$\beta_T + \beta_{TC}$	0.164	-0.458	0.259	-0.989*	-0.122	-2.099
(p-value)	(0.718)	(0.586)	(0.212)	(0.092)	(0.366)	(0.558)
$\beta_N + \beta_{NC}$	0.325	0.639	0.333	0.065	-0.046	2.546
(p-value)	(0.422)	(0.328)	(0.122)	(0.885)	(0.746)	(0.387)
$(\beta_T+\beta_{TC})- (\beta_N+\beta_{NC})$	-0.161	-1.097*	-0.074	-1.054**	-0.076	-4.645*
(p-value)	(0.563)	(0.094)	(0.555)	(0.021)	(0.330)	(0.070)

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.

Observations are taken from the price-contingent order forms of the participants of either 2009 or 2011 or both sales workshops.

Table 7. Determinants of the growth of purchase quantity between the 2009 and 2011 sales workshop.
Community fixed effect regression results

	d(Hybrid seed) (Kg) (1)	d(Hybrid seed) (Kg) (2)	d(Hybrid seed) (Kg) (3)
Profit gain from the use of hybrid seed in 2010 by himself (1,000Ush): Δπ_own	0.00399***	0.00272**	-0.00142
	(0.0005)	(0.0011)	(0.0014)
1{Δπ_own >0}		-1.223***	
		(0.30)	
1{Δπ_own >0} * Δπ_own		0.00429***	
		(0.00)	
Average profit gain from the use of hybrid seed in 2010 by his information peers: Δπ_info	0.00136**	-0.00142	0.00934***
	(0.0006)	(0.0011)	(0.0023)
1{Δπ_info>Δπ_own }		0.476	
		(0.29)	
1{Δπ_info>Δπ_own } * Δπ_info		0.00362***	
		(0.0012)	
Average profit gain from the use of hybrid seed in 2010 by his geographic peers: Δπ_geo	0.00111**	0.00165**	-0.00501**
	(0.0006)	(0.0008)	(0.0023)
1{Δπ_geo>Δπ_own }		-0.457*	
		(0.27)	
1{Δπ_geo>Δπ_own } * Δπ_geo		0.00108	
		(0.0012)	
1{Treatment household} * Δπ_own			0.00794***
			(0.0015)
1{Treatment household} * Δπ_info			-0.00850***
			(0.0025)
1{Treatment household} * Δπ_geo			0.00594**
			(0.0024)
1{Neighbor household} * Δπ_own			0.00336**
			(0.0016)
1{Neighbor household} * Δπ_info			-0.00705***
			(0.0025)
1{Neighbor household} * Δπ_geo			0.00541**
			(0.0025)

Price (market price = 0)	-1.347	-1.347	-1.347
	(0.91)	(0.91)	(0.90)
1{Credit sales}	0.743	0.744	0.744
	(0.62)	(0.62)	(0.61)
ΔDown-payment rate * 1{Credit sales}	-4.685***	-4.685***	-4.685***
	(1.66)	(1.65)	(1.64)
ΔInterest rate * 1{Credit sales}	-5.725***	-5.725***	-5.725***
	(1.70)	(1.69)	(1.67)
Random compensation (1000Ush) (demeaned)	0.076	0.069	0.077
	(0.06)	(0.06)	(0.06)
Random compensation * 1{Credit sales}	0.05	0.05	0.05
	(0.08)	(0.08)	(0.08)
Constant	0.12	-0.11	0.36
	(0.35)	(0.38)	(0.36)
Number of observations	2092	2092	2092
Number of households	239	239	239
Number of communities	57	57	57
R-sq	0.054	0.067	0.085

Appendix Table 1. Maize production and use of modern inputs

Year	2008		2009		2010	
Season	1	2	1	2	1	2
Treatment Households						
Number of maize producing households	270	260	374	231	251	191
Maize producing households with LOCAL seed						
Number of households	241	243	189	155	148	163
Fraction	0.89	0.93	0.51	0.67	0.59	0.85
Average yield (kg/ha)	1218.1	1089.8	869.0	1312.8	1120.1	868.0
	(1104.7)	(993.7)	(971.5)	(1042.5)	(911.5)	(857.4)
Average chemical fertilizer use (kg/ha)	1.6	0.3	2.0	3.1	7.6	1.0
	(15.3)	(4.1)	(16.4)	(12.3)	(34.7)	(4.6)
Maize producing households with HYB seed						
Number of households	29	17	352	152	130	39
Fraction	0.11	0.07	0.94	0.66	0.52	0.20
Average yield (kg/ha)	1448.9	1900.4	1841.9	1836.6	1588.6	1059.1
	(1486.2)	(2269.7)	(1476.7)	(1297.2)	(1547.9)	(1211.1)
Average chemical fertilizer use (kg/ha)	1.0	7.8	150.7	42.5	31.3	16.6
	(5.5)	(31.1)	(77.4)	(54.6)	(50.4)	(26.1)
Control Households						
Number of maize producing households	157	140	164	130	117	91
Maize producing households with LOCAL seed						
Number of households	145	136	146	112	77	76
Fraction	0.92	0.97	0.89	0.86	0.66	0.84
Average yield (kg/ha)	1338.9	1231.3	1077.1	1572.5	1334.9	1061.0
	(1416.8)	(1039.6)	(1081.8)	(1093.0)	(1204.5)	(863.5)
Average chemical fertilizer use (kg/ha)	0.5	1.2	1.2	3.2	1.6	1.9
	(4.6)	(8.0)	(5.7)	(28.1)	(4.9)	(7.7)
Maize producing households with HYB seed						
Number of households	12	4	18	65	50	16
Fraction	0.08	0.03	0.11	0.50	0.43	0.18
Average yield (kg/ha)	1265.5	1399.9	1317.4	1659.7	1387.4	636.0
	(871.6)	(451.8)	(1006.8)	(1164.3)	(937.5)	(650.1)
Average chemical fertilizer use (kg/ha)	8.2	12.4	19.1	28.6	20.7	7.1
	(19.9)	(14.3)	(31.2)	(36.4)	(28.8)	(17.7)
Neighbor Households						
Number of maize producing households	244	233	289	192	179	149
Maize producing households with LOCAL seed						
Number of households	228	226	255	150	115	126
Fraction	0.93	0.97	0.88	0.78	0.64	0.85

Average yield (kg/ha)	1017.5	1028.4	771.6	1174.3	1049.8	785.0
	(798.1)	(970.4)	(900.9)	(880.3)	(892.6)	(774.1)
Average chemical fertilizer use (kg/ha)	1.0	0.1	0.8	0.2	0.7	0.7
	(10.1)	(1.3)	(7.8)	(1.9)	(3.3)	(5.5)
Maize producing households with HYB seed						
Number of households	16	7	36	108	89	29
Fraction	0.07	0.03	0.12	0.56	0.50	0.19
Average yield (kg/ha)	1667.4	699.0	1335.8	1598.2	1386.6	1061.7
	(1615.1)	(791.4)	(1352.0)	(1387.2)	(1041.0)	(1277.5)
Average chemical fertilizer use (kg/ha)	7.4	12.2	32.1	30.6	26.0	13.0
	(24.9)	(21.2)	(54.9)	(51.0)	(42.0)	(25.6)

Standard deviations are in parentheses.

Some households plant both HYB and LOCAL seeds in the same season.

Maize production data is obtained from the RePEAT survey 2009 in Oct 2009 and the Sales Workshop 2011 in Feb 2011.

Appendix Table 2. Transition matrix of HYB seed adoption

Treatment households	*Sales 2011*			
Sales 2009	Not attended	Attend but Not purchased	Attend and Purchased	Total
Not attended	18	3	22	43
	(0.42)	(0.07)	(0.51)	
Attend but Not purchased	33	16	88	137
	(0.24)	(0.12)	(0.64)	
Attend and Purchased	24	24	193	241
	(0.10)	(0.10)	(0.80)	
Total	75	43	303	421
Control households	*Sales 2011*			
Sales 2009	Not attended	Attend but Not purchased	Attend and Purchased	Total
Not attended	2	8	2	12
	(0.17)	(0.67)	(0.17)	
Attend but Not purchased	32	24	44	100
	(0.32)	(0.24)	(0.44)	
Attend and Purchased	20	15	69	104
	(0.19)	(0.14)	(0.66)	
Total	54	47	115	216
Neighbor households	*Sales 2011*			
Sales 2009	Not attended	Attend but Not purchased	Attend and Purchased	Total
Not attended	19	9	21	49
	(0.39)	(0.18)	(0.43)	
Attend but Not purchased	41	20	70	131
	(0.31)	(0.15)	(0.53)	
Attend and Purchased	48	14	136	198
	(0.24)	(0.07)	(0.69)	
Total	108	43	227	378

Appendix Table 3: Labor input on maize plot by activity

Activity	Variable	Non-experimental plot			Experimental plot			Difference		
		N	Mean	Std. Dev	N	Mean	Std. Dev	in Mean	Std. Err.	
Land preparation										
	Family labor (Hours/ha)	165	387.1	(1005.72)	165	386.9	(467.24)	0.2	(86.33)	
	Hired labor cost (1000Ush/ha)	165	41.2	(82.15)	165	72.0	(101.18)	-30.8	(10.15)	***
	Family labor (Hours/ha) given zero hired labor	94	632.9	(1272.59)	91	553.0	(518.12)	79.9	(142.05)	
	Hired labor cost (1000Ush/ha) given zero family labor	48	99.2	(92.51)	37	168.8	(76.59)	-69.6	(18.35)	***
Planting and base fertilizer application										
	Family labor (Hours/ha)	165	135.2	(186.13)	165	235.2	(232.16)	-100.0	(23.17)	***
	Hired labor cost (1000Ush/ha)	165	11.0	(50.24)	165	23.8	(164.23)	-12.8	(13.37)	
	Family labor (Hours/ha) given zero hired labor	141	150.3	(195.98)	137	258.1	(237.11)	-107.8	(26.13)	***
	Hired labor cost (1000Ush/ha) given zero family labor	10	47.4	(44.02)	8	94.8	(82.55)	-47.4	(32.33)	
Weeding (1st)										
	Family labor (Hours/ha)	165	236.1	(391.30)	165	306.2	(391.36)	-70.1	(43.08)	
	Hired labor cost (1000Ush/ha)	165	22.0	(57.82)	165	31.4	(62.58)	-9.3	(6.63)	
	Family labor (Hours/ha) given zero hired labor	115	317.2	(440.74)	119	389.5	(422.66)	-72.3	(56.48)	
	Hired labor cost (1000Ush/ha) given zero family labor	30	99.6	(101.30)	25	135.1	(67.11)	-35.5	(22.85)	
Top-dressing fertilizer application										
	Family labor (Hours/ha)	165	7.6	(66.27)	165	143.4	(322.07)	-135.8	(25.60)	***
	Hired labor cost (1000Ush/ha)	165	1.5	(12.92)	165	7.0	(28.74)	-5.6	(2.45)	**
	Family labor (Hours/ha) given zero hired labor	5	206.2	(352.90)	128	180.2	(357.15)	25.9	(160.95)	
	Hired labor cost (1000Ush/ha) given zero family labor	1	158.1	.	7	101.2	(87.21)	57.0	.	
Weeding (2nd)										
	Family labor (Hours/ha)	165	94.5	(158.47)	165	205.6	(256.64)	-111.1	(23.48)	***
	Hired labor cost (1000Ush/ha)	165	6.8	(26.09)	165	20.3	(54.74)	-13.5	(4.72)	***
	Family labor (Hours/ha) given zero hired labor	75	202.3	(182.39)	102	304.5	(256.59)	-102.3	(33.00)	***
	Hired labor cost (1000Ush/ha) given zero family labor	13	74.7	(57.97)	19	131.1	(87.21)	-56.4	(25.67)	**
Harvesting										
	Family labor (Hours/ha)	165	114.6	(142.39)	165	223.1	(226.78)	-108.5	(20.85)	***
	Hired labor cost (1000Ush/ha)	165	6.9	(27.44)	165	10.2	(33.53)	-3.3	(3.37)	
	Family labor (Hours/ha) given zero hired labor	134	129.7	(145.83)	132	243.5	(229.91)	-113.9	(23.65)	***
	Hired labor cost (1000Ush/ha) given zero family labor	9	50.7	(57.63)	3	128.5	(69.19)	-77.7	(44.33)	

Other activity								
Family labor (Hours/ha)	165	91.2	(266.31)	165	212.0	(728.45)	-120.8	(60.38) **
Hired labor cost (1000Ush/ha)	165	10.0	(30.79)	165	26.5	(82.41)	-16.5	(6.85) **
Family labor (Hours/ha) given zero hired labor	81	156.5	(349.03)	86	337.3	(964.62)	-180.8	(111.01)
Hired labor cost (1000Ush/ha) given zero family labor	16	48.8	(61.61)	15	169.9	(167.83)	-121.0	(45.99) **
Total								
Family labor (Hours/ha)	165	1066.4	(1698.11)	165	1712.4	(2006.44)	-646.0	(204.63) ***
Hired labor cost (1000Ush/ha)	165	99.3	(197.22)	165	191.3	(346.28)	-91.9	(31.02) ***

Observations are households who planted both hybrid seeds with chemical fertilizers given for free from the project and local varieties in the 1st crop season in 2009.

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

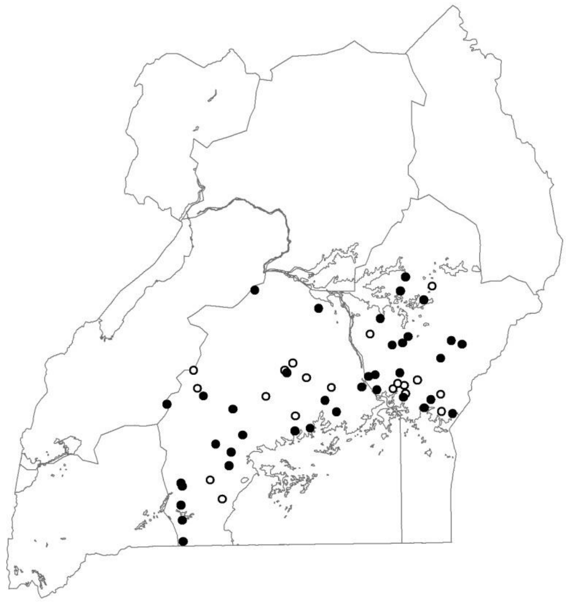


Figure 1. Survey Villages

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

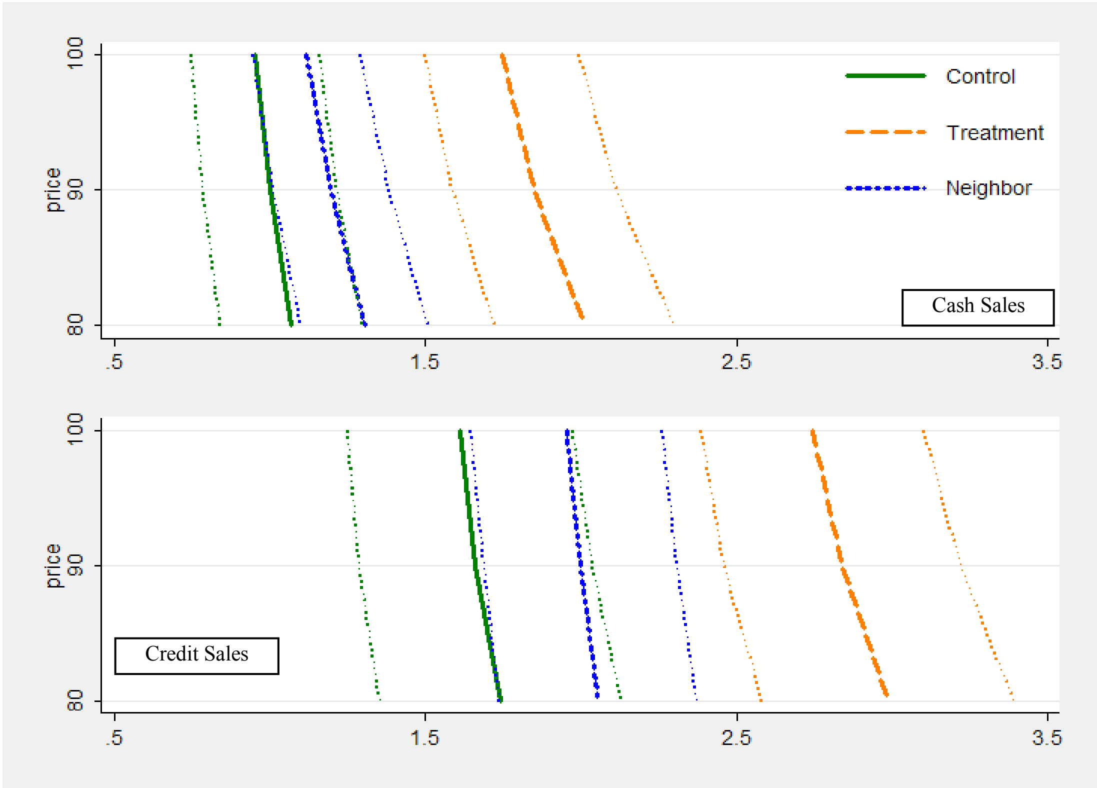
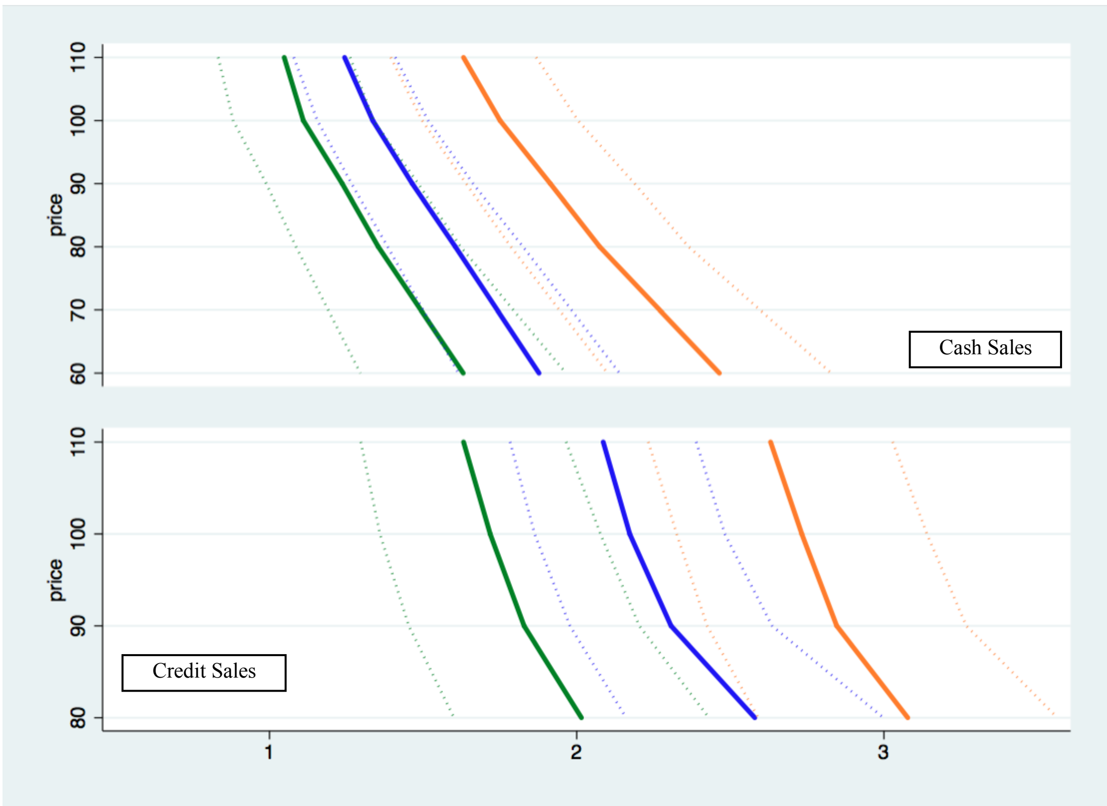


Figure 2. Hybrid seed: Estimated demand curves in Sales Workshop 2009 (above) and 2011 (below)



Note: The dotted lines indicate 95 % confidence interval. The estimated demand is the sample average of quantities given different prices and credit option availability that the sales workshop participants filled out into the price-contingent order form used in the sales workshop. The vertical axis represents the price index normalized by the market price set at 100. The horizontal axis represents the purchased quantity in kilograms.

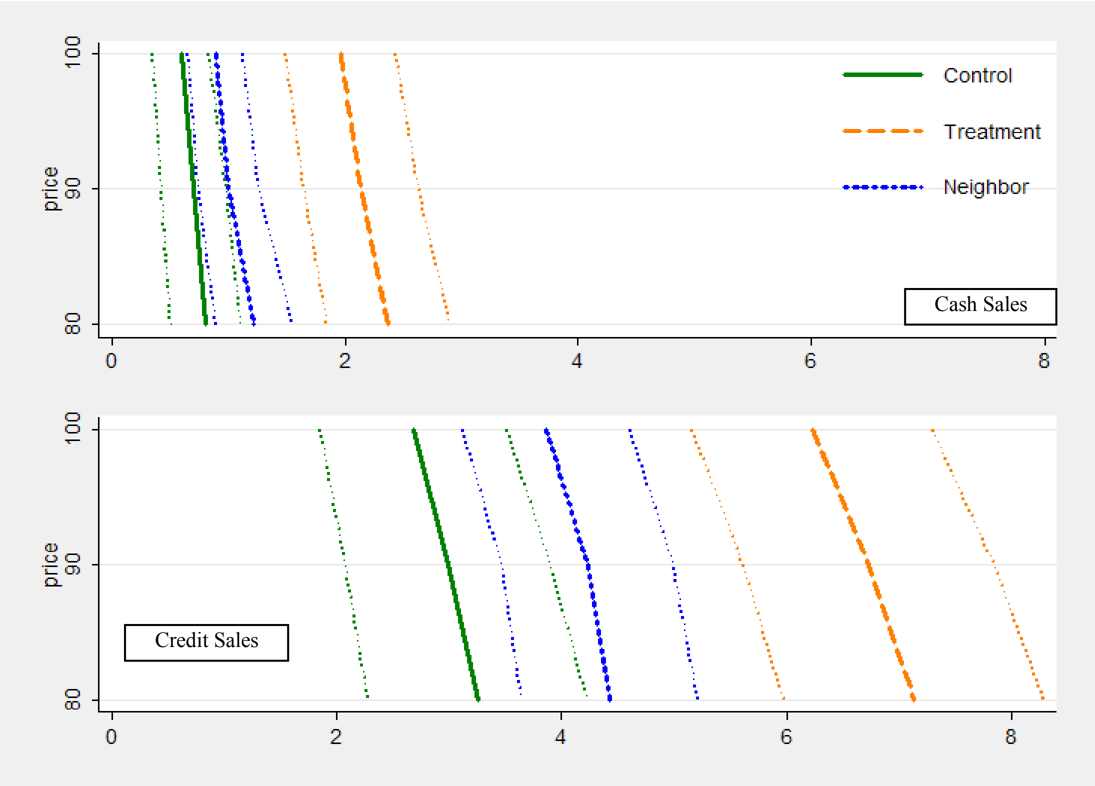
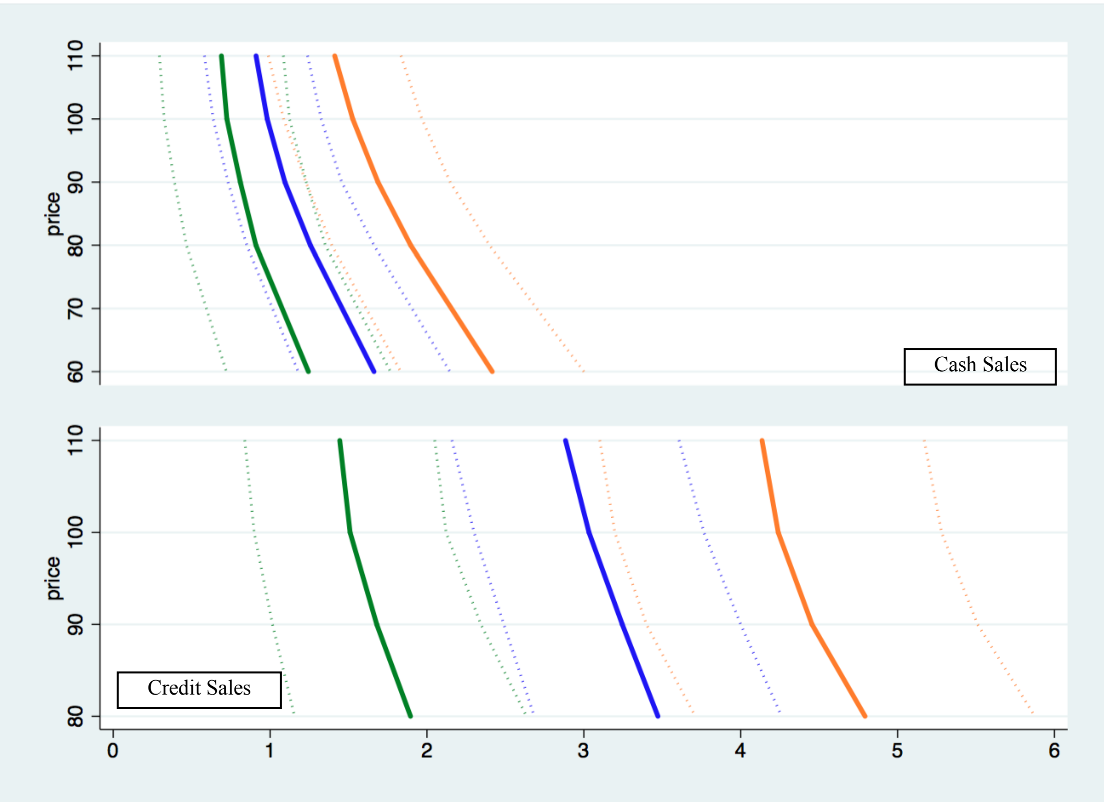


Figure 3. Base fertilizer: Estimated demand curves in Sales Workshop 2009 (above) and 2011 (below)



Note: The dotted lines indicate 95 % confidence interval. The estimated demand is the sample average of quantities given different prices and credit option availability that the sales workshop participants filled out into the price-contingent order form used in the sales workshop. The vertical axis represents the price index normalized by the market price set at 100. The horizontal axis represents the purchased quantity in kilograms.

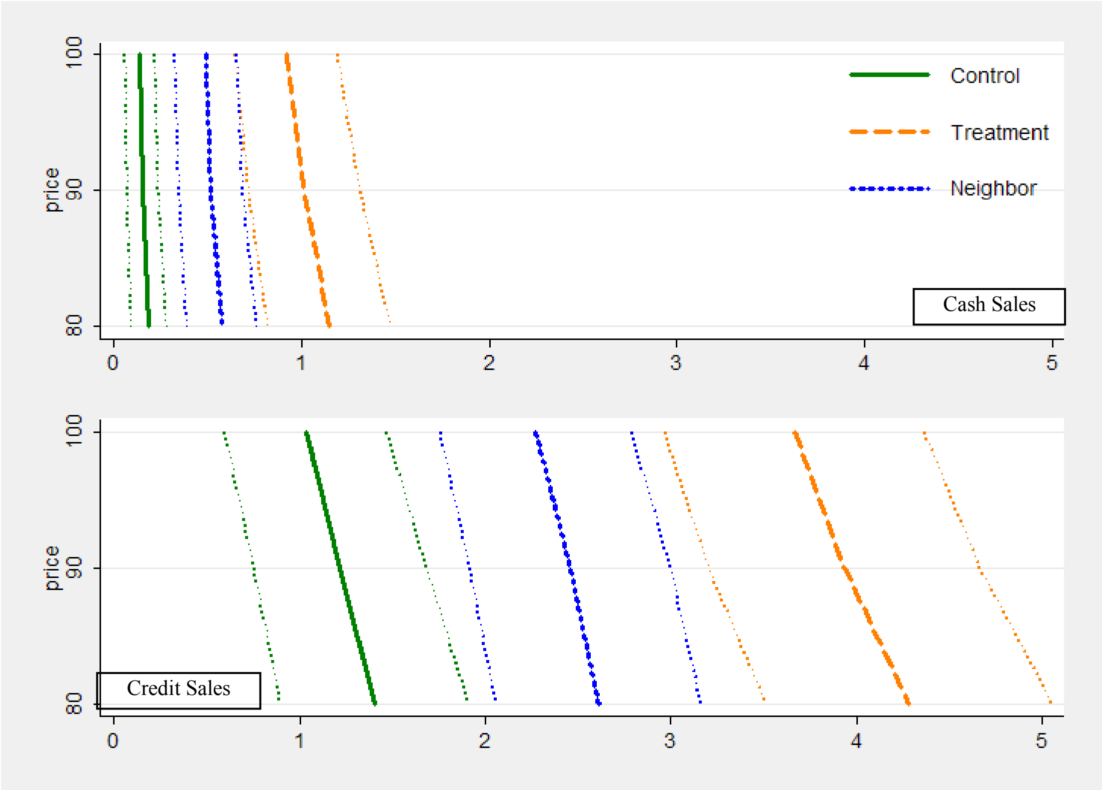
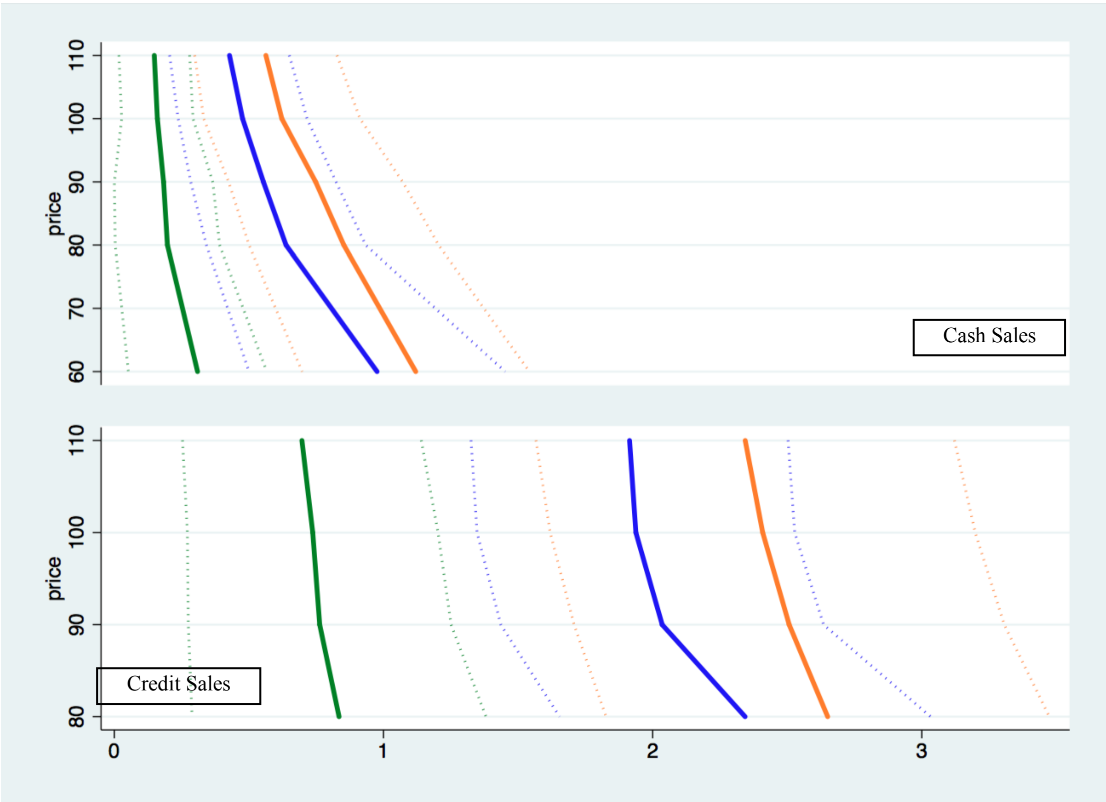


Figure 4. Top-dressing fertilizer: Estimated demand curves in Sales Workshop 2009 (above) and 2011 (below)



Note: The dotted lines indicate 95 % confidence interval. The estimated demand is the sample average of quantities given different prices and credit option availability that the sales workshop participants filled out into the price-contingent order form used in the sales workshop. The vertical axis represents the price index normalized by the market price set at 100. The horizontal axis represents the purchased quantity in kilograms.