ICT-mediated agricultural knowledge transfer in Uganda: What works?

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Abstract

In information dissemination campaigns by agricultural extension services, seemingly small attributes, the way it is delivered, who delivers the message or who it is delivered to, can result in significant differences in outcomes, such as knowledge transferred and adoption of recommended practices. In the context of ICT-mediated knowledge transfer, this study investigates the role of the gender composition of the person(s) who provide the information and the gender/age composition of the person(s) who receive the information in making the information transfer more effective. In addition, video as a way to deliver extension information is augmented to more demand-driven ICT solutions, such as Interactive Voice Response (IVR). Effectiveness is assessed in terms of knowledge gain, increased adoption, yield increase, and poverty reduction. We propose to do this using field experiments, where farmers are randomly assigned to particular interventions.

Motivation

In many instances, a simple piece of information makes a big difference. However, not every information campaign is effective, and often, seemingly small attributes, such as how the message is framed, the way it is delivered, or who it is delivered by and to, can result in significant differences in impact (Jack, 2013). Understanding the effect of these attributes through rigorous evaluation research should therefore be an essential part of any knowledge exchange model.

We propose an evaluation that will address key questions on the effectiveness of ICT-enabled extension and advisory service approach in Uganda. The questions are related to the gender/age composition of the receiver and the messenger of the information message, the way in which the message is framed, and the way it is delivered. The questions will be answered through field experiments, where farmers are randomly assigned to a group that receives particular interventions (de Janvry, Sadoulet, and Suri, 2016). Since we want to test more than one research hypothesis and are particularly interested in comparing the effectiveness of various attributes of an ICT-enabled extension approach, we opt for a factorial design. In such a design, farmers get a particular combination of interventions and, in general, a smaller sample size is needed to answer a fixed number of research questions.

We will work with maize farmers in southeast Uganda. Short videos that explain simple yet effective ways to increase maize productivity, such as best practices in row spacing and plant density, will be developed and shown to selected members within farm households. An alternative technology to deliver the same information, such as Interactive Voice Response (IVR), will be developed and implemented by a partner (Human Network International). Power calculations suggest we would need a sample of about 3,600 farmers, which will be drawn from six districts. The videos will be shown to farmers at the beginning of the main season, which starts in September 2017, and an endline survey will collect information on outcomes after harvesting, which ends in February 2018. We expect to collect endline data during March 2018 and to have results ready by July 2018.

The results of this study is expected to inform agricultural extension system reform currently underway in Uganda. Uganda's new director of extension services signaled a role for digital extension within the future extension strategy. While the subject of this research study is maize intensification, we believe the findings can be readily extended to include similar interventions on different crops and subjects, including extension on post-harvest storage and handling, agricultural value addition, or agricultural commodity marketing.

Research Questions

This research aims to answer which attributes of an agricultural extension information campaign are most important for its effectiveness. In particular, we will investigate attributes related to the gender composition of both messenger and recipient of the messages. In addition, we will look at the effect of framing the same information in different ways. Finally, we will also look at the model of delivery of the information.

Gender Composition of Messenger and Receiver

Research suggests the gender and age composition of both messenger and receiver are important in making information effective. However, agricultural extension information services are generally biased toward men. Most often, extension officers are male who target the main decision maker with respect to agriculture within households, which is also often considered to be the male farmer. The assumption that extension messages given to one household member will trickle down to the rest of the household, including women and younger household members, may be false. Men do not necessarily discuss production decisions or transfer extension knowledge to women household members, especially if extension messages were focusing on men's priorities and crops (Fletschner and Mesbah, 2011). Gender matching effects, where men learn more from other men and women learn more from other women, have also been found in the context of agricultural extension services (Doss and Morris, 2001). At the same time, farms are essentially run and managed at the household level, and it may therefore be more effective if information is targeted at this level. For instance, Lambrecht, Vanlauwe, and Maertens (2016) found joint male and female program participation leads to higher adoption rates of fertilizer in Eastern DR Congo. The analysis of a Digital Green project in Ethiopia also concluded that there is much to be learned from observing the interactions between men and women who learn about the same technologies and practices (Bernard et al., 2016).

We therefore want to investigate the relative importance of (i) the gender composition of the messenger, and (ii) the gender composition of the audience for effective agricultural extension information messages to encourage sustainable crop intensification in smallholder household farms and for improving gender equity in household farming. In particular, we will compare outcomes at the household level between:

- households that are shown a video with agricultural extension information and households that are shown a random video (placebo);

- households that are shown a video with agricultural extension information where the animator is an individual "peer" farmer (ie. a man or a women) and households that were shown a video providing the same information by a couple of peer farmers (ie. man and woman who are shown to participate as equals in the family farm and deliver the message as a couple);
- households in which one adult individual (husband or wife) is shown a video with agricultural extension information and households in which the couple (husband and wife) is shown a video with the same information;
- households where the gender composition of (the individual) messenger(s) and (individual) audience is matched and households where the gender composition of the messenger and audience differ.

To assess the effect the gender composition of messenger and receiver on equity within the household, we will compare outcomes within the household between:

- households where the video was shown to a man versus households where the video was shown to the husband
- households that were shown the video that promotes a household approach featuring a couple versus households that were shown a video where a single farmer provides the messenges
- households that are both shown the video that also projects a household approach to all the other households

For this research question, we will be particularly interested in how these interventions reverberate through intra-household decision-making and the allocation of time and resources to agriculture between the different individuals within the farm household. The outcomes of interest will therefore be disaggregated by gender and age, and interpreted in light of the interplay between efficiency at the household farm level, equity within the farming household and women's and youth's empowerment.

Different ICT Channels

The tools and technologies through which the information is transferred are also likely to influence effectiveness. There are many different ways of delivering agricultural extension messages through ICT. Broadly, one can differentiate between two different approaches. In one approach, extension resembles the traditional teacher-pupil model, where the farmer is assumed to absorb knowledge from experts. Showing videos to farmers or pushing information over a mobile phone would fall into this category. A second approach relies more on a consultative model, where the farmer is assumed to know his or her information needs are and requests this information from a service provider. Call centers and Interactive Voice Response (IVR) technology are examples of this second approach. In a third research question, we will compare the effectiveness in terms of changing knowledge, practices and outcome such as yields and poverty of video messages to more or less demand based options such as IVR. In particular, we will compare videos to videos augmented with IVR and videos augmented with IVR where the recipient is also provided with reminders of the existence of the IVR service.

Outcomes

The effectiveness of the different interventions will be judged by their effect on a range of outcomes at the farm household level. Therefore, a first set of outcomes will investigate changes in knowledge due to the interventions. It is further assumed that knowledge translates into increased adoption of the technologies. We will investigate both adoption as a binary outcome (yes/no), but also look at adoption intensity (adopted on share of total cultivated area, application rates, etc.). This, in turn, is expected to benefit agricultural production (yield). Finally, we expect this will affect household well-being, through increased consumption and income derived from marketing of more, better quality crops. We will therefore include consumption expenditure as a proxy for well-being.

Defining the outcomes will enable us to compare the cost-effectiveness of each intervention (e.g., is showing a video to a woman more cost effective than showing it to a couple in terms of its effect on productivity?). We will also collect information that is relevant for the particular attributes we focus on. For instance, showing extension information to the wife instead of the husband may result in substantially different labor allocation effects: women may prefer labor saving innovations, while men may focus more on yield increasing investments. Therefore, in the context of poorly functioning labor markets, we may want to include school attendance of adolescent girls.

Research Strategy

The questions will be answered through field experiments, where farmers are randomly assigned to a group that receives particular interventions (de Janvry et al., 2017). An identification strategy that is based on randomization allows us to quantify the causal linkage between an intervention and the outcomes. In particular, we establish the causal link between extension videos and the knowledge gained, between extension videos and yield changes, and between extension videos and poverty (measured by income). Note that this is different from looking at the direct causal link between for instance yield and poverty. In other words, if we find videos affect learning and videos affect poverty, we cannot be sure poverty is affected by another attribute related to our video (eg motivation). In a way, field experiments estimate a reduced form of relationships, and looking into the exact causal chain would require a full mediation analysis with an adapted design, such as those discussed in Imai et al. (2013). However, the study would still be useful in learning about the likely impact pathways. For one, we will include intermediate outcomes related to different pathways based on theory and previous research: Finding that videos have an effect on poverty and on measures of motivation but not on knowledge may make us more confident that the impact works through non-cognitive channels. Furthermore, we can explore causal links between intermediate outcomes and final outcomes (such as the effect of knowledge on yields) using statistical techniques (such as instrumenting knowledge by treatment assignment).

The research design itself will take the form of a mixed level factorial design. To answer the first research question, we define two different factors, each with three levels. The first factor relates to the messenger and has three levels (male, female and male+female). Similarly, the second factor relates to the recipient of the message and also has these three levels (male, female and male+female). The second research question will be added to the design as an extra factor, but this factor only has 2 levels (information given in an objective way, information provided using social marketing techniques).

The third research question, where video is now augmented with a demand-driven technology such as IVR, corresponds to adding an extra factor with two levels (no IVR, IVR, IVR + reminders). In practice, we therefore add the IVR treatment to one third of the participants who get to see a video and we add the IVR+reminders treatment to one third of the sample that gets the treatment. Finally, we will add a pure control group to the design, such that we do not only investigate relative effectiveness of the different attributes, but also relative to someone who did not get to see a video at all.

The interventions will be targeted at the individual (household) level as opposed to group screenings. Videos will be shown in the house or in the field if necessary. This option guarantees consistency in the treatment and requires the least amount of observations. The videos will be developed in house by the research team and produced by a professional media production company such as NOTV. For IVR, we will partner with Human Network International. Human Network International's 3-2-1develops content for farmers on a variety of crops and agricultural practices, and make the service available to farmers for free or at low cost.

Crop and Technology

The interventions for which we will investigate various attributes will be on maize intensification. Maize is widely consumed, yet its value to weight ratio is sufficiently high to also make it an important commodity. Therefore, increasing maize productivity at the farm household level has the potential to lead to improvements in both nutritional outcomes and income. Maize yields in Uganda are relatively low. While on-station trials report potential yields average about 3.8 metric tons per hectare (improved varieties, no fertilizer used), according to the latest UNPS data, average maize yields are much lower, at about 0.92 tons per hectare for the main growing season of 2014. There is a lot of variation in yields, with the top 10 percent of best farmers getting yields in excess of 2.3 metric tons. At the same time, the use of modern inputs such as inorganic fertilizer and modern technologies such as row planting is very low in Uganda. For example, use of inorganic fertilizer averages only 1 kg of nutrient per hectare per year, compared to Kenya (32 kg/ha); Rwanda (29 kg/ha); and Tanzania (6 kg/ha). Using the latest UNPS data, only 6 percent of maize plots are planted using improved seed varieties. This suggests substantial scope to increase yields through the use of modern

	subcounties	parishes	villages
Jinja	11	69	631
Mayuge	7	56	272
Iganga	12	66	382
Luuka	7	33	209
Kamuli	13	72	1031
Total	50	269	3131

Table 1: Administrative structure of study area

inputs and recommended practices.

Sampling

Sampling Frame

Maize is especially important in the East. We will sample from five districts from the East known for their maize production: Jinja, Mayuge, Iganga, Luuka and Kamuli. Table 1 gives an idea of how villages are distributed over parishes, which are in turn allocated to sub-counties within each of the 6 districts in our study.

Our study population consists of maize farmers within this region. Because of cost considerations, however, we will use two-stage cluster sampling to obtain a representative sample of this population. In particular, we will first randomly select parishes. Within each parish, we will then list all the households, from which we will then sample households to be included in the study. At the same time, we suspect that outcomes within parishes will be correlated, for instance due to local weather conditions, or development programs that are implemented in certain areas. Therefore, we try to turn our two-stage cluster sampling approach into a strength by using the first level of the clustering as blocking variables. In other words, in each parish, we will makes sure all possible treatment combinations are administered (and only once in each parish). From the research strategy above, we learn that we have a total of 55 different treatment combinations (3*3*2*3+1).

Statistical Power

We determine total sample size and the distribution over the different treatment combinations by running various power analyses for different research questions with different underlying assumptions. Instead of determining power analytically, we use simulation techniques. Simulation allows us to sample from actual data on outcome variables instead of from a theoretical distribution with an assumed mean and standard deviation, which is a much more intuitive way to think about statistical power. It is straightforward to build in flexibility, such as allowing for more than one treatment arm, or account for sampling design effects such as cluster sampling. The algorithm that was used to perform the power calculations can be found in the git repository.

The power calculations will be based on the first set of research questions (related to the gender composition of the messenger and the receiver), as the hypotheses we formulate here are most complex and the factorial design allows us to recycle observations for the third factor related to adding IVR to the video content. Not only do the two gender related factors in the first set of research question both have three levels (male, female, and both), we are also interested in particular interactions between the two factors, which needs to be accounted for when determining sample size. For the third factor, which is the one related to adding IVR to the video treatment, we are only interested in the main effects and there are only two levels (video and video + IVR). Therefore, in this factor, we can allocate half of the households where whoever gets to see any kind of video to one level of the factor and half to the other level. For reasonable effect sizes, these sample sizes are likely to result in sufficient power to estimate the additional effect of IVR.

A first set of power calculations takes **maize yield** data, taken from the Uganda National Household Survey of 2005/06, as the outcome variable of interest[1]. In particular, we calculate average yields of maize (defined as quantity harvested per acre planted) during the second season of 2005 at the household level[2]. We will sample from this distribution for the power

[1]While this is a relatively old survey, there are several reasons why we preferred it to more recent similar surveys such as the Uganda National Panel Survey of 2013/14. The most important reason relates to sample size. The UNHS interviewed about 6,000 households, while the UNPS interviewed only about 3,000 households.

[2]Using the UNHS may provide an overly pessimistic view. Experience with UNHS data suggests the yield data is very noisy. In addition, the first set of power calculations we used in the funding proposal for this study, we relied on rice yield data we collected

calculations. Mean yields in the sample was about 618 kg per acre with a standard deviation of about 314 kg per acre. This is within the 500-800 kg per acre range that experts estimate for maize yields in the area. We will also use location data from this study to get an idea of the impact of stratifying at this level on statistical power[3].

The corresponding expected effect size for each treatment combination on average yield at the household level is summarized in Figure 1. They range from a 2.5 percent increase in the treatment combination where the receiver is the woman and the messengers is a male to a 22.5 percent increase for the treatment combination where the video messages is shown to the couple and the message in the video is also delivered by a couple. The expected effect sizes are based on the interplay of the three effects mentioned above: gender-matching effect, a knowledge-is-power-effect, and the projection of a household approach. For instance, the effects on the diagonal in Figure 1 are higher because here the gender-matching effect is playing: We expect that men learn more from other man and women learn more from other women, which in turn would lead to higher yields among gender matched sub-samples. In Mozambique, Kondylis et al. (2016) find evidence of such a gender-matching or homophily effect in extension, whereby women seem to learn more from fellow women and men seem to learn more from fellow men. In particular, they find that among men who received information about pit planting from a male messenger, the proportion that are aware of pit planting is 10 percentage points higher. Female awareness, knowledge and adoption is the same irrespective of the presence of a male extension worker. However, if a female extension worker is added, awareness, knowledge and adoption among female farmers also increases by roughly the same proportions. We use these results to get an idea about the gender matching effect. In particular, we model a 10 percent increase in yields when messenger and recipient is male. We model a slightly lower effect when messenger and recipient is female (7.5 percent), as it is assumed women have less bargaining power within the household.

The expected effects emanating from the gender composition of the receiver is related to information deficiencies and a knowledge-is-power-effect. This can be directly when women are also important actors in agriculture.

ourselves in a previous study. When this data was used, we obtained substantially higher power for the same hypotheses.

[3]We use UBOS's Enumeration Area (EA) as location indicators, which is the lowest level of location identification that is provided without jeopardizing anonymity.

For instance, Kabunga, Dubois, and Qaim (2012) find that female farmers are less likely to adopt the tissue banana culture technology in Kenya, but that they would have an equal chance to adopt innovations, provided that they acquire sufficient knowledge about the innovation. In addition, knowledge may also affect technology adoption and subsequent yields through changes in relative bargaining power of the actors. Doss and Morris (2001) find that adoption of agricultural technologies among female farmers is lower than among male farmers. They find that this is due to gender-linked differences in access to complementary inputs. We assume only a very small effect (+1 percent) for the subset of women farmers who get to see a video where the messenger is a male farmer. As this effect seems to be partially driven by differences in access to complementary inputs, we assume a higher effect when the recipient is male and the messenger is female (+1.5 percent).

Lambrecht, Vanlauwe, and Maertens (2016) investigate the effect of participating in extension training as a couple. They investigate whether participation of female farmers in an agricultural extension programme in South-Kivu increases adoption of three technologies: improved legume varieties, row planting and mineral fertilizer. In their study, joint male and female programme participation leads to the highest adoption rates. In particular, they find that joint participation increases fertilizer adoption by 12.4 percentage points and row planting by about 13.4 percentage points. While these are large effects (as both fertilizer use and row planting is very rare in the area, with baseline percentages of 6 percent for fertilizer and 10 percent for row planting), the non-random nature of the intervention may lead to overestimation of the couple effect, and we model much more modest effects. Also, due to the homophily effect and the fact that man are likely to have more power within the household, we model a slightly higher increase in case the messenger is a man (+15 percent) versus a woman (+12.5 percent).

We also expect larger effects when the message is brought by a couple, as a cooperative approach to farming is likely to reduce inefficiencies within the farm household. We are not aware of previous studies that may guide us in the choice of the effect size, but we think it may be similar to the effect of providing training to a couple. We again expect this effect to be highest when the receiver is a male, due to his bargaining position (+15 percent). We expect only a slightly lower effect when the women receives this treatments (+12.5 percent). Finally, when information inefficiencies are addressed by showing the video to both husband and wife and a cooperative approach to farming is projected, we expect the largest effect (+20 percent)

Control 618 kg/ac		**Messenger**		
		Male	Female	Both
Receiver	Male	680 kg/ac 10.0 %	649 kg/ac 5.0 %	711 kg/ac 15.0 %
	Female	627 kg/ac 1.5 %	664 kg/ac 7.5 %	695 kg/ac 12.5 %
	Both	711 kg/ac 15.0 %	695 kg/ac 12.5 %	742 kg/ac 20.0 %

Figure 1: Expected Effect Sizes for Yields

At one extreme, we could calculate sample size required to identify all possible treatment combinations in Figure 1. For instance, we could compare control to MM (receiver=male and messenger=male), control to FM (receiver=female, messenger=male), control to MF (receiver=male, messenger=female), etc. Testing all interactions in this way would require a sample size well above what is possible. We therefore will base our power calculations on comparing groups of treatments based on the research questions outlined above.

A first question will be to find out if videos work, irrespective of who they are shown to and who features in the video. We thus calculate sample size by taking all treatment arms and interactions in our factorial design together and we simply test the different between treatment and control. This scenario is shown in the first graph in Figure 2. We find that we would be able to obtain sufficient power (.8) with a total sample size of about 500 observations. As these observations need to be balanced across the different cells in the experiment, this means we need at least 250 observations in the control and a minimum of 28 observations in each treatment combination.

A second question relates to the gender-matching or homophilly effect. This is likely to be the most stringent, as it is based on only 4 cells of the design in Figure 1. In particular, we will compare cells with matched gender (MM and FF) with those that have opposite sexes matched (MF and FM). The results for these power calculations are shown as the second figure in the first row in figure 2. We find that we would need about 1,800 observations in total to get sufficient power. This means that in each of the relevant cells (MM, FF, MF and FM), we would need about 450 observations.

A third question relates to the gender composition of the recipient. Here,

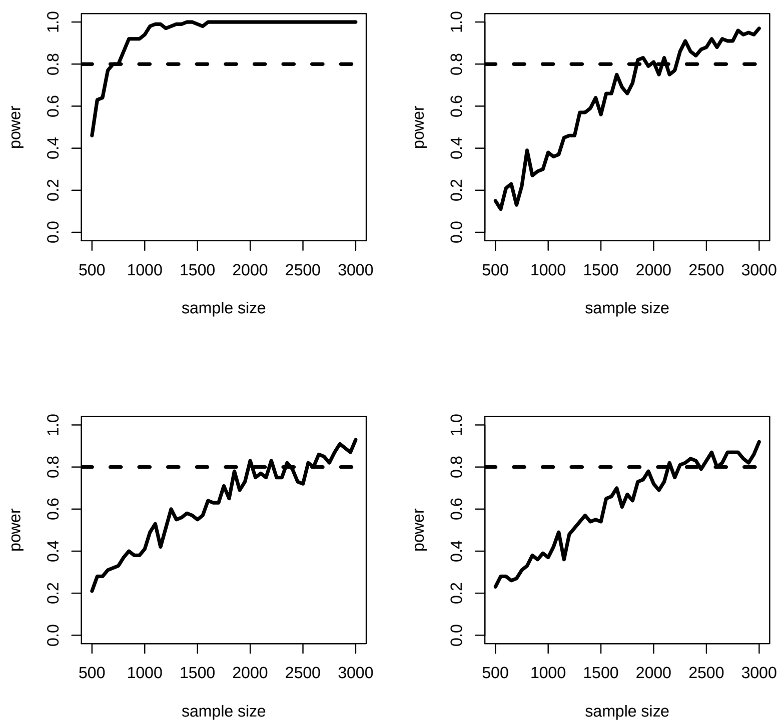

Figure 2: Power Curves for Maize Yield

we want to compare a situation where there is information asymmetry (where only one of the spouses was shown the video) to a situation where both husband and wife received the same information (both were shown the video), irrespective of who features in the video. In this case, we use all cells in figure 1 and compare BB, BF and BB to MM, MF, MB, FM, FF and FB. The results of these power simulations is shown as the third graph in figure 2. We find that we obtain sufficient power for a total sample size of 2,000 observations. Taking into account the fact that we need to balance across all other cells, we need 333 observations in each of BB, BF and BB and 167 observations in each of MM, MF, MB, FM, FF and FB.

A fourth question is related to the gender composition of the animator, where we expect that when the message is brought by a couple, and a household cooperative approach is thus promoted, leads to better outcomes then when the message is given by an individual (either a male or a female farmer). We calculate sample size that is needed to determine a significant difference in yields between these two groups and plot this in last figure in Figure 2. The fact that we expect relatively large effects from a cooperative approach means we obtain sufficient power with a total sample size of about 2150 observations. Again taking into account balance across other cells mean we need at least 359 observations in each of MB, FB and BB and at least 180 observations in each of the other cells.

A second set of power calculations was done for an outcome variable that captures equity within the household. The **gender productivity gap**, where women managed plots are farmed less extensively than male managed plots resulting in significantly lower yields, has been observed throughout Africa South of the Sahara and for a variety of crops (Udry, 1996). In Uganda, Duponchel (2015) find that female managed plots are almost 20 percent less productive than male managed plots. The gap is caused by a general lack of access to production factors compared to men. For instance, women may be forced to farm on inherently lower productivity plots and they may have less access to productivity enhancing tools, technologies and inputs such as fertilizer. Knowledge related to crop intensification is one such factor where access between men and women differs, and so finding out how changing particular attributes to extension videos affect this gap is an important outcome.

Using data from the latest Uganda National Panel Survey (2012-2013), we also find a significant gender gap among maize farmers in Uganda. Male farmers obtain yields of about 1427 kg per hectare. Women managed maize plots only get about 1385 tons. We thus model a difference of about 42 kg per hectare, with a standard error of about 40 kg per hectare[4]. The difference we find seems lower that what others find. For instance, Larson et al. (2015) find the gender gap to be about double of what we find, although they base their analysis on male versus female headed households, while we look at the gender of the person that manages the plot. According to FAO, female managed plots are in general 20-30 percent less productive. Duponchel (2015) estimate the gap to be 23 percent, but they aggregate all crops by weighing by prices and expressing yields in monetary terms. Peterman et al. (2011) estimate it as high as 50 percent.

There is no literature we are aware of that looks at the effect of the gender composition of the messenger and the gender composition of the receiver of agricultural extension messages on the agricultural productivity gap. Therefore, we will use our best judgment to determine expected effect sizes. Modeled effect sizes are summarized in Figure 3. Starting from a baseline situation where maize yields are about 42 kg/ha higher on male managed plot, showing a video to a man only is likely to further increase this gap. We therefore simulate a 15 percent higher yield gap in this group. Due to the homophily effect, we expect that the increase in male productivity is smaller when the messenger is a woman (as the message will be less effective), and so the gap will increase less (+10 percent). Finally, if the message is brought by a couple and a household approach to farming is projected, the man may be encouraged to share some of the knowledge with his wife. However, we expect the increase in yield on male managed plots to still be higher than any potential increase of yield on the female managed plot. As such, we expect the effect on the yield gap to be marginally positive (+2.5%).

When the information is shown to the woman but not to the man, it is expected that yields on female managed plots will increase, while yields on male managed plots are likely to remain the same. This would mean that the gap reduces. Again due to the homophily effect, we expect women to learn most form women, and so the reduction in the gap will be highest when the messenger is also a women (-20 %). The reduction will be smallest when the information is given by a man (-10 %). Finally, if the woman is sensitized on the importance of a household approach to farming, some of the information may be shared with the husband, also reducing the effect on

[4] In this case, the simulations are not based on draws from actual data, but from a normal distribution with mean 42 and standard deviation of 40.

Control 42 kg/ha		**Messenger**		
		Male	Female	Both
Receiver	Male	48.30 kg/ha +15.0 %	46.20 kg/ha +10.0 %	43.05 kg/ha +2.5 %
	Female	37.80 kg/ha -10.0 %	33.60 kg/ha -20.0 %	35.70 kg/ha -15.0 %
	Both	43.05 kg/ha +2.5 %	40.95 kg/ha -2.5 %	28.00 kg/ha -33.3 %

Figure 3: Expected Effect Sizes for Gender Productivity Gap

the gap somewhat (-15 %).

When the information is given to the couple, we expect little or no effect on the gap if the message is given by either male or female. We may expect a slight increase in the gap if the information is given to the male (+2.5%) and a slight decrease if he information is given by a female (-2.5%). Finally, if both spouses have all the information and the message is given that the household farm should be managed as a unit, we expect that the gap reduces by a third (-33.3%).

With respect to intra-household outcomes, we are also interested in four hypotheses. First, instead of comparing the treatment to control, we will compare the status quo (where a man is targeted by a male extension worker) to any other treatment combination. Second, we want to test the importance asymmetric information, and we will test if the gap significantly differs between households where the man was shown the video and households where the woman was shown the video. Third, we want to test if there is a difference depending on whether a household cooperative approach was promoted or the information was brought by an individual. Finally, we also want to separately compare changes in the gender yield gap for households that are both shown the video that also projects a household approach to all the other households.

We again ran a series of power simulations corresponding to these four hypotheses. The results are presented in Figure 4. To be able to answer the first question with sufficient power, we need a total sample size of about 600 observations. Of these, at least 300 observations should be in the MM cell, and about 38 observations in each of the other cells. To answer the second question, we need about 500 observations. These need to be equally

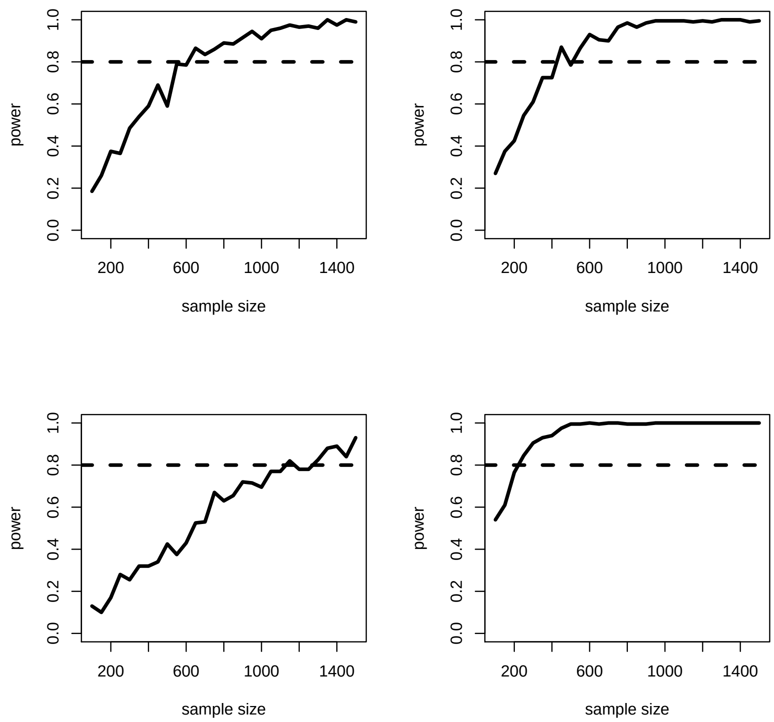

Figure 4: Power Curves for Gender Productivity Gap

divided over the first two rows of the matrix in figure 3, meaning at least 83 observations in each cell. To answer the third question, we need a total of about 1,100 observations. These observations should be distributed as follows: at least 183 in each of the cells in the last column and at least 92 in each of the other cells. The final question can already be answered with less than 300 observations. Of this, 150 should be in the BB cell, and about 20 in each of the other cells.

On the basis of the above, we come to the following ideal division of observations across the different treatment cells : {ctrl=250, MM=450, MF=450, MB=359, FM=450, FF=450, FB=359, BM=333, BF=333, BB=359}, leading to a total number of observations of 3,793. However, due to various constraints, we will relax power for the most stringent research hypothesis, which is the second question relating to the gender-matching or homophilly effect. If we only require 60 percent power, we can reduce sample size for MM, MF, FM and FF to 375, leading to a sample size of about 3,500 observations in total. To account for attrition, we add another 100 observations to each group according to their weight in the total, {ctrl=257, MM=385, MF=385, MB=369, FM=385, FF=385, FB=369, BM=342, BF=342, BB=369} or 3,588 observations.

Assignment to Treatment

Fieldwork

Calendar

In the East, there are two maize cropping seasons. For our study, we will concentrate on the second maize growing season, which runs from about August to January. In August, fields are prepared and planting is don in September. First weeding happens around the end of September or the beginning of October. By late October, a second round of weeding takes place as maize starts to flower. Mid to late December, harvesting starts. In higher areas, harvesting can go on until mid January. During the second season, farmers prefer early maturing varieties, as the rains are short. However, in general, early maturing varieties have lower yields. The full cycle from planting to harvesting in lowland areas takes about 3 to 3.5 months. In high altitude areas this can take up to 5 months. In our study, we will concentrate on lowland areas.

Barriers to maize intensification

The treatments consist of the provision of information that is assumed to increase maize productivity through encouraging adoption of modern technologies and recommended practices. The goal was to select those practices and technologies that are likely to have the largest impact on yield, household income and intra-household equity. The topics to be included in the video script were obtained from interviews with key stakeholder and experts, such as maize farmers, value chain actors, maize breeders, extension workers and other government staff such as the district agricultural officer. These interviews took place in May 2017.

The main factors affecting maize productivity are related to pests, poor soils, and poor seed quality. The three most important **pests** that affect maize farming are Striga, maize stalk borer, and now also Armyworm. Striga (in particular the Striga hermonihica variety), also called whichweed, is a parasitic plant that feeds off the roots of maize. Doing so, it starts to draw nutrients from the host, leading to severe stunting of the host crop. Since most of the damage is already done by the time the parasite emerges from the ground, weeding is not very effective. In addition, each Striga plant produces up to 50,000 seeds, which remain dormant in the soil until new maize is planted. Striga can reduce production from about 30 percent up to total loss of the crop. No single method is effective to control striga. A new hybird seed called Longe 7 HR, boosted with a herbicide, is said to be less affected by striga, but it is expensive at 10,000 UGX/kg and does poorly under dry conditions and in areas where the rains are short such as in the East[5]. Crop rotation with sweet potato or beans can reduce stiga infestation. Furthermore, (additional) inorganic fertilizer use has also been recommended to counter stiga. It has been observed that stiga proliferates when soils are poor. In addition, one can make up for the nutrients drained by the parasite by boosting the maize plant with DAP or NPK. Weeding, especially the first time the stiga comes up before it has had the chance to dig into the roots of the maize, is recommended, also to reduce the spread of seeds.

The stemborer is actually a moth that is active during night, laying eggs on maize plants. It is the larva of the moths that cause the damage. They enter inside maize stem, where they feed and grow for about three weeks. If larvae enter the maize plant at an early stage, this can kill the plant. At a later stage, since larvae make extensive tunnels inside the stem, the maize plants weaken. The stem may break, or the maize plants may fall over. Maize stemborer can reduce production by between 20 and 40 percent.

The fall armyworm is relatively new in Uganda[6]. As the stemborer, the damage is done by a larva from a moth. Currently, it is present in about 20 districts. In some districts, up to 40 percent of maize is affected. Yield losses are estimated at 10 to 15 percent nationwide. However, experts fear this is only the beginning, and armyworm may overtake stemborer as the most destructive pest. Armyworm is very difficult to control. One expert had some success with a chemical called Dudu Accelamectin, which required spraying only once and hence is cheap. However, other experts warned that

[5]In the East, early maturing varieties are preferred, such as Longe 10. In the future, it a similar HR strain of Longe 10 is expected to be released.

[6]Armyworm was discovered in Uganda in the first season of 2017. However, experts told us that it was also present in the second season of 2016 but was mistaken for stemborer.

the effectiveness of one single type of chemical depends on many factors such as location, type of seed used, etc. Other chemicals such as Rocket were also mentioned to be somewhat effective.

Poor soils, exhausted by continuous cultivation with little rotation, is a second main limiting factor. Soils lack macro-nutrients such as nitrogen (N), phosphorous (P) and potassium (K). Farmers rarely use organic fertilizer. Experts say it is virtually impossible to get decent yields without using inorganic fertilizer. In particular, at planting stage, DAP or NPK should be used in the soil. After about 4 weeks, a nitrogen based fertilizer such as Urea should be applied on the topsoil near the plants to boost vegetation. Sometimes it is also advised to split the application of urea, administering half a doze at 4 weeks and half a dose at tasseling stage. Fertilizer can easily double yields. Especially used in combination with improved seeds, the effects of fertilizer are significant.

Within Africa, farmers mainly rely on saved **seeds**, and maize in Eastern Uganda is no exception (McGuire and Sperling, 2016). However, as maize is cross pollinated, recycling leads to fast degeneration. However, hybrid seeds such as Longe 7, Longe 9 are available and have also been distributed through Operation Wealth Creation. Hybird seeds potentially triple yields. In addition to hybrid seeds, which need to be procured every seasons as they can not be recycled, the government also released Open Pollinated Varieties (OPV). These are improved varieties that can be reused for about 3 or 4 seasons. In general, they are lower yielding than hybrid seeds. Still, yield are likely to be about 30 to 40 percent higher than when saved seeds are used, up to 100 percent if OPVs are also used with fertilizer. OPVs are generally recommended to poorer farmers as they can be reused as seeds to some extent.

Most hybrid seeds take long to mature. Farmers also complain that hybrids do not withstand drought very well. However, new varieties have entered the market that are both high yielding and early maturing. For example, UH5354, marketed as Bazooka yields about 20 percent more than other hybirds and is drought resistant. Farmers that use these seeds report up to 40 bags of maize per acre. Today, yields are about 7-8 bags per acre. Similarly, there are several OPVs on the market that are also early maturing.

Finally, there are also **agricultural practices** that affect yields, but the effects are generally smaller than those related to improved seeds and inorganic fertilizer use. The most important are:

- **Timely planting**: maize should be planted at the onset of the rains. However, many farmers delay planting for several reasons. For instance, they may not be certain that the rains have really started. There may also be bottlenecks in land preparation, where the poor are often the last in line for the use of oxen or tractors. It is estimated that each day a farmer delays planting, yields reduce by 1.5 percent.

- **Plant spacing**: Plant that are too close to each other compete for light and nutrients, reducing yields. Plants that are to far from each other means space is wasted, also leading to lower yields. Related is the number of seeds that farmer plant in each hill. The recommended practice is to put in two, but farmers want to be sure of germination and put in more, sometimes up to 5. If they all germinate, there is competition for nutrients and sun. Usually there is also not enough thinning, or this is done too late when competition has already occurred. One expert told us that standard spacing is 75cm x 60cm with two plants per hill. However, they now recommend 75cm x 30cm with 1 plant per hill. The expert estimated the latter results in a 35 percent higher yield than the former.

- **Weeding**: The first weeding should be at 18-20 days after planting at the three leaf stage, and the second weeding at 2-3 weeks after first weeding. From emergence to 8 leaves (knee height), maize plant is a very poor competitor and unwanted stress such as weed competition must be prevented. Weeding must therefore be done within that period. A third weeding is optional. It is only dependent on weed pressure after the second weed. If needed, it should be done at tasseling stage. Weeding removing Striga at early stage before it can attach to the roots of the maize can also have a significant impact on yields. In addition, removing striga before it flowers reduces the spread of the pest. Proper weeding can increase yield by about 50 to 70 percent.

Instruments

We will use video to convey information to farmers with the aim of changing adoption behaviour. We will focus on providing information on seed selection, soil nutrient management (including promoting organic fertilizer application), weeding, timely planting and plant spacing[7]. From our conversations with experts, we learn that many farmers may already be aware of the existence and use of these technologies or practices. Therefore, simply providing information about the existence of modern technologies and recommended practices and on how to uses them may not be sufficient to change behavior. Often, access and affordability was mentioned as a problem[8]. In our videos, we will thus also try to alter the belief that seeds and fertilizers are "too expensive" by pointing out the costs and benefits of the different technologies and practices we promote[9]. In addition, we will encourage farmers to start small, using fertilizer and seeds on a small area of their field to experiment and see for themselves, and reinvest in subsequent years. Inter-temporal decision making, where costs today have to be compared to uncertain outcomes in a distant future, is often challenging for poorly educated farmers[10]. Fur-

[7]As mentioned above, pest control also ranks high among technologies that increase yields. However, we felt uncomfortable promoting chemicals in our videos that are potentially hazardous to humans. In Uganda, Endosulfan, DDT, Glyphosate, Linden and others—are still being used. Many of these are on the World Health Organization's list of banned chemicals and blacklisted by the Stockholm Convention on Persistent Organic Pollutants.

[8]Farmers indeed often mention they do not use modern inputs because they have no money, suggesting liquidity is the main constraining factor, and thus instead of providing information, a more effective strategy would be to provide credit or subsidize inputs. Recent research, however, finds that despite what farmers claim, liquidity is often not the most important constraining factor. Duflo, Kremer, and Robinson (2011) note that in Kenya, fertilizer is relatively cheap and can be bought in small quantities, putting it in reach of even the poorest households. They suggest the main reason for low fertilizer adoption rates should be attributed to the farmer's failure to commit. Ashraf, GinÃ©, and Karlan (2009) find that lack of credit was not the main reason why farmers did not produce high-value export crops, and that farmers that did produce export crops found access to credit on their own. Emerick et al. (2016) find that increasing access to drought tolerant seed that reduced downside risk increased the use of credit from existing sources. Finally, Karlan et al. (2014) compare outcomes related to agricultural production between households that were given cash to households that were provided with insurance and find that when provided with insurance, farmers are able to find resources to increase expenditure on their farms.

[9]The fact that farmers do not engage in a cost benefit analysis, where inputs are used to generate output, was illustrated by a complaint made by one of the farmers. He complained that farmers get low prices. To him, it did not make sense to buy seed at 6000 per kg and sell maize at only 300-400 per kg.

[10]Under-investment caused by low perceived returns in the future has also been documented in the demand for schooling (Jensen, 2010). A recent experiment investigates if rice farmers in Uganda are aware of the returns to different recommended rice growing

thermore, Duflo, Kremer, and Robinson (2011) point out farmers may have difficulties committing to fertilizer use in Kenya. In our video, we attempt to make farmers aware of this, and suggest some techniques to overcome this bias. We also pay considerable attention to the way the message is delivered. For instance, the message if brought by "peer farmers", as it is found that farmers find communicators who face agricultural conditions and constrains most comparable to themselves to be the most persuasive (BenYishay and Mobarak, 2014). The information is also presented as a success story, which is assumed to affect a range of non-cognitive farmer characteristics such as aspirations, locus of control and self-esteem (Bernard et al., 2015).

The video starts with a farmer (a male farmer, a female farmer, or a couple, see below) introducing themselves. He talks about how he used to struggle with his maize gardens and how at one point in time, he decided things needed to change. It is shown how the farmer sells a hen, and obtains a small loan from a friend. This money is than used to buy small quantities of improved seed and fertilizer in a local shop. It is then shown that, before planting the improved seed, the farmer prepares the garden. He is shown collecting manure wherever he can find it, and applies it to a small corner of the field of 20m by 20m. Next, it is shown in detail how the maize seeds are spaced 75cm x 30cm with 1 plant per hill and how the DAP should be applied. The viewer is reminded to plant in time. The next scene depicts the field after about 10 to 12 days when the maize has emerged from the ground. At this stage, it is recommended that the farmer engages into gap filling to replace seeds that did not germinate with new seeds to preserve optimal plant density. The next shot shows the field at 18 to 20 days after planing, when first weeding is done. Particular attention is paid to identification of striga in an early stage. It is also advised to weed again two to three weeks later. The next scene zooms in on urea fertilizer application. Here, the field is shown at about 4 weeks after planting when the maize is knee high. It is shown how Urea topsoil dressing should be applied. Finally, it is recommended to do one more round of weeding around the tasseling stage of the maize.

We then spend some time comparing the costs to the benefits the different improved inputs and recommended practices. For fertilizer and improved seed, the costs for one acre is calculated and compared to the value of what is harvested. The profit is then compared to the value of what would have

practices such as early transplanting and fertilizer use (Van Campenhout, Van Asten, and Walukano, 2017).

been harvested on that acre without improved seed and fertilizer. This would be less than half of what the profit would be when improved inputs are used. For recommended practices, we report what the expected yield increase would be if, for instance, recommended spacing was used or weeding is done in time.

Next, we try to promote a long run perspective, where the farmer is encouraged to start small (one tenth of an acre) and grow bigger over time. We also pay some attention to the commitment problem. We advise the farmer to, at time of harvest when the farmer sells most of his maize, immediately go to the farm supply store and purchase seeds and fertilizer, and store this in a safe place. If inputs are not available, farmers are encouraged to keep the money needed to buy the inputs in a separate, labeled container. It is sometimes argued that such mental accounting can be an effective commitment mechanism (Dupas and Robinson, 2013). In a last scene, the farmer recapitulates and once more directly addresses the viewer an encourages him or her to try this as well.

A total of three such videos will be produced. They will be identical in terms of the information that will be in the video, but they will differ according to the gender of the messenger, corresponding to one of the factors in the factorial experimental setup. In one version of the video, the actor will be a man. In a second version of the video, the actor will be female. In a third version, the video will feature a couple as the messenger. Here, both male and female will feature in the different scenes, and the person talking to the viewer will be altered between the man and the women. Finally, we will use a placebo video for the control. This will be a neutral video on a non-related topic, such as the tourist potential of the region. Farmers will be shown any of these four videos according to random treatment allocation. Videos will be shown twice to each farmer in the sample, once before planing (July) and once immediately after planting (August).

The videos will be embedded in a small Computer Assisted Personal Interviewing (CAPI) survey application implemented in Open Data Kit (ODK). The application will start by asking some identifying information about the farmer and recording consent. It will also be used to collect some basic farmer characteristics, which can be used to investigate balance at baseline. The application will also embed the video, which will be cued to make sure the correct video is shown to the right farmer. Finally, information will be gathered on viewing conditions, and some information will be collected to see if farmers understood the information that was given in the video.

After harvesting of maize in January of February 2018, an farmer level endline survey will collect information on a range out outcomes related to learning, adoption behaviour, maize production and farmer well-being more generally. We will also inquire about intra-household issues. This endline survey will also be implemented as CAPI, either using ODK, SurveyBe or Survey Solutions.

Empirical Analysis

Variables

Balancing Checks

Treatment Effects

Intent to Treat

Treatment on the Treated

Heterogeneous Effects

Standard Error Adjustments

While our main outcome variables are ultimately household welfare and potato yields, we will also estimate the impact of our interventions on a range of intermediate variables. The fact that we have many such variables may lead to the so-called "look elsewhere" effect, where one is bound to find significant effects simply due to the sheer number of parameters. Therefore, some form of multiple-inference correction is in order. In general, there are two ways in which to avoid false positives that result of multiple hypothesis testing. One can either reduce the number of hypothesis, or one can make the statistical test stricter by for instance reducing the significance threshold (such as the Bonferroni adjustment). We will address false positive arising from multiple hypothesis testing using both ways.

First of all, we will use the groupings presented in the section that lists the variables to create indices (directly related to yield, sales, welfare, crowding in other intensification methods,...). At the most basic level, each of the indices is a weighted mean of the several standardized outcomes within each group. In particular, for each variable within each group, we make sure positive direction always means better, otherwise we switch sign. We then demean the outcome and standardize by scaling by the control group standard deviation. We then create weighted averages for the outcomes in each group at the household level, using as weights the inverse of the co-variance matrix of the transformed outcomes within the group. This is done for each of the groups. The resulting variables can then be used to assess the impact of the particular intervention using the specifications outlined above.

However, we may be interested in identifying differential effects within each of the groups. For example, we may want to differentiate between the effect on potato sales immediately after the harvest and potato sales during the lean season. We will therefore also use Family Wise Error Rate Control. In particular, we will use the free step-down re-sampling method of **?**. Finally, we will also drop outcomes from our analysis for which 95 percent of observations are the same value. This is done to reduce the influence of outcomes with limited variation.

Research Team

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Deliverable and Calendar

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