Information and communication technologies (ICTs) to provide agricultural advice to smallholder farmers: Experimental evidence from Uganda

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Abstract

Agricultural advisory services generally rely on interpersonal knowledge transfer in which agricultural extension agents visit farmers individually or in groups to provide information and advice. This approach is not always effective and has often proved hard to bring to scale, particularly in highly dispersed smallholder farming systems. Information and communication technologies (ICTs) have been advanced as a promising way to overcome many of the problems associated with conventional agricultural extension. We evaluate the effectiveness of an ICT-mediated approach to deliver agricultural information in a field experiment conducted among small-scale maize farmers in eastern Uganda. However, different ICTs have different characteristics and farmers may also differ in their information needs. Our approach therefor consists of three complementary technologies: First, we investigate the effectiveness of audiovisual messages as a means of delivering information to farmers. Second, we quantify the additional impact of augmenting video with interactive voice response (IVR) technology—a more demand-driven approach to information provision. Third, we estimate the incremental effect of time-sensitive short message services (SMS) messages that remind farmers about key agronomic practices. We find that ICT-mediated audiovisual content is effective in delivering information, with households that were shown short videos on how to become a better maize farmer performing significantly better on a knowledge test, more likely to apply recommended practices, and using inputs more efficiently than households that did not see this video. These same households also reported maize yields about 10 percent higher than those that did not see the video. Incremental effects of IVR and SMS technologies are limited.

Conventional approaches to agricultural extension, such as training and visit (T&V) or farmer field schools (FFS), have met with mixed success (Bindlish and Evenson, 1997; Feder, 2006; Waddington et al., 2014). Information and communication technologies (ICTs) have been advanced as a promising way to overcome many of the problems associated with traditional agricultural advisory services, such as low cost-effectiveness and limited scalability (Aker, 2011), and an emerging literature explores the application of different ICTs to disseminate agricultural extension information to smallholders. For instance, various studies investigate the potential for audiovisual messages as a medium to transfer agricultural extension information (eg. Gandhi et al., 2009; Maredia et al., 2017; Van Campenhout et al., 2017). Cole and Fernando (2016) evaluate the impact of a toll-free hot-line among cotton farmers in Gujarat, India. Casaburi et al. (2014) test the effectiveness of short message services (SMS) messages with agricultural advice among sugarcane farmers in Kenya, and Larochelle et al. (2019) consider the use of SMS messages to promote integrated pest management among potato farmers in Ecuador.

However, different information technologies have different characteristics, making their effectiveness highly context specific. For instance, to introduce a new agronomic practice or technology, such as a new type of disease-resistant seed, showing a video may be more effective than a demand-driven technology such as a hot-line, where farmers are assumed to be aware of their information needs. At the same time, a video shown on a tablet computer or screened using a liquid-crystal display (LCD) projector is generally a one-off intervention, and particular details such as the exact dose of a new input may be missed or easily forgotten by farmers; having access to a demand driven information technology such as a hot-line may thus be more effective if agronomic practices are complex or require precise implementation. SMS messages are most likely too short to provide detailed information about modern inputs or agronomic practices. Therefore, effects, if any, are likely to work through behavioral channels: reminders have been found to be effective in overcoming inertia and procrastination, and can help prioritize in the event of competing obligations. SMS messages may therefore be effective in increasing the use of fertilizer, which is known to suffer from procrastination and competing obligations (Duflo, Kremer, and Robinson, 2011), or encourage farmers to engage more in tedious activities, such as weeding.

This article investigates the effectiveness of an ICT-mediated extension approach designed to provide information about improved maize cultivation practices to smallholder farmers in Uganda. We acknowledge that ICTs are not homogeneous and that farmers also have differing information needs. At the same time, we realize that many ICT applications have low fixed and near zero variable costs. Therefore, our approach combines three complementary technologies and the incremental effect of each is tested. First, we look at the effectiveness of short audiovisual messages that provide detailed information on how to improve maize cultivation, that were shown to farmers on tablet computers. Second, we estimate the additional effect of an IVR service that farmers are encouraged to call into if the need arises. Third, we evaluate the impact of augmenting this with SMS messages that remind farmers at particular points during the maize growing season about key farming practices, and that they can call the IVR system at any time. The outcomes used to assess the effectiveness of this approach include increases in knowledge about improved maize cultivation, changes in the use of improved inputs and recommended agronomic practices, and production.

We draw on a field experiment involving approximately 4,000 farm households sampled from the population of households cultivating maize across five districts of eastern Uganda. We find that providing information to farmers through short videos significantly increased their knowledge about modern agronomic inputs and recommended agronomic practices. In addition, farmers who were shown the video were also more likely to adopt a range of inputs and practices that were promoted in the videos. We also find clear effects on production, with maize yields 10 percent higher than in control households. We find that the IVR generated no additional impact on knowledge, nor did it have a strong influence on the use of modern inputs or management practices in farming. We only find a positive effect of IVR on the uptake of hybrid seed. There were no additional effects of the SMS messages.

The remainder of the article is organized as follows. The next section lays out the main research questions and explains how the study fits into the broader literature. Section 3 explains the experimental design. Section 4 describes the study site and context, while Section 5 describes the interventions used as the treatments in the field experiment. We then turn to the results in Section 6 with a discussion of baseline characteristics and sample balance. This is followed by analysis of the (incremental) impact of the three technologies tested, with subsections for impact on knowledge, practices adopted and inputs used, and production. A final section concludes.

Research Aim

The primary focus of this study is to test the effectiveness of a comprehensive ICT-mediated agricultural extension approach consisting of three complementary information technologies: video, IVR and SMS. In doing so, we aim to contribute to the literature on how ICTs can increase the adoption of modern inputs and improved crop management practices among smallholder farmers—a topic that has received considerable attention in recent years (Nakasone and Torero, 2016; Aker, 2011).

Several studies have reported positive impacts of ICTs applied to extension services. For example, Cole and Fernando (2016) found that the introduction of a toll-free hot-line, through which farmers can ask questions to agricultural experts, significantly increased cumin and cotton yields among farmers in Gujarat, India. Casaburi et al. (2014) found that in Kenya, sending SMS messages with agricultural advice to smallholder sugarcane farmers increased yields by 11.5% relative to a control group with no messages. Fu and Akter (2016) found that a multi-media mobile phone-based product linked to expert advisory services increased farmers' awareness and knowledge about specific solutions to their production constraints in Madhya Pradesh, India. Maredia et al. (2017), on the other hand, found that while mobile phone-based animated videos shown to farmers in Burkina Faso induced learning and understanding, it was no more effective in encouraging adoption than conventional approaches to information provision. In Uganda—the site of our study—Grameen Foundation had some success using smartphones to provide agriculture-related information to farmers through ICT-empowered community knowledge workers (Van Campenhout, 2017).

Our study combines three technologies, each with their own characteristics, and quantifies the additional effectiveness of each. First, video is an ICT intervention through which information is made available to the participating farmer on a limited number of occasions and at moments that are decided upon by the provider of the information. The strength of video is that it can combine audio and visual information in an attractive way that is recognizable to the potentially illiterate farmer. We hypothesize that the video-mediated approach may be particularly effective in disseminating information about new technologies and practices. However, we also note that the supply-driven nature of video and the management of its use by the information provider rather than the farmer, is a potential constraint to its effectiveness.

Second, we add an IVR service. In an IVR system, a farmer calls a phone number and navigates through a menu to select a topic. The farmer then gets to listen to a pre-recorded message with information on the selected topic. IVR services (and similarly hotlines, where a phone number can be called by a farmer and questions can be asked to an expert) are demand-driven approaches based on the assumption that farmers can identify their information needs and are capable of actively searching for additional information. One of the main advantages of this approach is that the information is supplied through a channel that is continuously accessible to the farmer, and can be used on a more timely and relevant basis. This technology may be more effective when farmers' key information constraints are associated with unanticipated shocks such pests, disease, or adverse weather conditions (Cole and Fernando, 2016).

Third, we add SMS reminders. SMS messages are often framed as a supply-driven behavioral "nudge" designed to remind people (with some considerable degree of persistence) to make decisions or take actions toward some particular objective. Timely reminders have often been found very effective in overcoming inertia, procrastination, competing obligations, or simple forgetfulness of human beings (Sunstein, 2014). However, SMS messages are short and can not be used to provide new and complex information. They also require that farmers are able to read.

Experimental Design and Estimation of Treatment Effects

We evaluate the effectiveness of ICT-mediated agricultural extension using a field experiment (de Janvry, Sadoulet, and Suri, 2017)[1]. The experiment has four treatment arms, and the IVR and SMS treatments are incremental in design. The experimental units are the households, who were randomly assigned to one of these your arms. A total of 3,703 households were shown a video, while 256 households (our control group) were shown a placebo video. From those 3,703 households that were shown a video, 2,414 also received an IVR starter kit: a flyer containing a toll-free phone number and instructions on how to use it. From those 2,414 households that were shown a video and received the IVR encouragement, 1,113 households were also allocated to the SMS treatment[2].

To evaluate the effectiveness of these different ICT channels, we start by comparing average household-level outcomes among households that were shown a video to average outcomes of households from the control group. This gives us the average treatment effect for the video intervention. To obtain the additional effect of the IVR treatment, we compare average outcomes of households that were shown a video and received the IVR intervention to households that were shown only a video. Finally, the additional effect of the SMS campaign is estimated by comparing outcomes of household that were shown a video, received IVR information and also received the eight SMS reminders to outcomes of households that are shown a video and received the information about the IVR system, but did not get the SMS reminders. In practice, this is done using a simple ordinary least squares (OLS) regression of the form:

$$y_i = \alpha + \beta_1 video_i + \beta_2.IVR_i + \beta_3.SMS_i + \varepsilon_i \quad (1)$$

with y_i the outcome used to assess impact as reported by household i; $video_i$ a dummy variable that is one if household i was shown a video and zero otherwise; IVR_i a dummy variable that is one if household i was given an IVR starter kit and zero otherwise; SMS_i a dummy variable that is one if household i was sent SMS messages and zero otherwise. In this regression, α is then the average outcome in the control group, β_1 provides an estimate of the effect of having been shown a video, β_2 provides an estimate of the incremental effect of also having been allocated to the IVR intervention and β_3 provides an estimate of the incremental effect of also having been allocated to the SMS intervention.

Context

We conducted the field experiment among smallholder maize farmers in Uganda. Maize is widely consumed throughout much of Uganda, yet its value-to-weight ratio is sufficiently high to also make it an important traded commodity. Therefore, efforts to increase maize productivity at the farm-household level are an important dimension of Uganda's strategy to increase food security and reduce poverty through both consumption and income channels. Yet, maize yields in Uganda are low when compared to neighboring countries and global averages: While research station trials conducted in Uganda report potential yields of about 1.6 metric tons per acre (using only improved varieties without fertilizer application), data from the Uganda National Household Survey (UNHS) 2005/06 indicate that average maize yields are much lower at about 618 kg per acre for the main growing season (Fermont and Benson, 2011). At the same time, the use of modern inputs such as inorganic fertilizer and adoption of modern management practices such as row planting is very low in Uganda.

Maize is especially important in eastern Uganda. We sampled from five districts in eastern Uganda known for their maize production: Bugiri, Mayuge, Iganga, Namayingo, and Namutumba. From this, we removed from our sample town councils and also two sub-counties that consisted of islands in lake Victoria. We used two-stage cluster sampling to obtain a representative sample of this population. In particular, we first selected parishes randomly and in proportion to the number of villages within each parish. In the selected parishes, all villages were included in the study. Within each village, we then listed all households, from which we randomly assigned households to be included in the study.

In eastern Uganda, there are two maize cropping seasons. For our study, we concentrated on the second maize-growing season of the year 2017, which ran from approximately August 2017 to January 2018 and is characterized by a shorter period of rainfall than the first maize-growing season. During this second season, the complete cycle from planting to harvest requires 3 to 3.5 months, and farmers tend to cultivate early-maturing but lower-yielding maize varieties as a result. Fields are prepared in August, planted in September, an harvested beginning in mid to late December and, at higher elevations, through mid January.

ICT interventions

The comprehensive ICT-mediated extension approach consisted of three ICT interventions: a short video, an encouragement to use an IVR system, and series of 8 SMS messages. The videos were shown on 10-inch Android tablet computers and screened by a trained field enumerator during a one-to-one meeting with either an individual farmer or the male and female co-head[3]. The control group received a placebo treatment, which was a music video of traditional dancing that contained no information related to farming or maize (Bernard et al., 2015). Videos (treatment or placebo) were screened twice to the households in the sample, once before the time for planting maize (July 2017) and once around planting time (August 2017).

The information contained in the treatment groups' video is expected to positively influence maize yields by encouraging the adoption of several improved technologies and practices which, in turn, are expected to positively affect maize productivity. The topics included in the video script were obtained from qualitative interviews with key informants that were conducted in May 2017. The key informants included maize farmers, traders, maize breeders, extension workers, district agricultural officers, and other government staff and experts.

A significant portion of the videos focuses on providing technical information on seed choice, soil nutrient management (including the promotion of both organic and inorganic fertilizer application), weeding (with particular attention on fighting striga), timely planting, and plant spacing, which were ranked among by the experts as the top challenges farmers face. We made sure to include information that is likely to be unknown to the farmer, as information is likely to be most valuable when individuals learn about a new technology or institutional innovation. However, other studies also provide evidence of behavioral change occurring through the compounding or re-emphasis of common knowledge that, through repetition, becomes more salient to the individual (Duflo, Keniston, and Suri, 2014). Therefore, the videos also contain information that farmers are assumed to know but do not seem to act upon.

Not all constraints to maize productivity improvement are information deficiencies directly related to the use of inputs, technologies, and crop management practices. Often, missing information problems manifest indirectly, as uncertainty about the distribution of the farm-household's profit function. This includes uncertainty about the correlations between expected and actual returns, the inter-temporality of income streams, estimates of fixed and variable costs, hidden transactions costs, probabilities of adverse events, and a range of other variables that farmers may simply be unable to conceptualize or measure. Thus, a significant portion of the videos also focuses on evaluating the costs and benefits of the different technologies and practices being promoted. In addition, the videos encourage long-term thinking, advising farmers to (a) start small and grow their farm enterprise over time, and (b) combine technologies and practices together rather than investing all of their money and effort into one single input, practice, or technology.

We also pay attention to how the information is packaged. For instance, prior studies have found that farmers find communicators who face agricultural conditions and constraints most comparable to their own to be the more persuasive than other communicators (BenYishay and Mobarak, 2018). Several studies point out the importance of role models on aspirations and future-oriented behavior (Bernard et al., 2015). A growing strand of the literature investigates how non-cognitive farmer characteristics such as aspirations, locus of control and self-esteem can lead to behavioral change such as technology adoption (Abay, Blalock, and Berhane, 2017). Therefore, in our video, the message is conveyed by individuals who are readily recognized as "peer farmers" and who provide information that is framed as a success story.

The two other treatments were incrementally added to the video treatment. For these two treatments, the IVR system and the SMS reminders, we collaborated with Viamo, a social enterprise that aims to connect individuals and organizations using digital technology to make better decisions. We set up an IVR system that provided the same information as was recommended in the video. Farm households that were allocated the IVR treatment were encouraged to call a toll-free number which explained the IVR system in their own language. The caller is then invited to select the number corresponding to the topic on which he or she wants more information (e.g., "Press 1 for seed selection, 2 for spacing and seed rate, 3 for soil nutrient management, 4 for advice on weeding"). Depending on what number was selected, the IVR then played an audio message of a conversation between two farmers where one farmer is explaining the recommended practice to the other farmer.

For the SMS campaign, we recorded telephone numbers for mobile phones owned by the household head at the time of the experiment's roll-out. Households that were allocated to the SMS treatment were sent eight SMS messages over the course of the two months following the first screening of the video. The messages all followed a similar structure: farmers were first reminded about an important technology or practice that was relevant at the particular time that the message was sent, followed by a reminder about the existence of the IVR service. The reminders were related to technologies and practices that were also promoted in the video and IVR. For example, the first message, that was sent out around planting time, read "You will get much more maize if you use hybrid seed instead of recycled seed. Call the maize hot-line on 0200522420 free for more advice!". About one month into the growing season, the following message was sent: "When your maize is knee high, apply 1 water bottle cap of urea around each plant. Call the maize hot-line on 0200522420 free for more advice!". All content was produced in the local language (Busoga).

Results

We now turn to the results, starting with orthogonality tests. We then estimate the (incremental) impact of the three information technologies on a range of outcomes related to knowledge, adoption of recommended practices and use of modern inputs, and production. Throughout the analysis, we focus on intent-to-treat effects. However, the IVR and SMS treatments are probably more effective for households that have (access to) a mobile phone, and averaging outcomes over all household may dilute the treatment effect, making it more difficult to detect a significant difference between the treatment group and control group. Therefore, we also estimated (conditional) treatment effects using a subsample containing only farmers that reported to have (access to) a mobile phone. Results were very similar and so not reported here to conserve space. Furthermore, while all households that were allocated to the video treatment did view it, compliance was not perfect for IVR and SMS treatments. Judged by the call log of the IVR system, we find that only a small number of households that were encouraged to use the IVR system also actually called in (8.9 percent or 214 households)[4]. For the SMS reminders, of the 1,113 households that were supposed to receive the reminders, only 860 (77.3 percent) did. We therefore also generated Local Average Treatment Effects (LATE) estimates, where the IVR encouragement was used as an instrument for having called into the IVR system (Angrist, Imbens, and Rubin, 1996). Similarly, we estimated LATEs where allocation to the SMS treatment is used as an instrument for having received the SMS message. However, also here, results were not substantially different from the intent-to-treat analysis and are not reported here. A much more elaborate report that includes both these additional analyses is available upon request from the authors.

Balancing Checks

While we did not conduct a dedicated baseline survey, we did collect some information prior to the experiment's roll-out to investigate balance. The choice of variables was based on those variables that other researchers in similar studies used in their orthogonality tests. In particular, we looked at balance tables in studies that investigate the adoption of yield-improving technologies and practices using randomized controlled trials (RCTs), including Duflo, Kremer, and Robinson (2011), Karlan et al. (2014), Ashraf, Gine, and Karlan (2009) and Bulte et al. (2014). We collected household characteristics such as household size, age, and, education level of household head. We then asked more specific questions related to maize farming, such as acreage and quantities produced in the last season. Furthermore, we asked if the household received agricultural extension services, whether it used improved maize varieties, and whether it applied fertilizer to maize. We also collected data on housing conditions (number of bedrooms) and distance to the nearest agro-input shop. As mobile phone ownership is relevant to the IVR and SMS interventions, we also report balance on household access to and ownership of a mobile phone.

In Table 1, we provide descriptive statistics and balance tests for the comparisons between the three information delivery packages. Averages for the control group are reported in the first column. We observe that few households that were included in our study had access to agricultural extension in the previous year (about 11 percent). We also observe that only about 17 percent of households reported to have used any fertilizer in the previous season, and

Table 1: Balance tests for ICT channel used to deliver information

	Mean	Video	+IVR	+SMS	N
Maize yield (kg/ac)	267.93	17.41	7.57	-9.15	3,959
	(230.20)	(18.97)	(11.30)	(11.93)	
Age of HH head (years)	40.50	-1.05	0.87 *	-0.73	3,910
	(14.33)	(0.88)	(0.52)	(0.55)	
HH head finshed primary school	0.37	-0.01	0.02	0.00	3,959
	(0.48)	(0.03)	(0.02)	(0.02)	
HH size	7.72	-0.30	0.42 ***	-0.21	3,959
	(3.17)	(0.22)	(0.13)	(0.14)	
Number of bedrooms	2.32	-0.12	0.10 **	-0.09 *	3,959
	(1.21)	(0.08)	(0.05)	(0.05)	
Access to extension last year	0.11	0.00	0.00	0.01	3,959
	(0.31)	(0.02)	(0.01)	(0.01)	
Has used fertilizer last season	0.17	0.04	0.01	-0.01	3,959
	(0.37)	(0.03)	(0.02)	(0.02)	
Has used improved seed last season	0.34	0.04	0.01	-0.01	3,959
	(0.47)	(0.03)	(0.02)	(0.02)	
Distance nearest agro input shop (km)	5.18	0.17	0.13	0.34	3,959
	(4.89)	(0.36)	(0.22)	(0.23)	
HH owns mobile phone	0.76	0.01	0.01	0.01	3,959
	(0.43)	(0.03)	(0.02)	(0.02)	
HH has access to a mobile phone	0.84	-0.01	0.02	-0.01	3,959
	(0.36)	(0.02)	(0.01)	(0.02)	
F-test		0.820	1.186	1.143	
P-value		0.621	0.291	0.323	

Note: First column reports control group means (and standard deviations below); Column 2 reports differences between placebo (control) and video treatment (and standard error below), column 3 between video only and video+ivr, column 4 between video+ivr and video+ivr+SMS; the last column is sample size; ***, ** and * denote that the difference is signficantly different from zero at the 1, 5 and 10 percent level, respectively.

only about 34 percent reported to have used improved seed bought from a shop or agro-input dealer during the last cropping season. This suggests ample scope to increase intensification investments through extension. We also find that farmers produced on average only 268 kg of maize per acre in the first cropping season of 2017. This is substantially lower than the average yield of 618 kg per acre we find in data from the 2005/06 Uganda National Household Survey. The low yields reflect the devastating impact of the fall armyworm outbreak and adverse weather conditions that plagued East Africa in 2017 (Stokstad, 2017).

Balance is tested by judging the significance of coefficient estimates in a regression (equation 1), and with a joint significance test (F-test). The second column in Table 1, denoted "Video", compares baseline characteristics between households that were shown the placebo video (control group) and households that were shown an intervention video (β_1 in equation 1). For example, we see that yields prior to the intervention were about 17 kg per acre higher in the group that was shown the intervention video than in the group that was shown the placebo video. However, this difference is not significantly different from zero. In fact, for the placebo video versus intervention video comparison, none of the differences in baseline characteristics is significant at the 10 percent significance level, and the F-statistic can not be rejected. In the third column, differences in baseline characteristics between households that received the intervention video and households that received the IVR starter kit on top of the video are shown (denoted "+IVR"; corresponding to β_2 in equation 1). Here, we see that, at baseline, households in the latter group were significantly larger than households that only saw the video. They also had significantly more bedrooms and the household head was slightly older. However, we can again not reject the null that jointly, baseline characteristics were unrelated to the treatment group for this comparison. For the final comparison (comparing farmers that received video and IVR to those that additionally received SMS messages; reported in column four and denoted "+SMS" and corresponding to β_3 in equation 1), we find that treatment household had slightly fewer bedrooms, but the figure is only significant at the 10 percent level and the joint test does not reject overall balance.

We find that about 84 percent of households had access to a mobile phone prior to the intervention. This is encouraging, as the usefulness of IVR depends on access to a mobile phone. Further, we find that there was no difference in this percentage between the various treatment groups. The incidence of mobile phone ownership was also high, with about three quarters of households reporting they own a mobile phone. Again, this is important as the success of the SMS intervention depends on being able to receive the messages.

Following implementation of the field experiment, attrition within the sample was relatively low. Only 8.63 percent of the sample could not be tracked or persuaded to complete the endline survey. In addition, there were no indications that attrition rates were different between or among the different treatment groups: attrition was 7.03 in the control group; 8.74 percent in the group that was shown a video; 8.90 percent in the group that was shown a video and received the IVR encouragement; and 7.45 percent in the group that also received an SMS in addition to the IVR encouragement and the video. In Appendix Table A.1 we compare baseline characteristics of attritors and do not find any statistically meaningful differences in the observable characteristics of attritors by treatment status.

Impact on knowledge

We first estimate the incremental impact of the three different ICT channels on knowledge outcomes. Knowledge outcomes were measured with a short quiz (Feder, Murgai, and Quizon, 2004a,b; Masset and Haddad, 2015) consisting of four multiple-choice questions that were asked during the endline survey to each of the two spouses in the farm household separately. For each question, three possible answers were read out to the respondent, who was then asked to indicate which answer he or she thought was correct. The respondent was also allowed to indicate if he or she did not know the correct answer. The household was considered knowledgeable on a particular topic if at least one of the spouses could indicate the correct answer.

The first question was related to planting. In our video, we recommended a spacing of

75cm x 30cm with 1 plant per hill, and this was the correct option. Other possible answers included a spacing of 75cm x 60cm with two plants per hill, which is standard for many farmers and recommended by many agricultural extension agents, and an intermediate alternative of 75cm x 30cm with 2 seeds per hill. Because our video recommended a technique that deviates from what is assumed to be standard spacing, we assumed that the recommended practice is new to most of the farmers. The second question is less related to technical knowledge, but more to viewing farming as a business. In the video, we paid ample attention to promoting an approach where farmers start small and grow over time by reinvesting, and we emphasized the benefits of combining inputs rather than investing only in e.g., improved seed. We wanted to see if farmers internalize this advice and ask what a successful farmer would do if he or she only has 40,000 shillings. The correct answer was to use this amount to purchase improved seed and fertilizer and start intensified farming on a small area. Alternative options were to: "use all the money to buy hybrid seeds, because without good seeds, yields will be low"; and "use all the money to buy fertilizer, because with poor soils, yields will be low". For the third question, we asked if farmers knew when weeding is most important. The video showed that weeding is most important during the first four weeks after planting, as maize is a poor competitor for light and nutrients. We assumed that most farmers would know the correct answer to this question given that weeding is part of well-established management practices in the study area. Alternative answers were: "when the maize is knee high" and "when the maize is at tasseling stage". Finally, we asked if farmers knew when spraying against fall armyworm is most effective. No information was given about fighting fall armyworm in the intervention, so unless one of our interventions encouraged farmers to search for additional information, we do not expect an impact. For this question, the correct option was: "During the evening, as fall armyworm eats during night," while the other options were: "Early in the morning when it is still cool" and "At noon because sunlight increases chemical performance."

To guard against over-rejection of the null hypothesis due to multiple inference, outcomes of the knowledge questions were combined into an index, constructed as the weighted mean of the individual standardized outcomes, using as weights the inverse of the co-variance matrix of the transformed outcomes (Anderson, 2008). However, we also see value in examining the impact on the questions individually, as they attempt to measure different aspects of the information intervention. To control the family-wise error rate (FWER) when examining results for each question individually, we use re-randomization to construct the joint null distribution for the family of outcomes we are testing. From this family-wise sharp null, we can obtain the corresponding FWER-consistent significance thresholds by determining which cuttoffs yield e.g., 10 percent-, 5 percent-, and 1 percent significant hypothesis tests across all tests and simulations.

Table 2 shows results for the three incremental levels of ICT-mediated information delivery using different information technologies. The first column reports mean scores in the control group (with standard deviations reported below in parentheses). For the four individual questions, this is simply the proportion of households in the control group that answered correctly on the particular question. For instance, we find that in 16 percent of the households in the control group, at least one of the spouses indicated the correct option among the response alternatives to the question on optimal maize seed spacing. This relatively low rate of correct responses is due to the fact that this is a fairly new and potentially controversial recommendation. We find that in about 91 percent of control households, at least one spouse knew inputs were best combined and in more than 95 percent of households it was known that weeding is most important during the first 4 weeks. In about one third of the households, at least one spouse knew how to fight fall armyworm. For the knowledge index, the mean is harder to interpret, as it is the result of a weighted mean after standardization of the individual components of the index.

In the second column, we report the impact of having been shown the video (with standard errors of the estimated coefficient reported below in parentheses). We find that having been shown the video increases the likelihood that at least one individual knows the recom-

Table 2: Impact of ICT treatments on knowledge outcomes

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
Knows optimal spacing (yes=1)	0.160	0.130***	0.000	-0.019	0.214	0.010	0.608	3,619
	(0.367)	(0.030)		(0.018)		(0.019)		
Knows inputs best combined (yes=1)	0.908	0.045**	0.009	-0.018	0.065	0.010	0.423	3,619
	(0.290)	(0.018)		(0.011)		(0.011)		
Knows optimal time for weeding (yes=1)	0.954	-0.017	0.297	0.009	0.306	0.000	0.984	3,619
	(0.210)	(0.017)		(0.010)		(0.010)		
Knows how to fight armyworm (yes=1)	0.336	-0.019	0.557	-0.015	0.444	0.017	0.413	3,619
	(0.473)	(0.032)		(0.019)		(0.020)		
Knowledge index	-0.077	0.127***	0.004	-0.021	0.309	0.019	0.502	3,619
	(0.562)	(0.043)		(0.025)		(0.026)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

mended spacing by 13 percentage points and this difference is significantly different from zero at the 1 percent FWER-adjusted significance level (randomization inference-based p-value are shown in the third column; asterisks denote significance as compared to FWER-adjusted thresholds). We also find that the video increased the likelihood that at least one spouse indicates that inputs are best combined for optimal results by 4.5 percentage points. This difference is statistically significant at the 5 percent FWER-adjusted significance level. For the question on weeding, the intervention does not seem to have had a significant effect. However, this result should be interpreted with care due limited variation in the outcome.[5] Finally, on the fall armyworm question, we find that households that were shown the video are no more likely than control households to know when one should spray to control the pest. This suggests that the videos did not encourage farmers to actively search information on important challenges that were not explicitly covered in the video. Overall, and as confirmed by the knowledge index, we conclude that the agricultural extension videos increased knowledge at the household level, and that this increase seems especially poignant for novel information provided in the videos.

The fourth column (+IVR) shows the incremental effect of IVR (with standard errors of the estimated coefficient reported below in parentheses, and corresponding randomization inference-based p-value in the fifth column). We see that being provided with an IVR encouragement does not additionally affect knowledge about the new recommended spacing. There is some indication that the IVR treatment reduces the likelihood that at least one spouse responded correctly on the question about how inputs should be combined, but the reduction is not significantly different from zero after taking multiple inference into account. Similarly, there is no additional effect on knowledge related to the optimal time for weeding and also no additional effect on knowledge about the best way to fight fall armyworm. The fact that there is no supplementary effect of the IVR encouragement on knowledge is confirmed by the non-significant difference in the knowledge index. The sixth column (+SMS) reports the additional effect of the SMS reminders on the various questions and the index (with randomization inference-based p-value reported in the seventh column). Similar to the impact of IVR, we do not find an additional effect of the SMS campaign on any of the questions. We also do not find an effect of the SMS campaign as judged by the knowledge index.

The lack of additional effects may be due to the way the experiment was designed. As we wanted to rule out any possibility that the effects were driven by differences in the content, we made sure that no new information was given in the IVR system and in the SMS campaign. In light of this, it may be less surprising that we do not find additional knowledge effects from the two interventions. This is also consistent with results from Casaburi et al. (2014), who find only an impact from their SMS messages if it is more likely that the farmers do not already know the information that is contained in them.

Adoption effects

We continue our analysis by examining the effect of our incremental treatments on household-level adoption of recommended farming practices. During the endline survey, we collected detailed information on practices employed on the household's maize plots. Results of mean adoption rates in the control group for different practices are reported in the first column of Table 3. For instance, in the video, we recommend to start planting maize immediately after the start of the rains. We find that 37 percent of households in the control group reported that they started planting within one day after the start of the rains on at least on plot—a relatively high rate of adoption for this practice that indicates the extent to which it is likely known among farmers. We also find that only 2.6 percent of households in the control group used the recommended way of plant spacing of 75cm x 30cm with a reduced seed rate of 1 seed per hill. This low rate in the control group is not surprising given that this was a new and somewhat controversial recommendation. Almost 69 percent of control households report removing striga before it flowered to reduce damage early on and prevent the weed from spreading. Finally, we find that about 43 percent of control households reported first weeding after 18-20 days as recommended in the video.

The second column in Table 3 again reports the difference in the adoption of practices between households that were shown the intervention video and households that were give the placebo treatment (with standard error of the estimate in parenthesis below and corresponding randomization inference-based p-values in column 3). We find that for the first recommended practice, early planting, there is no impact from the video treatment. However, the likelihood that households adopt the recommended 75cm x 30cm spacing with a reduced seeding rate increases significantly after having been shown the video: while only 2.6 percent of households in the control group report adopting this practice on at least one plot, this figure increases to 8.9 percent among households that were shown a video (and this difference is significant at the 1 percent FWER-corrected significance level). Similarly, we find that the proportion of households that removed striga early on increased from 68.5 percent to 74.7 percent as a result of being shown a video (randomization inference-based p-value of 0.020, significant at the 10 percent FWER-corrected significance level). Finally, while the proportion of households that reported having started weeding after 18-20 days is almost 2 percentage points higher among households that were shown the video, the difference is not significantly different from zero. Estimation results for the index that summarizes the different practices confirms that overall, we can conclude that the videos significantly increased the adoption of recommended practices. Results suggest this is particularly the case if it concerns practices that are new and less likely to be known by farmers.

The fourth and fifth column of Table 3 report results for the additional effect of the IVR encouragement, with estimates reported in column 4 and the corresponding randomization inference-based p-values in column 5. We do not find any significant additional effect of the IVR treatment on any of the recommended practices. The sixth and seventh column report results for the additional effect of the SMS campaign, with estimates reported in column 6 and the corresponding randomization inference-based p-values in column 7. While we do find that the proportion of households that reports to be removing striga before flowering is

Table 3: Impact of ICT treatments on adoption of recommended practices

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
Planted immediately after start of rains (yes=1)	0.370	-0.004	0.899	0.009	0.635	-0.002	0.944	3,500
	(0.484)	(0.034)		(0.020)		(0.021)		
Used spacing of 75cm x 30cm with a reduced seed rate (yes=1)	0.026	0.063***	0.001	-0.005	0.620	0.014	0.289	3,560
	(0.158)	(0.019)		(0.011)		(0.012)		
Removed striga early on (yes=1)	0.685	0.062*	0.020	-0.009	0.693	0.024	0.231	3,560
	(0.465)	(0.031)		(0.018)		(0.019)		
First weeding after 18-20 days (yes=1)	0.426	0.019	0.585	0.013	0.487	-0.009	0.724	3,560
	(0.495)	(0.034)		(0.021)		(0.022)		
Recommended practices index	-0.086	0.100***	0.003	0.005	0.760	0.020	0.395	3,500
	(0.478)	(0.037)		(0.022)		(0.023)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

2.4 percentage points higher in the treatment group, and while we also find a small positive effect on seed spacing and seeding rate, the differences are not significant. The fact that the both the IVR encouragement and the SMS campaign has no impact on adoption of practices is also reflected in the index estimation results.

Next, we examine results related to the use of modern inputs. During the endline survey, we collected detailed information on input use on the household's maize plots, specifically on the use of fertilizer and improved seed. Results are reported in Table 4. In the top panel of the table, we look at the three types of fertilizer that were recommended in the video separately, and again use an index to assess changes in overall fertilizer use. The first column in Table 4 reports mean adoption rates in the control group. We find that 26.4 percent of control households report that they used DAP or NPK on at least one of their maize plots, while the use of urea is less widespread with only 5.1 percent of control households reporting urea use on at least one plot. Among control households, 15.7 percent reported using organic fertilizer on at least one plot.

The impact of showing videos on fertilizer use is reported in column 2 and 3 of Table 4. We see that the video treatment reduced the use of DAP or NPK by 4.7 percentage points. This difference has an associated randomization inference-based p-value of 0.088. However, it is not significant after controlling FWER. We find the opposite result for urea use with estimates indicating an increase of almost 5 percentage points (with a randomization inference-based p-value of 0.011, and significance at the 5 percent level after controlling FWER). We also find that the use of organic fertilizer increased by about 50 percent as a result of the video treatment. Summarizing the three types of fertilizer in a index results in a positive difference between treatment and control, with the difference significant at the 10 percent level.

The opposing effects of the video on different types of fertilizer, the inorganic types in particular, may be due to the fact that in the video, we pay particular attention to the benefits of combining inputs and technologies. The video may thus encourage farmers to

Table 4: Impact of ICT treatments on fertilizer and improved seed use

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
				fertilizer use				
Used DAP/NPK on at least one plot? (yes=1)	0.264	-0.047	0.088	0.021	0.146	-0.008	0.725	3,560
	(0.442)	(0.029)		(0.017)		(0.018)		
Used urea on at least one plot? (yes=1)	0.051	0.049**	0.011	0.012	0.271	-0.021	0.113	3,560
	(0.221)	(0.020)		(0.012)		(0.013)		
Used organic fertilizer on at least one plot? (yes=1)	0.157	0.077***	0.005	-0.038**	0.012	0.032	0.102	3,560
	(0.365)	(0.028)		(0.017)		(0.018)		
Fertilizer index	-0.057	0.083**	0.035	-0.004	0.815	-0.002	0.984	3,560
	(0.547)	(0.042)		(0.024)		(0.026)		
				improved seed use				
Used hybrid maize seed on at least one plot? (yes=1)	0.289	0.006	0.865	0.040**	0.022	-0.046	0.029	3560
	(0.454)	(0.031)		(0.019)		(0.020)		
Used Open Polinated Varieties on at least one plot? (yes=1)	0.302	-0.029	0.379	0.009	0.590	0.024	0.440	3560
	(0.460)	(0.031)		(0.019)		(0.020)		
Seed index	0.032	-0.026	0.559	0.053**	0.030	-0.023	0.536	3558
	(0.700)	(0.048)		(0.028)		(0.029)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

reassess their mix of fertilizers, reducing the use of fertilizer types that are already used widely and increasing the use of fertilizer types that are less commonly used. In the light of this reasoning, the fertilizer index may need to be specified differently, as more is not necessarily better for each type of fertilizer. Specifically, and in the light of the imbalance in the control group, one may argue that DAP/NPK use is higher than optimal and urea use is lower than optimal. As such, a case can be made to include DAP/NPK use in the index with a negative sign. Doing so, we conclude that the video intervention has a significant effect on the fertilizer mix used by farmers (with a randomization inference-based p-value $<$ 0.001).

The incremental impact of the IVR encouragement is reported in columns 4 and 5 of Table 4. While the difference between treatment and control is positive for both types of inorganic fertilizer, the effects are not significant. However, we do find that the IVR encouragement reduced the proportion of households that reported using organic fertilizer by about 25 percent. With access to a more demand-driven ICT channel, farmers that used organic fertilizer may seek information on more complex but efficient types of fertilizers. If we judge the effectiveness of the IVR encouragement by including organic fertilizer use in the index with a negative sign, we do indeed find a significant impact (with a randomization inference-based p-value = 0.009). The additive effect of the SMS campaign is reported in columns 6 and 7 of Table 4. We do not find an effect of the SMS campaign on fertilizer use.

In the lower panel of Table 4, we report results for the use of improved seed. We differentiate between maize hybrids and open-pollinated maize varieties. In the first column, we see that use of improved seed is more common than fertilizer use: in the control group, about 30 percent of households report using open-pollinated varieties on at least on plot, and this percentage is only slightly lower for hybrids. We do not find that the video treatment changes these percentages (columns 2 and 3). However, we do find an effect from the IVR encouragement: the percentage of households that reported to have used hybrid seed on a least one plot was 4 percentage points higher in the treatment group. Apparently, providing farmers with a tool that allows them to actively seek out information about a new input or technology increases the likelihood that they also adopt hybrid maize seed. The impact of the IVR treatment on improved seed use is confirmed by the seed index. There is no additional effect of the SMS campaign on seed use.

Production effects

Finally, we now turn to the intervention's effects on production-related outcomes. We first examine household-level maize production. During the endline survey, we asked both spouses separately to estimate how much maize was harvested from each maize plot. These quantities were then summed over the different maize plots assessed by each spouse and the average between the two spouses was taken as the final estimate of household-level maize production.

The first column in Table 5 shows mean values for the production indicators for the control group. On average, control households produce (log(kg)) 5.814 or about 440 kg of maize. This was cultivated on (log(acre)) 0.018 or about 1.19 acres on average. It also shows that for the average household in the control, maize yields (log(kg/acre)) equal 5.850 or about 430 kg/acre.This is much higher than yields recorded at baseline (290 kg/acre) for the previous season, possibly because rainfall patterns were better during our intervention and farmers may have given greater attention to combating fall armyworm. Still, compared to figures recorded in FAOSTAT (1000 kg/acre) or figures from household survey data (typically around 600 kg/acre), yields were below what might be considered "normal" in Uganda. This is also confirmed by the fact that in less than 40 percent of households at least one spouse reported that yields were better than a typical year on at least one plot. We also look at labor use. The average household spent about 72 person-days on maize farming, which includes labor that was hired in. This translates in a labor productivity of 6.73 kg of maize per hour worked.

In the second column of Table 5 we report the impact of the video treatment (with corresponding randomization inference-based p-values in column 3) for the various production

Table 5: Impact of ICT treatments on production outcomes

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
Maize production (log(kg))	5.814	-0.013	0.804	0.048	0.202	0.040	0.340	3,344
	(0.765)	(0.059)		(0.035)		(0.036)		
Maize area (log(acre))	0.018	-0.092*	0.034	-0.014	0.573	0.023	0.462	3,341
	(0.580)	(0.045)		(0.026)		(0.028)		
Maize yield (log(kg/acre))	5.850	0.098*	0.028	0.036	0.266	0.004	0.913	3,302
	(0.658)	(0.049)		(0.029)		(0.030)		
Yield better than normal (yes=1)	0.387	0.023	0.496	0.000	0.991	0.035	0.149	3,560
	(0.488)	(0.034)		(0.020)		(0.021)		
Labour(log(mandays))	4.132	-0.010	0.790	-0.003	0.915	0.027	0.348	3,370
	(0.577)	(0.042)		(0.024)		(0.026)		
Labour productivity (log(kg/mandays))	1.650	0.028	0.592	0.062	0.070	0.000	0.955	3,341
	(0.720)	(0.057)		(0.033)		(0.035)		
Production index	-0.053	0.058**	0.024	0.008	0.581	0.005	0.712	3,302
	(0.365)	(0.026)		(0.015)		(0.016)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

related outcomes. We see that there is no impact on (log) maize production. However, we do see that households in the video treatment produced this same amount of maize on an area that is about 9.6 percent smaller than the area used for maize production by control households. As a result, we also find that among households in the video treatment, yields are about 10.3 percent higher than among the control group, and this difference is significant at 10 percent after controlling FWER. The fact that the video intervention has a clear effect on production-related outcomes is also reflected in the significant different in the production index between treatment and control. That said, we do not find that households in the video treatment were more inclined to feel that yields are better than normal than control households.

Results are again consistent with the content provided in the video. In particular, the video advised that farmers experiment on a small part of their field with modern inputs, following recommended practices, and advised against using improved seed on their entire field if this does not leave sufficient money for complementary inputs such as fertilizer. Further, the video advised farmers to cultivate a more commercial mindset, paying ample attention to the idea of starting small and growing over time through re-investing. Columns 4 and 5 report the additive effect of the IVR treatment on production-related outcomes. As with previous outcomes, there seems to be little impact from this treatment. Similarly, we do not find additional effects on production related outcomes of the SMS campaign.

Conclusion

In this study, we evaluated the effectiveness of three complementary ICT-mediated agricultural extension approaches that can be brought to scale relatively easily. The first approach–the use of short, appealing video messages animated by farmer-actors who farmers can relate to–is probably the approach containing the most substantial quantity of relevant information. While appealing because of its combination of both audio and visual information, the approach is also somewhat supply-driven, assigning farmers to a passive role as the recipient of information. The second approach–an interactive voice response (IVR) service–allows the farmer to play a more active role in information acquisition by allowing the farmer to call into a system that offers menu-based choices leading to pre-recorded message. The third approach consists of a series of short message services (SMS) messages that reminds the farmer of particular key inputs or practices–provide .

We test the effectiveness of these three ICT channels in an incremental fashion using a field experiment that involved nearly 4,000 smallholder maize farmers in eastern Uganda. To assess the effectiveness of the first channel, we compared outcomes of a random subset of farmers that was shown an informational video to a random subset of farmers that was shown a placebo video. From this initial treatment group, two-thirds of the farmers that were shown the video were randomly assigned to receive an IVR starter kit which encouraged them call into the IVR service to obtain information on maize cultivation that was consistent with the video's content. From this second treatment group, half were randomly assigned to receive a series of eight time-sensitive SMS reminders related to the recommended practices and technologies, along with a reminder to use the IVR service to obtain additional information. The design of this experiment allowed us to estimate the effect of the video treatment as well as the additional effects of the IVR encouragement and SMS treatments. Effectiveness was measured in terms of knowledge gained, practices and technologies adopted, and production increased.

Findings indicate that in our study site and context, video-enabled agricultural extension approaches affect a range of outcomes. Showing agricultural information videos to maize farmers increased knowledge outcomes, particularly on new practices and technologies, and increased the adoption of recommended practices, particularly those that were new and otherwise unknown to farmers. Videos also led to adjustments toward more balanced fertilizer use, with farmers increasing the use of certain types of fertilizers (urea and organic) and reducing the use of others (DAP, NPK). As a result, farmers that were shown agricultural information videos increased their maize yields by 10 percent. The IVR treatment offered in addition to the video treatment did not seem to additionally increase knowledge or adoption outcomes, although there is some evidence to suggest that farmers who received the IVR encouragement were more likely to use hybrid maize seed. We found no additional effect of being offered IVR on production. The SMS reminders provided in addition to the video treatment and IVR encouragement also did not have any additional effect.

One area that needs further attention is related to spillovers. It is well known that experimental studies of information treatments are especially prone to non-interference violations (Coppock, 2014). As such, our estimates are likely to underestimate the true effects of ICT-mediated extension approaches. On the other hand, there is considerable evidence that much of the learning among smallholders happens through peer learning (Bandiera and Rasul, 2006; Conley and Udry, 2010; BenYishay and Mobarak, 2018). Some studies have tried to understand how peer learning can be leveraged to accelerate agricultural technology adoption and diffusion (eg. Beaman et al., 2018; Magnan et al., 2015). The question then becomes which ICT-mediated extension approach maximizes spillover effects, for instance through ease of sharing of content. Future studies should be designed with such questions in mind, by for example ensuring exogenous variation in treatment saturation or by using a multilevel design where different levels correspond to different spillover networks and treatments are assigned so as to create variation in different levels (Baird et al., 2018).

Notes

[1]This study is part of a larger study that also looked at the role of gender in video mediated agricultural extension. The overall study took the form of a 3^3 factorial design (plus a separate pure control group), where one factor corresponds to the information technology and the other two factors varied the gender of the person to whom the video was shown within the household and the gender of the person who provides the information in the video. In this study, we restrict attention to the first factor. More information on the overall study can be found in the pre-analysis plan.

[2]Ex ante, we expected the largest effect size for the video intervention, and power calculations indicated

that we only needed about 250 observations in each group to detect this. Much smaller effects were expected from adding the other two technologies, so a larger sample was needed to retain statistical power. Power calculations were bases on an elaborate set of comparisons using different outcomes to power the complete 3^3 factorial design. We used simulation techniques that allowed us to to sample from actual data on outcome variables instead of from a theoretical distribution with an assumed mean and standard deviation. Apart from the sample size in the control group, sample size in other treatment arms are the result of binding constraints for minimal sample size needed to test differences in two other factors of the design. Detailed information on the power calculations can be found in the pre-analysis.

[3]In particular, the person or persons within the household to whom the video was shown was dictated by one of the other factors in the factorial design, and were either the man co-head within the household alone, the woman co-head within the household alone, or the man and woman co-heads as a couple together. As this factor was orthogonal to the factor corresponding to the information technologies in the factorial design, it does not matter who within the household the video is shown to, and the treatment effect corresponds to the average impact at the household level.

[4]This is a very low compliance rate, which partly reflects low demand for the service. Cole and Fernando (2016) find that for a similar service in India, compliance rates were as high as 88 percent. Among possible explanations for this difference are: the time frame (the 88 percent was measured after 2 years of intensive exposure to the system, compliance rates were much lower at midline; our IVR system was only 3 months operational); differences in treatment intensity (we only sent 8 reminders to only half of the IVR households while Cole and Fernando (2016) sent bi-weekly reminders); the different study population of Cole and Fernando (2016), that consisted of cotton farmers that expressed willingness to participate and owned a mobile phone; different technologies (hotline where direct questions can be asked to real person extension agents vs IVR that works with pre-recorded messages and a limited set of options). However, there are also signs that our indicator of compliance may under-report true compliance (because for instance encouraged farmers use different phones to call the IVR). This is illustrated by the fact that about 430 unique calls were made to the system, representing about 18 percent of encouraged households.

[5]In fact, our pre-analysis plan specifies that we would drop from the analysis variables where 95 percent of outcomes are the same value.

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Appendix

Table A.1: Baseline characteristics of attritors by treatment status

	Mean	Video	+IVR	+SMS	N
Maize yield (kg/ac)	232.87	66.58	26.37	-67.69	342
	(230.63)	(54.10)	(29.58)	(32.56)	
Age of HH head (years)	36.39	1.16	0.55	-0.61	339
	(14.61)	(3.21)	(1.76)	(1.94)	
HH head finshed primary school	0.22	0.10	0.08	-0.02	342
	(0.43)	(0.11)	(0.06)	(0.07)	
HH size	7.17	-0.03	0.24	0.48	342
	(3.43)	(0.81)	(0.44)	(0.49)	
Number of bedrooms	2.22	0.07	-0.13	0.10	342
	(1.26)	(0.29)	(0.16)	(0.17)	
Access to extension last year	0.22	-0.08	-0.06	0.00	342
	(0.43)	(0.07)	(0.04)	(0.04)	
Has used fertilizer last season	0.22	-0.01	-0.03	0.07	342
	(0.43)	(0.09)	(0.05)	(0.06)	
Has used improved seed last season	0.28	0.06	0.02	0.02	342
	(0.46)	(0.11)	(0.06)	(0.07)	
Distance nearest agro input shop (km)	5.72	0.24	-0.84	0.25	342
	(5.36)	(1.21)	(0.66)	(0.73)	
HH owns mobile phone	0.72	-0.02	0.05	0.04	342
	(0.46)	(0.10)	(0.06)	(0.06)	
HH has access to a mobile phone	0.83	-0.08	0.06	0.00	342
	(0.38)	(0.10)	(0.05)	(0.06)	
F-test		0.546	1.058	1.035	
P-value		0.872	0.395	0.415	

Note: First column reports control group means (and standard deviations below); Column 2 reports differences between placebo (control) and video treatment (and standard error below), column 3 between video only and video+ivr, column 4 between video+ivr and video+ivr+SMS; the last column is sample size; ***, ** and * denote that the difference is signficantly different from zero at the 1, 5 and 10 percent level, respectively.