Empowering women through targeting information or role models: Evidence from an experiment in agricultural extension in Uganda

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Abstract

Agricultural advisory services are generally biased towards men, with information targeted mainly to male members within the household, and in formats that often reinforce male dominance in agricultural decision making. Such biases affect women's ability to make informed decisions and limit their intra-household bargaining power. As women empowerment in agriculture has many well-established benefits, designing inclusive agricultural advisory services is key. In this study, we challenge the assumption that information is fully shared between co-heads of a household. We also test if portraying women as equally able farmers challenges gender norms and stereotypes in agriculture. We do this through a field experiment in eastern Uganda in which videos that provide information on recommended maize farming practices are shown to monogamous maize-farming households. In the experiment, we manipulate who within the household is exposed to the information contained in the video. Furthermore, we vary the gender of the person delivering the information in the video. We find that targeting the female co-head alone with information increases her knowl-

edge about the recommended practices, her role in agricultural decision making, her subsequent adoption of recommended practices and inputs, and yields on fields she manages; the male co-head's knowledge about the practices and his unilateral decision-making is reduced. When both co-heads are targeted, joint adoption of recommended practices and inputs increases, while the male co-head's unilateral decision-making reduces. We find some support that female role models in the extension videos challenge men's beliefs and stereotypes about women's roles in agriculture, and encourage the adoption of recommended practices by women. We conclude that, if the aim is to empower women, most gains can be made by re-designing agricultural advisory services to target information exclusively to the female co-head within the household. Challenging gender stereotypes may create room for more women involvement in agriculture.

A lack of information about the existence, use, and profitability of modern inputs, improved technologies, and recommended management practices is a major constraint to agricultural productivity growth, sustainable intensification, and food security in developing countries (Jack, 2011). Therefore, agricultural extension programs and advisory services are often important components of agricultural development strategies. However, agricultural extension services are typically biased toward men, with information targeted mainly to male members of a farm household (generally the male household head) and delivered by male extension agents in ways that does not always recognize the role of women in agriculture. Such biases affect women's ability to make informed decisions and limit their intra-household bargaining power.

There are many well-established benefits to empowering women in agriculture. A more prominent role for women in the farm household has been shown to result in a more efficient allocation of scarce resources within the household, a more equitable distribution of the returns to investments in household produc-

tion, and general improvements in welfare and reductions in poverty (de Brauw et al., 2014; Fiala and He, 2016; McCarthy and Kilic, 2017; Croppenstedt et al., 2013). Involving women in the choice of crops may also lead to more nutritious dietary outcomes at the household level (Quisumbing and Maluccio, 2003; Duflo and Udry, 2004). More generally and from a human rights perspective, there is intrinsic value in empowering women (Kabeer, 1999; Meinzen-Dick et al., 2019).

Women are likely to benefit from more inclusive agricultural extension models, as they face information deficiencies and asymmetries relative to men in a range of circumstances. In agriculture, women have been shown to be more deprived of information regarding good agronomic practices (Doss and Morris, 2000; Doss, 2001; Lambrecht et al., 2016). This unequal access may contribute to lower adoption rates of improved agricultural practices and technologies among women. For example, studies show that with equal access to extension services, land, and labor, men and women farmers in male-headed households in Ghana would be as likely to adopt modern agronomic practices (Doss and Morris, 2000). Kabunga et al. (2014) find that female farmers are less likely to adopt tissue banana culture technology in Kenya, but that they would have an equal chance to adopt innovations if they acquire sufficient knowledge about the innovation.

Women's access to information—particularly to information provided by agricultural extension services—may be subject to both extra-household and intra-household constraints. The extra-household constraints can be infrastructural and logistic, such as for instance women not being targeted, women lacking the money to travel to extension training locations, or women lacking the time to attend because of household management, domestic and reproductive responsibilities (Fletschner and Mesbah, 2011; Wodon and Blackden, 2006). Extra-household constraints may also exist in terms of information content or delivery: it may not be adapted to women's interests or needs, or may not rec-

ognize women's role as agricultural producers, and therefore may not appeal to women. Human capital constraints may also play a role given women's generally lower levels of education in many rural contexts in developing countries. Norms limiting women's mobility and women's interaction with men may impose additional constraints. These extra-household constraints to women's access to information mean that, in many situations, women may rely more on informal networks for gathering information. When these networks are gender-specific and gender-segregated, problems associated with asymmetric information persist (Zeltzer, 2020; Beaman and Dillon, 2018).

A (married) woman's interaction with her husband may often be her main (intra-household) source of information on agriculture. The assumption that information flows freely and frictionless within the household is implicit in most extension strategies that target the male household head (Fletschner and Mesbah, 2011). Yet the assumption requires that preferences of male and female co-heads within a household align; that household resources, including information, are shared; and that households cooperate to reach Pareto-optimal outcomes. However, the conceptualization of the agricultural household as a unit with such properties has been challenged in theoretical work (Lundberg and Pollak, 1994; Pollak, 1994; Alderman et al., 1995) and rejected in empirical work (Udry, 1996; Duflo and Udry, 2004; Ashraf, 2009; Iversen et al., 2011).

In this paper, we examine how the design of information and communication technology (ICT) applications used in agricultural extension information campaigns affects household member's access—the female co-head within the household in particular—to informational resources, their agency, and their achievements in smallholder semi-subsistence farming. We conduct a field experiment among 3,330 maize-farming households in eastern Uganda and zoom in on two design features. In a first treatment, we focus on targeting of the information,

and compare outcomes of households where the informational video was shown to the male co-head only (corresponding to the status quo in generic agricultural extension models), to outcomes in households where the female co-head was also exposed to the video—either alone or as part of the couple of co-heads. In a second treatment, we investigate the potential of role models to increase participation in maize farming, a traditionally male dominated activity (Porter and Serra, 2019). Here, we vary exposure to the gender of the actors in the videos, and compare outcomes within households that were shown a video with a male actor (again corresponding to the status quo of male extension providers in generic agricultural extension models) to outcomes within households that were shown a video that features a female actress—either alone or together with a male actor. The outcomes we use to assess impact of the treatments are individual level and joint outcomes (the female co-head's knowledge, decision making, adoption and production, the male co-head's knowledge, decision making, adoption and production, or joint knowledge, decision making, adoption and production) as reported by the female co-head.

We find that targeting the female co-head alone within the household (as opposed to targeting the male co-head alone) increased the female co-head's outcomes and reduced the male co-head's outcomes. In particular, the treatment increased the female co-head's knowledge of recommended agronomic practices. It also increased the female co-head's participation in agricultural decision making and her adoption of inputs such as inorganic fertilizer. Female co-heads also reported higher yields on the maize plots under their management. The increase in knowledge of the female co-head came at the cost of a decrease in knowledge of the male co-head, indicating frictions in the flow of information between spouses. The likelihood that male co-heads made agricultural related decisions unilaterally also reduced. Male co-heads' adoption of practices and inputs, and

production on fields managed by male co-heads alone does not differ between households where only the male co-head was exposed to the information and households where only the female co-head saw the video.

We further find that targeting both the female co-head and male co-head within the household jointly with information (as opposed to targeting the male co-head alone) increased joint outcomes. We also see a reduction in unilateral decision making by the male co-head. The increase in joint outcomes seems to be driven by the fact that couples jointly decide and adopt a novel planting method that was promoted, as well as by their joint use of organic fertilizer. We do not see an increase in production related outcomes on jointly managed plots.

The effectiveness of the use of female role models is less straightforward. We only find that in the subgroup where a video was shown in which a couple of male and female actors provided information (as opposed to the status quo where a male actor provides all the advice), men were less likely to take decisions without involving their wives. This suggests that the intervention challenged prevailing beliefs and stereotypes held by men that women are less able to make decisions related to agriculture. We also find that women role models may be important for adoption of inputs and recommended practices by female co-heads.

Our study contributes to the literature on the provision of agricultural extension information to address intra-household information asymmetries in the context of developing-country agriculture. Kondylis et al. (2016) start from the observation that information about sustainable land management practices in Mozambique does not reach female farmers as effectively as male farmers, and is not perfectly shared between male and female co-heads within farm households. They find a positive effect on awareness and adoption among female farmers when they introduce additional female extension agents who reach out to fe-

male farmers. Pan et al. (2018) explore similar issues in Uganda with women model farmers who facilitate training and access to hybrid maize seed, particularly for fellow women smallholder farmers. They find significant positive effects on the adoption of low-cost recommended agronomic practices and inputs by households, and on household food security. Lambrecht et al. (2016) investigate whether extension services are more effective if information is provided to both male and female co-heads together, the male co-head alone, or the female co-head alone in the household. Focusing on integrated soil fertility management practices in eastern DR Congo, they find that joint participation of male and female co-heads in extension information events increases adoption most.

We also contribute to the emerging literature that investigates the importance of female role models in challenging gender stereotypes and empowering women in domains where they are active but lack voice and agency. Role models are important in stimulating aspirations and the development of an internal locus of control. They can update beliefs in one's own ability (self-efficacy) or beliefs about the returns to investments, especially for disadvantaged social groups that have few examples of success (Beaman et al., 2012; Riley, 2017). Updated beliefs in self-efficacy and returns to investments can, in turn, raise aspirations and increase people's ambitions, which create the motivation to work hard and attain the success projected by the role model (Riley, 2017). Inspiring films about successful farmers' life choices promoted welfare-improving aspirations among Ethiopian farmers (Bernard et al., 2015). Women chief village councilors in rural India raised parents' and girls' aspirations with regard to education and adult life opportunities (Beaman et al., 2012). Kandpal and Baylis (2019) demonstrate that women in social networks of women who became empowered through a women's education program gained empowerment in terms of mobility and investment in girl children, but not in other domains where sticky

norms seem to prevent change. In Nicaragua, proximity of women promoters of a conditional cash transfer program made women more optimistic about the future, happier in life, and less fatalistic (Macours and Vakis, 2014). In Egypt, the prominent and visible role that women played in the Arab Spring protests, has inspired women to more autonomy in decisions about health, socialization and household decisions and less accepting attitudes towards domestic violence and girls excision (Bargain et al., 2019). Most of these studies show that role models not only increased aspirations, but also led to changes in choices made, such as women employment (Ghani et al., 2014) and investment in child education (Bernard et al., 2015; Macours and Vakis, 2014), particularly of girls (Beaman et al., 2012).

Role models have also been found important in challenging role incongruity, which can be defined as prejudiced views and cognitive biases about the capabilities of specific social groups in specific social roles that arise from a combination of perceptions about the characteristics of members of that social group and perceptions about the capabilities and characteristics that specific social roles require (Eagly and Karau, 2002). Peer effects (which are linked to recognition and conformity) and gender homophily effects may imply that information contained in a message brought by role models of the same sex is better understood and more trusted than messenger of the other sex, thereby contributing to changes in an individual's choices and chances of success.[1] BenYishay and Mobarak (2019) showed that the social identity of the person who provides extension information influences learning and adoption. Farmers appeared most convinced by communicators who share a group identity with them, or who face similar agricultural conditions.While female role models can affect women's empowerment directly as women start questioning cultural norms and gender stereotypes, the

[1]Gender homophily is defined as the preference for interaction with individuals of the same sex, and is linked to having more trust in individuals of the same social group (McPherson et al., 2001; Zeltzer, 2020).

indirect effect of role models may be even more important, particularly in the longer run, as role models challenge beliefs and stereotypes about lesser abilities of that group held by other groups whose abilities are not underestimated. For example, Beaman et al. (2009) show that the appointment of women leaders to Indian village councils improved men's perceptions of women's leadership abilities.

The remainder of the paper is structured as follows. In Section 1, we present the study context. In Section 2 we explain the methods, with subsections on the experimental design, sampling, the specification we will estimate, and the indicators that will be used to assess impact of the different interventions. We then turn to the results in Section 3, where we first discuss the impact of targeting the information to the female co-head, alone or as part of the couple. We then look at role model effects. We also have a subsection that reports on interactions between the two treatments. A final section concludes.

1 Study Context

We conducted a field experiment in 2017 among smallholder maize-farming households in eastern Uganda. Participants in the experiment were drawn from monogamous maize-cultivating households residing in five districts where maize is particularly important, both as a staple and as a marketable crop. The experiment was conducted during the second maize-growing season, which runs from approximately August to January of the following year, 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 three to three and a half months, and farmers tend to cultivate early-maturing but lower yielding maize varieties. Fields are prepared in August, planted in September, and harvested from December onward.

Maize yields in the study area, and in Uganda more generally, are well below their potential. Research station trials in Uganda have demonstrated that yields range between 730 kg per acre and 1,820 kg per acre (Fermont and Benson, 2011). Yet, on-farm estimates are generally lower. A recent study of on-farm yield reports figures between 270 kg per acre and 995 kg per acre (Gourlay et al., 2019). There is also evidence that maize plots under female management are less productive than maize plots under male management. Ali et al. (2016) observe that male-managed plots are on average 17.5 percent more productive than female-managed plots in Uganda. They link the productivity gap between male- and female-managed plots (controlled for plot size but without distinguishing between type of crops) to an unequal distribution between men and women of responsibilities and resources, including modern inputs such as improved varieties, fertilizer, and agrochemicals.

The public agricultural advisory system in Uganda has a turbulent history. The National Agricultural Advisory Services (NAADS), which was set up as a demand-driven public-private partnership in 2000, became a victim of political capture and governance problems, and was eventually replaced by Operation Wealth Creation in 2014 (Kjær and Joughin, 2019). The latter is organized by the army and approaches problems in the sector from a logistical angle. As a result, the focus has shifted from provision of advise towards (subsidized) input distribution. Data obtained from the Uganda National Panel Survey (wave 2013/2014) suggest that only 20 percent of households received extension in the past twelve months. While there is no reliable data on who was targeted within these households, a recent survey on public service delivery found that only 16 percent of extension agents in Uganda are women (Kabunga et al., 2016).

		Messenger		
		Man	Woman	Couple
Recipient	Man	385	385	369
	Woman	385	385	369
	Couple	342	342	369

Figure 1: Layout of experimental design

2 Methods

2.1 The Experiment: A Video Extension Information Intervention in a Factorial Design

We test the effectiveness of involving women in receiving and conveying agricultural extension information via ICT-enabled videos. To do so, we use a 3^2 factorial design, in which one factor corresponds to the gender of the person (or persons) who receives the information (henceforth referred to as the *recipient* factor) and the other factor corresponds to the gender of the person (or persons) who delivers the information (henceforth referred to as the *messenger* factor).[2] Each factor contained three levels: male alone, female alone, or male and female together (as a couple). The design is represented in Figure 1 below, with numbers shown in each of the nine treatment cells to indicate the number of households randomly allocated to one of these nine treatment combinations.[3]

[2] In the context of this study, we refer to these factors in terms of "gender" and not "sex" because the implicit differences in the person(s) receiving or delivering the information are social and cultural in nature, and not simply biological.

[3] Power calculations were based on a set of comparisons using different outcomes to power the complete 3^2 factorial design. We used simulation techniques that allowed us to sample from actual data on outcome variables (maize yields obtained from Uganda National Household Survey of 2005/06) instead of a theoretical distribution with an assumed mean and standard deviation.

The design was operationalized using short videos. Corresponding to the recipient factor, the video was shown to one of the three recipients: the male co-head within the household; the female co-head; or the male and female co-heads together as a couple. Corresponding to the messenger factor, we produced three versions of essentially the same video, with the only difference being the actor(s) featured in the video. In a first version of the video, a male actor-farmer is featured. The second version of the video features a female actor-farmer. In a third version of the video, both the male and female actor-farmers are featured. The videos can be found here. The videos were shown on 10-inch Android tablet computers by trained field enumerators during a private meeting with the participant (or participants if the recipient was the couple). The video was shown twice to our study participants, once before the maize planting time (July 2017) and once around the actual time of planting (August 2017).

The video itself consisted of a 10-minute aspirational story in which a farmer (man, woman, or a man and woman acting together as a couple) recounts how s/he used to struggle with low maize yields. The actor-farmer then shows what inputs s/he used and what recommended practices s/he followed to successfully increase his/her yields. The choice of what inputs and practices to promote in this video was based on key informant interviews conducted in May 2017 with agronomists, maize breeders, district agricultural officers and other government staff, extension workers, and maize farmers. The information provided in the video is also generally consistent with the package of recommendations promoted by the Ugandan Ministry of Agriculture, Animal Industry and Fisheries.

The video includes information about a range of productivity-enhancing strategies including: management of pests and disease, including striga (*Striga hermonihica*), a parasitic plant affecting maize growth; improvement of soil fertility through the timely application of organic and inorganic fertilizers; use of

fresh seed of improved maize varieties and hybrids; and crop management practices such as timely planting, optimal plant spacing, and timely weeding. The video also contained content on the costs and benefits of the different practices and inputs being promoted, and recommended that viewers take a long-term perspective on improving their maize cultivation by starting small and reinvesting profits on increasingly larger areas of land.

2.2 Sampling and treatment assignment

Households were sampled from five districts in eastern Uganda: Bugiri, Mayuge, Iganga, Namayingo, and Namutumba. From among these districts, we first removed town councils and two sub-counties that consisted of islands in Lake Victoria. We then used a two-stage cluster sampling approach to obtain a representative sample of this population. Specifically, 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 selected a random sub-set of monogamous households to be included in the study.

Treatment was randomized at the farm household level. Assignment of the households to a particular treatment combination was randomized using a random number generator. Information on the sampled households, including names, contact details, and their treatment assignment, were pre-loaded onto the tablets so that the correct video was automatically queued for screening. The integration of treatment assignment into our Computer Assisted Personal Interview (CAPI) system allowed us to monitor implementation fidelity in real time.

Endline data was collected after harvest between February and April 2018. Households were revisited and both male and female co-heads were interviewed

separately.

2.3 Estimation

We estimate average treatment effects using the following Ordinary Least Squares specification for the impact of the different treatments on outcome y in household i:

$$y_i = \alpha + \sum^{T_R=W,J} \beta^{T_R}.R_i^{T_R} + \sum^{T_M=W,J} \gamma^{T_M}.M_i^{T_M} +$$

$$\sum^{T_R=W,JT_M=W,J} \sum \delta^{T_R T_M} R_i^{T_R} M_i^{T_M} + \varepsilon_i \quad (1)$$

In this equation, R_i are indicator dummy variables that denote who within the household was shown the video (the recipient factor). If the video was shown to the female co-head alone in household i, $R_i^W = 1$ and $R_i^J = 0$. If the video was shown to the couple of female and male co-heads in household i, the $R_i^W = 0$ and $R_i^J = 1$. The comparison category thus consist of households where the video was shown to the male co-head only in household i, in which case both $R_i^W = 0$ and $R_i^J = 0$. Similarly, M_i are indicator dummy variables that correspond to the messenger factor. If the video that was shown in household i was the version with the female actress alone, $M_i^W = 1$ and $M_i^J = 0$. If the video where the couple was acting was shown, then $M_i^W = 0$ and $M_i^J = 1$. Also here, the comparison category consist of households where the video was shown with only a male actor, in which case $M_i^W = 0$ and $M_i^J = 0$.

We obtain four parameters of interest. First, β^W corresponds to the impact of showing a video to the female co-head only (as compared to a situation where the video is shown to the male co-head alone and keeping the version of the video fixed). Second, β^J corresponds to the impact of showing a video to the male and

female co-heads jointly (as compared to a situation where the video is shown to the male co-head alone and keeping the version of the video fixed). Third, γ^W provides and estimate of the effect of showing a video featuring a female role model (as compared to a situation where the video features a male actor only and controlling for who the video is shown to within the household). Fourth, γ^J provides and estimate of the effect of showing a video where a couple of male and female actors provides all the information (as compared to a situation where the video features only a male actor and keeping recipient fixed). We also test if $\beta^W = \beta^J$ and $\gamma^W = \gamma^J$.

Equation 1 also includes a full set of interactions and associated parameters (δ) allowing us to identify effects corresponding to each treatment cell in Figure 1 (Muralidharan et al., 2019). While our primary interest lies in the main effects and estimates of interactions are not reported in figures and tables to conserve space, some of these interactions may be informative for particular outcomes. For instance, positive significant coefficient estimates of δ^{WW} for knowledge outcomes may indicate that gender related homophily effects—the tendency of individuals to associate more to individuals of the same gender—are important for learning. When we discuss results, we thus include a subsection that highlights the most important findings from interaction effects.

2.4 Outcomes

Impact is assessed as changes in key outcomes along the impact pathway. We examine effects on women's outcomes, men's outcomes, and outcomes that are shared (joint) between the female and male co-heads of households. Those outcomes are cast as changes in (a) the knowledge of the female co-head, knowledge of the male co-head, or joint knowledge, about the information promoted in the video or re-activated by it; (b) the extent to which maize production related

decisions in the household are taken by the female co-head alone, by the male co-head alone, or jointly; (c) the adoption of the recommended practices and inputs decided upon unilaterally by the female co-head, unilaterally by the male co-head, or jointly; and (d) production related outcomes on plots that were female-managed, male-managed, or jointly managed. We aggregate outcomes within each of these four families of outcomes into four indices, which are 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). We further combine the four indices into an overall index that allows us to assess impact at a glance. Combining outcomes in indices is a common strategy to guard against over-rejection of the null hypothesis due to multiple inference.

Knowledge about the different practices recommended in the video is measured by the extent to which respondents answered correctly to multiple choice questions about the practices.[4] A woman's knowledge score is based on responses from the female co-head; a man's knowledge score is based on responses from the male co-head; the joint knowledge score is based on responses from both the female and male co-heads, where it was considered a correct joint answer if both of them got the answer correct, otherwise, not. We combine the outcomes of the four knowledge questions into a knowledge index, leading to a female co-head knowledge index, a male co-head knowledge index, and a joint

[4]First, respondents are considered knowledgeable about recommended plant spacing and seed rate if they correctly answered that the best spacing is two and a half feet between rows and one foot between plants, with one seed per hill. Second, respondents are considered knowledgeable about combining practices if they correctly answered that they would allocate 40,000 Ugandan shillings to buy improved seed and fertilizer, as combining inputs is a better strategy than putting all the eggs in one basket. Third, respondents are considered knowledgeable about optimal weeding if they correctly answered that weeding is most important during the first four weeks after planting. Fourth, respondents are considered knowledgeable about fall armyworm (*Spodoptera frugiperda*) control if they correctly answered that spraying in the evening is most effective since fall armyworm feeds during night. The information needed to correctly answer the first three questions was provided in the videos. The videos did not provide information on fall armyworm control, hence no effect was expected for this question.

knowledge index.

Agricultural decision making is based on the female co-head's answers about who made a series of five decisions related to household maize production. We differentiate between decisions that the female co-head reports that were made individually by herself, decisions that the female co-head reports that were made unilaterally by the male co-head, and decisions that the female co-head reports she made jointly with her spouse. For each maize plot within the household, we thus recorded if the following decisions were made by the female co-head, jointly or by the male co-head: whether to plant maize on the plot; when to start planting the maize on the plot; what spacing of maize plants to use and how many maize seeds per hill to plant on the plot; what strategies to use to control striga on the plot; and when to start weeding on the plot. To aggregate this at the household level, we consider, for each of these five decisions, the proportion of maize plots within the household on which the female co-head reported that she made the decision alone, that the decision was taken jointly with her husband, or that her husband took the decision alone. As a summary for individual co-heads and joint decision making, we constructed a women's decision-making index, a men's decision-making index, and a joint decision-making index based on the five decision-making outcomes aggregated at the household, again following Anderson (2008).

Decision making is central to women's empowerment. However, we also want to check if the practices and inputs that were recommended in the video were also implemented on the plots. For instance, it may be that, due to the video, women gain voice in the decision making process, but if additional investments are needed (for instance in terms of labour time or inputs), they may still be constrained and decide to use a second best technology. We thus also consider the proportion of the household's maize plots for which the female co-head decided

about a particular practice alone and adopted the practice that was recommended in the video. Similarly, we consider the proportion of the household's maize plots for which the female and male co-head decided and adopted a recommended practice jointly, as well as the proportion of household's maize plots for which the male co-head decided unilaterally and adopted the practice that was promoted in the video.[5] We measure adoption of the following practices as recommended in the video: planting within one day after the start of the rain; using the recommended spacing and number of seeds per hill; removing striga before it flowers; and doing the first weeding 18 to 20 days after planting. As before, we use the same method to construct a women's adoption index, a joint adoption index and a men's adoption index.

We measure use of inputs such as DAP (*Diammonium phosphate*), urea, organic fertilizer, maize hybrids, and open pollinated varieties (OPVs). Similar to adoption of recommended practices, we consider the proportion of the household's maize plots for which a particular input was used and this was decided individually by the female co-head. Similar outcomes for input adoption were constructed for joint input adoption and for unilateral adoption by the male co-head. Also here, adoption of different inputs is aggregated in a women's input use index, a joint input use index, and a men's input use index respectively.

Finally, we measured outcomes related to production, area of production, and productivity on maize plots under female, male and joint management. Female-managed (male-managed jointly managed) plots are defined as plots on which, according to female co-head respondents, female co-head alone (male

[5]It is important to note that our intervention may have changed both the likelihood that a co-head makes a decision as well as the likelihood that the decision maker then adopts what was recommended in the video. As both events are not independent, this means that, for instance, the estimated joint likelihood that the female co-head decided about a practice and adopted it corresponds to the conditional probability that a recommended practice is adopted by the female co-head multiplied by the probability that the female co-head individually made the decision on the practice. This should be kept in mind when comparing effects of adoption to effects of decision making.

co-head alone, female and male co-heads jointly) took at least three out of the five decisions listed above. We use the total amount of maize produced on female–managed maize plots within the household as our measure of production. The area of production is the total area (in acres) of female-managed maize plots in the household. Yield (in kg per acre) is the total amount of maize produced on female-managed plots divided by the total area of the female-managed maize plots in the household. A secondary, more subjective indicator for yield effects is an indicator variable that takes the value of one if the female co-head indicates that the yield on at least one of the maize plots under her management was greater than in a normal year. We also defined similar indicators for male-managed plots and for jointly managed plots. This family of outcomes is again summarized in production indices (one for female-managed, one for male-managed and one for jointly managed plots).

3 Results

In this section, we present the impact of the treatments on women's, men's and joint knowledge, decision making, adoption and production. We look at the impact of the information targeting treatment first, and then at the impact of the role model treatment. In both cases we report results for the two treatment levels:female co-head/actor alone or joint versus male co-head/actor alone. We consider interaction effects separately.

3.1 The impact of targeting information

Figure 2 summarizes the effect of targeting video-mediated agricultural information to specific individuals within the household (as compared to the status quo where only the male co-head within the household receives the information). The figure reports standardized coefficient estimates and corresponding

confidence intervals.[6] In particular, in the left panel, coefficient estimates corresponding to β^W in equation 1 are shown; in the second panel, coefficient estimates for β^J are shown. As mentioned in section 2.4, we examine effects on women's outcomes, men's outcomes, and joint outcomes separately, hence we have three estimates for each outcome in each treatment.

Judged by the overall index, the left panel of the figure shows that exclusively targeting female co-heads with information within the household (as opposed to targeting only the male co-head) significantly increased women's outcomes, while it significantly reduced men's outcomes. Joint outcomes were not affected by this shift in information targeting from the male co-head to the female co-head. This result is largely driven by important effects on decision making, with large reductions in male unilateral decision making and an increase in female unilateral decision making in all decision-making areas we measured.

The shift in decision making as a result of directly targeting female co-heads with information instead of male co-heads seems at least partly the result of a knowledge effect. The figure shows that women scored significantly better on the multiple choice question that tested knowledge related to recommended spacing and seed rate: while in the group of households where male co-heads were shown the video less than 13 percent of women indicated the correct option, this increased to more than 19 percent when female co-heads alone were targeted with information. When male co-heads were targeted with the information, about 26 percent of them knew the correct answer, and this reduced to 14 percent if the information was provided exclusively to female co-heads. A similar pattern is found for knowledge about the recommendation to combine practices, although baseline knowledge levels were higher and impact of the recipient treatment was smaller. Joint knowledge was not affected by targeting

[6] Indices are standardized by design (see Anderson (2008)), individual outcomes are standardized by the control group standard deviation. Non-standardized coefficient estimates can be found in a series of Appendix Tables (A1-A5).

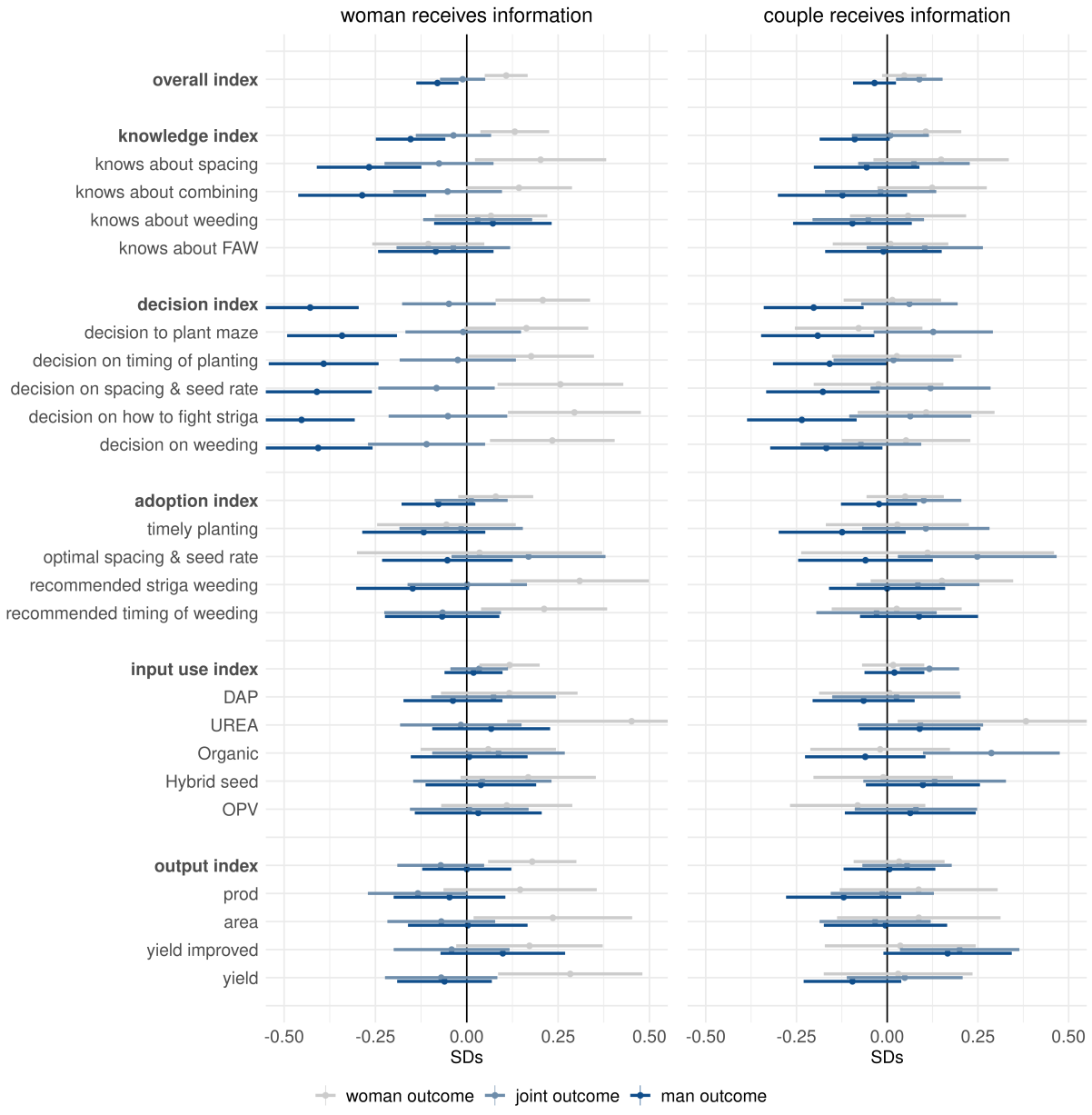

Figure 2: Impact of targeting information

female co-heads instead of male co-heads as the recipients of information. As expected, we also find no impact of the intervention on knowledge related to how to deal with fall armyworm, as this was not covered in the video. See Appendix Table A1 for detailed results.

Women gain individual agricultural decision-making power when information is exclusively targeted to them. The left panel in Figure 2 show a positive impact on women's decision-making index and all its components. The largest effect is found for the decision about what to do against striga: in the control households where male co-heads were shown the video, women decided on only 11 percent of maize plots within the household on strategies to combat the striga infestation. This increased to 20 percent of the maize plots within households where female co-heads were exposed to the agricultural extension video alone. We register even larger reductions in men's unilateral decision making as a result of targeting female co-heads alone instead of male co-heads: continuing with the example of decisions related to fighting striga, we see that in the comparison group men decided on 30 percent of the maize plots within the households. This reduces by almost 20 percentage points in the subgroup of households where female co-heads were shown the video. Joint decision making remains unchanged. See Appendix Table A2 for more details.

The change in intra-household decision making as a result of targeting information to female co-heads alone does not seem to fully translate into actual adoption of the agronomic practices that were recommended in the video, as is evident from the statistically insignificant effect on women's adoption index. However, empowering women with information seems to have increased the likelihood that they adopted improved inputs unilaterally. In particular, we find a of significant increase in the use of urea and hybrid seed, albeit from a very low base. The only cases where the shift in decision making about recommended

agronomic practices also translated into action is for the female-decided adoption of the recommended strategy to fight striga and the recommendation to start weeding about 18 to 20 days after planting. The fact that both of these practices are related to weeding may indicate that it is easier for women to adopt practices that are culturally more in line with prevailing norms and customs in agriculture. At the same time, the fact that women also increased their use of urea and hybrid seed seems to suggest that access to financial resources for buying inputs is not necessarily a constraining factor. More details are in Appendix Tables A3 and A4.

Turning to production outcomes, we again find a large impact of exclusively empowering women with information on women's production index. We find that, in the comparison group where male co-heads were targeted with information, women produced on average only 59 kg of maize on an average acre under their management. When female co-heads are targeted with information, yields more than double. The effect on production related outcomes is evident both at the extensive and the intensive margin, with women producing higher quantities of maize on larger plots (although total production quantity is too noisy for a precise coefficient estimate). Interestingly, exclusively targeting female co-heads with information does not seem to affect yields on male-managed nor jointly managed plots.See Appendix Table A5 for details.

When information is directed towards the couple (female and male co-heads together instead of only to the male co-head), we expect largest effects on joint outcomes. Judged by the overall index in the right panel of Figure 2, this seems to be the case. The significant increase in joint outcomes in agriculture is now primarily driven by an increase in jointly decided adoption of recommended agronomic practices and use of improved inputs. In particular, details on jointly decided adoption of recommended practices show that targeting the couple led

to a 2.7 percentage point increase in the share of households maize plots were recommended seed spacing and seed rate was used (and this was a joint decision). We also find a significant positive impact of targeting information to the couple instead of only to the male co-head on jointly decided use of organic fertilizer. While use of organic fertilizer was already higher when male and female co-heads jointly decide on its use rather than unilaterally, pointing out the importance of organic fertilizer to male and female co-heads together more than doubled the joint use of organic fertilizer. The positive effect on jointly decided adoption of recommended practices and inputs when the female and male co-heads receive the information together is consistent with Lambrecht et al. (2016) who found a positive impact of joint participation in an extension program on fertilizer adoption on jointly (and male-) managed plots. Details can again be found in Appendix Table A3

Somewhat surprisingly, the positive impact on jointly decided adoption and input use happened despite the fact that the treatment did not increase joint knowledge, nor joint decision making. Furthermore, the increased jointly decided use of organic fertilizer and adoption of optimal plant spacing and seed rate did not translate in higher production on jointly managed plots. We also see that targeting couples with information reduced the likelihood that male co-heads take decisions unilaterally. However, effect sizes are generally only half of what they are if the female co-head was targeted individually rather than the couple. Equality of coefficients is rejected for all decisions.

Taken together, the above results suggest that, to some extent, both female and male co-heads monopolize agricultural extension information. Involving female co-heads in receiving extension information (either alone or as part of the couple—Appendix Table A1 shows we can not reject the null that coefficients for targeting female co-heads and targeting couples are the same) increases women's

individual knowledge. This finding suggests that male co-heads do not necessarily pass the information to their spouse. The fact that men's knowledge is reduced when the information if targeted exclusively to female co-heads suggests that female co-heads also do not necessarily share information with their spouse.

The fact that we cannot reject the hypothesis that women's knowledge gains are similar regardless of whether the female co-head saw the extension video alone or together with her male co-head suggests that the presence of the male co-head in the exposure process does not influence her knowledge.[7] This also suggests limited discussion of the content of the video between female and male co-heads even when the video was shown to both of them as a couple. Hence, from a knowledge transfer point of view, if the aim is to increase women's knowledge, it seems most effective to exclusively target the female co-head.

Men's unilateral decision making is reduced as a result of involving women in receiving information, no matter if this happens by targeting the female co-head alone or together with the male co-head. If this reduction only occurred in the former case, men's reduced decision making could have been related to a lack of information. The fact that the reduction occurs in both cases suggests that men's unilateral decision making does not only decrease due to a lack of direct access to information. Apparently, the fact that women can also access information leads men to refrain from unilateral decision making. This may mean that men change their opinion on the role of women in the decision-making process.

Women seem to gain in maize production outcomes if they receive agricultural extension information alone. However, these effects are not there if the

[7]Interestingly, unlike for the female co-head, the presence of the spouse in the exposure process does influence the knowledge of the male co-head, who appears to learn somewhat less when information is provided to the couple than when this information is targeted to him alone, although the reduction is only significant at the 10 percent level and only for the knowledge index (see Appendix Table A1)

information is given to the couple. This suggests that a woman's monopoly over information is essential for her individual achievements in terms of maize production. The fact that giving the information to the couple instead of only the male co-head increased women's agency in terms of joint decision making and jointly decided adoption but not joint achievements in terms of maize production implies that, despite women's greater (joint) agency, these joint achievements are not different from what men individually achieve.

A question that remains is the extent to which the increased efforts by women that result from exclusively giving them extension information, in terms of applying the recommended practices and inputs and larger areas of maize cultivation under their management, augment their work burden. Indeed, we observe that the time women spent on preparing fields and weeding went up by 1.4 and 3.3 person-days/maize season, respectively, as a result of providing only the female co-head with information (instead of only the male co-head). Women appear to increase the adoption of labor-based improved agronomic practices such as weeding and fighting striga. This suggests the need for further research on the labor and drudgery implications of these outcomes and the need to reflect upon making less labor-intensive improved agronomic practices accessible to women.

3.2 Role model effects

Figure 3 summarizes the effect of showing a video where the information is given by a female actor (left panel) or by a male and female actor acting as a couple (right panel). The comparison group here is a video where all information is provided by a male actor alone. The left panel now shows (standardized) coefficient estimates corresponding to γ^W in equation 1; in the right panel, coefficient estimates for γ^J are shown. More details can be found in Appendix

Tables A6 to A10.

Due to a combination of role model, peer and gender homophily effects, we had expected that women would learn more if women (also) provide the information. We had also expected that female role models would increase aspirations leading to more agency on the part of women and action in the sphere of adoption, and this would eventually be reflected in women's production related outcomes. The left panel of Figure 3 shows no overall impact of the treatment where a female actor is the messenger (as opposed to the treatment where a male actor is the messenger). We do not see effects on any of the outcome family indices. Some individual effects, such as increased male knowledge about seed spacing and subjective positive yield assessments on jointly managed plots, turn up significant, but there is no clear pattern.

We had also hoped that showing a female and male actor as a couple in the video would encourage more cooperation within the household. However, the right panel of Figure 3 shows outcomes are also not significantly different in the subgroup of households where a couple gave the information (as opposed to outcomes in households where a male actor gave the information). There are, however, negative effects on men's unilateral decision making, which may make way for more involvement of women in decision making and action.

3.3 Interaction effects

Up to now, we have only considered main effects, looking at each treatment while controlling for the orthogonal treatment. However, for some outcomes and hypotheses, interaction effects may be more relevant. For example, while we may not find that women learn more if the messenger is a woman in general, there may be a significant effect in the subgroup where a video with a female actor as a role model was targeted to the female co-head alone. Or, providing

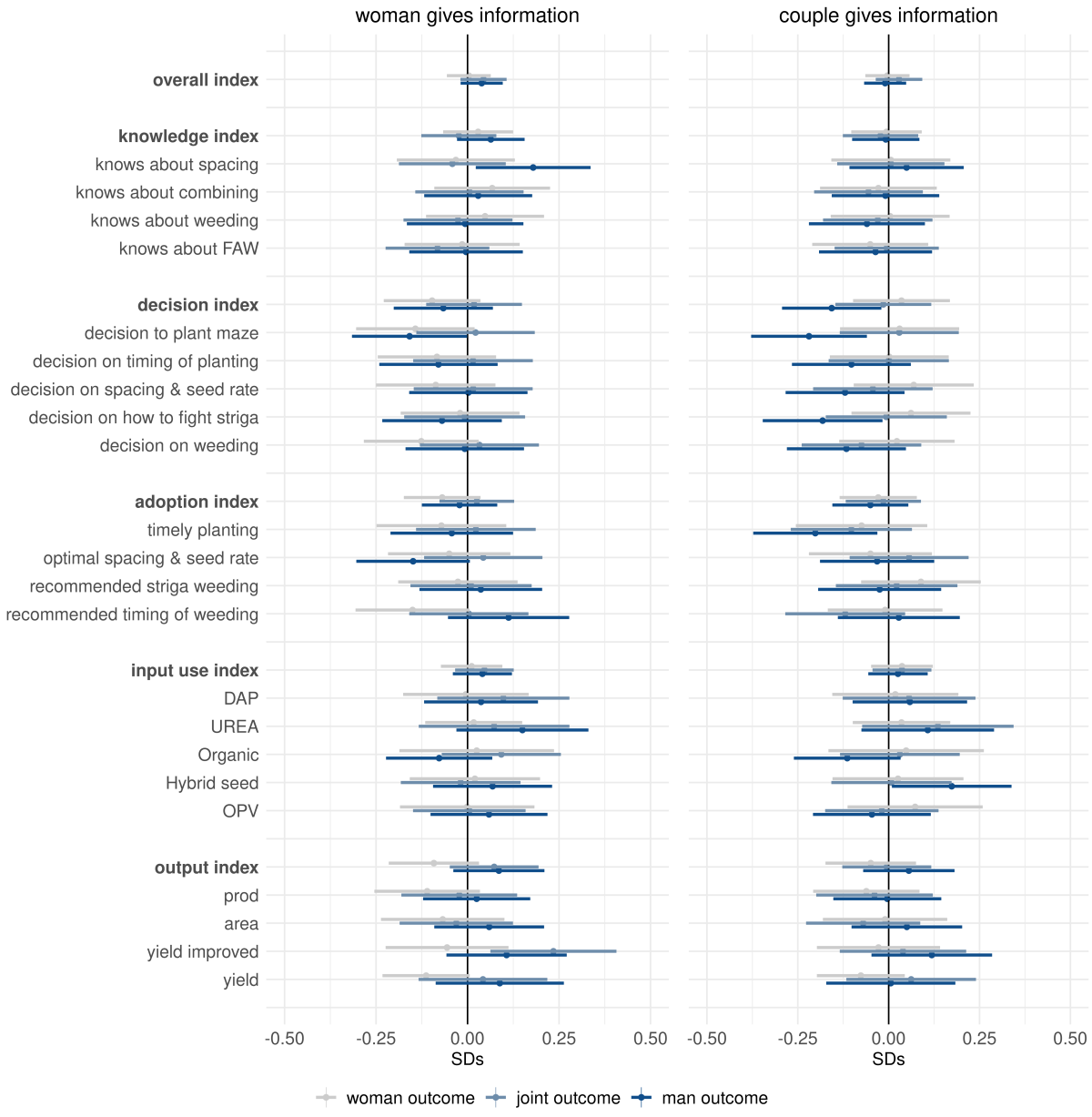

Figure 3: Impact of targeting information

information to a couple may only translate in increased joint decision making if the video also demonstrates that women are equally capable maize farmers, for instance by having a female actor (also) explain and demonstrate the recommended practices. Therefore, in this section, we report some of the more striking interaction effects ($\delta^{T_R T_M}$ in Equation 1). We only report results of outcome indices. To conserve space, we do not report the estimates in tables, but the results are available upon request.

When considering the overall index, none of the interaction effects are significant. Zooming in on the knowledge indices, we find interaction effects are also not significantly different from zero. This may indicate that for learning, there are no gender homophily effects and women learn equally well from men than women.

With respect to decision making within the household, we have seen above that men take less unilateral decisions in households where the messenger is a couple. We also find a significant positive interaction effect between the recipient being a women and the messenger being a couple, offsetting the negative couple messenger effect. The interaction effect between the recipient being a couple and the messenger being a couple is not significantly different from zero. This pattern, where a couple role model reduces male unilateral decision making only if the male co-head was exposed to the role model, is consistent with indirect effects of involving women as role models that challenge men's beliefs and stereotypes about their female co-heads' role in agriculture.

While we find no overall effects of female role models on female decided adoption of recommended practices, we do find a significant interaction effect of the messenger being a woman and the recipient being a woman on female decided adoption of recommended practices. The interaction effect of the messenger being a woman and the recipient being a couple on female decided adoption of

recommended practices is also positive and significant, but only at the 10 percent level. This suggests that female role models, peer and/or gender homophily effects are important for adoption of recommended practices decided upon by women. We do not find significant interaction effects for input use, nor for production related outcomes.

4 Conclusions

In smallholder agriculture in developing contexts, women often perform a lot of the work, yet have little say in which crops to plant, what technologies and inputs to use. Targeting women with relevant information in formats that are appealing and accessible to them have been found to increase empowerment in a variety of settings, and so providing extension information tailored to women may be an effective way to increase their voice in agricultural production. However, public agricultural advisory services, the main source of agricultural information in many developing countries, remains severely male biased, with predominantly male extension officers targeting the main decision maker within the household, which is assumed to be the male co-head.

In this paper, we test how gender related attributes of information and communication technology (ICT)-mediated agricultural extension information campaigns affect individual household member's informational capital, their agency, and their achievements in farming. We do this through a field experiment in the form of a factorial design that was run in eastern Uganda. Working with monogamous maize farming households, in one treatment, we assess the importance of the gender of the person within the household who is targeted with information for women's, joint and men's knowledge, decision making, adoption of recommended agronomic practices and inputs, and production related outcomes. In a cross treatment, we test if the gender of the person who provides

this information makes a difference on the same outcomes.

The ICT-mediated agricultural extension information intervention is implemented using short videos shown twice to farmers. In these videos, farmer-actors explain and demonstrate various strategies and practices to intensify the production of maize. In a 3^2 factorial design, as a first treatment, three constellations of recipients of information in the household were randomized: the male co-head alone, the female co-head alone, the male and female co-heads together as a couple. As the second, crossed treatment, three versions of essentially the same video were randomized across farming households: one version portrays a male farmer, another a female farmer, the third a couple formed by male and female actor-farmers.

The results of this study clearly show that significant advances in women's empowerment in agriculture in terms of knowledge, decision making, input use and achievements in terms of maize production can be made by giving women direct and exclusive access to ICT-mediated agricultural extension information. Providing information to the couple leads to increased jointly decided use of improved inputs and recommended practices. Furthermore, the results of this study suggest that women as role models, through peer effects, gender homophily effects, and/or through challenging role incongruity, influence women and men in different ways. In particular, men's unilateral decision making seems to reduce when they are shown a video where both a man and a woman give information as a couple and are portrayed as equally important actors in successful maize farming instead of a video with a man as messenger and role model. Women are more likely to adopt recommended practices when they receive extension information explained and demonstrated by a woman.

Our study reveals that, consistent with non-unitary household models, information is not fully shared between household members. As a result, targeting

particular individuals within the household has real effects. This is something that needs to be recognized by generic agricultural extension systems that, often for reasons of convenience, mainly inform the male co-head within the household. We further find some evidence that including women as role models affects outcomes in agriculture, both directly by increasing aspirations of women and indirectly by challenging the idea that maize growing is a male activity.

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