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Accelerating Technical Change through Video-Mediated Agricultural Extension

Evidence from Ethiopia

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Notices

ABSTRACT

Despite a rapidly growing enthusiasm around applications of information and communications technologies (ICTs) to smallholder agriculture in developing countries, there are still many questions on the effectiveness of ICT-based approaches. This study assesses the effects of video-mediated agricultural extension service provision on farmers' knowledge and adoption of improved agricultural technologies and practices in Ethiopia. The study focuses on a program piloted by the Government of Ethiopia and Digital Green and poses three questions. First, to what extent does video-mediated extension lead to increased uptake of improved agricultural technologies and practices by smallholder farmers? Second, is video-mediated extension targeted at both spouses of the household more effective than when only targeted at the (typically male) household head? Third, how cost-effective is a video-mediated approach to extension provision? The study explores these questions with a randomized controlled trial designed to evaluate the video-mediated approach as applied to three priority crops (teff, wheat, maize) and three technologies (row planting, precise seeding rates, and urea dressing). The trial was implemented in 347 *kebele*s (village clusters) during the 2017 *meher* (rainy) season in Ethiopia's four most agriculturally important regional states. Analysis of data from our surveys of 2,422 households and 896 extension agents indicates that the video-mediated approach is more effective than the conventional approach in achieving several key outcomes. Specifically, we find that video-mediated extension reaches a wider audience than the conventional approach and leads to higher levels of agricultural knowledge and uptake of technologies in those *kebele*s randomly assigned to the program. While our results do point to greater participation and greater knowledge of female spouses in *kebeles* where both male and female spouses were targeted by the program, we do not find clear evidence that the more inclusive approach translated into higher uptake of the subject technologies and practices. Finally, we find that the video-mediated approach becomes less costly as the scale of operation increases.

Keywords: Agricultural extension, information and communications technologies, video-based extension, crop management, Ethiopia

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1. INTRODUCTION

Despite a rapidly expanding body of analytical insight on applications of information and communications technologies (ICTs) to smallholder agriculture in developing countries, there are still many questions about the effectiveness of novel ICT-based approaches (Nakasone and Torero, 2016; Aker, 2011). This is particularly the case with ICT-mediated agricultural extension and advisory services that aim to improve the ways in which farmers manage crops, livestock, and natural resources. While several prior studies have explored the impact of simple, low-cost text and voice messaging services provided to farmers via mobile phones, more sophisticated approaches have received far less attention. These include the use of videos to convey information to farmers using intermediaries such as community organizers, lead farmers, or extension agents, and intermediation tools such as portable projectors and tablet computers.

The video medium offers several advantages over traditional information dissemination approaches used by extension agents and other intermediaries. First, video can be tailored and customized to localized information needs via the strategic use of languages, actors, music, settings, and other variables that may appeal directly to the viewing audience. Studies in both economics and psychology suggest that information targeted to an individual's specific needs is more effective than broader messaging, and that videos featuring role models similar to viewers across multiple dimensions of character or identity reinforce persuasiveness (see Bernard et al. (2015) for a review). Second, video can allow for consistent content delivery, thereby reducing errors in conveying sensitive detailed information such as crop timings, input quantities, or other variables that require more accuracy than an extension agent may be able to retain and communicate correctly. Third, videos can be produced at a relatively low fixed cost, which increases the approach's cost effectiveness as the number of viewers increases. Thus, whether used alone or in tandem with conventional extension approaches, video can be a powerful medium.

The present study seeks to complement this evidence by assessing the effect of video-mediated extension on farmers' agricultural practices in Ethiopia. We use Digital Green's scaling-up efforts with the Ethiopian Ministry of Agriculture (MoA)[1] and regional bureaus of agriculture to generate insights into the impact of the video-mediated extension approach relative to the conventional extension approach, with a randomized controlled trial (RCT) implemented in 347 *kebeles*[2] during the 2017 *meher* (rainy) season. The trial was conducted in four regional states of Ethiopia that together account for most of the country's agricultural production.

The study aims to contribute evidence in support of ongoing reforms within Ethiopia's extension system—reforms that have been pursued as both small experiments and large programmatic changes during the past three decades (Davis et al., 2010). A pillar of these reforms has been the large increase in the number of agricultural extension agents (Development Agents (DAs)) deployed to advise farmers: over the past 10-15 years, approximately 90,000 DAs have been trained and 18,000 Farmer Training Centers (FTCs) constructed to support these efforts. This investment reflects the Government of Ethiopia's effort to accelerate agricultural growth, a commitment set forth under the broad umbrella of Ethiopia's Growth Transformation Plan (GTP), the country's guiding strategy for economic growth and poverty reduction.

Our results show clear evidence that, relative to the conventional approach, Digital Green's video-mediated extension approach led to increases in extension's reach and greater knowledge among farmers about several improved agricultural technologies and practices that feature prominently in MoA's extension program and those of the regional bureaus of agriculture. Specifically, we find that video-mediated extension reached a wider audience than the standard extension approach, likely due to increased interest by farmers in the medium. In turn, we find a higher level of knowledge—greater technical understanding of the focal agricultural technologies and practices—among farmers in those *kebele*s selected for video-mediated extension.

Our results also show clear evidence that the video-mediated extension approach led to increases in the uptake of improved agricultural technologies and practices by farmers. Following government priorities, we focus on three main crops (teff, wheat, and maize) and three technologies (row planting, precise seeding rates, and urea side and top dressing). For each crop,

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[1] During the past 20 years, the official name of the Ministry of Agriculture has changed to include mention of mandated topics such as rural development, natural resources, and livestock resources. At the time this paper was prepared, the official name had reverted to the Ministry of Agriculture.

[2] *Kebele* is the smallest administrative unit in the country, typically covering 10 to 25 villages.

we find that video-mediated extension led to a 3 to 10 percentage point increases in uptake of key technologies. Compared to control group levels, these increases represent up to a 35 percent increase in uptake of a given technology for a given crop.

While our results also point to greater participation and greater agricultural knowledge of spouses who also received the video-mediated extension, we do not find clear evidence that targeting both spouses translated into higher uptake of technologies. We also find no immediate evidence of video-mediated extension on higher-order outcomes such as crop yields, output, or area under cultivation, although these will be the subject of further analysis as additional data are collected.

The remainder of this paper is organized as follows. Section 2 provides background and context for this study and presents the main research question, focusing on the potential effect of video-mediated extension provision based on prior studies and the links between gender and extension services. Section 3 presents the experimental set-up of the study: the interventions, experimental design, sampling, timing, experimental integrity, and empirical strategy. Section 4 presents estimates of the intervention's main impacts, followed by a discussion of the cost-effectiveness analysis in Section 5. Section 6 examines the policy implications of these findings, avenues for future research, and concluding thoughts.

2. BACKGROUND

ICTs, extension, and developing-country agriculture

Our study contributes to the emerging literature on the role of ICTs in developing-country agriculture, specifically where it intersects with the wider literature on the role of human capital, learning externalities, and information delivery in agricultural development (e.g., Foster and Rosenzweig, 1995; Hanna et al., 2014). To date, most studies in this subset of the literature have focused on evaluating simple, low-cost text and voice messaging services provided to farmers over mobile networks, and more often for price-related information (see Nakasone and Torero (2016) and Aker (2011) for reviews). Fewer studies examine the role of ICTs in the provision of production-related information and advice. Exceptions include the use of short message services containing information on crop management advice and weather forecasts in India (Fafchamps and Minten, 2012), integrated pest management practices in Ecuador (Larochelle et al., 2017), agronomic advice in India (Cole and Fernando, 2014) and advice on timing of sugarcane farm operations in Kenya (Casaburi, et al., 2014); animated videos on post-harvest management in Burkina Faso (Maredia et al., 2017) and insecticidal neem use in Benin (Bello-Bravo et al., 2018); and interactive crop advisory services via mobile phones in India (Fu and Akter, 2012). Results from these studies vary from no effects of the ICT-based approach on production and yields (Fafchamps and Minten, 2012) to significant changes in input and technology use (Cole and Fernando, 2014).

To the best of our knowledge, only two studies have sought to measure the relative effectiveness of using videos to promote agricultural technologies and practices with any degree of rigor. Both were conducted in partnership with Digital Green, a non-governmental organization specialized in video-mediated extension approaches. In 2007, a small-scale trial conducted in India found that combining a training-and-visit extension approach with Digital Green's approach to be ten times more cost-effective in promoting farmers' adoption of technologies compared to the sole reliance on the training-and-visit extension approach (Gandhi et al. 2007). This was followed by a large-scale randomized controlled trial covering 420 villages in the Indian state of Bihar to assess the effectiveness of the Digital Green approach in promoting System of Rice Intensification (SRI) practices among smallholder farmers. Findings indicate that the probability of adoption increased by 5 percentage points for those who viewed Digital Green videos, which is a 50 percent increase over the 10 percent adoption rate observed in the control group (Vasilaky et al., 2015).

Our study extends this work by presenting new evidence on the use of localized videos to convey information to farmers, to augment extension services, and to effect changes in crop management decisions—a combined topic of study that has received relatively little attention in this growing literature. In doing so, it shifts the focus of inquiry from India, where a broad range of ICT applications to smallholder agriculture have received considerable attention, to Ethiopia, where mobile phone penetration and internet connectivity ranks among the lowest in Africa, but where the public extension system has a large footprint across the country.

Ethiopia's extension system

Ethiopia's extension system—one of the largest in Africa today—has seen its reach and methods evolve considerably during the past four decades (Bachewe et al., 2017; Berhane et al., 2018; CSA, 2017; Davis et al., 2010). The system currently employs over 70,000 extension agents, with approximately 43 development agents (DAs) per 10,000 farmers, and hosts more than 15,000 farmers training centers (FTCs) that serve as a focal point for agricultural development activities at the local level, and 25 Agricultural Technical Vocational Education and Training (ATVET) institutes that prepare and update extension staff in both general and specialized fields of expertise (Berhane et al., 2018; ATA, 2014; Davis et al., 2010).

Agricultural extension services in Ethiopia were formally introduced in 1953/54 with just two extension agents attached to the newly established Imperial Ethiopian College of Agriculture and Mechanical Arts, now known as Haramaya University (Gebremedhin et al., 2006; Kassa, 2002). It was not until the socialist regime (1974-1991) that the mandate, role, and scale of Ethiopia's extension service broadened significantly (Kassa, 2002). Table 1 summarizes the scale, reach, and approaches used during Ethiopia's modern history.

In the mid-1980s, Ethiopia's extension system adopted the training-and-visit approach that focused on training and using "contact" farmers to reach other farmers with the community (Kassa, 2002).[3] By the mid-1990s, this approach had evolved into the Participatory Demonstration and Training Extension System (PADETES) approach, which expanded the role of local demonstration trials on new technologies and practices, and led to an increase in the number and reach of DAs and the construction of farmer training centers at the *kebele* level (Kelemework and Kassa, 2006; Kassa, 2002, 2003). By about 2010, the extension system transitioned to a Participatory Extension System (PES) approach, highlighted by the organization of farmers in local development groups and "one-to-five" syndicates to promote localized information sharing and peer learning effects.

Yet it is often difficult to draw a robust causal link between an extension system's size and approach, on the one hand, and outcomes such as technology adoption, productivity growth, or poverty reduction, on the other hand. Prior studies on Ethiopia suggests a somewhat ambiguous link between the extension system's size and approach, on the one hand, and outcomes such as technology adoption, productivity growth, or poverty reduction, on the other hand (Dercon et al., 2009; Nisrane et al., 2011; Spielman et al., 2011; Krishnan and Patnam, 2014; Abay et al., 2018). Specifically, studies of Ethiopia's extension system tend to suggest

[3] See Feder et al. for a critical review of the origins and evolution of the training-and-visit (T&V) extension system.

only a weak relationship between the technical support provided by DAs to farmers and productivity growth: yield effects are more likely a function of extension's role in supplying physical inputs such as inorganic fertilizers and improved cultivars than improving farmers' awareness, understanding, and ability to innovate and adapt with better farming practices, marketing tactics, and risk management strategies (Berhane et al., 2018; Dercon et al., 2009). While these findings may seem surprising given the scale and reach of Ethiopia's extension system, a deeper analysis of the system suggests that this is entirely plausible given the organizational culture, daily practices, technical and functional skills, and professional incentives facing Ethiopia's extension (Leta et al., 2017; Davis et al., 2010; Gebremedhin et al., 2006; Kassa, 2002).

In fact, despite changes in the extension approaches and methods described above, the actual role of DAs seems not to have changed substantially in Ethiopia. DAs have been continuously involved not only in providing advice and training to farmers, but also in estimating seed and fertilizer requirements, estimating crop production, and in other responsibilities less directly associated with extension service provision (Kassa, 2003). Berhane et al. (2018) indicates that only about 35-50 percent of DAs' work time was spent on training and advising farmers, while the remainder of their time was spent on activities such as supplying inputs, managing loan repayments, collecting taxes, mobilizing communities, and supervising road construction.

In fact, the official title given to extension agents—"development" agents—suggests a wider mandate and role for DAs beyond the provision of extension services to farmers, even though DAs are placed under the administration of regional bureaus of agriculture and are trained under curricula developed by the MoA. But irrespective of their title and role, there seems to be keen interest in strengthening their skills and professionalizing their service throughout Ethiopia. And this is where ICTs enter the picture.

Table 1. Estimated extension agent numbers, coverage, and approaches under different regimes in Ethiopia, 1953/54 to 2017/18

Year	Estimated no. of extension agents	Estimated no. of farm households reached	Main extension approach	Main characteristics
The imperial period (pre-1974)				
1953/54	2	Two extension posts (Assela and Fitche)	Community development (Demonstration, field day)	Two extension agents were hired by IECAMA, the forerunner in the provision of national agricultural extension services
1963-1967	132	77 extension posts	Package approach (demonstration, adult educational meetings, agricultural youth clubs)	The mandate of agricultural extension services transferred to the Ministry of Agriculture; introduction of the comprehensive package approach
1971-1974	>275	346 extension posts (>15,000 households)	Package approach (field day; model farmers; individual farmer extension approach)	Introduction of the first Minimum Package Program – I (MPP-I), the first nationwide extension program
The socialist period (1974-1991)				
1980-1985	2,090	About 1.91 million^{+} (440 out of 580 *woreda*s (districts) covered)	Package approach (peasant associations and producers' cooperatives)	Implementation of the second Minimum Package Program – II (MPP-II); Extension service responsibility was given to the commodity based specialized departments
1986-1990	n/a	1.829 million^{+}	Modified Training and Visit extension approach (contact farmers)	Peasant Agricultural Development Program (PADEP) replaced the MMP-II
Post-1991 period				
1995/2001	>14,000	35 thousand in PADETS areas; 4.2 million in total	PADETES (on-farm technology demonstration plots)	Participatory Demonstration and Training Extension System (PADETES) based on pilot extension program of the SG-2000 package approach
2009/10	45,800	9 million	Menu-driven household package approach (FTCs; farmer groups)	Participatory Extension System (PES); organization of farmers in development groups and one-to-five syndicate
2017/18	72,000	12.7 million*	Menu-driven household package approach (FTCs; farmer groups)	Participatory Extension System (PES); organization of farmers in development groups and one-to-five syndicate

Note: * indicates that the figure is a 2016/17 estimate; $^{+}$ indicates that the estimate is based on the number of farmers that adopted the extension package.
Source: Authors, compiled from CSA (2017, 2016); Davis et al. (2010); Wubneh (2007); Gebremedhin et al. (2006); Kassa (2003; 2002); World Bank (1988; 1980); and MoA (various years).

Video-mediated extension

In an effort to give DAs new tools that might hasten a shift to a more effective knowledge-driven extension system, Digital Green and the Government of Ethiopia piloted a video-mediated approach to extension in 2014. The approach aimed to increase the growth rate of yields and output for major food staples by encouraging farmers to adopt productivity-enhancing agricultural technologies and practices. It was expected to both augment and accelerate the adoption process at a relatively low cost per farmer by integrating locally produced content in local languages and featuring local actors with Ethiopia's existing extension infrastructure. An early assessment of Digital Green's approach in Ethiopia based on monitoring data from the pilot phase suggests considerable potential in the approach—particularly in its ability to provide localized content and reach women farmers (Bernard et al., 2016).

Based on the strengths of results from the pilot phase, Digital Green is currently scaling up its operations in Ethiopia to 68 *woredas* (districts). This scaling-up effort provides an opportunity to provide rigorous insights and evidence on the effectiveness of Digital Green's video-mediated extension approach.

There are two independent reasons that make the use of localized video content effective (Bernard et al., 2016). The first reason is relatively straightforward: locally produced content can be tailored to the specific information needs of local individuals and communities. Several studies demonstrate the importance of locally relevant information, drawing attention to evidence from studies in the economics on education (Jensen, 2012), entrepreneurship (Jensen, 2010) and agriculture (Hanna et al., 2014). Psychologists similarly find a positive relationship between locally relevant information and public health (Bull et al., 1999; Marcus et al., 1998), weight gains (Campbell et al., 1994), smoking habits (Prochaska et al., 1993; Shiffman et al., 2000), and education (Kim and Keller, 2008).

The second reason relates to the idea that persuasion—the ability of an intervention to change behaviors toward some desired outcome—depends on the way messages are framed so that individuals can relate to it. In particular, people tend to receive, accept, and internalize messages better from those whom they recognize as similar to them. Social psychologists suggest that attitudes and behaviors are strongly affected by the experience of others in one's immediate environment (Bandura, 1977, 1986). With video content, exposure to role models with whom a viewer identifies can substitute for an individual's experience or the experience of actual peers and may be a particularly powerful way of framing a message to promote attitude and behavior change.

For example, Chong and La Ferrara (2009) and Jensen and Oster (2009) show that exposure to TV soap operas featuring strong women and smaller families led to reduced fertility and increased women's autonomy in Brazil and India, respectively. Other studies rely on videos purposefully designed to convey specific messages on issues such as financial literacy (Berg and Zia, 2013), or HIV prevention (Banerjee et al., 2018). Others rely on videos with more aspirational messages. In Ethiopia, Bernard et al. (2014) show that screening short documentaries featuring rural individuals who affected their life outcomes through perseverance and hard work led to significant changes in viewers perception and future-oriented behavior. In Uganda, Riley (2017) shows that screening an inspirational movie among secondary school students that contained a locally relevant theme and strong role model significantly improved educational attainment.

Overall, the literature from both economics and psychology suggest both information targeted to an individual's specific needs is more effective than broader messaging. Both literatures further suggest that videos featuring role models similar to viewers across multiple dimensions of character or identity reinforce persuasiveness. These insights provide fertile ground for applications of the video medium to agricultural extension and advisory services.

Gender and extension

These insights also open the door to consideration of the gender dimensions of extension and advisory services. The specialization of labor along gender lines in agricultural households is often used to justify targeting the dissemination of certain technologies to men (e.g., production technologies for cereal crops) and others to women (e.g. nutrition and health-related technologies). This implicitly assumes that, for a given technology, the spouse of the targeted individual is not involved in the adoption decision or does not contribute labor to the implementation of the technology.

However, there is plenty of evidence to suggest that few technologies and practices can be reduced and assigned as "male" or "female" for a given household. There is also ample evidence suggesting that adoption of many technologies, whether related to agriculture or nutrition, is more an outcome of intra-household decision-making processes (e.g. Udry, 1996; Doss and Morris, 2001; Hoel et al., 2017). Such processes are, in turn, influenced by the extent to which spouses have access to similar information. Thus, targeting information to one spouse may contribute to lower-than-optimal adoption rates if the non-targeted spouse does not have the same level of information.

Yet despite their participation in providing labor and other inputs to production, and despite their influence on household decision-making processes, women often lack access to extension services in many developing countries. In a study on the adoption of improved maize technologies in Ghana, Doss and Morris (2001) find that women are less likely to adopt technologies, and that their low adoption rates are correlated with a lack of access to complementary inputs and information. In particular, they find that women receive more than four times fewer visits by extension agents than their male counterparts, although the authors recognize that this may be related to women having less access to land to start with. In eastern Democratic Republic of Congo, Lambrecht et al. (2016) study the relative impact of male versus female targeting of extension services on the adoption of improved legume varieties, row planting, and mineral fertilizer by farm households. Examining the correlation between adoption and the gender of the recipient of extension services, they find that that joint male and female program participation leads to the highest adoption rates in male-headed households, and that women's participation in extension is particularly conducive to adoption of labor-intensive technologies.

At this stage however, the literature on the potential impact of increasing women's access to extension services remains weak. In a recent paper, Doss (2015) revisits the argument that the social rates of return on investments in agricultural development are higher when those investments are targeted to women. Reviewing prior empirical studies, Doss (2015) finds only meager evidence to support these claims, not the least because none of the supporting studies rely on convincing identification strategies in their empirical specifications, in turn implying that the results are best interpreted as correlations but not causal relationships. Instead, she suggests that research should focus on identifying where the best returns to investments are found by relying on gender disaggregation as useful analytical categories since farming and food preparation are deeply gendered activities. Some evidence points to the importance of women not only as recipients but also as messengers of agricultural information—a policy experiment in

Mozambique by Kondylis et al (2016) finds that women's awareness and adoption of technologies is higher when the messenger of the information was female.

In Ethiopia, because women play an important role in agriculture, there is considerable scope to study the interaction between extension agents and women farmers. Women—not just women who head their own households but also women who are part of male-headed households—are potentially central to the adoption of new technologies and practices. Palacios-Lopez et al. (2015) estimate that women contribute 29 percent of the agricultural labor force in Ethiopia: 26 percent for land preparation, 26 percent for planting and weeding-related activities, and 37 percent for land preparation. Several recent studies have documented the effect of targeting agricultural extension to women on input use, technology adoption, productivity, and incomes, though often as a secondary topic of inquiry (see Ragasa et al. (2013) for a review). Yet numerous studies also point out that Ethiopian women have had historically limited access to extension services (Mogues et al., 2009; Ragasa et al., 2013; Buchy and Basaznew, 2017).

3. STUDY SETTING, DESIGN, AND DATA

Our study explores three broad research questions. First, to what extent does video-mediated extension lead to increased farmer uptake of improved agricultural technologies and practices by smallholder farmers? Second, is agricultural extension targeted at both spouses of the household more effective than when targeted at the (typically male) household head only? Third, how cost-effective is a video-mediated approach to extension provision?

We explore these questions in the context of Digital Green's rollout of the video-mediated extension approach in 68 *woredas* located in Ethiopia's four most agriculturally important regional states (Amhara; Oromia; Southern Nations, Nationalities, and Peoples (SNNP); and Tigray) during the 2017 *meher* (rainy) season that begins in May/June and continues through harvest beginning in November. The rollout was conducted in close collaboration with the MoA, the bureaus of agriculture in each regional state, and local extension staff at both the *woreda* and *kebele* levels. In this section, we describe the intervention as well as our experimental design, sampling strategy, timeline, and experimental integrity.

The intervention: video-mediated extension

To assess the effect of video-mediated extension provision, we compare how farmers respond to the same information on selected technologies and practices that is disseminated through two different approaches: the conventional extension approach and a video-mediated approach. The video-mediated approach is comprised of three interlinked components: producing localized video content, screening videos in DA-facilitated group sessions, and verifying the uptake of the selected technologies and practices in the field. We describe each of these components in detail.

Video production: The cornerstone of Digital Green's approach is the production of localized video content. Digital Green works with partners—subject matter specialists from the *woreda* extension office, DAs from a nearby *kebele*, local civil society organizations, and model farmers—to produce short videos on selected technologies and practices. The videos all feature farmers from the locality speaking in local languages and are filmed on a farm. Each video is 10-15 minutes long and designed to address a specific aspect of the technology, often at a specific time in the crop calendar, for example, land preparation, seeding and basal fertilizer application, and weed management. The information contained in these videos are typically those recommended by the MoA and the regional bureaus of agriculture and are often products of research conducted by the Ethiopian Institute of Agricultural Research and regional agricultural research institutes.

Video screening. Videos are screened by local DAs assigned to the *kebele* using USB-charged PICO projectors. Videos are screened to members of *kebele* development groups, which are semi-formal administrative structures within each *kebele* that comprises 25-30 farm households and are designed to provide community members with a grassroots forum to discuss local development issues. DAs assigned to a given *kebele* have access to these development groups as part of their day-to-day work, and screen videos with one or several groups in a manner designed to facilitate effective learning and discussion. Specifically, DAs screen the videos several times during the meeting, and pause the videos at certain intervals to entertain questions or provide additional details. DAs augment their facilitation with input from model farmers belonging to the development group(s). In each video, emphasis is placed on conveying what Digital Green describes as the "non-negotiable" elements of the technology package that must be adopted to achieve success. These screening sessions are conducted several times during the season, each time with new content that is synchronized with the crop calendar. In control *kebeles* where no video screening is conducted, DAs provide information to farmers through a combination of approaches, including individual farm visits, development group meetings, community gatherings, and FTC trainings, all of which are conducted directly or through model farmers, depending on the modality.

Adoption monitoring, and verification. DAs and Digital Green staff conduct follow-ups with farmers to verify their adoption of technologies and practices presented in the videos, either by querying farmers directly or by verifying adoption visually. This follow-up feeds into Digital Green's connect online-connect offline (COCO) system for project monitoring, evaluation, and learning (Bernard et al., 2016).

Subject technologies and practices. The three technologies and practices promoted through the video-mediated extension approach in this intervention have been topics of considerable research in Ethiopia.

Row planting—planting in row with spacing between plants and rows—is a recommended agronomic practice to ensure proper light interception, which is among the main factors that determine crop growth (Charles-Edwards, 1982). It also facilitates better weed management and ensure even distribution of seeds and thereby uniform access for plan inputs like water and nutrients (Fufa et al., 2011). Row planting has been shown to increase the number of plant tillers, number of kernels per spikes, and seed weight which contributes to increase in yields under research station trials (Berhe et al., 2011; Fufa et al., 2011; Lafond, 1994). However, recent farmer level experimental evidence on row planting for teff and wheat suggest much lower impact (Vandercasteelen et al., 2018; Abate et al., 2018). For maize, row planting has been promoted in Ethiopia for several decades and is a more established practice. Despite this, broadcasting seeds is not an uncommon practice among Ethiopia's maize farmers.

More precise seeding rates have been shown to increase yield by ensuring even distribution of seed and thereby reducing the competition between plants for water, light, and nutrients (Fufa et al., 2011. Reducing seed rate also allow for optimal trilling and increase the number of kernels per spike (Carr et al., 2003). More precise seeding rates are often associated with row planting: for teff and wheat, row planting requires lower seeding rates, while for maize it may actually require a higher seeding rate depending on how the farmer otherwise broadcasts maize seed. However, lower seeding rates for teff and wheat is also recommended for those farmers that broadcast plant.

Urea top or side dressing is another recommended practice associated with the strategy of multiple nitrogen applications, i.e., splitting nitrogen application to make efficient use of nitrogen fertilizer when it is difficult to precisely assess the mineral nitrogen content of the soil and predict the nitrogen requirement of the crop *ex ante* (Spiertz and De Vos, 1983; Baligar and Bennett, 1986). Top dressing or foliar urea fertilization, in particular, is promoted because it reduces potential nitrogen losses and has the ability to provide nitrogen when root activities are impaired, for instance, under dry conditions (Gooding and Davies, 1992). While row planting and more precise seeding rates are relatively novel practices for many Ethiopian teff and wheat farmers, they are more commonly practiced—though not universally—by Ethiopian maize farmer.

Several of these technologies have figured prominently in past efforts to accelerate productivity growth in cereal staples by the extension system, and by organizations such as Sasakawa Global 2000, a non-governmental organization that piloted the PADETES approach with the MoA during the 1990s. Others are more recent entrants into the landscape, gaining attention through the Ethiopian Agricultural Transformation Agency (ATA), which has actively promoted packages comprising these three practices (ATA, 2013). These include teff, wheat, and maize row planting, reduced (precise) seeding rate, and urea top or side dressing. We therefore expect to find differential effects of the intervention across the three crops.

Experimental design

This study uses a three-arm stratified cluster randomized controlled trial implemented in the four main regions in Ethiopia during the 2017 *meher* (rainy) season. Stratification was done at the level of the *woreda*. Clusters are defined at the *kebele* level, which is the primary level at which agricultural extension is organized in Ethiopia. Within each *woreda*, *kebeles* were randomly allocated to one of three groups:

T0) A control group (denoted “Control”) in which the Government of Ethiopia’s conventional extension approach is targeted at the (typically male) household;

T1) A treatment group (denoted "Regular DG") in which Digital Green's standard video-mediated approach (described above) is targeted at the (typically male) household head; and

T2) A treatment group (denoted "DG + spouse") in which Digital Green's standard video-mediated approach is targeted at both the household head and his/her spouse.

With this design, we are able to test the impact of the Digital Green video-mediated approach on our outcomes of interest for any household that participated in the treatment ("Any DG", which is equal to T1+T2), and the distinct treatments (T1, T2) separately.

In each group, the same suite of agricultural technologies and practices was promoted to farmers using the video-mediated extension approach in the treated *kebeles* and the conventional extension approach in the control *kebeles*. The three technologies were row planting, more precise seeding rates, and urea top or side dressing, and the three crops were teff, wheat, maize. The homogeneous content promoted in the treated and control *kebeles* ensures that we can evaluate the *medium* used for promotion rather than the content itself. Table 2 summarizes the experimental design and the variation in intervention by treatment status.

Table 2. Experimental design and interventions

	Treatment status		
	Conventional extension approach (Control)	**Digital Green approach (Regular DG)**	**Gendered Digital Green approach (DG + Spouse)**
Extension content			
Source	MoA	MoA	MoA
Extension method			
Delivery method	Mainly words (heterogenous)	Video-mediated (homogenous)	Video-mediated (homogenous)
Customization to local context	Low	High	High
Trainer	DAs	DAs + peers	DAs + peers
Extension targeting			
Target group	Household heads	Household heads	Household heads and spouses
Monitoring and follow-up	Rarely	Frequently	Frequently

Source: Authors.

Outcomes of interest

Our primary outcomes of interest are: (i) farmers' access to extension services and advice from DAs; (ii) farmers' awareness and understanding of the subject technologies and practices; and

(iii) farmers' uptake of the subject technologies and practices in the ensuing agricultural season. We are further interested in (iv) variations in these outcomes resulting from the distinctly gendered targeting strategies used in the two treatment arms.

We measure farmers' access to extension services and advice from DAs in several ways, all very straightforward and consistent. First, we measure access to extension using farmers' responses to the question, "Has a DA directly provided you with advice/training on <crop>?" for each of the three focus crops. Access to extension to extension equals 1 if farmers answer to the question is in the affirmative and zero if not. To measure the intensity to access, we also look at the number of times a DA provided advice for a specific crop. Further, we explore DA effort by estimating treatment effects on whether the DA visited a farmer's plot and the number of plots visited (Table A6).

We measure knowledge as the score from a set of questions about the subject technologies and practices that were asked of participants in the household survey described below. These questions were drawn directly from the list of "non-negotiable" elements of the subject technologies and practices as set forth by the Ethiopian government's own technical recommendations, and as incorporated into both the video and the non-video extension materials used by DAs. The knowledge tests were crop-specific, and were made up of 17 questions on teff, 16 on wheat, and 16 on maize. The questions were multiple choice and each question had one correct answer. For each respondent, the number of correct responses were totaled and divided by the total number of questions for a given crop yielding a percentage score. We also use a weighted knowledge score in keeping with Shikuku (2019) where the inverse of the probability of answering a question correctly is used to weight correct responses. The final crop-specific score is the total of standardized weighted responses to all knowledge test questions.

Next, we measure uptake of the subject technologies and practices, based on participants' responses to questions in the household survey. The question for each crop and technology was structured as follows, "During *meher* 2017-18 has anyone tried <technology> on your farm?" Farmers uptake equals 1 if they respond 'yes' to the above question and zero if they respond 'no'. In the case of row planting, we also calculated the share of area row planted as area row planted divided by total area cultivated using plot level data. In the spirit of Rogers (2010 [1962]), we use the term "uptake" to describe a farmer's decision to experiment with or trial a new technology or practice either in temporal terms (e.g., experimenting for a single season) or spatial terms (e.g., experimenting on a single plot). This is preferable than to using the term “adoption” which implies a more sustained use of the technology over multiple seasons or years, or at a larger spatial scale on the farm. We measure uptake as both a binary variable an as an intensity, which is the share of cultivated area (by crop) allocated to the technology or practice.

Data and sampling

Data were collected using two separate questionnaires from both household heads and spouses. The household head questionnaire covered topics including household characteristics, assets, access to services, technology adoption, knowledge of agricultural practices, experience with video, crop sales, non-farm income, savings, food security, shocks, and plot-level information on land use, production, and inputs. The spouse questionnaire included sections on assets, technology adoption, knowledge of agricultural practices, and experience with video.

A total of 2,422 farm households were randomly selected from 30 *woreda*s and 347 *kebele*s located in the study area (Table 3). The sampled households were selected using a four-stage sampling process, as follows.

1. *Defining the study population*. In the first stage, we purposefully selected 30 *woredas* for the study based on three criteria: (i) *woredas* that were not saturated or fully covered by Digital Green prior to the 2017 *meher* season; (ii) *woredas* that Digital Green planned to expand into in that same season; and (iii) *woredas* that would not be fully saturated during the 2017 expansion to ensure the presence of within-*woreda* control *kebeles*. *Woredas* with less than nine potential expansion *kebele*s for the 2017 *meher* season were excluded from the study.
2. *Stratification of the treatment at the woreda level.* In the second stage, we randomly selected *kebele*s from *woredas* with nine or more eligible *kebele*s.[4] Within each *woreda*, selected *kebeles* were randomly allocated to one of the three treatment arms such that each arm contained an equal number of *kebeles*.
3. *Stratification of the sample by development group distance.* Even though the *kebele* is the lowest administrative unit in Ethiopia, it typically comprises several development groups. Given the limited number of PICO projectors available for video screenings, it was infeasible

[4] In *woredas* with 9-15 *kebeles,* we randomly allocated from among those *kebeles.* In *woredas* with more than 15 *kebeles,* we randomly chose only 15 *kebeles* prior to random allocation.

in all *kebeles* for DAs to reach all development groups in a *kebele* with the video-mediated approach. Feedback from people directly involved in the video-mediated approach suggested that in such cases, DAs would likely focus their effort on the development groups close to the FTC. To assess the effectiveness of Digital Green's approach on farmers, regardless of their location, we encouraged DAs to first focus their effort on 10 development groups—five of which were selected from the closest development groups (where distance to the FTC was less than the *kebele* median), and five from development groups located further away (where distance to the FTC was greater than the median).

4. *Sampling farmers.* For the last stage, we randomly selected seven households from each *kebele*: 2 from the closest targeted development group, 2 from the furthest development group, and 3 from the development group situated at the median distance from the FTC. Selecting farmers within the 10 development groups aimed to increase the statistical power by ensuring that a large share of the surveyed farmers targeted for treatment at the *kebele* level did, in fact, participate in the treatment. Despite this, and as will be discussed later, the participation rate was still limited even with this sampling procedure.

The random selection of households for the survey followed the same procedure in both treatment and control *kebele*s, thereby ensuring comparability of farmers across groups. Our design sought not to affect, in any possible way, the way extension was conducted in the control *kebele*s. For this reason, we did not encourage DAs to focus their attention on 10 development groups as we did in the treatment group *kebeles*. We discuss the implication of this difference below.

Additional data were collected with a survey of 896 extension agents at baseline (2017) and followed up with midline survey (2018) of 781 DAs. All DAs in service in the selected *kebeles* in all three arms of the trial were included in the sample of respondents for these surveys. The DA baseline survey collected information on their profiles, motivation, workload, and *kebele*-level production figures for the previous year.

Table 3. Sample size

Sample	Regular DG	DG + Spouse	Control	Total
Total number of *woreda*s	30	30	30	30[5]
Total number of *kebele*s	115	116	116	347
Total number of households	798	812	812	2422

Source: Authors.

Timeline

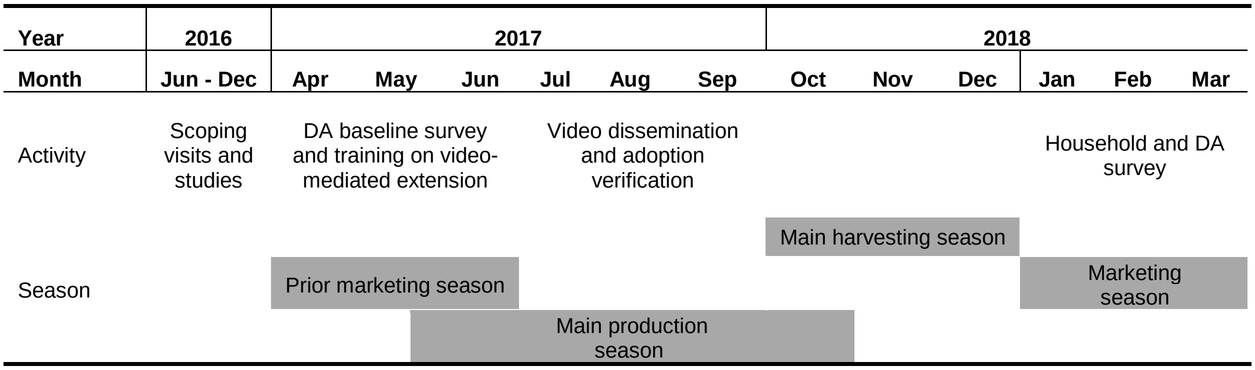
Figure 1 summarizes the timeline of Digital Green's intervention and our accompanying study[6]. We first conducted a baseline survey of all DAs working in our study *kebeles* during April–May 2017, just prior to the 2017 *meher* season. After the baseline, we conducted extensive training on the study design for *woreda*-level Bureau of Agriculture functionaries and DAs, in collaboration with Digital Green, to ensure experimental integrity.

After these trainings, the intervention was implemented by *woreda*-level subject matter specialists and DAs with support from Digital Green throughout the main production period of the *meher* season (June-September 2017). We also conducted a rapid assessment of the implementation process during the initial implementation in order to provide Digital Green with feedback on operations and progress. The household survey and DA follow-up survey were conducted January-March 2018, after the harvest for all three crops.

[5] Random assignment of *kebeles* to treatment and control groups was stratified by *woreda*. This implies that each of the 30 *woredas* selected for the study contained *kebeles* assigned to both treatment groups and the control group. For this reason, a total of 30 *woredas* are shown in the last column.

[6] This timeline represents the first year of the study. The intervention continued for a second year in 2018. Analysis of data from year 2 are in progress and results are forthcoming.

Figure 1. Timeline of intervention and evaluation



Source: Authors.

Experimental integrity

Balance of initial characteristics

We assess the extent to which random assignment of the treatment generated comparable treatment and control groups at different levels—*kebele*, household head, spouse, and DA. First, we check for balance between treatment and control groups at the household level and find that these groups are comparable on household level variables (Table 4). Next, we run balance tests on baseline levels of our main outcome variables of interest, measured using farmer recall data. We find no statistically significant difference between the treatment groups for most outcome variables (Table 4). However, we do observe a small difference between "Control" and "Regular DG" on prior experience with recommended seeding rates and urea top dressing for teff, and between "Control" and "DG + Spouse" for recommended seeding rates for wheat (Table 5). Balance tests for household spouse- and DA-level covariates and *kebele* characteristics are reported in Appendix Table A1–Table A3, and indicate that the control and treatment groups are comparable both at the spouse and *kebele* levels.

Compliance with treatment assignment

Next, we test whether field implementation of the intervention complied with the research design. We do this by assessing the extent to which sample households participated in the intervention. We find relatively low levels of compliance for treatment households (Table 6). A total of 41 percent and 42 percent of households in the "Regular DG" and "DG + spouse" groups participated in least one video-mediated extension activity, respectively. On the other hand, the level of contamination of the intervention in the "Control" is low—only 4 percent of the sample households from the control group participated in video-mediated extension training. Table 6 also assesses the participation rates in video-mediated extension by crop and video topic. We find no discernable differences in participation patterns by crop and topic.

Table 4: Balance test for household level covariates

Variable	Entire sample	Regular DG	DG Spouse	Control	DG Reg-Control	(DG + Spouse) − Control	(DG + Spouse) − DG Regular
HH size	5.919	5.965	5.892	5.900	0.065	-0.009	-0.073
	(2.184)	(2.199)	(2.180)	(2.175)	(0.145)	(0.147)	(0.151)
Male HH head	0.902	0.897	0.906	0.901	-0.004	0.005	0.009
	(0.298)	(0.304)	(0.291)	(0.298)	(0.016)	(0.017)	(0.017)
HH age	45.842	45.905	45.983	45.639	0.266	0.344	0.078
	(12.937)	(13.018)	(12.922)	(12.887)	(0.731)	(0.727)	(0.692)
HH head literacy	0.496	0.461	0.484	0.542	-0.081**	-0.058*	0.023
	(0.500)	(0.499)	(0.500)	(0.499)	(0.036)	(0.034)	(0.033)
Distance to the nearest (in minutes):							
Asphalt road	104.566	109.654	102.070	102.062	7.593	0.009	-7.584
	(106.259)	(106.500)	(98.762)	(112.995)	(9.336)	(9.568)	(8.819)
Dry season road	27.526	32.089	27.804	22.762	9.327**	5.042	-4.285
	(47.453)	(46.983)	(57.774)	(34.229)	(3.610)	(3.490)	(4.087)
All weather road	30.420	35.858	28.926	26.569	9.289**	2.357	-6.932*
	(41.725)	(48.275)	(37.565)	(38.074)	(3.689)	(3.074)	(3.709)
Market	69.817	76.397	68.836	64.330	12.067**	4.506	-7.561
	(60.745)	(70.273)	(54.714)	(55.630)	(5.419)	(5.016)	(5.471)
Admin. center	131.30	125.748	118.174	149.889	-24.141	-31.716	-7.574
	(613.75)	(82.509)	(88.301)	(1,053.322)	(38.775)	(38.912)	(8.428)
Agri. coop	51.368	51.128	53.067	49.905	1.223	3.161	1.939
	(87.814)	(50.014)	(102.73)	(100.007)	(5.161)	(5.926)	(5.162)
Input dealer	57.614	60.797	57.514	54.586	6.211	2.927	-3.283
	(69.096)	(55.374)	(88.514)	(58.179)	(5.105)	(5.414)	(5.440)
FTC	31.173	31.551	31.484	30.490	1.061	0.994	-0.067
	(36.432)	(45.669)	(30.293)	(31.532)	(2.364)	(2.047)	(2.309)
DA house/office	32.935	34.888	32.065	31.884	3.004	0.181	-2.823
	(38.153)	(34.721)	(31.008)	(46.837)	(2.639)	(2.300)	(2.373)
RuSACCOs[a]	81.535	79.698	77.355	87.520	-7.822	-10.165	-2.343
	(197.206)	(69.368)	(73.141)	(325.515)	(13.091)	(13.236)	(6.784)
Microfinance	103.627	105.906	105.084	99.931	5.975	5.153	-0.822
	(89.296)	(73.910)	(107.40)	(82.942)	(7.588)	(8.812)	(8.199)
Bank	116.153	123.218	114.353	111.009	12.209	3.345	-8.865
	(100.111)	(126.556)	(84.725)	(83.191)	(9.007)	(8.532)	(9.159)
No. of parcels	3.691	3.663	3.687	3.723	-0.060	-0.036	0.024
	(2.150)	(2.072)	(2.160)	(2.217)	(0.183)	(0.184)	(0.175)
HH cultivated teff	0.636	0.655	0.635	0.617	0.038	0.018	-0.020
	(0.481)	(0.476)	(0.482)	(0.486)	(0.048)	(0.048)	(0.049)
No. of teff plots	1.068	1.080	1.124	1.000	0.080	0.124	0.044
	(1.244)	(1.234)	(1.327)	(1.163)	(0.116)	(0.120)	(0.124)
HH cultivated wheat	0.616	0.617	0.617	0.615	0.002	0.002	0.000
	(0.486)	(0.487)	(0.486)	(0.487)	(0.049)	(0.048)	(0.050)
No. of wheat plots	0.866	0.866	0.823	0.909	-0.043	-0.086	-0.043
	(0.928)	(0.934)	(0.828)	(1.012)	(0.097)	(0.090)	(0.087)
HH cultivated maize	0.550	0.564	0.555	0.531	0.033	0.025	-0.008
	(0.498)	(0.496)	(0.497)	(0.499)	(0.051)	(0.048)	(0.048)
No. of maize plots	0.701	0.703	0.691	0.708	-0.005	-0.017	-0.012
	(0.759)	(0.711)	(0.726)	(0.835)	(0.081)	(0.080)	(0.071)
Observations (no.)	2,422	798	812	812	1,610	1,624	1,610

Note: Note: For columns 1-4, standard deviations in parentheses. For columns 5-7, standard errors clustered at the *kebele* level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a] The term RuSACCO refers to a rural savings and credit cooperative.

Source: Authors' calculations.

Table 5. Balance tests on main outcome variables

Variables	Entire sample	Regular DG	DG Spouse	Control	DG Regular − Control	(DG + Spouse) − Control	(DG + Spouse) − DG Regular
Before 2017/18 meher HH tried (___) for teff							
Row planting	0.167	0.169	0.192	0.139	0.030	0.053	0.023
	(0.373)	(0.375)	(0.394)	(0.346)	(0.031)	(0.033)	(0.033)
Recommended seeding rates	0.320	0.342	0.340	0.278	0.064*	0.062	-0.002
	(0.467)	(0.475)	(0.474)	(0.448)	(0.036)	(0.038)	(0.038)
Urea top dressing	0.361	0.385	0.382	0.318	0.067*	0.064	-0.003
	(0.480)	(0.487)	(0.486)	(0.466)	(0.039)	(0.041)	(0.041)
Before 2017/18 meher HH tried (___) for wheat							
Row planting	0.224	0.227	0.233	0.213	0.014	0.020	0.006
	(0.417)	(0.419)	(0.423)	(0.410)	(0.036)	(0.035)	(0.036)
Recommended seeding rates	0.282	0.284	0.309	0.251	0.033	0.058*	0.025
	(0.450)	(0.451)	(0.462)	(0.434)	(0.030)	(0.032)	(0.032)
Urea top dressing	0.347	0.346	0.361	0.334	0.012	0.027	0.015
	(0.476)	(0.476)	(0.481)	(0.472)	(0.036)	(0.038)	(0.038)
Before 2017/18 meher HH tried (___) for maize							
Row planting	0.480	0.474	0.478	0.489	-0.015	-0.011	0.004
	(0.500)	(0.500)	(0.500)	(0.500)	(0.048)	(0.048)	(0.048)
Recommended seeding rates	0.400	0.407	0.401	0.392	0.016	0.010	-0.006
	(0.490)	(0.492)	(0.490)	(0.488)	(0.040)	(0.040)	(0.041)
Urea side dressing	0.396	0.400	0.400	0.389	0.011	0.011	0.000
	(0.489)	(0.490)	(0.490)	(0.488)	(0.045)	(0.046)	(0.045)
Observations (no.)	2,422	798	812	812	1,610	1,624	1,610

Note: For columns 1-4, standard deviations in parentheses. For columns 5-7, standard errors clustered at the *kebele* level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table 6. Videos watched by topics and treatment groups

Share of participants who:	Total	Regular DG	DG + Spouse	Control
Attended at least one video-based extension or training (%)	29	41	42	4
Watched a video on…				
teff land preparation (%)	12	20	17	1
teff seed selection and seeding rate (%)	12	18	17	0
teff row planting (%)	16	24	23	1
teff transplanting (%)	9	13	13	0
fertilizer application (urea top dressing) on teff plots (%)	14	21	20	1
teff harvest and storage (%)	10	15	14	1
wheat land preparation (%)	15	24	21	1
wheat seed selection and seeding rate (%)	17	25	24	1
fertilizer application (urea top dressing) on wheat plots (%)	19	27	27	1
wheat crop management (%)	15	23	22	0
wheat harvest and storage (%)	13	20	18	1
maize land preparation (%)	13	19	18	1
maize seed selection and seeding rate (%)	14	22	21	1
fertilizer application (urea side dressing) on maize plots (%)	16	22	24	1
maize crop management (%)	15	22	21	1
maize harvest and storage (%)	10	16	15	1
Observations (no.)	2,422	798	812	812

Source: Authors' calculations.

Empirical strategy

Our empirical strategy closely follows the study design through simple comparisons of mean outcomes across treatment and control groups. We focus here on intent to treat (ITT) estimates, which capture the effect of being randomly allocated to a *kebele* where video-mediated extension approach was introduced, regardless of whether the household member(s) actually participated in a video screening. To estimate these ITT effects, we include all sample households—whether or not they were actually "treated" (i.e., received extension services)—in our analysis. Thus, we are estimating the intervention's effect on the group for whom it was intended.

We restrict our analysis to ITT estimates for two reasons. One is statistical. To estimate the Treatment Effect on the Treated (TOT)—the impact of the intervention on those who were actually "treated"—one needs to assume an absence of spillovers from participants to non-participants within a given *kebele*. Given the nature of how information is shared between peers within a *kebele*, we argue that such an assumption is overly restrictive. The other reason is operational. From a policy perspective, ITT estimates are often more relevant as they measure average changes in outcomes across all individuals that are targeted by the intervention. Given that 100 percent compliance with the intervention is nearly impossible in a real-world scenario, ITT estimates are a good proxy for the impacts that can be expected beyond the experimental scenario.

We estimate ITT effects using ordinary least square (OLS) with the following specification:

$$y_i = \alpha + \beta T_k + X_i'\delta + \mu_w + \varepsilon_i \qquad (1)$$

where y_i denotes the level of outcome y measured at the household level i (for instance whether the household has tried row-planting of a wheat plot over the study period). The variable T_k indicates the treatment status of *kebele* k which, in this specification, clubs both treatment arms ("Regular DG" and "DG + spouse") into a single treatment ("Any DG"). The variable X is a vector of household- and development group-level characteristics that account for baseline imbalances between groups and augments the overall power of our estimates. These include distance to nearest FTC, whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. We account for *woreda*-level stratification of our design through μ_w, a set of *woreda*-level fixed effects. Lastly, we account for treatment assignment at the *kebele* level by clustering standard errors at that level.

We also estimate ITT effects for each of the two treatment arms that measure the differential impact of video-mediated extension when it is targeted only to heads of households ("Regular DG") and when it includes both the heads and spouses in the same household ("DG + spouse"). This differential effect is estimated as:

$$y_i = \alpha + \beta^1 T_k^1 + \beta^2 T_k^2 + X_i'\delta + \mu_w + \varepsilon_i \qquad (2)$$

where T_k^1 is treatment for "Regular DG" and T_k^2 is treatment for "DG + spouse". We also test for the equality of coefficients between "Regular DG" and "DG + spouse" (i.e., $\beta^1 = \beta^2$) to assess the additional effect of treating spouses in households where the head of the household is treated.

Next, we consider two issues related to selection: one regarding cropping patterns, and the other regarding participation in extension activities.

First, because a given technology may not have the same constraints or relevance across crops, for most outcomes we restrict our estimation of the intervention's impact to the sample of households cultivating one of the three focus crops (teff, wheat, or maize). However, if treatment allocation affected crop choices, then the sub-sample of households cultivating a particular crop may no longer be fully comparable across treatment groups, which could bias the treatment estimates. We expect these effects to be limited for two reasons. One, Digital Green's intervention was introduced relatively late in the season, at a time when most households had already made their choices about crops to be grown. This is further supported by results in Appendix Table A4 which provides no evidence to suggest that one's decision to grow each of the three crops is affected by one's treatment status. Two, cropping patterns in the study area tend to be static from year to year since time-invariant factors such as site-specific agroecological characteristics tend to dictate crop choices.

Second, and as described above, DAs in treatment groups were encouraged (but not compelled, and not monitored) to first focus their video-mediated extension efforts to 10 development groups from which we later sampled households randomly for our household survey. This design may lead to an over-representation of extension participants in our treatment groups as compared to the control group. Further, if DAs in the control group targeted their effort to particular types of development groups (for instance, those closer to FTCs), extension participants may not be fully comparable across samples. While our main estimation strategy relies on the above-described ITT, we also test for the robustness of these results when restricting the sample to those development groups effectively reached by DAs in the treatment or control *kebeles*, that is, those development groups where at least one farmer received advice from a DA. However, our results are not meaningfully affected by this, such that the obtained ITT results are unlikely to be driven by selection and can be interpreted as an ITT estimate of the video-mediated extension approach's impact.

4. RESULTS

This section presents results from estimation of Equations (1) and (2) on a series of outcomes including: access to extension; improvements in knowledge about the subject technologies and practices; and the uptake of the subject technologies and practices. For each, we present a graphical representation of the overall treatment effect, alongside details on the separate treatment effects for "DG regular" and "DG + spouse" in a related table.

Extension access and knowledge outcomes

We find evidence of an increase in access to extension by farmers in *kebeles* selected for video-mediated extension (Table 7, Panel A, columns 1, 3, and 5). These results indicate that a farmer in a treated *kebele* is, on average, 10.8 percentage points more likely to have received DA advice regarding teff cultivation than a farmer in a control *kebele*. With 45.3 percent of the farmers having received such advice in the control *kebeles,* the effect of the video-mediated approach represents a 23.8 percent increase over the control *kebeles*. This effect is not limited to farmers cultivating teff: comparable (in fact, larger) effects are found for farmers cultivating wheat and maize. In the case of wheat, treated farmers are 15.6 percentage points more likely to have received DA advice, a 36.7 percent increase over the mean of farmers in the control *kebeles*. For maize, treated farmers are 12.4 percentage points more likely to have received DA advice, a 24.9 percent increase over the mean of the control *kebeles*.

Our results are robust to several other measures of access, including dichotomous measures (whether a DA provided advice to a farmer, and whether a DA visited a farmer's plot), intensity measures (the number of times a DA provided advice to a farmer, or visited a farmer's plot), and crop-specific measures (the number of a farmer's plots visited by a DA, for any crop vs. the crops specifically targeted by the intervention). We also explore heterogenous effects of distance to FTC on these different measures of access. We find small positive effects on access (measured by the dichotomous and intensity measures) for respondents situated medium distance from the FTC. These results are presented in Appendix Table A7–Table A8. Columns 2, 4 and 6 of Table 7 further disaggregate results between the "Regular DG" and "DG + spouse" treatment groups. We do not find evidence of differential treatment effects across these groups—where the respondent is the head of household—as indicated by the reported tests of equality of coefficients.

Panel B of Table 7 reports similar estimates, but uses responses provided by spouse of the household head. These results indicate that the "DG + spouse" treatment led to a significant increase in spouses' access to DA advice, even when the "Regular DG" did not. Specifically, spouses in the "DG + spouse" group are 4.7 percentage points more likely to have received DA advice on wheat, a 25.1 percent increase over spouses in the control group. Similarly, for maize, spouses in the "DG + spouse" group are 5.3 percentage points more likely to have received DA advice, a 20.1 percent increase over spouses in the control group.

Table 7. Estimates of treatment effects on access to extension for household head and spouse, by crop

	Teff		Wheat		Maize	
	DA directly provided advice/training		DA directly provided advice/training		DA directly provided advice/training	
Panel A: Effect on household head						
Any DG	0.108***		0.156***		0.124***	
	(0.0243)		(0.0247)		(0.0270)	
Regular DG		0.103***		0.149***		0.135***
		(0.0282)		(0.0296)		(0.0303)
DG + spouse		0.112***		0.163***		0.113***
		(0.0275)		(0.0282)		(0.0313)
Test of equality (F)		0.1		0.22		0.56
Test of equality (Prob > F)		0.756		0.637		0.454
Constant	0.466***	0.466***	0.474***	0.473***	0.514***	0.514***
	(0.0332)	(0.0332)	(0.0324)	(0.0324)	(0.0324)	(0.0323)
Control mean	0.453	0.453	0.425	0.425	0.497	0.497
Observations (no.)	1,540	1,540	1,492	1,492	1,332	1,332
R-squared	0.341	0.341	0.371	0.372	0.350	0.351
Panel B: Effect on spouse						
Any DG	0.0194		0.0421*		0.0278	
	(0.0244)		(0.0228)		(0.0239)	
Regular DG		0.0108		0.0377		0.00205
		(0.0275)		(0.0272)		(0.0256)
DG + spouse		0.0283		0.0465*		0.0527*
		(0.0272)		(0.0258)		(0.0280)
Test of equality (F)		0.51		0.11		4.06
Test of equality (Prob > F)		0.477		0.746		0.045
Constant	0.279***	0.279***	0.207***	0.207***	0.281***	0.282***
	(0.0286)	(0.0286)	(0.0256)	(0.0256)	(0.0283)	(0.0282)
Control mean	0.242	0.242	0.185	0.185	0.262	0.262
Observations (no.)	1,334	1,334	1,284	1,284	1,165	1,165
R-squared	0.292	0.292	0.299	0.300	0.279	0.281

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. The spouse regressions control only for distance to the nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

We find similar results when we restrict our sample to those development groups where at least one farmer received advice from a DA, indicating that the intervention did not lead to a change in the type of development group that DAs decided to work with, but rather to a change in their reach to farmers within these groups (Table 8). We also find comparable results on the application of DAs advise at the plot level (Table A10).

Table 8: Estimates of treatment effects on access to extension for household head, by crop (sample restricted to development groups where DA provided advice to at least one household)

	Teff		Wheat		Maize	
	DA directly provided advice/training		DA directly provided advice/training		DA directly provided advice/training	
Any DG	0.0631**		0.0847***		0.0591**	
	(0.0274)		(0.0271)		(0.0283)	
Regular DG		0.0515		0.0872***		0.0799***
		(0.0326)		(0.0315)		(0.0299)
DG + spouse		0.0743**		0.0824***		0.0403
		(0.0292)		(0.0295)		(0.0333)
Test of equality (F)		0.63		0.03		1.94
Test of equality (Prob > F)		0.4293		0.8635		0.1647
Constant	0.644***	0.644***	0.680***	0.680***	0.667***	0.668***
	(0.0363)	(0.0363)	(0.0336)	(0.0336)	(0.0337)	(0.0337)
Control mean	0.662	0.662	0.677	0.677	0.699	0.699
Observations	1,159	1,159	1,094	1,094	1,031	1,031
R-squared	0.211	0.211	0.263	0.263	0.234	0.236

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Next, we investigate whether video-mediated extension led to improvements in farmers' knowledge and understanding of the focal technologies and practices. Table 9 reports results on farmers' scores on the knowledge tests conducted during the survey of household heads and spouses. Results are reported as percentage increases in knowledge test scores attributable to the treatment.

On average, farmers in the control group *kebeles* responded correctly to 37-43 percent of the questions, depending on the crop. Our results point to small (1-2 percentage point) increases in knowledge test scores among farmers in treated *kebeles*. These results are only statistically significant for the sub-group of teff producers. Note, however, that results in Panel A of Table 9 suggest some potential differences across our two treatment arms. In particular, while the "Regular DG" treatment led to no increase in knowledge scores for farmers cultivating wheat, "DG + spouse" did lead to an increase in knowledge scores for household heads (Table 9, Panel A).

Table 9. Estimates of treatment effects on knowledge test scores of household head and spouse, by crop

	Teff				Wheat				Maize			
	Knowledge score (percent)		Knowledge score (inverse probability weighted)		Knowledge score (percent)		Knowledge score (inverse probability weighted)		Knowledge score (percent)		Knowledge score (inverse probability weighted)	
Panel A: Effect on household head												
Any DG	1.808***		1.300*		1.144		1.301*		0.939		1.519*	
	(0.684)		(0.682)		(0.795)		(0.706)		(0.748)		(0.782)	
Regular DG		1.699**		1.416*		0.296		0.965		1.034		1.564*
		(0.755)		(0.760)		(0.910)		(0.818)		(0.891)		(0.947)
DG + spouse		1.918**		1.185		1.961**		1.625**		0.847		1.475*
		(0.811)		(0.774)		(0.912)		(0.806)		(0.878)		(0.892)
Test of equality (F)		0.08		0.11		3.53		0.69		0.04		0.01
Test of equality (Prob > F)		0.7745		0.7428		0.0612		0.4082		0.8428		0.9268
Constant	37.74***	37.74***	20.49***	20.49***	39.00***	38.97***	20.91***	20.89***	43.69***	43.70***	32.00***	32.00***
	(0.854)	(0.855)	(0.801)	(0.801)	(0.939)	(0.938)	(0.931)	(0.931)	(0.997)	(0.995)	(0.950)	(0.948)
Control mean	37.455	37.455	20.003	20.003	38.289	38.289	19.641	19.641	43.750	43.750	32.236	32.236
Observations	1,540	1,540	1,540	1,540	1,492	1,492	1,492	1,492	1,332	1,332	1,332	1,332
R-squared	0.176	0.176	0.209	0.209	0.135	0.137	0.154	0.154	0.209	0.209	0.270	0.270
Panel A: Effect on spouse												
Any DG	0.943		-0.0832		1.150		0.513		0.638		0.992	
	(0.686)		(0.564)		(0.815)		(0.649)		(0.944)		(0.884)	
Regular DG		0.499		0.331		0.693		-0.212		0.775		1.449
		(0.824)		(0.634)		(0.910)		(0.726)		(1.089)		(1.031)
DG + spouse		1.398*		-0.507		1.609*		1.241		0.506		0.549
		(0.773)		(0.589)		(0.961)		(0.768)		(1.037)		(0.964)
Test of equality (F)		1.19		3.01		0.99		3.79		0.08		0.94
Test of equality (Prob > F)		0.2761		0.0838		0.3197		0.0525		0.7827		0.3322
Constant	33.39***	33.38***	9.459***	9.465***	34.99***	34.98***	13.37***	13.36***	40.64***	40.64***	26.72***	26.70***
	(0.831)	(0.831)	(0.638)	(0.639)	(0.912)	(0.912)	(0.714)	(0.712)	(1.038)	(1.041)	(1.040)	(1.043)
Control mean	32.154	32.154	8.519	8.519	33.826	33.826	12.404	12.404	40.225	40.225	26.039	26.039
Observations	1,334	1,334	1,334	1,334	1,284	1,284	1,284	1,284	1,165	1,165	1,165	1,165
R-squared	0.231	0.231	0.131	0.132	0.176	0.176	0.145	0.148	0.269	0.269	0.245	0.246

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. The spouse regressions control only for distance to the nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Panel B of Table 9 reports results for the same estimations based on responses from the surveyed spouses. We find that “DG + spouse” led to positive and significant effect on spouses’ knowledge, while “DG regular” did not. However, this effect is limited to farmers cultivating teff and wheat only. In the case of teff, spouses in the “DG + spouse” group scored 1.4 percent more than those in the control group, which translates to a 4.3 percent increase over the mean of the control group. Similarly, for wheat, spouses in the “DG + spouse” group scored 1.6 percent more than those in the control group, an increase of 4.8 percent over the control.

Overall, the results suggest that DG’s video-mediated extension approach led to an increased reach of farmers by DAs, which translated into small increases in knowledge. As expected, these effects are broadly similar across treatment groups when one considers household head respondents. However, they are significantly higher in the “DG + spouse” group, when one considers spouse respondents. This supports existing evidence that agricultural extension in Ethiopia is mainly targeted at household heads only. In the following sections, we investigate whether this may be a source of inefficiency. Of the 2082 spouses in our sample 37 were male spouses and 4 were male household heads responding for the female spouses. We find that our spouse estimates for access to extension are robust to restricting our sample to the 2041 female spouses where the respondent was female (Table A15–Table A17).

Technology uptake

We now turn to farmers’ uptake of the technologies and practices promoted in the intervention: row planting, recommended seeding rates, and urea top or side dressing. We see an overall positive impact of the video-mediated approach on farmers’ decision to experiment with or trial a technology during the 2017/18 *meher* season. Effects are somewhat comparable in magnitude across crops and technologies, ranging from a 3-10 percentage point increase in uptake. Relative to the mean of the control group, these increases represent substantial differences in uptake in the treatment groups. For example, the 6 percentage-point increase in teff row planting observed among farmers in treated *kebeles* translates into a 36 percent increase over the mean of the control (Table 10, Panel A). Similar patterns are found for recommended seeding rates and urea dressing, with larger increases observed for teff and wheat relative to maize (Table 11 and Table 12, respectively). These crop-specific findings are consistent with the fact that the subject technologies and practices for maize have been part of Ethiopia’s extension packages for a much longer time.

We further report on the intensity of uptake, or the share of cultivated area on which farmers applied row planting (Table 10, Panel A). Results are consistent with those obtained from the binary uptake variable. For example, between farmers in treatment and control *kebeles,* we find a 0.067 and 0.053 percentage point difference in the share of teff and wheat area row planted, respectively. This translates to a 48 percent and 23 percent increase over the mean of the control for teff and wheat, respectively.

We further disaggregate results by treatment arm. We do not find evidence of statistically significant treatment effects. This suggests that the increase in DA access and knowledge attributable to the video-mediated approach did not translate in changes in the households' technology adoption decision above and beyond that of the "Regular DG" treatment arm. These results are supported by plot-level estimates of the uptake of row planting (Table A9), where we interact our treatment variable with the gender of plot owner. Our results show no marginal "DG + Spouse" effects beyond those of the "Regular DG" approach even where the spouse is the (partial) owner of the plot. We find that our spouse estimates for technology adoption are robust to restricting our sample to female spouses where the respondent was female (Table A15–Table A17).

Finally, we pooled the "Regular DG" and "DG + spouse" treatment groups and examined heterogeneous effects along three dimensions—distance to FTC, whether there was a model farmer in the household, and asset quantiles (Table A18–Table A20). We find no evidence of distance to FTC affecting adoption of row planting, recommended seeding rates, or urea dressing for teff, wheat or maize, except that farmers living far from the FTC in treatment *kebeles* are less likely to adopt urea top dressing. We find no differential effects in adoption for households with model farmers in treatment *kebeles*. With regard to heterogeneity in asset holdings, we find that treatment households in the top half of the asset distribution are less likely to use the recommended seeding rate.

Table 10. Estimates of treatment effects on uptake of row planting as reported by household head, by crop

	Teff				Wheat				Maize			
	Row planting		Share of area row planted		Row planting		Share of area row planted		Row planting		Share of area row planted	
Panel A: Effect on household head												
Any DG	0.0576***		0.0673***		0.0349*		0.0529**		0.0355*		0.00345	
	(0.0215)		(0.0182)		(0.0206)		(0.0222)		(0.0205)		(0.0217)	
Regular DG		0.0604**		0.0702***		0.0293		0.0503*		0.0414*		0.00671
		(0.0241)		(0.0200)		(0.0255)		(0.0259)		(0.0248)		(0.0248)
DG + spouse		0.0547**		0.0643***		0.0403*		0.0555**		0.0297		0.000290
		(0.0241)		(0.0209)		(0.0223)		(0.0246)		(0.0233)		(0.0258)
Test of equality (F)		0.07		0.1		0.2		0.05		0.22		0.06
Test of equality (Prob > F)		0.795		0.754		0.652		0.829		0.641		0.807
Constant	0.135***	0.135***	0.135***	0.135***	0.183***	0.182***	0.232***	0.232***	0.653***	0.653***	0.760***	0.760***
	(0.0242)	(0.0242)	(0.0217)	(0.0217)	(0.0244)	(0.0244)	(0.0250)	(0.0250)	(0.0292)	(0.0291)	(0.0280)	(0.0280)
Control mean	0.160	0.160	0.140	0.140	0.174	0.174	0.226	0.226	0.650	0.650	0.795	0.795
Observations	1,540	1,540	1,540	1,540	1,492	1,492	1,492	1,492	1,332	1,332	1,332	1,332
R-squared	0.457	0.457	0.463	0.463	0.426	0.426	0.531	0.531	0.398	0.398	0.371	0.371
Panel B: Effect on spouse												
Any DG	0.0489**				0.0218				-0.0375			
	(0.0202)				(0.0199)				(0.0231)			
Regular DG		0.0519**				0.0186				-0.0374		
		(0.0219)				(0.0235)				(0.0271)		
DG + spouse		0.0459*				0.0250				-0.0376		
		(0.0239)				(0.0226)				(0.0275)		
Test of equality (F)		0.08				0.07				0		
Test of equality (Prob > F)		0.780				0.786				0.993		
Constant	0.134***	0.134***			0.193***	0.193***			0.686***	0.686***		
	(0.0216)	(0.0215)			(0.0215)	(0.0215)			(0.0227)	(0.0227)		
Control mean	0.119	0.119			0.148	0.148			0.676	0.676		
Observations	1,334	1,334			1,284	1,284			1,165	1,165		
R-squared	0.361	0.361			0.353	0.353			0.406	0.406		

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. The spouse regressions control only for distance to the nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table 11. Estimates of treatment effects on uptake of recommended seeding rates as reported by household head and spouse, by crop

	Teff		Wheat		Maize	
	Recommended seeding rates		Recommended seeding rates		Recommended seeding rates	
Panel A: Effect on household head						
Any DG	0.0697***		0.0790***		0.0336	
	(0.0266)		(0.0254)		(0.0264)	
Regular DG		0.0755**		0.0723**		0.0341
		(0.0305)		(0.0304)		(0.0312)
DG + spouse		0.0639**		0.0854***		0.0331
		(0.0306)		(0.0293)		(0.0296)
Test of equality (F)		0.15		0.17		0
Test of equality (Prob > F)		0.696		0.677		0.974
Constant	0.344***	0.344***	0.214***	0.213***	0.468***	0.468***
	(0.0332)	(0.0332)	(0.0298)	(0.0297)	(0.0372)	(0.0372)
Control mean	0.311	0.311	0.222	0.222	0.436	0.436
Observations (no.)	1,540	1,540	1,492	1,492	1,332	1,332
R-squared	0.173	0.173	0.216	0.217	0.198	0.198
Panel B: Effect on spouse						
Any DG	0.0401		0.0389		-0.0183	
	(0.0264)		(0.0244)		(0.0312)	
Regular DG		0.0368		0.0188		-0.0224
		(0.0301)		(0.0297)		(0.0358)
DG + spouse		0.0435		0.0590**		-0.0142
		(0.0301)		(0.0277)		(0.0356)
Test of equality (F)		0.05		1.74		0.05
Test of equality (Prob > F)		0.816		0.188		0.815
Constant	0.273***	0.273***	0.209***	0.208***	0.412***	0.412***
	(0.0300)	(0.0300)	(0.0259)	(0.0260)	(0.0342)	(0.0342)
Control mean	0.245	0.245	0.178	0.178	0.403	0.403
Observations (no.)	1,334	1,334	1,284	1,284	1,165	1,165
R-squared	0.194	0.194	0.171	0.173	0.178	0.178

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. The spouse regressions control only for distance to the nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table 12. Estimates of treatment effects on uptake of urea top or side dressing, as reported by household head, by crop

	Teff		Wheat		Maize	
	Urea top dressing		Urea top dressing		Urea side dressing	
Panel A: Effect on household head						
Any DG	0.0815***		0.0835***		0.0316	
	(0.0239)		(0.0262)		(0.0208)	
Regular DG		0.0744***		0.0926***		0.0385
		(0.0266)		(0.0306)		(0.0253)
DG + spouse		0.0887***		0.0748**		0.0250
		(0.0292)		(0.0294)		(0.0248)
Test of equality (F)		0.25		0.37		0.23
Test of equality (Prob > F)		0.621		0.545		0.632
Constant	0.331***	0.331***	0.277***	0.277***	0.473***	0.473***
	(0.0299)	(0.0299)	(0.0307)	(0.0307)	(0.0278)	(0.0277)
Control mean	0.371	0.371	0.333	0.333	0.506	0.506
Observations (no.)	1,540	1,540	1,492	1,492	1,332	1,332
R-squared	0.287	0.287	0.285	0.285	0.439	0.439
Panel B: Effect on spouse						
Any DG	0.0259		0.0307		-0.00637	
	(0.0227)		(0.0244)		(0.0226)	
Regular DG		0.0103		0.0200		0.00423
		(0.0267)		(0.0275)		(0.0268)
DG + spouse		0.0417		0.0415		-0.0166
		(0.0263)		(0.0289)		(0.0266)
Test of equality (F)		1.31		0.57		0.53
Test of equality (Prob > F)		0.253		0.450		0.467
Constant	0.295***	0.295***	0.278***	0.278***	0.505***	0.504***
	(0.0267)	(0.0267)	(0.0274)	(0.0274)	(0.0252)	(0.0252)
Control mean	0.319	0.319	0.297	0.297	0.504	0.504
Observations (no.)	1,334	1,334	1,284	1,284	1,165	1,165
R-squared	0.289	0.290	0.279	0.280	0.397	0.397

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. The spouse regressions control only for distance to the nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

These results are interesting from several angles. First, if we cast the "DG + Spouse" treatment as a doubling of extension intensity—a two-fold increase in the household's exposure to and interaction with DAs through the video-mediated approach—we might expect to find stronger effects on uptake than the singular "Regular DG" approach. However, we also recognize that there are several factors that militate against this hypothesis. A simple explanation may be that decision-making on crop management practices is strictly reserved to male household heads. But that is a rather weak explanation given the prevalence of women-headed households in which women do make decisions on crop management practices in Ethiopia. A more sophisticated explanation would explore the dynamics of intra-household decision-making as a function of the distribution of bargaining power and sociocultural norms, taking advantage of Ethiopia's rich heterogeneity that is also captured in our sample. Such analysis would be consistent with the analysis of bargaining power in Ethiopia by Mabsout and Staveren (2010) and gender relations in Ethiopia's wheat sector by Drucza and Tsegaye (2018), notwithstanding gains made by rural Ethiopian women as a result of land and social welfare policy changes evaluated by Kumar and Quisumbing (2015). In addition to this, it would be useful to evaluate these effects in relation to gender-unintentional (Gates, 2014) extension provision, consistent with findings of Ragasa et al. (2013), within the context of the video-mediated approach. This is a topic for future research.

Crop yields

Finally, we examine the intervention's effect on crop yields. Initially, we find no statistically significant effects of the treatment on yields based on farmers' self-reported area and harvest quantity (Table A11–Table A12). We then examine yields based on the same harvest quantities, but use area calculated from plot perimeters collected with GPS devices for a random sub-sample of parcels within a 45-minute walk from the respondents' dwellings. With this measurement, we do find a significant and positive effect of the treatment for teff at the plot level, with the video-mediated intervention resulting in a 15-20 percent increase in teff yields (Table A13). These findings are robust to controlling for plot ownership. However, we do not find similar results for the other crops.

While evidence of a treatment effect on teff yields is encouraging, the general findings also reflect the ongoing discussion about area, production, and yield measurement error in household surveys that rely fully or partly on farmers' own assessments of plot size and harvest quantities. Recent evidence from Ethiopia illustrates the extent and magnitude of this problem in sharp relief (Abate et al. 2015; Abay et al., 2019). We attribute the non-results on wheat and maize yields for both measurement approaches to the fact that several of the subject practices have been shown to offer limited yield gains under farmers' conditions in Ethiopia. Results from a randomized controlled trial of the Ethiopian government's wheat technology package conducted by Abate et al. (2018) found a 14 percent increase on wheat yields, but only when measured with crop cuts and with farmer predicted yields that control for farmer type and household characteristics; farmers' actual reported yields showed a smaller and statistically insignificant yield attributable to the package. They explain this difference in outcomes to measurement errors in plot size and advise caution in the use of both farmer-reported plot sizes and output. This is consistent with similar findings from a randomized controlled trial of row planting and lower seeding rates for teff conducted by Vandercasteelen et al. (2020, 2018), which found no statistically significant effects of the package on yields, whether measured with data from crop cuts or calculated from farmer-reported output and enumerator-measured area. Although the results of this particular study differ from ours, it raises similar issues about area, production, and yield measurement error in the Ethiopian context.

5. COST-EFFECTIVENESS ANALYSIS

While results thus far point to an increase in technology uptake resulting from the video-mediated extension approach, a key tenet of the approach is its potential to increase adoption rates at a relatively low cost per farmer.[7] In this section, we analyze the cost effectiveness of the video-mediated approach using the results presented earlier and project cost data provided by Digital Green.

Because the video-mediated approach is an intervention designed to *augment* the existing extension system, we calculate the cost per *additional* adoption resulting from the approach. This is a measure of marginal cost-effectiveness, which is the incremental cost of an additional adoption that results from adding the video-mediated approach to the existing system. We define the marginal cost-effectiveness ratio (MCER) as:

$$MCER_t^j = \frac{c_{tp}^j}{n_{tp}^j} \qquad (1)$$

where c_{tp}^j measures the total costs of using video-mediated extension to promote technology *j* in year *t* in the sample of *woredas* and *kebeles* assigned to the intervention *p*. The term n_{tp}^j denotes the corresponding number of additional adopters, that is, those farmers who would *not* have adopted technology *j* had there been no video-mediated approach in their locality.

Costs used in our calculations include the incremental cost of Digital Green's video-mediated approach compared to the conventional extension approach, which can be expressed as follows.

[7] We revert to the use of the term "adoption" here simply for ease of exposition, and still recognize that results reflect farmers experimenting with or trialing the subject technologies and practices.

$$Costs = \left(\boldsymbol{c}_{\boldsymbol{tp}}^{\boldsymbol{j}}\right) \qquad (2)$$

Drawing on Digital Green's own internal cost-effectiveness analysis manual and Mogues et al. (2017), we focus on project-level costs associated with the video-mediated approach. Digital Green's costs include personnel costs, training costs, operational costs, capital costs, and indirect costs incurred only in *kebeles* where video-mediated extension was conducted. We consider two cost scenarios: one which captures the marginal cost effectiveness of the intervention based on the coverage of the randomized controlled trial reported on in this paper (the "Experimental Scenario"); and another which assumes that the intervention is targeted to all *kebeles* in the targeted *woredas*, and to all development groups in each *kebele* (a "saturation" scenario).

Table 13 summarizes all costs that we account for in this analysis. Several features of these costs are worth highlighting. First, the costs analyzed here are the total costs incurred by Digital Green in promoting the video-mediated approach in this intervention during one *meher* season (2017), in 240 *kebeles* in 30 *woredas*. Second, certain costs are recurrent, such as personnel, operational, and indirect costs. For other costs such as equipment (computers, cameras, PICO projectors) and DA training costs, we assume a three-year lifespan, such that annualized costs represent one-third of the effective cost incurred during the one-year implementation of intervention.

Third, other costs can be classified as fixed costs. This includes costs at the *woreda*-level (see upper panel in Table 13). This implies that their contribution to the total cost is only affected by the number of *woredas*, not by the number of *kebeles* in each *woreda*. For example, extension staff need only one camera and one computer per *woreda* to produce and record videos, irrespective of whether one or all *kebeles* in a given *woreda* are targeted. Other costs are fixed at the *kebele*-level (lower panel in Table 13). This means that their contribution to the total cost is affected by the number of *kebeles*, but not by the number of development groups targeted in each *kebele*. For example, extension staff needs only one PICO projector per *kebele* to screen videos to farmers.

We take three technologies into consideration with respect to adoption rates: row planting, recommended seeding rates, and urea top or side dressing. We assign the same weight to each technology in the absence of additional information on how to otherwise assign these weights. Thus, the cost per technology is obtained from dividing the total costs by three. With this in mind, we let c_{tp}^{j} measure the yearly total costs of using video-mediated extension to promote technology j in 240 *kebeles* in 30 *woredas*.

Table 13. Annualized costs of the video-mediated intervention

Costs	Experimental scenario		Saturation scenario
Digital Green's costs	**Costs in treatment *kebeles* (USD)**	**Annualized costs (USD)**	**Annualized costs (USD)**
A. Woreda-level costs			
Personnel	31,416	31,416	
Training	137,645	45,882	
Operational	32,933	32,933	
Laptop (30 - 1 per *woreda*)	7,767	2,589	
Camera (30 - 1 per *woreda*)	43,096	14,365	
Indirect costs	76,782	76,782	
Total costs	329,639	203,967	
B. *Kebele*-level costs			
PICOs (240 - 1 per *kebele*)	52,235	17,412	
Total costs (A+B)		221,379	269,261
Row planting		73,793	89,754
Recommended seeding rates		73,793	89,754
Urea top or side dressing		73,793	89,754

Source: Authors' calculations based on secondary data from Digital Green.

Next, we measure the percent increase in the adoption rate of technology j attributable to the video-mediated approach using estimates of the coefficient β on the treatment variable T specified in Equation 1 earlier. Since we use ITT estimates, the coverage area consists of the development groups and their members in the treatment group that were targeted by the intervention. If we let N_t^j be the number of targeted households in the treatment *kebeles*, then the total number of additional adopters can be expressed as:

$$n_{tp}^{j} = \beta^{j} N_t^j$$

Corresponding estimates are provided in Table 14 below, under the "Experimental scenario" column.

Table 14: Additional adopters

Variable	Experimental scenario	Saturation scenario
Coverage: N_t^j		
Number of treated *kebeles*	231	450
Number of treated development groups per *kebele*	10	30
Number of treated farmers per development group	25	25
Number of farmers targeted	57,750	337,500
Impact estimates (ITT) on household head: β^j		
Row planting	0.043	
Recommended seeding rates	0.078	
Urea top or side dressing	0.069	
Additional adopting farmers: n_{tp}^j		
Row planting	2,458	14,363
Recommended seeding rates	4,516	26,391
Urea top or side dressing	4,000	23,375

Source: Authors' calculations.

The marginal cost-effectiveness ratio described above can now be calculated as:

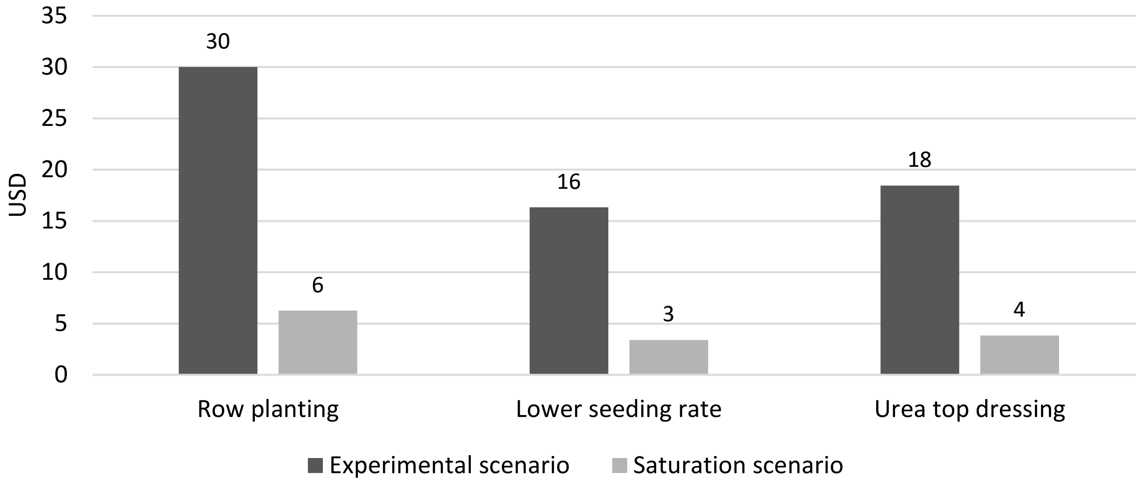
$$MCER_t^j = \frac{c_{tp}^j}{n_{tp}^j} = \frac{c_{tp}^j}{\beta^j N_t^j}$$

In Figure 2, we report the marginal costs of adoption for each of the three technologies considered. Under the experimental scenario, the cost of each additional adoption of row planting was USD 30 (ETB 691).[8] Similarly, for recommended seeding rates and urea dressing, the cost of each additional adoption was USD 16 (ETB 376) and USD 18 (ETB 424), respectively.

In Figure 2 we also report MCERs under the saturation scenario. The corresponding increase in coverage is shown in column 3 of Table 14. On the cost side, as shown in column 4 of Table 13, those that are fixed at the *woreda*-level are not affected by the increase in per-*woreda* coverage. However, all *kebele*-level costs increase with the number of additional *kebeles* that are included. To account for the potential difficulties of reaching all development groups in a *kebele* with one PICO projector, we account for two PICO projectors per *kebele* in the saturation scenario.

[8] At the time this study was conducted, and the intervention was implemented in 2017, the exchange rate was approximately 23 ETB/USD.

Figure 2. Marginal cost-effectiveness ratios of video-mediated agricultural extension



Given the particular importance of fixed costs at the *woreda* level, the associated MCERs under full saturation are much lower than that of the experimental coverage. Securing one additional adoption of row planting costs just USD 6 (ETB 144); recommended seeding rates just USD 3 (ETB 78), and urea dressing costs just USD 4 (ETB 88) (Table 15).

Table 15. Marginal cost-effectiveness ratios in USD and ETB

Technology	Experimental Scenario		Saturation Scenario	
	USD	ETB	USD	ETB
Row planting	30	691	6	144
Seeding rates	16	376	3	78
Urea top or side dressing	18	424	4	88

Note: Calculated at the 2017 exchange rate of 23 ETB/USD.
Source: Authors' calculations.

6. CONCLUSIONS AND POLICY IMPLICATIONS

Overall, several important findings emerge from our evaluation of the video-mediated extension approach employed by MoA, Digital Green, and the regional bureaus of agriculture across Ethiopia's main agricultural regions. First, the approach has a demonstrated capacity to reach a wider audience than the conventional approach employed by DAs and *woreda*-level extension staff, with gains observed particularly for spouses of the (typically male) heads of household. Second, the approach leads to higher levels of knowledge about the subject technologies and practices, again with gains observed for spouses. Third, the video-mediated approach results in increased uptake of the technologies and practices that are central to the extension program of MoA and the regional bureaus. Our estimates indicate that the video-mediated approach led to a 3 to 10 percentage point increases in uptake of many of the technologies and practices (row planting, recommended seeding rates, and urea top or side dressing) recommended for teff, wheat, and maize cultivation. These estimates represent up to a 35 percent increase in uptake of a given technology for a given crop when compared to mean of the control group.

While these results hold when both the head of household and the spouse are targeted by the video-mediated approach, we do not observe any marginal gains in uptake rates by treating both. This suggests the need for further analysis of the gender dimensions of video-mediated extension. As suggested by Doss (2015), "whether or not specific interventions should explicitly target women rather than men, it is clear that a gender-blind approach to designing interventions will miss out on key constraints, opportunities, and impacts." There is value in disentangling inequalities in intra-household bargaining power from social institutions and cultural norms, and further disentangling these effects from gender-unintentional practices within the extension system.

Importantly, we do not find statistically significant yield effects resulting from the video-mediated approach. We attribute this to challenges in accurately measuring both output and area. This opens the door to future research that integrates more accurate ground-truthing methods for yield measurement such as crop cuts with yield estimation using satellite imagery and associated analytical tools.

Despite this, it is also important to recognize the policy relevance of our findings. Unlike many prior studies on ICTs in agricultural extension, the program studied here represents a large-scale intervention of the Ethiopian government that is fully integrated into existing policy and practice. We provide clear evidence of the potential contribution of video mediation to existing extension policy and programming in Ethiopia and encourage further innovation in the program's design to generate additional outcomes. We also assess the marginal cost-effectiveness of the video-mediated approach under the experimental and a full saturation scenario. The cost of each additional adoption under the experimental scenario ranges from USD 16 – 30. However, these figures decrease to USD 3 – 6 when we assume that the video-mediated approach is extended to all *kebeles* in the treatment *woredas*.

Further, this study helps shift focus in national and global discourse on agricultural extension to the power that ICTs can have in augmenting—rather than replacing—extension services and agents. This, in turn, may draw attention to more constructive ways of thinking about lowering costs, improving efficiency, and increasing the impact of existing extension systems, while drawing attention away from offhanded dismissals of these systems as relics of past eras. Clearly, and despite what skeptics may suggest, there remains some value to be gained from direct, person-to-person interactions between extension agents and farmers.

As Ethiopia and other developing countries explore innovative ways to strengthen their extension and advisory services to farmers, these findings provide much-needed evidence on what works—and for whom—in the arena of innovative extension methods and tools.

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APPENDIX: SUPPLEMENTARY TABLES

Table A1: Balance test for spouse-level covariates

	Entire sample	Regular DG	DG + Spouse	Control	DG Regular − Control	(DG + Spouse) − Control	(DG + Spouse) − DG Regular
Spouse age	37.129	36.804	37.389	37.196	-0.391	0.193	0.584
	(10.421)	(10.226)	(10.277)	(10.758)	(0.658)	(0.661)	(0.575)
N	2,008	670	669	669	1339	1338	1339
Spouse received formal education	0.332	0.321	0.330	0.344	-0.024	-0.014	0.010
	(0.471)	(0.467)	(0.471)	(0.476)	(0.036)	(0.034)	(0.035)
Cultivated ___ in 2017/18 *meher*							
Teff	0.641	0.662	0.642	0.618	0.044	0.024	-0.020
	(0.480)	(0.473)	(0.480)	(0.486)	(0.050)	(0.050)	(0.050)
Wheat	0.617	0.623	0.612	0.615	0.008	-0.003	-0.011
	(0.486)	(0.485)	(0.488)	(0.487)	(0.050)	(0.050)	(0.052)
Maize	0.560	0.568	0.582	0.529	0.039	0.053	0.014
	(0.497)	(0.496)	(0.494)	(0.500)	(0.052)	(0.051)	(0.051)
Before 2017/18 tried ___ for teff							
Row planting	0.137	0.139	0.165	0.108	0.031	0.057*	0.027
	(0.344)	(0.346)	(0.372)	(0.311)	(0.030)	(0.031)	(0.031)
Recommended seeding rates	0.232	0.236	0.250	0.210	0.025	0.040	0.014
	(0.422)	(0.425)	(0.433)	(0.408)	(0.036)	(0.038)	(0.036)
Urea top dressing	0.277	0.277	0.296	0.258	0.020	0.038	0.019
	(0.448)	(0.448)	(0.457)	(0.438)	(0.039)	(0.040)	(0.038)
Before 2017/18 tried ___ for wheat							
Row planting	0.176	0.173	0.181	0.174	-0.001	0.007	0.008
	(0.381)	(0.379)	(0.385)	(0.380)	(0.034)	(0.035)	(0.036)
Recommended seeding rates	0.206	0.205	0.211	0.202	0.003	0.009	0.006
	(0.405)	(0.404)	(0.408)	(0.402)	(0.028)	(0.031)	(0.031)
Urea top dressing	0.275	0.267	0.292	0.265	0.002	0.027	0.024
	(0.446)	(0.443)	(0.455)	(0.442)	(0.036)	(0.039)	(0.038)
Before 2017/18 tried ___ for maize							
Row planting	0.437	0.429	0.447	0.435	-0.006	0.012	0.018
	(0.496)	(0.495)	(0.498)	(0.496)	(0.051)	(0.050)	(0.049)
Seeding rates	0.328	0.337	0.328	0.320	0.017	0.008	-0.009
	(0.470)	(0.473)	(0.470)	(0.467)	(0.041)	(0.040)	(0.040)
Urea side dressing	0.350	0.347	0.343	0.360	-0.013	-0.017	-0.003
	(0.477)	(0.476)	(0.475)	(0.480)	(0.046)	(0.045)	(0.045)
Observations (no.)	2,082	692	696	694	1,386	1,390	1,388

Note: Note: For columns 1-4, standard deviations in parentheses. For columns 5-7, standard errors clustered at the *kebele* level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A2: Balance test for DA level covariates

Variable	DG Regular (n=316)	DG + Spouse (n=312)	Control (n=268)	F-test of differences in means
DA's basic demographics				
Gender (1=Male)	0.76	0.72	0.76	0.489
Age (in completed years)	27.5	28.1	27.5	0.524
Qualification after secondary education				
Certificate (1=Yes)	0.25	0.23	0.26	0.771
Diploma (1=Yes)	0.52	0.55	0.55	0.725
Degree (1=Yes)	0.21	0.20	0.17	0.536
Number of years of schooling (number)	14.3	14.4	14.1	0.036
Total years of experience as a DA	5.39	5.99	5.33	0.370
Years of experience in the current *kebele*	1.90	1.91	1.80	0.837
Own smart phone (1=Yes)	0.50	0.43	0.44	0.284
Computer literate (1=Yes)	0.43	0.39	0.41	0.483
DA grew-up in the same locality (1=Yes)	0.06	0.09	0.10	0.146
DA grow-up farming (1=Yes)	0.92	0.89	0.89	0.260
Distance from home to FTC (minutes)	65.4	58.7	62.8	0.536
Extension delivery methods				
Extension approaches				
Door-to-door (1=Yes)	0.94	0.94	0.95	0.758
Farm-to-farm (1=Yes)	0.99	0.99	1.00	0.080*
Community meetings (1=Yes)	0.99	0.98	0.99	0.922
Dev't group meetings (1=Yes)	0.97	0.97	0.98	0.442
Demonstration (1=Yes)	0.92	0.93	0.93	0.887
Training at FTC (1=Yes)	0.86	0.92	0.88	0.102
Extension delivery techniques				
Word (speech/writing) (1=Yes)	0.99	0.99	0.99	0.864
Picture and images (1=Yes)	0.53	0.50	0.54	0.585
Audio (sounds) (1=Yes)	0.15	0.18	0.16	0.545
Video (sounds and pictures) (1=Yes)	0.06	0.10	0.06	0.132
Incentives				
Salary (net fixed monthly salary in '000 birr)	2.24	2.35	2.23	0.216
Housing allowance (1=Yes)	0.38	0.41	0.43	0.720
Transport allowance (1=Yes)	0.03	0.06	0.03	0.312
Health allowance (1=Yes)	0.01	0.01	0.02	0.166
Annual leave taken in 2017 (No. of days)	2.02	2.71	2.67	0.400
Received promotion in the past three years (1=Yes)	0.42	0.41	0.37	0.534
Satisfied with existing incentive structure (1=Yes)	0.25	0.21	0.35	0.008***
Workload				
Number of dev't groups being served (No.)	15.7	16.1	16.1	0.925
Number of actual working days per week				
During typical planting week	5.37	5.56	5.44	0.238
During typical harvesting week	4.72	4.80	4.73	0.806
During the slack season	3.86	3.74	3.76	0.738
Number of actual working hours per day				
During typical planting week	9.36	9.44	9.22	0.689
During typical harvesting week	8.23	8.23	8.00	0.606
During the slack season	6.36	6.23	6.21	0.854
Time allocation (%)				
Field/farmers home	20.7	21.1	20.1	0.725
Providing training (at FTC or anywhere)	13.5	15.1	15.5	0.016**
Receiving in-service training	8.29	7.75	7.86	0.419
Office (meeting, preparing report)	8.97	9.39	9.01	0.621
Administering credit repayment	6.37	6.17	6.34	0.892
Collecting agricultural data	9.46	8.31	8.41	0.068*
Administering taxes	6.29	5.76	6.37	0.373
Supplying agricultural inputs	10.7	10.5	10.8	0.903
Mobilizing farmers for community works	12.4	12.2	12.0	0.793
Involved in *kebele*'s agricultural planning (1=yes)	0.93	0.97	0.96	0.135

Note: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A3: Balance test for *kebele* level covariates

Variable	DG Regular (n=112)	DG + Spouse (n=112)	Control (n=110)	F-test of differences in means
Population size (no. of households)	823.1	805.3	1056.2	0.058*
Cultivated land area (hectares in '000, 2017)	1.1	1.1	1.0	0.881
Total length of paved road (km)	34.7	11.9	8.96	0.248
Total length of unpaved road	22.8	13.7	17.5	0.491
Number of local markets in the *kebele*	1.01	1.79	0.60	0.118
Distance to the nearest daily market (km)	12.6	11.7	6.48	0.000***
Number of grain traders in the *kebele*	9.26	10.0	14.5	0.109
Number of input dealers in the *kebele*	1.04	1.64	0.59	0.389
Number of seed producers in the *kebele*	19.0	23.5	28.1	0.673
Number of agricultural coops in the *kebele*	1.27	2.32	1.54	0.318
Number of MFI	2.10	1.69	1.83	0.901
Number of commercial banks	0.11	0.15	0.29	0.522
Number of milling machines	1.87	2.62	2.70	0.069*
Number of privately-owned tractors	0.22	0.96	1.03	0.049**
Number of privately-owned harvesters	0.24	0.71	0.43	0.331
Mobile signal in the *kebele* (1=Yes)	0.88	0.84	0.93	0.081*
Share of household own mobile phone (%)	61.5	71.7	63.3	0.401
Access to electricity (1=Yes)	0.36	0.37	0.41	0.660
Number of male Development Agents (DAs)	2.37	2.27	2.34	0.764
Number of female DAs	0.90	0.95	0.79	0.369
Total number of DAs	3.28	3.23	3.13	0.671

Note: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A4: The effect of treatment assignment on crop choice (teff, wheat, and maize)

	Teff				Wheat				Maize			
Variables	**Cultivated teff**	**Cultivated teff**	**Teff area cultivated (ha)**	**Teff area cultivated (ha)**	**Cultivated wheat**	**Cultivated wheat**	**Wheat area cultivated (ha)**	**Wheat area cultivated (ha)**	**Cultivated maize**	**Cultivated maize**	**Maize area cultivated (ha)**	**Maize area cultivated (ha)**
Any DG		0.0273		0.0493		0.00697		-0.0347		0.0245		0.0168
		(0.0326)		(0.0422)		(0.0265)		(0.0383)		(0.0266)		(0.0183)
Regular DG	0.0420		0.00930		0.00539		-0.0376		0.0272		0.0334	
	(0.0382)		(0.0467)		(0.0307)		(0.0420)		(0.0313)		(0.0228)	
DG + spouse	0.0132		0.0894*		0.00849		-0.0320		0.0219		0.000706	
	(0.0368)		(0.0483)		(0.0315)		(0.0432)		(0.0296)		(0 .0208)	
Constant	0.619***	0.619***	0.588***	0.588***	0.585***	0.585***	0.555***	0.555***	0.547***	0.547***	0.310***	0.309***
	(0.0333)	(0.0333)	(0.0626)	(0.0626)	(0.0280)	(0.0280)	(0.0352)	(0.0351)	(0.0287)	(0.0287)	(0.0209)	(0.0208)
Control mean	0.617	0.617	0.605	0.605	0.615	0.615	0.540	0.540	0.531	0.531	0.326	0.326
Observations	2,422	2,422	1,540	1,540	2,422	2,422	1,492	1,492	2,422	2,422	1,332	1,332
R-squared	0.244	0.243	0.301	0.299	0.354	0.354	0.243	0.243	0.361	0.361	0.371	0.370

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A5: DAs effort as measured by provision of advice and frequency of provision, by treatment group and crop

	All (1)		Teff (2)		Wheat (3)		Maize (4)	
Panel A: DA directly provided advice								
DG Spouse	0.164	***	0.112	***	0.163	***	0.113	***
	(0.0230)		(0.0275)		(0.0282)		(0.0313)	
Regular DG	0.152	***	0.103***		0.149	***	0.135	***
	(0.0240)		(0.0282)		(0.0296)		(0.0303)	
Test of equality								
F	0.26		0.1		0.22		0.56	
Prob > F	0.6127		0.7563		0.6366		0.4539	
Constant	0.511	***	0.466		0.473	***	0.514	***
	(0.0273)		(0.0332)		(0.0324)		(0.0323)	
Control mean	0.473		0.453		0.425		0.497	
Observations	2,422		1,540		1,492		1,332	
R-squared	0.318		0.341		0.372		0.351	
Panel B: Number of time DA directly provided advice								
DG Spouse	0.849	***	0.344	***	0.538	***	0.401	***
	(0.181)		(0.126)		(0.110)		(0.131)	
Regular DG	1	***	0.418	***	0.576	***	0.46	***
	(0.207)		(0.130)		(0.127)		(0.131)	
Test of equality								
F	0.53		0.33		0.1		0.21	
Prob > F	0.4672		0.5644		0.7487		0.6504	
Constant	2.317	***	1.314	***	1.152	***	1.562	***
	(0.200)		(0.128)		(0.127)		(0.131)	
Control mean	2.286		1.285		1.162		1.466	
Observations	2,422		1,540		1,492		1,332	
R-squared	0.284		0.263		0.291		0.288	

Note: “Regular DG” denotes the main treatment arm in which DAs screened videos to development groups comprised of (typically male) heads of households, while “DG Spouse” denotes the additional treatment arm in which DAs screened videos to development groups comprised of (typically male) heads of household and the female spouse of the household’s head. Robust standard errors in parentheses, clustered at the *kebele* level; *woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors’ calculations.

Table A6: DAs effort as measured by plots visited, by treatment

	All		Teff		Wheat		Maize	
	(1)		(2)		(3)		(4)	
Panel A: DA visited a plot (1=Yes)								
Regular DG	0.0624	**	0.0596	**	0.0568	*	0.0475	
	(0.0264)		(0.0292)		(0.0305)		(0.0308)	
DG Spouse	0.0583	**	0.0454	*	0.0587	**	0.0310	
	(0.0244)		(0.0273)		(0.0288)		(0.0289)	
Test of equality								
F	0.03		0.29		0.0		0.3	
Prob > F	0.8695		0.591		0.9484		0.5854	
Constant	0.373	***	0.295	***	0.296	***	0.397	***
	(0.0273)		(0.0321)		(0.0312)		(0.0330)	
Control mean	0.337		0.275		0.289		0.350	
Observations	2,421		1,540		1,491		1,332	
R-squared	0.256		0.316		0.301		0.293	
Panel B: Number of plots visited by DA								
DG Spouse	0.137	**	0.0811	**	0.0783	*	0.0373	
	(0.0574)		(0.0386)		(0.0428)		(0.0440)	
Regular DG	0.141	**	0.0628		0.0738	*	0.0397	
	(0.0623)		(0.0412)		(0.0407)		(0.0431)	
Test of equality								
F	0.0		0.19		0.01		0.0	
Prob > F	0.9597		0.661		0.9173		0.9579	
Constant	0.763	***	0.404	***	0.396	***	0.498	***
	(0.0656)		(0.0489)		(0.0444)		(0.0432)	
Control mean	0.674		0.351		0.355		0.445	
Observations	2,421		1,540		1,491		1,332	
R-squared	0.299		0.260		0.246		0.277	

Note: "Regular DG" denotes the main treatment arm in which DAs screened videos to development groups comprised of (typically male) heads of households, while "DG Spouse" denotes the additional treatment arm in which DAs screened videos to development groups comprised of (typically male) heads of household and the female spouse of the household's head. Robust standard errors in parentheses, clustered at the *kebele* level; *woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A7: Heterogenous effects measured by distance to FTC, DA advice received, and number of times DA advice received

	Any crop		Teff		Wheat		Maize	
	DA advice	**Times**	**DA advice**	**Times**	**DA advice**	**Times**	**DA advice**	**Times**
Treated *(1=yes)*	0.128***	0.442	0.103**	0.235	0.0951**	0.380**	0.0721*	0.132
	(0.0365)	(0.288)	(0.0462)	(0.178)	(0.0457)	(0.167)	(0.0430)	(0.188)
Medium distance from FTC	-0.156***	-1.110***	-0.0656	-0.457**	-0.173***	-0.601***	-0.113**	-0.516**
	(0.0455)	(0.296)	(0.0530)	(0.193)	(0.0559)	(0.178)	(0.0541)	(0.227)
Far from FTC	-0.0555	-0.455	-0.0281	-0.117	-0.112**	-0.0491	-0.101**	-0.572***
	(0.0434)	(0.322)	(0.0513)	(0.205)	(0.0570)	(0.272)	(0.0497)	(0.182)
Treated * Medium	0.0909*	1.065***	0.0363	0.425*	0.119*	0.556**	0.0942	0.445
	(0.0536)	(0.382)	(0.0645)	(0.246)	(0.0655)	(0.239)	(0.0652)	(0.282)
Treated * Far	-0.0294	0.124	-0.0336	-0.0775	0.0418	-0.185	0.0471	0.423*
	(0.0529)	(0.405)	(0.0617)	(0.257)	(0.0685)	(0.321)	(0.0620)	(0.254)
Constant	0.531***	2.629***	0.470***	1.412***	0.513***	1.268***	0.549***	1.761***
	(0.0350)	(0.252)	(0.0432)	(0.157)	(0.0426)	(0.148)	(0.0384)	(0.161)
Control mean	0.473	2.286	0.453	1.285	0.425	1.162	0.497	1.466
Observations	2,422	2,422	1,540	1,540	1,492	1,492	1,332	1,332
R-squared	0.320	0.287	0.342	0.266	0.374	0.297	0.352	0.290

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A8: Heterogenous effects by distance to FTC, DA effort measured by plots visited

	Crop			
	All	**Teff**	**Wheat**	**Maize**
Panel A: At least one plot visited by DA				
Treated *(1=yes)*	0.0315	0.0452	0.0231	0.0183
	(0.0396)	(0.0460)	(0.0466)	(0.0508)
Medium distance from FTC	-0.161***	-0.0895**	-0.140***	-0.171***
	(0.0409)	(0.0454)	(0.0520)	(0.0529)
Far from FTC	-0.105***	-0.0452	-0.0948*	-0.119**
	(0.0406)	(0.0498)	(0.0510)	(0.0569)
Treated * Medium	0.0766	0.0501	0.0721	0.0564
	(0.0498)	(0.0560)	(0.0627)	(0.0661)
Treated * Far	-0.0117	-0.0438	0.0174	-0.00873
	(0.0518)	(0.0607)	(0.0630)	(0.0711)
Constant	0.392***	0.300***	0.319***	0.411***
	(0.0339)	(0.0419)	(0.0381)	(0.0436)
Control mean	0.337	0.275	0.289	0.350
Observations	2,421	1,540	1,491	1,332
R-squared	0.258	0.317	0.302	0.293
Panel B: Number of plots visited by DA				
Treated *(1=yes)*	0.0927	0.0538	0.101	0.0162
	(0.108)	(0.0758)	(0.0702)	(0.0710)
Medium distance from FTC	-0.361***	-0.140*	-0.128*	-0.230***
	(0.106)	(0.0730)	(0.0774)	(0.0764)
Far from FTC	-0.254**	-0.127	-0.0982	-0.163*
	(0.115)	(0.0790)	(0.0740)	(0.0842)
Treated * Medium	0.148	0.0773	-0.0238	0.0692
	(0.129)	(0.0915)	(0.0969)	(0.0912)
Treated * Far	-0.0561	-0.0437	-0.0536	-0.0230
	(0.139)	(0.0964)	(0.0934)	(0.101)
Constant	0.794***	0.416***	0.380***	0.513***
	(0.0909)	(0.0694)	(0.0520)	(0.0590)
Control mean	0.674	0.351	0.355	0.445
Observations	2,421	1,540	1,491	1,332
R-squared	0.300	0.262	0.246	0.278

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1. *Source*: Authors' calculations.

Table A9: Adoption of row planting at a plot level, by crop

	Teff				Wheat				Maize			
	Row planted				Row planted				Row planted			
Any DG	0.0504***	0.0497**			0.0386*	0.0624*			-0.00879	-0.0712**		
	(0.0182)	(0.0251)			(0.0222)	(0.0372)			(0.0207)	(0.0337)		
Regular DG			0.0513***	0.0760***			0.0400	0.0571			-0.00545	-0.0423
			(0.0190)	(0.0291)			(0.0265)	(0.0439)			(0.0250)	(0.0380)
DG + spouse			0.0495**	0.0247			0.0372	0.0691*			-0.0120	-0.105**
			(0.0211)	(0.0285)			(0.0230)	(0.0397)			(0.0236)	(0.0414)
Test of equality (F)			0.01	3.04			0.02	0.09			0.07	2.23
Test of equality (Prob > F)			0.913	0.082			0.901	0.762			0.797	0.137
Spouse is part or whole owner of parcel		-0.0121		-0.0121		0.00655		0.00666		0.00559		0.00555
		(0.0213)		(0.0213)		(0.0320)		(0.0320)		(0.0268)		(0.0268)
Spouse is part or whole owner of parcel x Any DG		0.00200				-0.0354				0.0906***		
		(0.0276)				(0.0394)				(0.0347)		
Spouse is part or whole owner of parcel x Regular DG				-0.0337				-0.0263				0.0557
				(0.0319)				(0.0462)				(0.0395)
Spouse is part or whole owner of parcel x DG + Spouse				0.0355				-0.0456				0.131***
				(0.0330)				(0.0419)				(0.0443)
Constant	0.142***	0.149***	0.142***	0.149***	0.260***	0.254***	0.260***	0.254***	0.804***	0.803***	0.804***	0.803***
	(0.0184)	(0.0210)	(0.0183)	(0.0209)	(0.0240)	(0.0327)	(0.0240)	(0.0327)	(0.0216)	(0.0303)	(0.0216)	(0.0303)
Control mean	0.131	0.131	0.131	0.131	0.211	0.211	0.211	0.211	0.837	0.837	0.837	0.837
Observations	2,587	2,587	2,587	2,587	2,096	2,096	2,096	2,096	1,697	1,697	1,697	1,697
R-squared	0.417	0.417	0.417	0.418	0.485	0.485	0.485	0.485	0.378	0.386	0.378	0.388

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories) and plot area.
*** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A10: Applied DA advice at the plot level by crop

	Teff Applied DA advice				Wheat Applied DA advice				Maize Applied DA advice			
Any DG	-0.0503	-0.115**			-0.0324	-0.0397			-0.0494**	-0.0696		
	(0.0321)	(0.0523)			(0.0262)	(0.0478)			(0.0240)	(0.0444)		
Regular DG			-0.0581*	-0.0819			-0.0492	-0.0469			-0.0450	-0.0582
			(0.0340)	(0.0545)			(0.0311)	(0.0532)			(0.0281)	(0.0501)
DG + spouse			-0.0426	-0.146**			-0.0144	-0.0306			-0.0536**	-0.0829
			(0.0371)	(0.0605)			(0.0307)	(0.0541)			(0.0261)	(0.0519)
Test of equality (F)			0.25	1.68			1.12	0.11			0.11	0.24
Test of equality (Prob > F)			0.617	0.196			0.291	0.738			0.736	0.622
Spouse is part or whole owner of parcel		-0.0399		-0.0399		-0.0104		-0.0109		0.0405		0.0405
		(0.0520)		(0.0520)		(0.0458)		(0.0458)		(0.0401)		(0.0402)
Spouse is part or whole owner of parcel x Any DG		0.0958*				0.0109				0.0305		
		(0.0565)				(0.0531)				(0.0494)		
Spouse is part or whole owner of parcel x Regular DG				0.0384				-0.00397				0.0222
				(0.0596)				(0.0588)				(0.0565)
Spouse is part or whole owner of parcel x DG + Spouse				0.150**				0.0234				0.0411
				(0.0655)				(0.0600)				(0.0597)
Constant	0.395***	0.419***	0.395***	0.419***	0.452***	0.458***	0.452***	0.459***	0.733***	0.707***	0.733***	0.707***
	(0.0325)	(0.0484)	(0.0325)	(0.0484)	(0.0344)	(0.0507)	(0.0344)	(0.0507)	(0.0308)	(0.0421)	(0.0309)	(0.0421)
Control mean	0.390	0.390	0.390	0.390	0.417	0.417	0.417	0.417	0.729	0.729	0.729	0.729
Observations	2,587	2,587	2,587	2,587	2,096	2,096	2,096	2,096	1,697	1,697	1,697	1,697
R-squared	0.213	0.215	0.213	0.217	0.215	0.215	0.216	0.216	0.269	0.273	0.269	0.273

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories) and plot area. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' calculations.

Table A11: Treatment effect on yield and harvest quantity, by crop

	Teff				Wheat				Maize			
	Yield (quintal/hectare)		Harvest quantity (quintal)		Yield (quintal/hectare)		Harvest quantity (quintal)		Yield (quintal/hectare)		Harvest quantity (quintal)	
Any DG	-7.142		0.426		-1.343		-0.601		-156.0		-112.2	
	(7.867)		(0.639)		(2.770)		(1.324)		(141.9)		(106.3)	
Regular DG		-7.008		0.181		-2.615		-1.094		-148.0		-105.8
		(8.465)		(0.729)		(2.495)		(1.383)		(136.1)		(102.0)
DG + spouse		-7.276		0.673		-0.118		-0.126		-163.7		-118.3
		(7.440)		(0.650)		(3.488)		(1.641)		(149.5)		(111.9)
Test of equality (F)		0.01		0.87		0.97		0.42		0.19		0.22
Test of equality (Prob > F)		0.9158		0.3505		0.3243		0.5177		0.6633		0.6432
Constant	14.59**	14.59**	4.623***	4.621***	19.44***	19.38***	11.37***	11.35***	199.8	200.2	137.8	138.2
	(5.732)	(5.730)	(0.617)	(0.617)	(1.687)	(1.650)	(1.197)	(1.187)	(157.1)	(157.5)	(117.9)	(118.2)
Control mean	15.716	15.716	5.318	5.318	22.199	22.199	11.659	11.659	185.858	185.858	124.543	124.543
Observations	1,540	1,540	1,540	1,540	1,492	1,492	1,492	1,492	1,332	1,332	1,332	1,332
R-squared	0.033	0.033	0.149	0.149	0.044	0.045	0.179	0.179	0.016	0.016	0.015	0.015

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories), whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' calculations.

Table A12: Treatment effect on yield at the plot level, by crop

	Teff				Wheat				Maize			
	Yield (quintal/hectare)				Yield (quintal/hectare)				Yield (quintal/hectare)			
Any DG	0.616*	0.426			-0.458	-0.332			0.457	-0.0139		
	(0.350)	(0.544)			(0.515)	(0.798)			(1.150)	(1.681)		
Regular DG			0.582	0.300			-0.805	-0.741			1.021	1.000
			(0.365)	(0.579)			(0.601)	(0.939)			(1.239)	(1.953)
DG + spouse			0.650	0.548			-0.0896	0.177			-0.0972	-1.203
			(0.441)	(0.672)			(0.606)	(0.995)			(1.294)	(1.863)
Test of equality (F)			0.03	0.15			1.28	0.7			1.08	1.47
Test of equality (Prob > F)			0.869	0.694			0.259	0.403			0.299	0.226
Spouse is part or whole owner of parcel		0.0838		0.0843		0.503		0.497		0.188		0.180
		(0.443)		(0.443)		(0.833)		(0.832)		(1.732)		(1.733)
Spouse is part or whole owner of parcel x Any DG		0.265				-0.190				0.685		
		(0.550)				(1.038)				(2.021)		
Spouse is part or whole owner of parcel x Regular DG				0.394				-0.0800				0.0410
				(0.611)				(1.196)				(2.219)
Spouse is part or whole owner of parcel x DG + Spouse				0.143				-0.404				1.549
				(0.662)				(1.208)				(2.368)
Constant	8.455***	8.406***	8.455***	8.406***	16.57***	16.25***	16.57***	16.25***	26.29***	26.17***	26.26***	26.14***
	(0.337)	(0.453)	(0.337)	(0.453)	(0.528)	(0.686)	(0.528)	(0.685)	(1.145)	(1.636)	(1.144)	(1.637)
Control mean	8.263	8.263	8.263	8.263	16.185	16.185	16.185	16.185	25.961	25.961	25.961	25.961
Observations	2,587	2,587	2,587	2,587	2,096	2,096	2,096	2,096	1,697	1,697	1,697	1,697
R-squared	0.174	0.175	0.174	0.175	0.161	0.162	0.162	0.162	0.262	0.263	0.263	0.263

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories). Outliers *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' calculations.

Table A13: Treatment effect on yield using GPS-measured plot area and farmer self-reported harvest quantities, at the plot level, by crop

	Teff				Wheat				Maize			
	Yield (quintal/hectare)				Yield (quintal/hectare)				Yield (quintal/hectare)			
Any DG	1.154***	1.573**			-0.122	0.283			3.142	-6.159		
	(0.373)	(0.665)			(0.884)	(1.561)			(2.576)	(5.582)		
Regular DG			1.216***	0.710			-0.518	0.0735			3.965	-2.728
			(0.438)	(0.787)			(1.056)	(1.772)			(2.878)	(6.291)
DG + spouse			1.093**	2.250***			0.256	0.489			2.305	-10.57*
			(0.429)	(0.709)			(1.032)	(1.814)			(3.099)	(5.882)
Test of equality (F)			0.08	4.76			0.49	0.06			0.3	2.35
Test of equality (Prob > F)			0.7793	0.0301			0.4866	0.8134			0.5844	0.1266
Spouse is part or whole owner of parcel		0.500		0.477		-0.0093		-0.0193		-11.30**		-11.38**
		(0.680)		(0.679)		(1.676)		(1.678)		(4.892)		(4.890)
Spouse is part or whole owner of parcel x Any DG		-0.643				-0.600				14.14**		
		(0.822)				(2.022)				(6.108)		
Spouse is part or whole owner of parcel x Regular DG				0.680				-0.914				10.26
				(0.980)				(2.194)				(6.995)
Spouse is part or whole owner of parcel x DG + Spouse				-1.779**				-0.335				19.05***
				(0.876)				(2.343)				(6.484)
Constant	7.787***	7.463***	7.788***	7.466***	20.94***	20.92***	20.93***	20.91***	33.97***	41.32***	33.92***	41.31***
	(0.393)	(0.609)	(0.394)	(0.609)	(0.884)	(1.369)	(0.884)	(1.369)	(2.675)	(4.940)	(2.682)	(4.936)
Control mean	7.949	7.949	7.949	7.949	20.261	20.261	20.261	20.261	35.165	35.165	35.165	35.165
Observations	757	757	757	757	766	766	766	766	848	848	848	848
R-squared	0.167	0.167	0.167	0.176	0.171	0.171	0.172	0.172	0.121	0.128	0.121	0.130

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories). Outliers *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' calculations.

Table A14: Treatment effects on harvest quantity at a plot level, by crop

	Teff				Wheat				Maize			
	Harvest quantity (quintal)				Harvest quantity (quintal)				Harvest quantity (quintal)			
Any DG	-0.0303	0.284			0.205	0.203			-92.58	-8.364		
	(0.362)	(0.518)			(0.575)	(1.093)			(85.56)	(12.50)		
Regular DG			-0.0249	0.690			-0.180	-0.413			-94.56	-11.51
			(0.411)	(0.796)			(0.603)	(0.939)			(88.14)	(16.06)
DG + spouse			-0.0356	-0.103			0.615	0.971			-90.65	-4.718
			(0.352)	(0.448)			(0.823)	(1.730)			(84.26)	(11.27)
Test of equality (F)			0	1.08			0.84	0.75			0.04	0.28
Test of equality (Prob > F)			0.965	0.299			0.360	0.388			0.848	0.597
Spouse is part or whole owner of parcel		-0.0841		-0.0846		-0.329		-0.333		96.50		96.54
		(0.564)		(0.564)		(0.880)		(0.880)		(89.31)		(89.40)
Spouse is part or whole owner of parcel x Any DG		-0.443				0.00519				-119.2		
		(0.748)				(1.206)				(110.0)		
Spouse is part or whole owner of parcel x Regular DG				-1.007				0.348				-118.6
				(0.996)				(1.088)				(110.4)
Spouse is part or whole owner of parcel x DG + Spouse				0.0866				-0.486				-120.7
				(0.705)				(1.933)				(111.6)
Constant	1.825**	1.879***	1.825**	1.875***	-0.827	-0.623	-0.820	-0.611	1.973	-66.99	1.954	-67.03
	(0.713)	(0.622)	(0.713)	(0.621)	(1.409)	(1.362)	(1.405)	(1.359)	(20.06)	(73.65)	(20.08)	(73.76)
Control mean	3.319	3.319	3.319	3.319	7.918	7.918	7.918	7.918	93.423	93.423	93.423	93.423
Observations	2,587	2,587	2,587	2,587	2,096	2,096	2,096	2,096	1,697	1,697	1,697	1,697
R-squared	0.120	0.121	0.120	0.122	0.288	0.288	0.288	0.288	0.011	0.012	0.011	0.012

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories) and plot area. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' calculations.

Table A15: Estimates of treatment effects on access to extension for female spouse, by crop

	Teff		Wheat		Maize	
	DA directly provided advice/training		DA directly provided advice/training		DA directly provided advice/training	
Any DG	0.0213		0.0378*		0.0266	
	(0.0245)		(0.0229)		(0.0236)	
Regular DG		0.0118		0.0361		0.00147
		(0.0278)		(0.0275)		(0.0254)
DG + spouse		0.0311		0.0395		0.0506*
		(0.0272)		(0.0255)		(0.0278)
Test of equality (F)		0.6		0.02		3.67
Test of equality (Prob > F)		0.4407		0.8993		0.0565
Constant	0.279***	0.279***	0.208***	0.208***	0.282***	0.283***
	(0.0290)	(0.0290)	(0.0260)	(0.0260)	(0.0282)	(0.0281)
Control mean	0.242	0.242	0.188	0.188	0.264	0.264
Observations	1,314	1,314	1,257	1,257	1,144	1,144
R-squared	0.296	0.297	0.303	0.303	0.278	0.280

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A16: Estimates of treatment effects on knowledge test scores of female spouse of household head, by crop

	Teff				Wheat				Maize			
	Knowledge score (percent)		Knowledge score (inverse probability weighted)		Knowledge score (percent)		Knowledge score (inverse probability weighted)		Knowledge score (percent)		Knowledge score (inverse probability weighted)	
Any DG	1.021		-0.0326		1.103		0.440		0.322		0.786	
	(0.696)		(0.568)		(0.813)		(0.658)		(0.942)		(0.888)	
Regular DG		0.548		0.376		0.668		-0.241		0.440		1.231
		(0.835)		(0.635)		(0.909)		(0.734)		(1.090)		(1.031)
DG + spouse		1.509*		-0.453		1.539		1.121		0.208		0.358
		(0.790)		(0.600)		(0.956)		(0.772)		(1.035)		(0.971)
Test of equality (F)		1.31		2.82		0.9		3.38		0.06		0.89
Test of equality (Prob > F)		0.2542		0.0939		0.3428		0.0668		0.8132		0.3458
Constant	33.26***	33.27***	9.414***	9.409***	34.75***	34.74***	13.26***	13.25***	40.81***	40.81***	26.82***	26.80***
	(0.836)	(0.835)	(0.644)	(0.644)	(0.914)	(0.914)	(0.726)	(0.724)	(1.049)	(1.052)	(1.055)	(1.058)
Control mean	32.018	32.018	8.484	8.484	33.780	33.780	12.432	12.432	40.434	40.434	26.160	26.160
Observations	1,314	1,314	1,314	1,314	1,257	1,257	1,257	1,257	1,144	1,144	1,144	1,144
R-squared	0.234	0.235	0.134	0.135	0.179	0.180	0.148	0.151	0.266	0.266	0.242	0.243

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A17: Estimates of treatment effects on adoption of technologies/practices as reported by female spouse, by crop

	Teff		Wheat		Maize	
Panel A: Effect on row planting						
Any DG	0.0509**		0.0194		-0.0413*	
	(0.0207)		(0.0210)		(0.0233)	
Regular DG		0.0554**		0.0243		-0.0412
		(0.0222)		(0.0247)		(0.0274)
DG + spouse		0.0463*		0.0145		-0.0414
		(0.0242)		(0.0242)		(0.0276)
		0.19		0.15		0
Test of equality (F)		0.6654		0.696		0.9949
Test of equality (Prob > F)						
	0.131***	0.131***	0.238***	0.238***	0.689***	0.689***
Constant	(0.0221)	(0.0221)	(0.0231)	(0.0232)	(0.0228)	(0.0229)
Control mean	0.116	0.116	0.186	0.186	0.681	0.681
Observations	1,314	1,314	1,257	1,257	1,144	1,144
R-squared	0.362	0.362	0.400	0.400	0.402	0.402
Panel B: Effect on seeding rate						
Any DG	0.0371		0.0514**		-0.0258	
	(0.0271)		(0.0254)		(0.0307)	
Regular DG		0.0327		0.0358		-0.0308
		(0.0305)		(0.0307)		(0.0352)
DG + spouse		0.0416		0.0670**		-0.0209
		(0.0309)		(0.0291)		(0.0354)
		0.1		0.99		0.08
Test of equality (F)		0.7551		0.3217		0.7751
Test of equality (Prob > F)						
	0.274***	0.274***	0.222***	0.222***	0.420***	0.420***
Constant	(0.0307)	(0.0307)	(0.0271)	(0.0271)	(0.0339)	(0.0339)
Control mean	0.244	0.244	0.186	0.186	0.408	0.408
Observations	1,314	1,314	1,257	1,257	1,144	1,144
R-squared	0.188	0.188	0.145	0.146	0.181	0.181
Panel C: Effect on urea top or side dressing						
Any DG	0.0239		0.0296		-0.0118	
	(0.0231)		(0.0256)		(0.0229)	
Regular DG		0.00708		0.0237		0.00071
		(0.0269)		(0.0287)		(0.0273)
DG + spouse		0.0413		0.0355		-0.0239
		(0.0269)		(0.0306)		(0.0267)
Test of equality (F)		1.52		0.16		0.74
Test of equality (Prob > F)		0.2182		0.6917		0.3918
Constant	0.294***	0.295***	0.332***	0.332***	0.508***	0.508***
	(0.0273)	(0.0273)	(0.0290)	(0.0290)	(0.0258)	(0.0258)
Control mean	0.318	0.318	0.340	0.340	0.508	0.508
Observations	1,314	1,314	1,257	1,257	1,144	1,144
R-squared	0.287	0.288	0.261	0.261	0.394	0.395

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for distance to nearest FTC (categories). *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A18: Heterogenous effects on row planting for household head, by crop

	Teff			Wheat			Maize		
	Row planting			Row planting			Row planting		
Any DG	0.0297	0.0524**	0.0540*	0.0300	0.0433*	0.0319	0.0228	0.0355	0.0249
	(0.0282)	(0.0234)	(0.0295)	(0.0367)	(0.0242)	(0.0321)	(0.0407)	(0.0252)	(0.0293)
Medium distance to FTC	-0.0275	0.0153	0.0110	-0.0847**	-0.0673***	-0.0678***	-0.0450	-0.0171	-0.0163
	(0.0309)	(0.0190)	(0.0187)	(0.0361)	(0.0214)	(0.0219)	(0.0490)	(0.0275)	(0.0274)
Far from FTC	-0.0200	-0.00637	-0.00628	-0.0295	-0.0380*	-0.0387*	-0.0211	-0.0283	-0.0273
	(0.0283)	(0.0215)	(0.0217)	(0.0337)	(0.0227)	(0.0232)	(0.0538)	(0.0286)	(0.0287)
Any DG x Medium distance from FTC	0.0555			0.0183			0.0380		
	(0.0383)			(0.0450)			(0.0592)		
Any DG x Far from FTC	0.0202			-0.0162			-0.0109		
	(0.0395)			(0.0446)			(0.0632)		
Model farmer in household		0.0522*			0.0954***			0.0598	
		(0.0297)			(0.0308)			(0.0425)	
Any DG x Model farmer in household		0.0138			-0.0344			-0.00579	
		(0.0381)			(0.0398)			(0.0484)	
Top asset quantile			0.0344			0.0670*			0.0472
			(0.0244)			(0.0354)			(0.0356)
Any DG x Top asset quantile			0.00457			-0.00669			0.0203
			(0.0334)			(0.0424)			(0.0427)
Constant	0.154***	0.121***	0.119***	0.255***	0.225***	0.220***	0.662***	0.638***	0.632***
	(0.0252)	(0.0246)	(0.0274)	(0.0312)	(0.0272)	(0.0321)	(0.0376)	(0.0313)	(0.0333)
Control mean	0.160	0.160	0.160	0.174	0.174	0.174	0.650	0.650	0.650
Observations	1,540	1,540	1,540	1,492	1,492	1,492	1,332	1,332	1,332
R-squared	0.458	0.461	0.459	0.450	0.455	0.454	0.399	0.401	0.402

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A19: Heterogenous effects on recommended seeding rate for household head, by crop

	Teff			Wheat			Maize		
	Recommended seeding rate			Recommended seeding rate			Recommended seeding rate		
Any DG	0.0444	0.0717**	0.112***	0.0703	0.0976***	0.115***	-0.000586	0.0242	0.0834**
	(0.0486)	(0.0297)	(0.0357)	(0.0485)	(0.0287)	(0.0357)	(0.0539)	(0.0340)	(0.0352)
Medium distance to FTC	-0.0644	-0.0341	-0.0399	-0.0517	-0.0406	-0.0392	-0.101	-0.0446	-0.0433
	(0.0529)	(0.0308)	(0.0309)	(0.0491)	(0.0300)	(0.0300)	(0.0618)	(0.0359)	(0.0356)
Far from FTC	-0.0920*	-0.0632*	-0.0636*	-0.0505	-0.0184	-0.0183	-0.0577	-0.0527	-0.0497
	(0.0524)	(0.0326)	(0.0328)	(0.0536)	(0.0328)	(0.0329)	(0.0687)	(0.0374)	(0.0371)
Any DG x Medium distance from FTC	0.0325			0.00987			0.0780		
	(0.0646)			(0.0615)			(0.0750)		
Any DG x Far from FTC	0.0428			0.0440			0.00746		
	(0.0662)			(0.0667)			(0.0810)		
Model farmer in household		0.115***			0.0876**			0.0733	
		(0.0400)			(0.0429)			(0.0582)	
Any DG x Model farmer in household		-0.0154			-0.0361			0.0239	
		(0.0503)			(0.0535)			(0.0658)	
Top asset quantile			0.108***			0.104***			0.136***
			(0.0346)			(0.0398)			(0.0406)
Any DG x Top asset quantile			-0.0826*			-0.0589			-0.101**
			(0.0447)			(0.0484)			(0.0484)
Constant	0.361***	0.312***	0.290***	0.274***	0.237***	0.209***	0.491***	0.450***	0.402***
	(0.0422)	(0.0339)	(0.0365)	(0.0412)	(0.0336)	(0.0364)	(0.0498)	(0.0432)	(0.0416)
Control mean	0.311	0.311	0.311	0.222	0.222	0.222	0.436	0.436	0.436
Observations	1,540	1,540	1,540	1,492	1,492	1,492	1,332	1,332	1,332
R-squared	0.174	0.182	0.178	0.174	0.177	0.178	0.199	0.204	0.204

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

Table A20: Heterogenous effects on urea top or side dressing for household head, by crop

	Teff			Wheat			Maize		
	Urea top dressing			Urea top dressing			Urea side dressing		
Any DG	0.104**	0.0822***	0.113***	0.141***	0.0903***	0.0796**	0.0415	0.0345	0.0341
	(0.0469)	(0.0260)	(0.0321)	(0.0482)	(0.0298)	(0.0387)	(0.0435)	(0.0248)	(0.0315)
Medium distance to FTC	0.0507	0.0374	0.0325	0.0418	0.0186	0.0169	-0.0143	0.00173	0.00546
	(0.0552)	(0.0304)	(0.0305)	(0.0551)	(0.0330)	(0.0330)	(0.0456)	(0.0286)	(0.0282)
Far from FTC	0.0324	0.0112	0.0113	0.105*	0.0242	0.0233	0.0803	0.0343	0.0372
	(0.0488)	(0.0299)	(0.0302)	(0.0572)	(0.0342)	(0.0342)	(0.0562)	(0.0309)	(0.0308)
Any DG x Medium distance from FTC	-0.0328			-0.0421			0.0207		
	(0.0658)			(0.0685)			(0.0586)		
Any DG x Far from FTC	-0.0337			-0.123*			-0.0682		
	(0.0616)			(0.0699)			(0.0661)		
Model farmer in household		0.105**			0.0564			0.0511	
		(0.0435)			(0.0419)			(0.0428)	
Any DG x Model farmer in household		-0.0104			-0.00420			-0.0142	
		(0.0537)			(0.0498)			(0.0496)	
Top asset quantile			0.116***			0.0263			0.0981***
			(0.0348)			(0.0400)			(0.0352)
Any DG x Top asset quantile			-0.0641			0.0121			-0.00643
			(0.0435)			(0.0501)			(0.0457)
Constant	0.316***	0.301***	0.273***	0.311***	0.328***	0.332***	0.466***	0.460***	0.427***
	(0.0409)	(0.0305)	(0.0348)	(0.0401)	(0.0329)	(0.0376)	(0.0363)	(0.0297)	(0.0313)
Control mean	0.371	0.371	0.371	0.333	0.333	0.333	0.506	0.506	0.506
Observations	1,540	1,540	1,540	1,492	1,492	1,492	1,332	1,332	1,332
R-squared	0.287	0.294	0.293	0.241	0.241	0.240	0.440	0.440	0.447

Note: Robust standard errors in parentheses, clustered at the *kebele* level. *Woreda* fixed effects. Controls for whether household head received formal education, distance to nearest dry season road, distance to nearest all-weather road, and distance to nearest marketplace. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

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