Lifting quality constraints to agricultural technology adoption in the Ugandan market for maize seed

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Abstract

We test two hypothesis on how (perceived) quality of agricultural inputs affect adoption. First, poor quality is caused by agro-input dealers' lack of knowledge on proper handling and storage; a training is expected to improve input quality and subsequent adoption. Second, information asymmetry crowds out the market for quality inputs—a classic lemons problem. Here, we implement an information clearinghouse based on crowd-sourced reviews similar to yelp.com. Both hypotheses are tested in a randomized control trial for the case of improved maize seed varieties in Uganda. We find positive effects for the information clearing house, but not for the training.

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1   Introduction

Over the next few decades, farmers in sub-Saharan Africa will need to produce more food on less land and under increasingly difficult climatic conditions (Tilman et al., 2011). The use of climate-smart agricultural practices and improved inputs such as higher-yielding and drought-tolerant crop varieties are thought to be at least part of the solution (Evenson and Gollin, 2003). Unfortunately, there is concern that the use of improved inputs and technologies across the region seems to be stagnating—or at least advancing at a slower pace than required (Suri and Udry, 2022). As a result, differences in agricultural yields between sub-Saharan Africa and countries in Latin America and Asia have almost doubled since 1961 (Magruder, 2018).

Several key constraints have been rigorously tested in the last decade. This includes poor access to information (Ashraf, Giné, and Karlan, 2009), procrastination and time-inconsistent preferences of farmers (Duflo, Kremer, and Robinson, 2011), heterogeneity in uncertainty and the net benefits to the technology due to infrastructure and transaction costs (Suri, 2011), missing markets for risk and credit (Karlan et al., 2014), and opportunities and challenges related to learning about a new technology (Conley and Udry, 2010; Hanna, Mullainathan, and Schwartzstein, 2014).

More recently, issues related to input quality as a constraint to widespread adoption have emerged. In a widely cited article, Bold et al. (2017) argue that because quality is often difficult to assess by the farmers from simple visual inspection, information asymmetries between sellers and buyers characterize the markets for seed and fertilizer, crowding out the market for quality

2

seed. However, it is not clear if these quality issues are due to agro-input dealers intentionally adulterating inputs, or if this is simply because they lack knowledge and skills to preserve quality. Furthermore, it is not clear if these quality issues are real: While some studies argue that input quality is indeed lacking (Bold et al., 2017; Ashour et al., 2019; Barriga and Fiala, 2020), others argue that farmers' perceptions may be to blame (Michelson et al., 2021; Wossen, Abay, and Abdoulaye, 2022).

We attempt to answer some of these questions by means of a field experiment in the Ugandan market for improved maize seed varieties (high-yielding cultivars like open-pollinated and hybrid varieties). To test if low seed quality is primarily due to poor handling and storage, we organize trainings for a random sub-sample of farmers. Furthermore, we implement an information clearinghouse which is based on crowd-sourced ratings and works through reputational mechanisms like yelp.com or tripadvisor.com. By aggregating the experiences of many users under similar conditions, farmers can learn more about an agro-input dealer and the quality of the products they sell than if they have to rely on own experience only. This allows farmers to switch to the hightes rated input dealers. However, as the ratings are also available to the agro-input dealers, it also provides dealers with an incentive to increase the quality of products and services. If the quality of seed in the market is already sufficient, the same clearinghouse will work by rectifying the misperception of non-adopters. Both interventions are tested in a randomized control trial (RCT) among 350 agro-input dealers and an associated 3500 smallholder maize farmers in their catchment areas in eastern Uganda over the course of two agricultural seasons.

The results show that the training does not have a clear positive impact on dealers or their customers, suggesting that providing dealers with information does not work as long as they do not have an incentive to learn. On the other hand, the information clearinghouse affects both actors positively. Treated farmers start switching to different shops. Treated dealers anticipate this and increase their efforts to outperform their competitors: they seek knowledge about seed handling and improve their services. Treated shops are also more likely to be registered with the Uganda National Agro-Input and Dealers' Association (UNADA), perhaps to signal quality, and are inspected more often. Dealers in the clearinghouse treatment group are more successful: we measure a higher revenue at midline and more customers at endline. Farmers in the treatment group perceive the quality of maize seed at agro-input shops to be better and are more likely to adopt improved maize seed at both midline

and endline. As a result, their yield at endline significantly exceeds yields of control farmers. Hence, a clearinghouse clearly improves the Ugandan market for maize seed by improving quality in the eyes of farmers and by rectifying the misperception of non-adopters. All this proves that the perceived quality of seed is an important constraint to its adoption.

The paper is structured as follows: Section 2 provides information on the background of the study, section **??** introduces the model and section 3 the experimental design. The interventions, empirical strategy and data are described in sections 4, 5 and 6. After presenting the results in section 7, we outline potential threats to validity in section 8. Then we discuss our findings and conclude in sections 9 and 10.

2   Background

2.1   Agro-input dealers

Both interventions target agro-input dealers. Agro-input shops are businesses that sell inputs and equipment used in agricultural production, such as agricultural technologies like fertilizer and improved seed.[1] These dealers play an important role in the seed system because they create a market for agricultural technologies, develop and disseminate knowledge, and sometimes perform additional tasks like providing farm credit (Hornum and Bolwig, 2021). Furthermore, they are part of an important network with connections to actors across the value chain, such as manufacturers of inputs (e.g. seed companies), government organizations (e.g. breeders) and other agribusinesses. While the importance of the dealers in the seed supply chain seems straightforward and some authors emphasize the role of private agents (De Janvry et al., 2016), there are very few studies which target these actors. As the shops form a key link between the producers and users of agricultural technologies, the activities of these dealers play an important role and quality issues may arise at their level. That is why our interventions specifically target agro-input shops and dealers.

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[1]Agro-input shops sell only *improved* seed. The alternative to improved seed is farmer-saved seed which farmers harvest themselves in one crop season and save to plant it in the following season. This seed is usually free of charge (if farmers themselves save it) or cheap (if neighbors, relatives etc. save it) and not sold by agro-input shops.

2.2   Potential causes of (perceived) quality deterioration

On the one hand, the quality of maize seed could deteriorate because *agro-input dealers lack knowledge*. They could handle and store seed incorrectly and sell inferior seed without being aware. There is some evidence of this kind of quality reduction. In a comprehensive study of the Ugandan seed supply chain, Barriga and Fiala (2020) document various issues related to handling and storage that may reduce the quality of this input. For example, dealers often repack seed from larger bags packed by seed companies into smaller packages in order to offer quantities which are convenient and affordable for smallholder farmers. Important information including the expiry date and variety name can be lost during repackaging. Furthermore, seed is often repacked into bad material e.g. air tight polyethylene bags (Buveera) which affect aeration and seed viability. The open air storage of bags can also lower the quality of seeds (Bold et al., 2017). Temperature control after the seed leaves the breeders is crucial, too (Barriga and Fiala, 2020). Inventory carryover, poor rotation of seed stock and storage in moist conditions or in direct sunlight further reduce seed quality. That is because the bio-deterioration of maize is sensitive to temperature and humidity (Curzi, Nota, and Di Falco, 2022), seed moisture affects the occurrence of storage fungi (Govender, Aveling, and Kritzinger, 2008), and many quality attributes of seed tend to degrade with storage duration time and shelf life (Hoffmann et al., 2021).

On the other hand, the quality of maize seed could deteriorate because *agro-input dealers lack incentives*. The ability of smallholder farmers to assess seed quality before purchase is severely limited, as they can only visually examine seed purity and the presence of mold. Some dealers will exploit this information asymmetry and their malpractices will lead to poor seed quality. In a context relatively similar to ours, Hoffmann et al. (2021) look at maize grain as an output in rural Kenya and find that there is no incentive for sellers to address food safety losses because they are not observable for buyers, so that there is no correlation between prices and this unobservable quality attribute. Dealers may also sacrifice quality to increase profits, e.g. by mixing improved and new seed with not improved seed or old seed, to cut costs. There is empirical evidence of this kind of adulteration at some point in the Ugandan agricultural input supply chain. Bold et al. (2017) find that hybrid maize seed contains less than 50% authentic seeds and that 30% of nutrient is missing in fertilizer. Ashour et al. (2019) find that the average

bottle of herbicide is missing 15% of the active ingredient and nearly one in three bottles contains less than 75% of the ingredient advertised. Recently the topic has also received considerable attention from local news channels (Kazibwe, 2021; Muganga, 2023) and policy makers. A National Seed Policy report written by the Ugandan Ministry of Agriculture, Animal Industry and Fisheries states that 30-40% of seed traded in the market is counterfeit (2018). Note that both, buyers and sellers, suffer from the resulting poor average quality in this lemon market. For example, Gharib et al. (2021) find that concerns about seed quality reduce farmers' willingness to invest in seeds, as farmers are willing to pay 15% more for bags directly from the seed company than for bags from local retailers.

Thirdly, the quality of maize seed could be sufficient but *non-adopting farmers misperceive* it. Michelson et al. (2021) establish that the nutrient content of fertilizer in Tanzania is good and meets industry standards but that farmers believe that it is adulterated. One would simply need to correct farmers' beliefs which are inconsistent with the reality to increase adoption. Also Wossen, Abay, and Abdoulaye (2022) show that farmers in developing countries routinely misperceive input quality and that rectifying this misperception may improve farmers' investment choices and productivity outcomes.

2.3 Potential solutions

If a lack of dealer knowledge leads to deterioration in maize seed quality, an *agro-input dealer training* could help. Lack of information is pervasive in developing countries and often leads to sub-optimal outcomes for the rural poor. As a result, a simple piece of information can make a great difference (Duflo and Banerjee, 2011). Also in the context of agricultural technology adoption among smallholders, knowledge gaps have been identified as a key constraint, and governments around the world invest in public agricultural advisory services (Anderson and Feder, 2004). While the need for policies and interventions that strengthen input marketing capacity and infrastructure has been acknowledged decades ago (Tripp and Rohrbach, 2001), we find no examples of studies that look at knowledge gaps at the dealer level.

Figure 1 illustrates how an agro-input dealer training could work. Dealers could handle and store maize seed in better ways after learning how to do so during the training. Better handling and storage could lead to better maize seed quality. If farmers start purchasing better seed, their perceptions could improve, and ultimately, they could start adopting (more) improved seed.
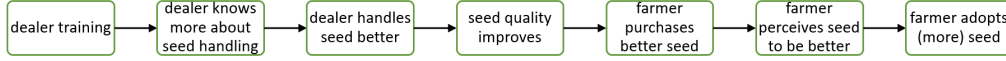
Figure 1: Theory of change - Agro-input dealer training

On the other hand, if a lack of incentives for dealers leads to deterioration in maize seed quality, this classic lemons technology problem can be solved by reducing information asymmetries between the two parties. In Kenya, seed companies have started marketing their seed using novel packaging features to signal product quality and authenticity (Gharib et al., 2021). Uganda does regulate seed quality by means of certifications and standards, but they provide farmers with a relatively weak and unreliable indication of quality. We bought seed bags from agro-input dealers in our sample, and only 8% of them have a certification sticker from an inspection agency. Alternatives such as electronic verification systems have also been experimented with, but the cost of implementation has proven challenging, and they depend on the reliability of the underlying seed certification system.

That is why we test an alternative, decentralized *clearinghouse* that is based on crowd-sourced information and works through reputational mechanisms, much like yelp.com or tripadvisor.com. This implies that we ask smallholder farmers to rate dealers in their proximity on a number of seed quality characteristics. Then we disseminate these average dealer ratings back to farmers and dealers. Studies in other contexts have shown that new crowd-based sources of pre-purchase information can be particularly useful. For instance, Reimers and Waldfogel (2021) compare the impacts of professional critics and Amazon star ratings of books on consumer welfare. The aggregate effect of star ratings on consumer surplus is more than ten times the effect of traditional review outlets.

Information clearinghouse mechanisms in developing countries have been studied to some extent, but mostly to address market price information asymmetries between smallholder farmers and middlemen. Assuming that middlemen are better informed about prevailing prices in the market than farmers, theory suggests that providing farmers with price information improves the functioning of rural agricultural markets. However, evidence is mixed: while Goyal (2010) finds that internet kiosks that provide wholesale price information significantly increase soy prices in India, Fafchamps and Minten (2012) do not find a statistically significant effect of market information delivered

to farmers' mobile phones in a neighboring state. A clearinghouse that relies on crowd-sourced ratings may be more effective in increasing seed quality in the market. While prices can generally be observed quite easily, assessing an experience good such as seed is much more difficult. Aggregating the experiences of many users may thus be a particularly powerful way to reveal the quality of the product.

A study by Hasanain, Khan, and Rezaee (2019), who set up an innovative rating system for public veterinary services in Pakistan, is probably the closest to ours. They find that farmers who use the clearinghouse enjoy a 25% higher success rate of artificial insemination. Their research suggests that this is mostly due to increased veterinarian effort, as few farmers seem to be switching from veterinaries that receive poor ratings to veterinaries that receive good ratings. In Hasanain, Khan, and Rezaee's study, veterinaries provide their services directly, without an intermediary. If producers do not sell to customers directly, so that more entities and transactions are involved, there is even more scope for information asymmetries. That is why reducing asymmetric information can be even more important in markets with intermediaries like agro-input dealers.

An information clearinghouse could work through different impact pathways which are illustrated in Figure 2. Firstly, farmers who already adopt at baseline could switch from low rated shops to higher rated shops after learning that their usually chosen dealer received a poor rating. Secondly, dealers could anticipate this and increase their efforts to outperform their competitors. Farmers could also pressure their usual dealers to improve. If dealers do not know how to increase their efforts, they will seek information. All these scenarios lead to seed of better quality, farmers purchasing better seed which improves their experiences by reducing risk and increasing profitability and later their perception of seed. Thirdly, farmers who did not buy seed before could start adopting improved seed when they realize that an agro-input dealer in their vicinity has a good rating, meaning that the quality of the seed sold there is better than expected. As mentioned above, the literature indicates that this pathway of improving the perception of quality without actually improving quality could be very relevant (Michelson et al., 2021; Wossen, Abay, and Abdoulaye, 2022). Ultimately, all this is expected to lead to increased adoption of improved maize seed.
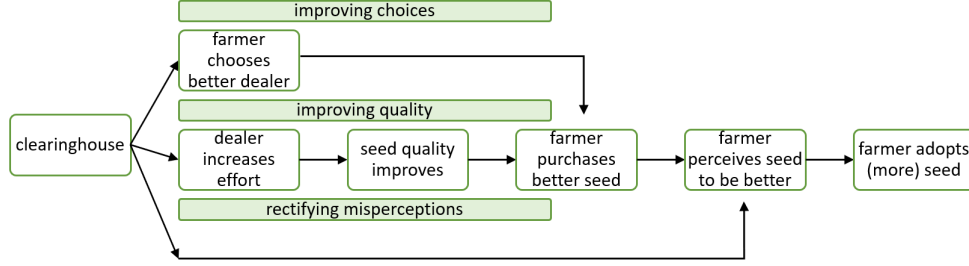
Figure 2: Theory of change - Information clearinghouse

3   Experimental design

To evaluate the impact of both interventions, we conduct an RCT. We randomize at the level of the *catchment area*. A catchment area is defined as the area that is served by an agro-input dealer, as the area where this shop's customers live. Often, dealers are clustered in towns, villages, markets, trading centers and other key market sheds. If the catchment areas of two or more shops overlap because these dealers operate in the same town, street or right next to each other, they are assigned to the same catchment area. This is done on the basis of geographical location.[2] We randomize at catchment area level for three reasons. Firstly, because randomizing at the level of the individual agro-input shop prompted ethical concerns and it is important to think about the ethics of experimentation, especially when the participants are vulnerable (Deaton, 2020). As both treatments could lead to serious comparative advantages, randomizing at catchment area level reduces the risk of harming someone with our experiment. Secondly, it erases any spillover concerns. Thirdly, randomizing at area level allows us to measure the effect of the treatments on farmers. If we would randomize at shop level, one dealer may be rated or trained but his or her neighbor may not. Some farmers would then have access to treated and control dealers, so that it would be difficult to distinguish treatment and control farmers. If we want to know if the clearinghouse leads to e.g. increased improved maize seed adoption,

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[2]The haversine function is used to construct an adjacency matrix based on shop GPS coordinates, and dealers that are less than 5 kilometer apart are assigned to the same catchment area. The 5 kilometer threshold was selected based on a visual inspection of the map, the size of an average village and the reported distance between farmers and dealers.
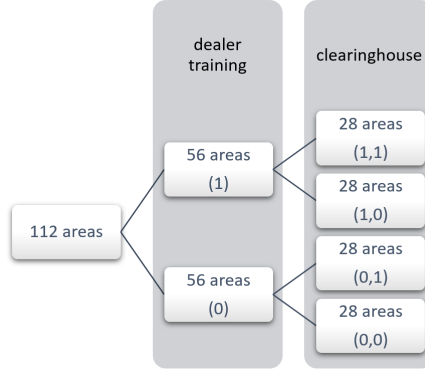
Figure 3: Factorial design

we need to be able to connect each farmer unambiguously to treatment or control. For these reasons we opted to randomize at catchment area level at the expense of statistical power, and collect data from a large sample to compensate for that.

We used simulations to determine the sample sizes for this experiment. Simulating provides a flexible and intuitive way to analyze power. Furthermore, instead of relying on theoretical distributions for the outcome variables that take assumptions and return analytic solutions, simulations can sample from real data. Power simulations with previously collected data[3] demonstrate that if the number of catchment areas is larger than 112, our experiments will return statistically significant results 80% of the time. This corresponds to about 318 agro-input dealers. Based on further simulations, we decide to collect information on 10 farmers per dealer, leading to a sample size of 3,180 households.[4]

The two interventions are combined in a field experiment which takes the form of a 2^2 factorial design. Factorial designs allow the recycling of treated units in the orthogonal factor as controls. As such, less observations than in parallel designs are needed to estimate main effects. The resulting layout is illustrated in Figure 3.

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[3]We use data from 78 agro-input dealers and 1,529 smallholder farmers in the catchment areas of these dealers that were collected in three districts in eastern Uganda in July 2019. These surveys were part of another study of the maize value chain and can be found here.

[4]More detailed information can be found in our pre-analysis plan.

4 Interventions

4.1 Agro-input dealer training

Content and training material

To determine the content of the training and to make sure it is locally anchored, we consulted experts from different Ugandan institutions and organizations like the ministry of agriculture, the seed sector and agro-input dealer associations. A series of semi-structured interviews and a workshop were organized. The experts identified common problems and malpractices by dealers, and then determined effective and realistic solutions and best seed storage and handling practices. We then developed a training manual to ensure standardization and a simple but visually appealing poster illustrating the most important best practices.

Training

Of each treated shop, the owner who decides upon investments and capital-intensive practices and the attendant who is in charge of day to day activities and decides upon labor-intensive practices were invited. We handed out one free portable seed moisture meter per shop as an incentive and tried to increase attendance by all means.[5]

The trainers explained the correct handling and storage practices for improved maize seed and used the poster and an example seed bag for illustration. Afterwards the dealers rehearsed the more challenging practices like correctly applying the moisture meter. At the end of the training, they were asked to answer a couple of multiple choice questions. The dealers were told at the beginning of the training that receiving a moisture meter was conditional on passing this test, which might have motivated them to pay closer attention. They also received the poster as a handout which could be hung in their store.

The trainings took one day and were organized in May 2021, late enough so that dealers were not busy with selling for the first agricultural season but early enough so that they could use the newly learned practices on the seed of the second agricultural season. A timeline is illustrated in Figure 4.

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[5]The trainings took place in locations that were easily reachable. All attendants were compensated for transport, lunch and drinks were provided. The training took place at a time of the year when dealers were not too busy.
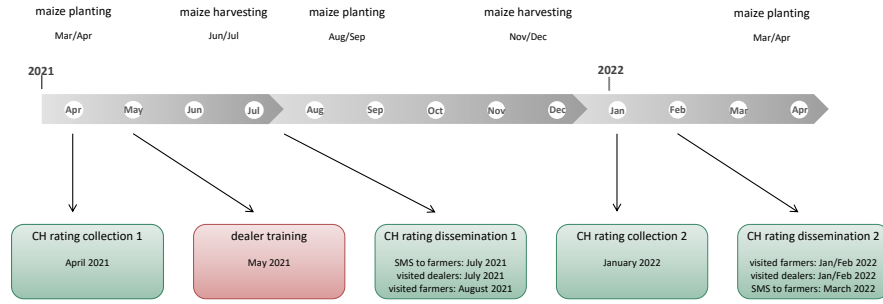
Figure 4: Timeline

4.2 Information clearinghouse

Collection and computation of ratings

When we collected baseline data from smallholder farmers, we also asked them to rate agro-input dealers in their proximity on a number of characteristics. It may be argued that by asking farmers to rate dealers, one also makes farmers aware of the existence of all dealers in the area, and that this awareness effect may potentially confound the clearinghouse effect. We thus also iterated through the dealers in control catchment areas, to make control farmers similarly aware of the existence of dealers in their vicinity. However, control farmers were not asked to rate dealers as the process of rating and thinking about a dealer's seed could make quality more salient, and is therefore part of the treatment.

Farmers' responses to the questions which are outlined in Table 1 constitute the ratings. For example, we asked farmers to rate the maize seed that an agro-input shop sells on a scale of one to five stars on germination. They were collected *after* harvest, when smallholders were able to assess seed quality based on observing germination and yield, the resistance against droughts, pests and diseases, and how fast the seed matures, see Figure 4 which shows

Table 1: Questions for farmers to rate dealers

	min	max
Do you know this *shop name* or *dealer name*, sometimes called *nickname*, located in *market name*? The place can be described as *description*.	no	yes
Please rate this agro-input shop on:		
Quality and authenticity of seed	1 star	5 stars
Please rate the maize seed that this agro-input shop sells on:		
General quality	1 star	5 stars
Yield as advertised	1 star	5 stars
Drought tolerance as advertised	1 star	5 stars
Pest/disease tolerance as advertised	1 star	5 stars
Speed of maturing as advertised	1 star	5 stars
Germination	1 star	5 stars

a timeline of the interventions.

Based on the answers of all farmers in a catchment area, we computed the ratings for each agro-input shop. These ratings were translated into words and stars, so that they are easily understandable for farmers and dealers who are not used to interpreting numbers. More details about the rating computations can be found in appendix A.1.

Dissemination of ratings to farmers

For the success of the clearinghouse it is crucial to disseminate the agro-input dealer ratings *before* farmers start buying seed for the next agricultural season, so that they can use this information when choosing whether and where to purchase inputs, see Figure 4. Ratings were disseminated to farmers in person and by means of text messages.

Text messages   We sent farmers one text message per dealer in their proximity. This message was translated into three local languages - Lusoga, Lugwere, Samia - chosen at the sub-county level to increase specificity. Please see Table 17 in the appendix for more details about these messages. Also in control catchment areas, farmers received text messages with the names of

dealers in their proximity, so that they were aware of the presence of these dealers. Dillon, Aker, and Blumenstock (2020) demonstrate the importance of these control messages. They introduced a "Yellow Pages" phone directory with contact information for local enterprises in central Tanzania. They find that enterprises randomly assigned to be listed in the directory receive more business calls, make greater use of mobile money, and are more likely to employ workers. As we are not interested in this kind of knowledge effect, i.e. farmers knowing which dealers operate in their proximity, we also disseminate control dealer information, so that we are able to measure the pure clearinghouse effect of making unobservable seed quality observable. An additional advantage is that control farmers will also believe that they are somewhat treated, so that treated and control farmers will adjust their behavior similarly (Bulte et al., 2014) and effort responses will not explain the treatment effect, if we find one.

In person   The enumerators also re-visited the farmers in our sample. For this purpose, we designed a visually appealing dissemination app which cycles through all dealers in the proximity of each farmer and states: "We wanted to let you know that customers from *shop name* rate the quality of maize seed sold there as okay/good/very good/excellent! The quality of the maize seed that this agro-input shop sells got a score of *score* out of 5!" in treated catchment areas. Then the enumerator showed the stars associated with the score. Again, we also cycled through dealers in control areas without providing the rating.

Dissemination of ratings to dealers

Agro-input dealers received their ratings by means of a report on laminated paper which was delivered to their shops. The front shows a visually appealing certificate with a logo and the own general rating, see Figure 5. It can be used to display the ratings in the shop, similar to a "certificate of excellence" from TripAdvisor.

The back of the report shows more detailed information. In addition to the dealer's general rating, it shows the dealer's specific ratings (overall quality, yield, drought and disease resistance, speed of maturing, and germination) and the average ratings of other agro-input dealers in the same catchment area in a table, visualized by stars. This shows dealers their relative position in the area and could stimulate competition. Dealers were not

Figure 5: SeedAdvisor certificate

informed about the individual ratings of their competitors, they only learned about the catchment area averages.

The intervention was repeated in the course of 2022, see Figure 4. We expect dealers to be more likely to change their behavior if they know that the clearinghouse will remain in place for some time, so that they will be scored again. It could also increase farmers' trust in the ratings.

5 Empirical strategy

Due to the random assignment to treatment and control groups, comparing outcome variable means of treated and control participants provides unbiased estimates of the effects of the interventions. Note that impact will be judged by looking at outcomes at the agro-input dealer level as well as at the farmer level. To increase power, we condition the estimates on baseline values of the outcome variables. We estimate the following specification using Ordinary Least-Squares to get the average treatment effects of both interventions:

$$Y_{1ij} = \alpha + \beta T_j + \gamma' X_{ij} + \delta Y_{0ij} + \varepsilon_{ij} \tag{1}$$

where Y_{1ij} is the outcome variable for dealer or farmer i in catchment area j at mid- or endline, Y_{0ij} is the corresponding outcome at baseline, T_j is a dummy for the treatment status of catchment area j, X_{ij} is a vector of all interactions between the different orthogonal treatments in the factorial design (Muralidharan, Romero, and Wüthrich, 2019), and ε_{ij} is a dealer- or farmer-specific error term. The coefficient β is our estimated average treatment effect.

Because we randomize at catchment area level, we use cluster-robust variance-covariance matrices. For outcomes at the farmer level where we have almost 3500 observations in 130 clusters, the original form of the sandwich estimator (Liang and Zeger, 1986) which does not make any small-sample correction is used. For outcomes at the agro-input dealer level where we have almost 350 observations in 130 clusters, we approximate the leave-one-cluster-out jackknife variance estimator (Bell and McCaffrey, 2002).

We account for multiple hypothesis testing by aggregating different outcomes within each domain into summary indices, following Anderson (2008).[6] However, interpreting these overall impacts can be difficult while effects on individual outcomes show us which variables drive the results and inform us about the different impact channels. That is why we also report the treatment effects on individual variables even though they have to be interpreted with care.

6 Data

6.1 Sample

Our sample consists of agro-input dealers and smallholder maize farmers who live in the catchment areas of these dealers. The dealer sample was obtained by listing all input shops in 11 districts in southeastern Uganda, which roughly corresponds to the Busoga kingdom, during a census. We

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[6]Each index is computed as a weighted mean of the standardized values of the outcome variables. The weights of this efficient generalized least squares estimator are calculated to maximize the amount of information captured in the index by giving less weight to outcomes that are highly correlated with each other.

found 348 dealers, sufficient to detect treatment effects according to our power simulations, see section 3.

After the census, these agro-input shops were assigned to 130 catchment areas. 1 to 18 dealers operate in an area, with a mean of 2.7. To connect shops and villages, we asked dealers where most of their customers come from. Then enumerators were instructed to randomly sample ten households that grow maize in these villages. Consequently, about 3500 smallholder maize farmers were sampled, sufficient to detect treatment effects according to our power simulations.

Baseline data was collected from dealers in September and October 2020 and from farmers in April 2021. Midline data was collected in January and February 2022, and endline data was collected in July and August 2022.

6.2 Descriptive statistics

This subsection describes the baseline sample. Information about the average *agro-input shop* can be found in Table 2. When enumerators approached a shop, they tried to interview the person who is most knowledgeable about the day to day operations of the business, inventories, sales, and so on. The average respondent is 32 years old. 60% are male and more than 90% finished primary education. In 55% of the cases, the respondent is the owner of the shop.

We see substantial heterogeneity among agro-input shops. Some are small informal stores which are located in rural areas and sell maize seed only during the planting season whilst usually selling other products. Others have many customers, are efficient, located in towns and specialized in inputs and equipment used in agricultural production. The average shop was established 5 years ago and is located 7 kilometers from the nearest tarmac road. It has 41 customers per day. 74% are specialized shops which only sell farm inputs.

We also collected a variety of variables related to the quality of maize seed sold at these agro-input shops. Enumerators asked if they could inspect the area where seed is stored and noted that there is quite some room for improvement. 65% of shops have problems with pests like rats or insects and 16% store maize seed in open containers. When we asked dealers about the services they provide, around half reported to offer credit and extension or training. On the other hand, 2 in 3 shops received a complaint about seed they sold from a customer since last season.

We also purchased a bag of maize seed. However, only 232 of the 348

17

shops in our sample had seed in stock at the time of the baseline interview. We measured the moisture in the bag and found that it was 13.6% on average, with a minimum of 10.3 and a maximum of 17.4. Note that seed moisture content determines whether molds and storage pests thrive, so that moisture should stay below 13%. While 68% of seed bags show a packaging date, only 18% show an expiry date, and 8% show a certification sticker.

Table 3 reports means in the *farmer* sample. When approaching a household, enumerators were instructed to interview the person who is most knowledgeable about maize farming. However, a set of questions deals with the household head, who could be or could not be the respondent. 78% of household heads in our sample are male, 51% have finished primary education. The average household head is 49 years old.

On average, 9 people belong to one household and share 3 rooms. The homestead is located 4 kilometers from the nearest agro-input shop and 9 kilometers from the nearest tarmac road. The average farmer started growing maize 23 years ago and has 3 acres of land for crop production.

Half of the farmers in our sample adopted improved maize seed on at least one of their fields last season. Of these adopting farmers, 2 out of 3 bought seed at an agro-input shop. Only 25% applied chemical fertilizers like Di-Ammonium Phosphate (DAP) or Nitrogen, Phosphorus, and Potassium (NPK) on a randomly selected maize field. Productivity is low with 500 kilograms per acre.

6.3 Orthogonality tests of randomization balance

To test if treatment and control groups are comparable in terms of a set of baseline characteristics we include standard orthogonality tables with pre-registered variables (Tables 2 and 3). Some of these characteristics are unlikely to be affected by the intervention, while others are picked from the primary and secondary outcomes. Very few of the pre-registered baseline characteristics are significantly different between treated and control dealers and farmers, the baseline sample is balanced.

7 Results

This section presents results on the impact of the agro-input dealer training and the information clearinghouse. We investigate a set of primary outcomes

Table 2: Descriptive statistics and orthogonality tests at dealer level

	mean	training	CH
Respondent's age in years	32.43	0.56	-2.24$^+$
	(11.49)	(1.19)	(1.21)
Respondent is male	0.59	0.02	-0.01
	(0.49)	(0.06)	(0.06)
Respondent finished primary education	0.92	0.01	-0.01
	(0.27)	(0.03)	(0.03)
Respondent owns shop	0.55	0.03	0.02
	(0.50)	(0.06)	(0.06)
Respondent received training on maize seed handling	0.53	0.05	0.12$^+$
	(0.50)	(0.07)	(0.07)
Respondent knows how to store seed after repackaging	0.27	0.07	0.08
	(0.44)	(0.06)	(0.06)
Shop's distance to nearest tarmac road in km	6.56	-0.92	-1.58
	(10.39)	(2.21)	(2.24)
Shop only sells farm inputs	0.74	-0.09	0.03
	(0.44)	(0.07)	(0.06)
Years since shop establishment	5.34	-0.09	0.21
	(6.30)	(0.77)	(0.78)
Number of customers per day	41.49	11.35	6.43
	(46.49)	(7.16)	(6.72)
Amount of maize seed sold last season in kg	910.88	275.42	258.56
	(2683.24)	(408.65)	(386.41)
Amount of maize seed lost/wasted last season in kg	3.50	1.99	2.40
	(18.65)	(2.47)	(2.30)
Shop has problem with pests	0.65	-0.01	-0.03
	(0.48)	(0.06)	(0.06)
Shop stores maize seed in open containers	0.16	0.00	0.08
	(0.36)	(0.05)	(0.05)
Shop received seed related complaint from customer	0.64	-0.11*	0.07
	(0.48)	(0.05)	(0.05)
Moisture in randomly selected seed bag in percent	13.58	0.12	-0.11
	(1.52)	(0.26)	(0.27)

Note: 1st column reports sample means at baseline and standard deviations below; 2nd-3rd column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; **, * and + denote significance at the 1, 5 and 10 percent levels.

Table 3: Descriptive statistics and orthogonality tests at farmer level

	mean	training	CH
Household head's age in years	48.62	-0.08	-0.24
	(13.38)	(0.56)	(0.56)
Household head is male	0.78	-0.02	0.03
	(0.42)	(0.03)	(0.03)
Household head finished primary education	0.51	0.00	0.04
	(0.50)	(0.03)	(0.03)
Homestead's distance to nearest tarmac road in km	9.39	0.33	-1.23
	(10.81)	(1.69)	(1.71)
Homestead's distance to nearest agro-input shop in km	3.78	-0.11	0.11
	(4.79)	(0.37)	(0.37)
Number of people in household (incl. respondent)	8.70	-0.16	-0.09
	(3.98)	(0.18)	(0.18)
Number of rooms in house	3.49	-0.01	0.02
	(1.45)	(0.09)	(0.09)
Farmer's land for crop production in acres	3.35	0.07	0.00
	(4.32)	(0.21)	(0.22)
Years since farmer started growing maize	23.09	0.61	-0.55
	(13.14)	(0.55)	(0.58)
Yield in kg/acre	499.52	43.75	8.61
	(771.17)	(28.99)	(27.66)
Farmer planted improved maize seed on any field last season	0.49	0.02	0.01
	(0.50)	(0.02)	(0.02)
Farmer bought this seed at agro-input shop	0.32	-0.01	0.01
	(0.47)	(0.02)	(0.02)
Amount of maize seed bought at agro-input shop in kg	3.53	0.04	-0.19
	(9.20)	(0.43)	(0.44)
Farmers thinks seed at agro-inputs shop is counterfeit	0.68	0.01	0.00
	(0.46)	(0.03)	(0.03)
Farmer used DAP/NPK	0.25	0.04	0.02
	(0.43)	(0.03)	(0.04)
Farmer used organic manure	0.07	-0.01	0.01
	(0.26)	(0.01)	(0.01)

Note: 1st column reports sample means at baseline and standard deviations below; 2nd-3rd column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; **, * and + denote significance at the 1, 5 and 10 percent levels.

and various secondary outcomes to explore the effects in detail, to identify steps along the causal chain and understand the mechanisms at work. As agro-input dealers and farmers could benefit from the interventions, we will assess changes in outcomes at both levels in separate subsections. We account for multiple hypothesis testing by aggregating different outcomes within each domain into overall summary indices, following Anderson (2008).[7] The information which variables are included in which indices can be found in the notes below the respective tables.

Note that all outcome variables have been registered in a pre-analysis plan which can be found in the American Economic Association (AEA)'s registry for RCTs. Additionally, we completed the entire econometric analysis on simulated data in a mock report and added it to the AEA registry before midline data was collected.[8] All documents, codes, and data are under revision control and publicly accessible via GitHub which provides time-stamped recordings of all changes made over the course of the project.

7.1 Impact on agro-input dealers

Primary outcome variables

The average treatment effects on primary outcomes at agro-input dealer level are reported in Table 4. At midline, the overall index is significantly larger among information clearinghouse treated dealers. There is also some evidence that individual outcomes were positively impacted. For instance, we see that dealers in the treatment group sold more maize seed at a higher price and therefore report significantly larger revenues. On the other hand, the dealer training does not affect the index significantly. In fact, considering variables individually suggests a negative impact of the training on the average sales price of improved maize varieties.

At endline, the clearinghouse intervention significantly increased primary outcomes at the agro-input dealer level as measured by the overall index.

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[7]In the regressions with these overall indices, we do not control for the baseline values because this would imply having the result only for dealers and farmers who have no missing values for any of the variables constituting these indices at mid-/endline *and* at baseline, leading to less observations and statistical power.

[8]Mock reports serve to tie the hands of researchers, reducing their freedom in choosing which specifications and variables to select when testing hypotheses. Humphreys, De la Sierra, and Van der Windt (2013) argue that mock reports can reduce intentional and unintentional fishing, and make published research more reliable.

The effect is driven by a substantial increase in the number of maize seed customers that shops attract and by an increase in the index which measures dealer efforts and services. Furthermore, all other effects go in the expected direction and some are close to the significance threshold. For instance, we see that shops in the clearinghouse treatment group apply better seed storage and handling practices,[9] have lower moisture levels in randomly sampled seed bags, sell more maize seed, and are rated better by farmers.[10] Results are more puzzling for the dealer training. Here, we find that exposed dealers sell and earn less. We also do not find that dealers that received the training use more of the proper seed storage and handling practices that they were taught. The index of primary outcomes confirms that the dealer training had no statistically significant impact.

Secondary outcome variables

As a first set of secondary outcomes at dealer level, we construct more *indices* which aggregate different variables according to Anderson (2008). The results are reported in Table 5.[11] A first index which proxies dealer's motivation and satisfaction remains constant among treatment groups. A second index which reflects self-ratings of agro-input dealers is similarly unaffected by the two treatments. While the index of dealer efforts and services among the primary outcomes in Table 4 was based on what dealers reported, we also asked farmers which services the dealers offer. We find convincing evidence that the information clearinghouse increases farmers' perceptions about dealers' efforts and services at midline. Surprisingly, we find that the dealer training seems to have the opposite effect. To investigate changes in skill and knowledge, we construct two more indices. For the index of dealer's knowledge about seed storage and handling and a similar index for knowledge related to seed, the difference between treatment and control groups is not significantly different from zero at midline. At endline however, we find a positive

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[9]These agro-input shop features were noted by our enumerators who inspected the area where seed was stored.

[10]Note that the rating indices are pre-registered outcomes but treatment and control groups can be compared only at endline. At base- and midline, only clearinghouse treated farmers rated dealers in their proximity because being confronted with these questions is part of the treatment. Hence control dealers were not rated and this line is left blank at midline. At endline, all farmers rated all shops, so that this variable can be investigated.

[11]These variables are not further adjusted for multiple hypothesis testing by means of an overall index because all of them are indices.

Table 4: Effects on primary dealer outcomes

	baseline	midline			endline		
	mean	training	CH	obs.	training	CH	obs.
Transf. quantity of maize seed sold in kg (IHS)†	5.898	-0.092	0.284	292	-0.499$^+$	0.239	286
	(1.965)	(0.220)	(0.227)		(0.250)	(0.253)	
Sales price of maize seed in UGX/kg	4273.897	-192.784$^+$	99.272	275	-33.867	145.861	264
	(955.073)	(114.934)	(113.292)		(143.152)	(138.816)	
Transf. revenue from maize seed in mln UGX (IHS)†	1.108	-0.069	0.185$^+$	292	-0.227$^+$	0.143	286
	(1.023)	(0.104)	(0.108)		(0.118)	(0.118)	
Transf. number of maize seed customers per day (IHS)†	3.248	-0.056	0.127	294	-0.190	0.310**	288
	(0.941)	(0.098)	(0.101)		(0.116)	(0.112)	
Moisture in randomly selected seed bag in percent	13.563	0.017	-0.122	175	-0.041	-0.220	261
	(1.442)	(0.142)	(0.144)		(0.198)	(0.197)	
Index of capital-intensive seed handling practices[1]†	0.000	-0.019	0.000	270	-0.087	0.070	265
	(0.508)	(0.063)	(0.072)		(0.092)	(0.081)	
Index of labor-intensive seed handling practices[2]†	0.010	0.058	0.099	285	0.083	0.074	274
	(0.484)	(0.070)	(0.065)		(0.067)	(0.068)	
Index of all seed handling practices[3]	0.009	0.042	0.052	251	0.021	0.083	248
	(0.382)	(0.051)	(0.053)		(0.063)	(0.059)	
Index of dealer's efforts and services[4]†	0.000	-0.063	0.066	243	-0.031	0.086$^+$	297
	(0.454)	(0.062)	(0.060)		(0.051)	(0.048)	
Index of shop's maize seed ratings by farmers[5]	-0.018				0.020	0.122	327
	(0.595)				(0.102)	(0.101)	
Overall index	0.007	-0.004	0.214$^+$	215	-0.058	0.239*	258
	(0.591)	(0.130)	(0.121)		(0.128)	(0.117)	
Max. number of obs. for dealer survey outcomes				306			297

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; *, ** and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

[1]The index of capital-intensive seed handling and storage practices contains 6 variables: whether roof is leak-proof, whether roof is insulated, whether walls are insulated, whether shop is ventilated, whether any official certificate is displayed, whether expired seed is handled correctly.

[2]The index of labor-intensive seed handling and storage practices contains 6 variables: whether seed is stored in dedicated area, whether shop has no pest problem, whether seed is stored in correct lighting, whether seed is stored on correct surface, whether seed is not stored in open containers, cleanness and professionality rating by enumerator.

[3]The index of all seed handling and storage practices contains 12 variables: the ones included in the index of capital-intensive practices and the ones included in the index of labor-intensive practices.

[4]The index of dealer's efforts and services contains 7 variables: whether shop offers explanations, complementary input recommendations, extension/training, discounts for larger quantities, credit, did not receive seed related customer complaint, accepts mobile money.

[5]The index of shop's maize seed ratings by farmers contains 6 ratings: general quality, yield, drought tolerance, pest/disease tolerance, time of maturity, germination. Ratings are aggregated at shop level (one shop is rated by multiple farmers), then the index is computed.

23

impact on dealer's knowledge about seed handling. Somewhat surprisingly, we do not find that knowledge is significantly affected by the training that we provided, but does increase due the clearinghouse. This seems to suggest that if dealers are provided with the right incentive, they actively seek out information. However, merely providing the information to dealers does not increase their knowledge.

We also consider outcomes associated with particular seed types. Because dealers often do not stock all types, sample sizes are smaller here. The next set of variables deals with *Longe 10H*, a popular hybrid maize variety. At midline, Table 6 reveals that the only significant result is found for the agro-input dealer training, which seems to have reduced the cost at which seed was obtained and stock-outs, measured as the number of times per month a shop ran out of Longe 10H. For the clearinghouse treatment, many coefficients go in the expected direction but none of the comparisons is significant. At endline however, the results regarding Longe 10H are generally consistent with the findings for primary dealer outcomes. Most importantly, we find a significant and positive overall effect of the clearinghouse treatment as judged by the overall index. This is driven by increased sales and decreased stock-outs, for which both coefficient estimates are just above the significance threshold. For the agro-input dealer training, we do not find an overall effect at endline.

The same questions were asked for *Longe 5*, a commonly traded open-pollinated maize variety. Table 7 shows that again, the clearinghouse treatment affected this family of outcomes significantly, as measured by the overall index at endline.

We also collected information about *memberships, licenses, and inspections*. Table 8 reports that there is no impact of the interventions at midline. At endline, we measure a positive impact of the information clearinghouse on the overall index. This result is driven by an almost 12 percentage point increase in the likelihood that the agro-input shop is registered with UNADA. The clearinghouse also crowds-in shop inspections, perhaps due to increased registrations, licenses, and memberships of shops in the treatment group. Alternatively, dealers could voluntarily expose themselves to increased scrutiny and actively seek inspections to signal costumers that they offer products of good quality. The dealer training did not affect this set of outcome variables at endline.

Table 5: Effects on secondary dealer outcomes: Indices

	baseline mean	midline training	midline CH	obs.	endline training	endline CH	obs.
Index of dealer's motivation and satisfaction[1]	0.000 (0.674)	0.033 (0.082)	0.000 (0.085)	306	-0.109 (0.082)	-0.076 (0.086)	286
Index of dealer's self-ratings[2]	0.000 (0.651)	-0.068 (0.084)	-0.002 (0.079)	306	-0.132 (0.086)	0.080 (0.079)	297
Index of dealer's efforts and services according to farmers[3]	-0.027 (0.583)	-0.151* (0.074)	0.301** (0.069)	259	0.006 (0.092)	0.086 (0.084)	271
Index of dealer's knowledge about seed storage[4]	0.000 (0.482)	0.091 (0.076)	0.115 (0.075)	306	0.030 (0.053)	0.124* (0.055)	297
Index of dealer's knowledge about seed[5]	0.000 (0.533)	0.102 (0.072)	0.065 (0.070)	306	-0.009 (0.080)	-0.007 (0.078)	297
Max. number of obs.				306			297

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; ** and * denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

[1]The index of dealer's motivation and satisfaction contains 3 variables: whether dealers see themselves working as agro-input dealers in future, would recommend working as dealers, how happy dealers feel when they come to work. We report the mean and standard deviation at midline because these variables were not collected at baseline.

[2]The index of dealer's self-ratings contains 5 ratings: location, price, product quality, stock, reputation.

[3]The index of dealer's efforts and services according to farmers contains 7 variables: whether shop offers refund/insurance, credit, training/advice, delivery, after-sales service, accepts different payment methods, sells small quantities. The answers are aggregated at dealer level, then the index is computed.

[4]The index of dealer's knowledge about seed storage contains 5 variables: whether dealer knows how long seed can be carried over, how seed should be stored after repackaging, what the min. distance between floor and seed is, how seed should be stored in storeroom, whether seed should be repackaged.

[5]The index of dealer's knowledge about seed contains 4 variables: whether dealer knows which seed variety to recommend if farmer complains about poor soil, if farmer complains about little rain, if farmer is late for planting, what to tell clients about yield benefits of hybrid seed.

Table 6: Effects on secondary dealer outcomes: Longe 10H

	baseline	midline			endline		
	mean	training	CH	obs.	training	CH	obs.
Transf. amount carried forward in kg (IHS)†	0.318	-0.186	0.090	262	-0.012	-0.034	250
	(1.083)	(0.212)	(0.215)		(0.138)	(0.134)	
Transf. amount shop bought from provider in kg (IHS)†	4.212	0.118	0.206	257	-0.022	0.283	243
	(2.723)	(0.218)	(0.213)		(0.250)	(0.253)	
Transf. cost in UGX/kg (IHS)	9.209	-0.056*	-0.035	180	-0.026	0.008	179
	(0.130)	(0.024)	(0.022)		(0.029)	(0.030)	
Transf. quantity sold in kg (IHS)†	4.132	0.050	0.236	256	-0.205	0.352	242
	(2.749)	(0.206)	(0.204)		(0.231)	(0.239)	
Transf. sales price in UGX/kg (IHS)	9.417	-0.025	-0.013	194	-0.019	0.010	187
	(0.145)	(0.026)	(0.026)		(0.030)	(0.029)	
Transf. amount lost/wasted in kg (IHS)†	0.018	-0.001	0.019	257	-0.058	-0.038	243
	(0.197)	(0.093)	(0.097)		(0.037)	(0.041)	
Transf. number of times per month shop ran out (IHS)†	0.632	-0.236+	-0.045	192	-0.180	-0.205	185
	(0.788)	(0.129)	(0.133)		(0.128)	(0.136)	
Overall index	0.116	0.119	0.034	249	0.014	0.206**	233
	(0.470)	(0.074)	(0.075)		(0.063)	(0.067)	
Max. number of obs.[1]				268			254

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; **, * and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.
[1]The comparisons were only made for shops which had Longe 10H in stock at mid- or endline.

Table 7: Effects on secondary dealer outcomes: Longe 5

	baseline	midline			endline		
	mean	training	CH	obs.	training	CH	obs.
Transf. amount carried forward in kg (IHS)†	0.414	0.247	-0.092	270	-0.095	-0.004	263
	(1.243)	(0.324)	(0.306)		(0.148)	(0.155)	
Transf. amount shop bought from provider in kg (IHS)†	5.350	-0.005	0.253	262	-0.179	0.289	260
	(2.228)	(0.221)	(0.215)		(0.232)	(0.235)	
Transf. cost in UGX/kg (IHS)	8.507	-0.019	-0.030^{+}	231	-0.010	0.001	231
	(0.082)	(0.015)	(0.016)		(0.021)	(0.020)	
Transf. quantity sold in kg (IHS)†	5.258	-0.040	0.304	261	-0.215	0.316	259
	(2.190)	(0.222)	(0.216)		(0.234)	(0.230)	
Transf. sales price in UGX/kg (IHS)	8.730	0.017	-0.015	249	-0.002	0.013	241
	(0.110)	(0.016)	(0.016)		(0.022)	(0.022)	
Transf. amount lost/wasted in kg (IHS)†	0.245	-0.150	0.031	266	-0.055	-0.033	261
	(0.894)	(0.128)	(0.128)		(0.055)	(0.058)	
Transf. number of times per month shop ran out (IHS)†	0.498	0.053	0.086	248	0.094	-0.054	237
	(0.767)	(0.100)	(0.101)		(0.120)	(0.126)	
Overall index	0.054	0.024	0.031	259	-0.020	0.148*	253
	(0.506)	(0.095)	(0.094)		(0.069)	(0.069)	
Max. number of obs.[1]				275			269

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; **, * and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

[1] The comparisons were only made for shops which had Longe 5 in stock at mid- or endline.

Table 8: Effects on secondary dealer outcomes: Memberships, licenses, inspections

	baseline	midline			endline		
	mean	training	CH	obs.	training	CH	obs.
Shop is registered with UNADA†	0.442	0.040	0.066	252	-0.050	0.118[+]	258
	(0.497)	(0.072)	(0.068)		(0.072)	(0.070)	
Shop has trading license issued by local government†	0.749	-0.042	0.021	288	-0.033	0.008	285
	(0.435)	(0.053)	(0.054)		(0.056)	(0.057)	
Shop is member of other professional association†	0.345	-0.035	0.058	268	0.001	0.069	267
	(0.476)	(0.051)	(0.052)		(0.073)	(0.066)	
Transf. number of shop inspections (IHS)†	0.956	0.037	-0.097	293	0.038	0.292*	273
	(0.772)	(0.247)	(0.259)		(0.109)	(0.111)	
Shop received warning after inspection†	0.317	0.045	0.005	291	0.013	-0.009	284
	(0.466)	(0.072)	(0.073)		(0.062)	(0.063)	
Shop's products were confiscated after inspection†	0.145	0.021	-0.027	293	0.014	-0.025	285
	(0.353)	(0.046)	(0.046)		(0.033)	(0.036)	
Overall index	-0.004	-0.005	0.047	266	-0.006	0.203**	253
	(0.433)	(0.056)	(0.055)		(0.078)	(0.074)	
Max. number of obs.	306						297

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; **, * and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

7.2 Impact on smallholder farmers

Primary outcome variables

Table 9 reports the effects of the interventions on a set of key outcomes at the smallholder level. We do not find an impact on the overall primary outcome index at midline. Looking at the variables individually, we do see a significant impact of the information clearinghouse intervention. Most strikingly, there is a substantial increase in the share of farmers who switched to a different agro-input shop. In areas where the clearinghouse was implemented, we record a 4 percentage point higher propensity to switch, which corresponds to a 25 percent increase relative to the baseline mean. Furthermore, the clearinghouse increased adoption. Treated farmers are 4 percentage points more likely to have used improved maize seed on any field. We also see a 6 percentage point increase in the share of farmers who used quality maize seed bought from an agro-input dealer. Finally, for our measure of effort perception, farmers indicate that dealers in areas exposed to the clearinghouse provide more services such as training, credit, etc. than dealers in control areas. However, this estimate is based on a very small sample. We do not find an effect of the dealer level training on farmer outcomes at midline, except for the affected index of shop services which is based on a very small sample.

At endline, we see that the information clearinghouse has a positive impact on farmers when looking at the overall index. Considering individual primary outcomes, we find that farmers who were exposed to the clearinghouse treatment are 4 percentage points more likely to have used improved seed on at least one of their maize plots. Two other important outcome are related to the perception of product quality, shop and seller.[10] To be able to calculate these indices at the smallholder level, the farmer needs to have rated at least one dealer in the neighborhood on all the components of the indices, which leads to a reduction of the sample size which in turn may have affected power. Nonetheless, we see that the index of farmer's maize seed ratings of shops nearby is significantly affected by the treatment. Other variables that are significantly impacted include the likelihood that farmers switch shops, or the efforts and services that farmers receive from dealers. It is also encouraging that results at the farmer level are consistent with outcomes at the dealer level. For instance, in Table 4 we also see that dealers report more customers and provide more effort and services. We again do not find an impact of the dealer training on farmers at endline.

Table 9: Effects on primary farmer outcomes

	baseline mean	midline training	midline CH	midline obs.	endline training	endline CH	endline obs.
Farmer planted improved maize seed on any field†	0.492 (0.500)	-0.021 (0.020)	0.035+ (0.020)	3206	-0.009 (0.020)	0.042* (0.020)	3282
Farmer bought maize seed at agro-input shop for any field†	0.325 (0.468)	-0.014 (0.021)	0.059** (0.021)	3145	0.004 (0.020)	0.031 (0.020)	3225
Amount of this seed farmer bought at agro-input shop in kg	9.519 (6.920)	0.512 (0.348)	-0.105 (0.358)	599	0.457 (0.419)	0.378 (0.431)	621
Index of farmer's maize seed ratings of shops nearby[1]	0.000 (0.637)				0.021 (0.054)	0.092+ (0.054)	1664
Index of farmer's general ratings of shops nearby[2]	0.000 (0.657)				-0.026 (0.043)	-0.005 (0.042)	1706
Index of services of shops nearby according to farmers[3]	-0.037 (0.609)	-0.138+ (0.073)	0.161* (0.067)	312	0.034 (0.081)	0.131+ (0.077)	320
Farmer switched to different agro-input shop[4]†	0.168 (0.374)	-0.013 (0.014)	0.042** (0.014)	3407	-0.024 (0.015)	0.026+ (0.015)	3441
Index of farmer's practices on randomly selected field[5]†	0.008 (0.400)	0.011 (0.019)	-0.026 (0.019)	2929	0.001 (0.021)	0.016 (0.021)	3053
Farmer thinks maize seed at agro-input shops is adulterated	0.685 (0.465)	-0.033 (0.027)	-0.041 (0.027)	2113	-0.041 (0.028)	0.020 (0.028)	2167
Farmer planted land race maize seed on randomly selected field†	0.448 (0.497)	0.015 (0.021)	-0.013 (0.020)	2954	0.009 (0.022)	-0.024 (0.022)	3047
Overall index[6]	0.009 (0.698)	0.008 (0.033)	0.017 (0.034)	2933	-0.023 (0.034)	0.063+ (0.034)	3083
Max. number of obs.				3407			3441

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; **, * and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

[1]The index of farmer's maize seed ratings contains 6 ratings: general quality, yield, drought tolerance, pest/disease tolerance, time of maturity, germination. The ratings are aggregated at farmer level (one farmer rates multiple shops), then this index is computed.

[2]The index of farmer's general ratings contains 6 ratings: general quality, location, price, product quality, stock, reputation. The ratings are aggregated at farmer level (one farmer rates multiple shops), then this index is computed.

[3]The index of services of shops nearby contains 7 variables: whether shop offers refund/insurance, credit, training/advice, delivery, after-sales service, accepts different payment methods, sells small quantities. The answers are aggregated at shop level, then the index is computed at farmer level. Only 320 farmers answered all 7 questions for at least one shop nearby at baseline and at endline.

[4]We report the mean and standard deviation at midline because this variable was not collected at baseline.

[5]The index of farmer's practices contains 10 variables: whether farmer spaced seed correctly, sowed correct number of seeds/hill, applied organic manure, DAP/NPK, Urea, pesticides/herbicides/fungicides, weeded sufficiently, weeded at correct time, planted at correct time, re-sowed.

[6]We report the mean and standard deviation at midline because not all variables in this index were collected at baseline.

Secondary outcome variables

To explore impact pathways at the level of the smallholder, we often consider outcomes associated with a randomly selected maize field.[12] In Table 10 we look at the *adoption of improved maize seed* on that field. While we do not find any significant impact of the agro-input dealer training at midline, we do find some interesting results for the information clearinghouse treatment even though the overall index is not impacted. It improves the adoption of improved seed varieties by increasing the likelihood that treated farmers plant seed bought at agro-input shops and decreasing the likelihood that they plant farmer-saved seed. At endline we again find that farmers that were exposed to the clearinghouse are more likely to have planted seed that was bought at an agro-input shop. Most of the other variables also go into the expected direction, but estimates are not significantly different from zero. According to the index, we also do not find an impact of the clearinghouse. We find no effect of the dealer training on the adoption of improved maize seed.

In Table 11, we zoom in on the *maize seed that farmers planted* on the randomly selected field, and investigate their quality perceptions. On fields exposed to the clearinghouse treatment, farmers use more expensive seed leading to higher seed costs. This is consistent with the explanation that the clearinghouse increases the adoption of commercial seed. At midline, the overall index is also affected by the clearinghouse. We see no effect of the training.

We further look at *harvest* related outcomes, like maize yield and revenue, associated with the randomly selected field.[13] Table 12 shows that there is no impact of the agro-input dealer intervention at mid- or endline. For the information clearinghouse treatment, the impact is ambiguous at midline. There are some indications of reduced productivity, but farmers also seem to save less seed to sow in the upcoming season, signaling that they plan to buy improved seed. At endline, judged by the index, the clearinghouse treatment had a significant and positive impact on this family of outcomes.

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[12]Farmers often have more than one field. As outcomes on different plots from the same farmer are likely to be strongly correlated, it is not cost effective to ask questions about all fields. An unbiased estimate of the outcome at the household level can be obtained by randomly selecting one plot.

[13]Note that inter-cropping was not taken into account when calculating these numbers because if maize is inter-cropped, it is almost always the main crop, so that there are equal numbers of maize crops on inter-cropped and not inter-cropped plots.

Table 10: Effects on secondary farmer outcomes: Adoption on randomly selected maize field

	baseline mean	midline training	midline CH	obs.	endline training	endline CH	obs.
Farmer planted hybrid seed†	0.264 (0.441)	0.002 (0.022)	0.009 (0.022)	2654	-0.023 (0.023)	0.032 (0.023)	2700
Farmer planted open-pollinated seed†	0.260 (0.439)	-0.017 (0.022)	0.002 (0.022)	2654	0.010 (0.020)	-0.007 (0.021)	2700
Farmer planted farmer-saved seed†	0.579 (0.494)	0.020 (0.022)	-0.042^{+} (0.022)	3153	-0.009 (0.020)	-0.016 (0.020)	3240
Farmer planted seed bought at agro-input shop†	0.330 (0.470)	-0.010 (0.022)	0.047^{*} (0.022)	3153	0.012 (0.019)	0.036^{+} (0.019)	3240
Farmer planted hybrid or open-pollinated seed[1]	0.477 (0.500)	-0.024 (0.022)	0.033 (0.021)	2954	-0.004 (0.020)	0.021 (0.021)	3047
Overall index	-0.003 (0.553)	0.000 (0.024)	0.002 (0.024)	2867	-0.010 (0.025)	0.026 (0.025)	2963
Max. number of obs.				3407			3441

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; **, * and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.
[1] For this variable, only seed which was not farmer-saved counted as hybrid seed and only seed which was not recycled too often counted as open-pollinated seed.

Table 11: Effects on secondary farmer outcomes: Seed planted on randomly selected maize field

	baseline	midline			endline		
	mean	training	CH	obs.	training	CH	obs.
Index of farmer's seed ratings[1]†	-0.004	-0.055	0.052	3012	0.038	0.060	3123
	(0.606)	(0.037)	(0.038)		(0.038)	(0.039)	
Farmer was satisfied with seed quality†	0.678	-0.011	0.010	3217	0.012	0.002	3299
	(0.467)	(0.020)	(0.021)		(0.022)	(0.023)	
Farmer would use seed again†	0.764	0.007	0.018	3217	0.011	0.020	3299
	(0.425)	(0.019)	(0.019)		(0.020)	(0.020)	
Amount of seed farmer used in kg†	8.859	0.055	-0.160	2909	0.018	-0.039	2991
	(6.332)	(0.222)	(0.229)		(0.244)	(0.247)	
Price of seed in UGX/kg†	1922.330	-73.500	220.627$^+$	2982	124.242	163.688	3047
	(2947.034)	(122.416)	(123.758)		(136.416)	(139.864)	
Transf. cost of seed in UGX (IHS)	4.237	-0.181	0.499*	2848	0.283	0.350$^+$	2942
	(5.320)	(0.235)	(0.235)		(0.208)	(0.209)	
Overall index	-0.005	-0.023	0.057$^+$	2859	0.025	0.042	2953
	(0.568)	(0.032)	(0.032)		(0.031)	(0.032)	
Max. number of obs.				3407			3441

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; **, * and $^+$ denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.
[1] The index of farmer's seed ratings contains 6 ratings: general quality, yield, drought tolerance, pest/disease tolerance, time of maturity, germination.

This is driven by a significant increase in production and an equally large increase in productivity, suggesting the increase in production is due to an increase in the intensive margin. Note that picking up a yield effect of this size is particularly convincing because this outcome is relatively far down the causal impact chain and shows high variability. The increase in production and yield at endline is most likely due to increased adoption at midline.

7.3 Heterogeneity analysis for competitive areas

One could argue that the information clearinghouse will not work in areas with only one agro-input dealer, as farmers would be less likely to switch to better dealers and dealers would have no incentive to improve their services and increase their efforts if there is no threat of competition nearby. In our sample, 46 of 130 catchment areas are served by only one dealer. We exclude these smallest clusters which leaves us with 302 shops and 3020 farmers in 84 areas.[14] Tables 13 and 14 report that the effects are not stronger here. We conclude that the clearinghouse does not work better in more competitive areas and that our results for the entire sample are not driven by these dealers. One potential explanation for this is that some dealers provide great seed but farmers are not aware of it, so that the clearinghouse corrects a misperception. This way the intervention can also work in areas without dealer competition and the results of the heterogeneity analysis stand to reason.

8 Threat to validity

Table 15 reports attrition levels in the treatment and comparison groups. We failed to collect data from 12% of dealers and 2% of farmers at midline, and from 14% of dealers and 1% of farmers at endline. To test if non-response is related to one of the treatments, we regress the likelihood of leaving the sample on the treatment indicators. We find that clearinghouse treated dealers are significantly less likely to leave the sample.

Whether our estimates are biased or not depends on whether this attrition is random or not. For instance, a non-random subset of agro-input dealers might have left the sample, meaning that attritors and non-attritors differ significantly, which could bias our results. It is for instance plausible that the

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[14]Note that samples sizes are smaller which has implications for statistical power.

Table 12: Effects on secondary farmer outcomes: Harvest on randomly selected maize field

	baseline	midline			endline		
	mean	training	CH	obs.	training	CH	obs.
Production in kg	463.203	-0.806	-20.372	2884	16.959	38.570*	2898
	(399.595)	(14.050)	(14.529)		(17.957)	(17.833)	
Yield in kg/acre†	443.222	-12.216	-23.006	2878	5.118	44.372**	2889
	(304.964)	(16.234)	(16.964)		(15.596)	(15.603)	
Transf. amount sold in kg (IHS)†	3.168	-0.046	-0.201	3063	-0.147	0.139	3137
	(3.220)	(0.126)	(0.124)		(0.159)	(0.157)	
Transf. revenue in UGX (IHS)†	2.764	-0.141	-0.393	3058	-0.354	0.263	3109
	(2.873)	(0.260)	(0.257)		(0.341)	(0.336)	
Transf. amount kept as seed in kg (IHS)	2.254	-0.098	-0.188*	2931	-0.043	0.036	2861
	(1.803)	(0.092)	(0.092)		(0.108)	(0.104)	
Overall index	-0.018	-0.018	-0.073+	2945	0.008	0.097*	2926
	(0.819)	(0.043)	(0.043)		(0.043)	(0.043)	
Max. number of obs.				3407			3441

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; **, * and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

Table 13: Effects on primary dealer outcomes: Heterogeneity analysis

	baseline mean	midline training	midline CH	midline obs.	endline training	endline CH	endline obs.
Transf. quantity of maize seed sold in kg (IHS)†	0.136 (1.942)	-0.013 (0.239)	0.305 (0.253)	249	-0.315 (0.271)	0.073 (0.272)	245
Sales price of maize seed in UGX/kg	28.105 (963.152)	-276.253* (129.655)	56.030 (127.407)	237	-36.637 (157.902)	121.043 (152.272)	228
Transf. revenue from maize seed in mln UGX (IHS)†	0.072 (1.054)	-0.043 (0.113)	0.177 (0.119)	249	-0.113 (0.132)	0.079 (0.133)	245
Transf. number of maize seed customers per day (IHS)†	0.033 (0.969)	-0.051 (0.105)	0.089 (0.111)	255	-0.128 (0.126)	0.229+ (0.118)	249
Moisture in randomly selected seed bag in percent	13.559 (1.465)	-0.009 (0.150)	0.011 (0.148)	154	-0.108 (0.221)	-0.055 (0.217)	226
Index of capital-intensive seed handling practices[1]†	-0.001 (0.510)	0.009 (0.063)	0.011 (0.081)	232	-0.053 (0.093)	0.044 (0.083)	233
Index of labor-intensive seed handling practices[2]†	0.004 (0.489)	0.092 (0.073)	0.119+ (0.068)	247	0.066 (0.072)	0.088 (0.072)	240
Index of all seed handling practices[3]	0.004 (0.388)	0.067 (0.051)	0.066 (0.056)	218	-0.003 (0.064)	0.073 (0.060)	220
Index of dealer's efforts and services[4]†	0.000 (0.454)	-0.057 (0.071)	0.030 (0.066)	206	-0.012 (0.052)	0.041 (0.051)	256
Index of shop's maize seed ratings by farmers[5]	-0.020 (0.600)				0.053 (0.112)	0.165 (0.112)	288
Overall index	-0.004 (0.599)	0.038 (0.132)	0.196 (0.128)	182	-0.038 (0.140)	0.181 (0.128)	225
Max. number of obs. for dealer survey outcomes				263			257

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; *, ** and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

[1] The index of capital-intensive seed handling and storage practices contains 6 variables: whether roof is leak-proof, whether roof is insulated, whether walls are insulated, whether shop is ventilated, whether any official certificate is displayed, whether expired seed is handled correctly.

[2] The index of labor-intensive seed handling and storage practices contains 6 variables: whether seed is stored in dedicated area, whether shop has no pest problem, whether seed is stored in correct lighting, whether seed is stored on correct surface, whether seed is not stored in open containers, cleanness and professionality rating by enumerator.

[3] The index of all seed handling and storage practices contains 12 variables: the ones included in the index of capital-intensive practices and the ones included in the index of labor-intensive practices.

[4] The index of dealer's efforts and services contains 7 variables: whether shop offers explanations, complementary input recommendations, extension/training, discounts for larger quantities, credit, did not receive seed related customer complaint, accepts mobile money.

[5] The index of shop's maize seed ratings by farmers contains 6 ratings: general quality, yield, drought tolerance, pest/disease tolerance, time of maturity, germination. Ratings are aggregated at shop level (one shop is rated by multiple farmers), then the index is computed.

Table 14: Effects on primary farmer outcomes: Heterogeneity analysis

	baseline	midline			endline		
	mean	training	CH	obs.	training	CH	obs.
Farmer planted improved maize seed on any field†	0.002 (0.500)	-0.024 (0.022)	0.028 (0.022)	2774	-0.005 (0.021)	0.045* (0.021)	2848
Farmer bought maize seed at agro-input shop for any field†	0.003 (0.470)	-0.019 (0.022)	0.055* (0.022)	2717	0.002 (0.021)	0.033 (0.021)	2794
Amount of this seed farmer bought at agro-input shop in kg	-0.039 (6.887)	0.473 (0.379)	-0.390 (0.390)	521	0.673 (0.450)	-0.072 (0.464)	538
Index of farmer's maize seed ratings of shops nearby[1]	0.000 (0.637)				0.037 (0.057)	0.116* (0.057)	1483
Index of farmer's general ratings of shops nearby[2]	0.000 (0.657)				-0.011 (0.044)	-0.024 (0.043)	1521
Index of services of shops nearby according to farmers[3]	-0.035 (0.598)	-0.133+ (0.075)	0.126+ (0.069)	291	0.033 (0.083)	0.134+ (0.078)	299
Farmer switched to different agro-input shop[4]†	0.168 (0.374)	-0.018 (0.016)	0.040* (0.016)	2959	-0.024 (0.016)	0.030+ (0.016)	2996
Index of farmer's practices on randomly selected field[5]†	0.009 (0.402)	-0.013 (0.020)	-0.032 (0.020)	2519	-0.009 (0.022)	0.017 (0.023)	2637
Farmer thinks maize seed at agro-input shops is adulterated	0.004 (0.463)	-0.029 (0.029)	-0.036 (0.028)	1818	-0.039 (0.031)	0.013 (0.031)	1870
Farmer planted land race maize seed on randomly selected field†	-0.001 (0.497)	0.017 (0.023)	0.000 (0.022)	2541	0.008 (0.024)	-0.022 (0.024)	2637
Overall index[6]	0.010 (0.696)	-0.026 (0.035)	-0.006 (0.036)	2519	-0.036 (0.036)	0.068+ (0.036)	2667
Max. number of obs.				2959			2996

Note: 1st column reports baseline means and standard deviations below; 2nd, 3rd, 5th and 6th column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 4th and 7th column reports number of observations; *, ** and + denote significance at the 1, 5 and 10 percent levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes; IHS stands for Inverse Hyperbolic Sine.

[1]The index of farmer's maize seed ratings contains 6 ratings: general quality, yield, drought tolerance, pest/disease tolerance, time of maturity, germination. The ratings are aggregated at farmer level (one farmer rates multiple shops), then this index is computed.

[2]The index of farmer's general ratings contains 6 ratings: general quality, location, price, product quality, stock, reputation. The ratings are aggregated at farmer level (one farmer rates multiple shops), then this index is computed.

[3]The index of services of shops nearby contains 7 variables: whether shop offers refund/insurance, credit, training/advice, delivery, after-sales service, accepts different payment methods, sells small quantities. The answers are aggregated at shop level, then the index is computed at farmer level. Only 299 farmers answered all 7 questions for at least one shop nearby at baseline and at endline.

[4]We report the mean and standard deviation at midline because this variable was not collected at baseline.

[5]The index of farmer's practices contains 10 variables: whether farmer spaced seed correctly, sowed correct number of seeds/hill, applied organic manure, DAP/NPK, Urea, pesticides/herbicides/fungicides, weeded sufficiently, weeded at correct time, planted at correct time, re-sowed.

[6]We report the mean and standard deviation at midline because not all variables in this index were collected at baseline.

37

worst performing shops in the clearinghouse control group went bankrupt. Our clearinghouse treatment might have prevented bankruptcy and helped dealers to stay in the market because it served as some kind of advertisement if the rating was good.

On the other hand, it is plausible that enumerators invested less effort when searching control dealers because they did not have to deliver their SeedAdvisor certificates. Carrying this certificate might have made them more persistent when looking for a shop because they did not want to return to their supervisor without having delivered that paper. Moreover, the certificate might have helped enumerators to find the treated dealers because they were able to show the names to neighbors etc. (instead of just asking) who in turn helped finding them. In that case, a larger number of random dealers left the control sample, meaning that the dealers who were not found are not different from the ones that were found. The sub-sample of dealers that remained in the control group would then be representative for the entire control group, hence our estimates would be unbiased. Attrition would only reduce power.

We noticed the attrition problem after midline data collection and instructed our enumerators to be more thorough at endline. Consequently, 7 of 28 clearinghouse control dealers who were not found for the midline interview, were found for the endline interview later that year. This supports our claim that at least a share control dealer attrition can be explained by a lack of enumerator effort instead of bankruptcy. Anyway, even if attrition is non-random: when attrition bias is likely to be negative and treatment effects are expected to be positive, the unadjusted selection-contaminated estimates provide *lower* bounds for the true treatment effect (Angrist, Bettinger, and Kremer, 2006; Duflo, Glennerster, and Kremer, 2007). We refrain from estimating *upper* bounds which are robust to non-random attrition (e.g. Manski, 1989; Lee, 2002) because our ordinary estimates are lower bounds for the true effect and therefore the most conservative estimates.

9   Discussion

Why does the agro-input dealer training not work?

The training has to increase agro-input dealer's knowledge about seed storage to improve their behavior and subsequently seed quality, see Figure 1. Deal-

Table 15: Attrition

	mean	training	CH
	midline		
Agro-input dealer left the sample	0.121	-0.007	-0.108**
	(0.326)	(0.034)	(0.035)
Farmer left the sample	0.018	-0.005	0.001
	(0.134)	(0.005)	(0.005)
	endline		
Agro-input dealer left the sample	0.144	0.017	-0.079^{+}
	(0.351)	(0.040)	(0.042)
Farmer left the sample	0.008	-0.003	-0.001
	(0.091)	(0.003)	(0.003)

Note: 1st column reports sample means at mid- or endline and standard deviations below; 2nd-3rd column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; **, * and + denote significance at the 1, 5 and 10 percent levels.

ers cannot handle seed correctly if they do not know how to do so. However, the dealer knowledge indices in Table 5 do not seem to be significantly affected by the training treatment. That is why we zoom into their knowledge at midline in January and February 2022 after being trained in May 2021. Table 16 shows that the training has no measurable effect on the individual knowledge questions even though it addressed these topics specifically and knowledge was not surprisingly high at baseline. Dealers do not learn or do not remember what they have learned during the training, despite receiving a poster which illustrates the most important practices to hang in their store. We conclude that providing dealers with information about seed handling and storage does not work as long as dealers do not have an incentive to learn.

Why does the information clearinghouse work?

The clearinghouse is a unique intervention because it solves a variety of potentially interlinked problems simultaneously. If the quality of maize seed at agro-input shops is good, it corrects the misperception of farmers. If the quality of maize seed is poor, it provides farmers with information about where to find better seed and dealers with an incentive to change their behavior. Our results in Section 7 show that all 3 impact pathways play a

Table 16: Effects of training on dealer's knowledge about seed storage

	baseline mean	midline training	obs.
Dealer knows...			
...how long seed can be carried over	0.336	0.085	306
	(0.473)	(0.078)	
...how seed should be stored after repackaging	0.270	0.067	306
	(0.445)	(0.065)	
...min. distance between seed and floor	0.526	0.079	306
	(0.500)	(0.060)	
...how seed should be stored in storeroom	0.552	0.007	306
	(0.498)	(0.058)	
...whether seed should be repackaged	0.638	0.008	306
	(0.481)	(0.064)	
Index of dealer's knowledge about seed storage	0.000	0.091	306
	(0.482)	(0.076)	

Note: 1st column reports sample means and standard deviations below; 2nd column reports differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; 3rd column reports number of observations; **, * and + denote significance at the 1, 5 and 10 percent levels; larger indices indicate more desirable outcomes.

role. We find evidence of farmers switching to different shops, the behavior of dealers is also affected as we see significant effects on several measures of their efforts and services, and the clearinghouse improves smallholder perceptions of the maize seed at shops nearby. Clearly, both actors take the ratings serious. Hereafter we attempt to disentangle the different impact pathways and investigate what exactly is going on.

We demonstrate that the intervention affects several measures of adoption already at midline. If we assume that changing dealer behavior and farmers noticing this change takes some time, rectifying incorrect perceptions of smallholders must have played an important role in increasing their adoption. Furthermore, the heterogeneity analysis in Subsection 7.3 shows that the clearinghouse also works in areas with only one agro-input shop and no competition where farmers are less likely to switch and dealers have less incentives to increase their efforts. Also note that the average agro-input shop was rated 3.4 out of 5 at baseline which indicates that seed quality was not so poor to begin with. We interpret this as support for the hypothesis that the quality of maize seed at some shops in our sample is sufficient but non-adopting farmers misperceive it. This is in line with Michelson et al. (2021) and Wossen, Abay, and Abdoulaye (2022) who establish that input quality is good but that farmers' beliefs are often incorrect, so that one simply needs to rectify this misperception to increase adoption. The information clearinghouse provides an innovative way to do so.

In addition, the clearinghouse works through the other impact channels simultaneously. At endline, when all farmers rated all dealers, we find that smallholders perceive seed at clearinghouse treated dealers to be better. The rectifying incorrect perceptions argument made above does not explain why seed at treated shops received higher ratings. Clearly something else has changed due to the clearinghouse. It would be straightforward to assume that farmers perceive seed at treated shops to be better because the clearinghouse has improved seed quality. Unfortunately, we cannot verify this because are not able to objectively measure seed quality as DNA fingerprinting is the only reliable way to detect varietal purity. That is why we cannot confidently conclude that farmers' perceptions of seed improve because treated dealers improve seed quality by handling seed better. Instead, there could be other variables at play, farmers could for example rate seed at treated dealers better because these dealers decide to provide advice and recommendations in response to the clearinghouse, which is surely useful but has no impact on the actual quality of maize seed. Even though we cannot conclude that the

clearinghouse improved objective maize seed quality, it did so in the eyes of smallholder farmers, which is what counts after all.

Potential threats to the functioning of the information clearinghouse

Farmers cannot assess maize seed quality The objective of the clearinghouse is to make maize seed quality observable, so that its functioning would be endangered if farmers' ratings do not actually measure quality but for example the personal relationship between a farmer and a dealer. Some could even argue that farmers cannot assess the quality of maize seed at all, even not after using it, because there are so many factors at play in agricultural production: if farmers experience a disappointing harvest, they cannot safely conclude that the seed material was poor because it could have also been poor soil, insufficient, late or too much rain, or own mismanagement like late planting or insufficient weeding. Misattribution occurs when farmers mistakenly ascribe bad outcomes to bad inputs, rather than to other possible causes. Learning about the true quality becomes more difficult when this misattribution is present (Hoel et al., 2021). Tjernström et al. (2021) agree that sub-Saharan Africa's soil heterogeneity hampers farmer learning about the returns to inputs. Maize seed would then be a credence good instead of an experience good and clearinghouse ratings of farmers would be useless. Even though farmers and dealers might still change their behavior in the short run because they expect the clearinghouse to work, this effect would fade out as soon as both actors learn that the ratings are unreliable.

We argue that farmers' ability to infer maize seed quality is indeed not perfect but they can assess it to some extent. Shortly after planting, farmers can observe germination rates, i.e. the proportion of seeds that germinate, and later how fast the seed matures. Some seed may also be more susceptible to pests and diseases, while other seed may be particularly tolerant in terms of drought. After harvest, the farmer can observe the yield. All these attributes of seed quality can be judged to some extent after one agricultural season.

To support our claim, we test if the ratings are correlated with objective indications of seed quality. We find that specialized agro-input shops which only sell farm inputs have higher ratings. Dealers with better labor-intensive seed handling practices have higher ratings, so do dealers with better capital-intensive seed handling practices. Furthermore, farmers did not only rate the seed of agro-input shops but also the seed they used on a randomly selected

maize field, using the same questions. We find that these seed ratings are positively correlated with farmers' yield. All this shows that the clearinghouse ratings do measure maize seed quality to some extent.

Some dealers will cheat Another danger to the functioning of the clearinghouse could be agro-input dealers who start to influence ratings in a dishonest manner, e.g. by faking ratings or by bribing farmers. Note that during this trial, rating and rated participants were connected by asking dealers where their customers come from, and collecting ratings from ten randomly selected farmers in that village. Dealers would need to understand our experimental design in order to know which farmer they would need to influence, so that it is almost impossible that they cheat during this trial. However, if the clearinghouse intervention would be scaled up, these kind of challenges would need to be addressed. However, the objective of this paper is to test whether a prediction of the theory occurs in practice, namely whether making quality observable improves the market for maize seed, and not to provide a policy intervention, sophisticated enough to be applied without further considerations.

10 Conclusion

Even though agricultural technologies like high yielding seed varieties and fertilizers are seen as the key to agricultural productivity, the adoption by smallholders remains persistently low in sub-Saharan Africa, which hinders poverty alleviation at the individual and aggregate level. We study a particular constraint to technology adoption: the perceived quality of agricultural inputs like improved maize seed. We hypothesize that seed quality deteriorates because agro-input dealers lack knowledge and incentives. Alternatively, quality could be sufficient but farmers misperceive it.

To assess the importance of this potential constraint to agricultural technology adoption, we test two interventions in the market for seed. A training informs agro-input dealers about correct seed handling and storage practices. An information clearinghouse based on crowd-sourced ratings reduces the information asymmetry between seller and buyer by making the quality of maize seed observable. Both interventions are tested in an RCT among 350 agro-input dealers and 3500 smallholder maize farmers in Uganda.

The results of our analyses show that training dealers does not work as

long as they do not have an incentive to learn. However, the clearinghouse clearly improves the Ugandan market for maize seed as sellers and buyers behave in the way the theory of change in Figure 2 predicted. It improves maize seed quality at agro-input shops in the eyes of the farmers, and increases adoption.

We conclude that the adoption of agricultural inputs is constrained by the perception of smallholders they are of insufficient quality. A crowd-sourced information clearinghouse can be an important institutional innovation to solve the problem of asymmetric information in the market for agricultural inputs. It may be preferable to alternative strategies due to its likely lower cost and self-sustaining nature, and helps to overcome problems such as insufficient public investment in regulatory systems, regulatory enforcement, and market surveillance.

Implications for policy are that any strategy which reduces the information asymmetry between seller and buyer by making input quality more observable, e.g. forms of a clearinghouse, certification, electronic verification, inspection etc., is likely to improve the market and increase adoption. However, one reason why the clearinghouse works so well is that peers, who are familiar with the heterogeneous conditions farmers face, provide the ratings. The opinion of a peer who knows the local weather and soil could be more useful and trustworthy for smallholders than the judgment of an inspector or seed certification/ verification system. Smallholders know best which dimensions of input quality matter for them. That is why strategies which make input quality observable by consulting peers are most likely to be equally successful as the clearinghouse. Furthermore, solutions have to be cheap, self-sustaining and scalable.

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A   Appendix

A.1   Details about rating computations

What to do if a treated dealer does not receive a single rating?   If a shop in a treated catchment area is not rated by a single farmer, e.g. because no farmer in our sample knows him or her, we could fill in the catchment area mean as his or her rating. However, this is not as innocent as it seems because it is likely that the lack of ratings is not random. Poor quality dealers have less customers, so their likelihood to get rated is lower. Giving them average catchment area ratings inflates the ratings of these low quality dealers. Instead, we simply told farmers that we do not have information about this shop (implicitly informing the farmer that it exists). 16 of 193 treated dealers were not rated by a single farmer in the first round.

Should more ratings lead to better ratings?   Some shops were not rated by any smallholder in the first round, while others were rated by up to 22 smallholders. If dealer A is rated by 10 farmers and gets rating 3,5 and dealer B is rated by 1 farmer and gets rating 3,6, we treat dealer B as the better dealer. Even though receiving many (few) ratings can be related to good (poor) quality (the lack of ratings could be nonrandom, see previous paragraph), there could be other reasons why dealers are rated by many (few) farmers. Furthermore, giving higher ratings to better-known dealers could harm new dealers entering the market and dealers who are discriminated, e.g. due to their gender. Also on TripAdvisor, having more reviews than a rival hotel does not lead to a better rating.

Should ratings depend on catchment area dealer performance? The following examples show that ratings should not depend on catchment area averages. In an area with poor quality dealers in which one dealer is a bit better than the rest but still poor, we do not want this dealer to be rated well (i.e. expose farmers to poor quality dealers). Similarly, in an area with good dealers in which one dealer is a bit worse than the rest but still good, we do not want this dealer to be rated poorly (which would be unfair towards him or her). On the other hand, less than 9% of shops received a rating below 3 out of 5, so we would throw away valuable data if we would only disseminate good scores without any variation. Therefore, we take the distribution of ratings into account by using quintiles. Consequently, less

dealers receive rating 4 or 5, more dealers receive rating 1 or 2. This could strengthen the effect of the treatment on dealer effort. If dealers get ratings 1 or 2 instead of 4 or 5, they could feel more inclined to improve their scores. Consequently, also the effect on seed quality itself could be larger. However, the clearinghouse should also have a signaling effect, which might be weaker if more dealers are rated 1 or 2 instead of 4 or 5 (dealers would seem to be of worse quality to farmers). Therefore, we chose words with a positive connotation as the quintile names for rating dissemination. As most dealers received a good or very good rating before taking the distribution into account, we ensure that even a 2 is still communicated as "good" to farmers to not weaken the signaling effect. That is why the first quintile is translated to "okay" and gets one star, the second one is named "good" and receives two stars, the third quintile is "very good" and gets three stars, the fourth and fifth one are "excellent" and awarded with four and five stars. This way of considering the distribution of the original ratings when choosing the names also helps us to disseminate ratings as truthfully, purely and as closely to reality as possible.

Are female dealers rated worse than male dealers?   Because we found significant differences between the ratings of female (41% of dealers) and male agro-input dealers (59% of dealers) after controlling for some potentially confounding variables like education and for several indications of quality, we have no reason to believe that these differences in perception can be explained by differences in real quality. Instead, it is likely that women are perceived to be worse due to discrimination (De, Miehe, and Van Campenhout, 2022), so that we adjusted the ratings of female dealers accordingly to prevent that they are harmed by our intervention. We regressed all seed quality attributes on the gender dummy and added the resulting coefficients to the initial ratings of female dealers.

A.2   Details about rating dissemination

Table 17: Text messages to disseminate ratings to farmers

treatment SMS	Hello from AgroAdvisor!
	Did you know that customers from *shop name*
	rate the quality of maize seed sold there
	as okay/good/very good/excellent?
control SMS	Hello from AgroAdvisor!
	Did you know that you can get quality
	maize seed in your area
	from *shop name*?