The (perceived) quality of agricultural technology and its adoption: Experimental evidence from Uganda

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Abstract

Recently, issues related to the (perceived) quality of inputs and technologies have been proposed as an important constraint to their adoption by smallholder farmers in low income countries. Taking maize seed embodying genetic gain as a case, we train random agro-dealers to test whether under-adoption by farmers is caused by low quality due to sellers' lack of knowledge about proper storage and handling. In a second hypothesis, we randomly introduce an information clearinghouse similar to popular crowd-sourced review platforms such as yelp.com or trustpilot.com to test whether information asymmetries crowd out quality seed. We find that the information clearinghouse treatment improves outcomes for both agro-dealers and farmers, with agro-dealers receiving more customers and reporting higher revenues from maize seed sales, and farmers reporting significantly higher use of improved maize seed varieties obtained from agro-dealers, leading to higher maize productivity after two seasons. The primary mechanisms behind this impact appear to be an increased effort to signal quality by agro-dealers and a general restoration of trust in the market for improved seed. The agro-dealer training does not have a clear impact on agro-dealers, nor on farmers in associated catchment areas. However, we do find that the information clearinghouse increases agro-dealer knowledge about proper seed storage and handling. Upon exploring interaction effects between the training and the clearinghouse treatment, we also find that the training becomes effective for agro-dealers that are also in

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the clearinghouse treatment group. This underscores the importance of incentives to make supply side interventions such as trainings effective.

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1 Introduction

The adoption of new agricultural inputs and technologies (such as seed embodying genetic gain, inorganic fertilizers, or agro-chemicals) remains tepid in areas where they can make the largest difference in terms of food security, poverty reduction, and biodiversity preservation (Suri and Udry, 2022; Gollin, Hansen, and Wingender, 2021; Borlaug, 2007). Several explanations for the low uptake of agricultural technology among small-scale, resource-poor farmers in low- and middle-income countries have been explored and tested with increasing depth and rigor in recent years. These include access to information about existence, use, and benefits of the technology (Ashraf, Giné, and Karlan, 2009; Van Campenhout, 2021), procrastination and time-inconsistent preferences (Duflo, Kremer, and Robinson, 2011), heterogeneity in the net benefits derived from the technology (Suri, 2011), missing markets for risk and credit Karlan et al. (2014), and challenges related to learning about new technologies (Hanna, Mullainathan, and Schwartzstein, 2014).

More recently, issues related to the quality of inputs and technologies have been proposed as a key constraint to their adoption by smallholder farmers. Bold et al.

(2017) build on the observation that farmers generally cannot easily assess quality from visual inspection at the time of purchase, so information asymmetries between sellers and buyers characterize the market for agricultural inputs, in turn crowding out the market for quality inputs in Uganda, similar to the lessons learned from Akerlof's seminal "Market for Lemons" study (1970). However, subsequent research suggests ambiguity in whether these quality issues are attributable to agro-dealers intentionally adulterating their products, or whether they lack the requisite knowledge and skills to preserve quality (Barriga and Fiala, 2020). Furthermore, it is not always clear whether these quality issues are significant: while some studies argue that input quality is indeed lacking (Ashour et al., 2019), others argue that farmers may mistakenly perceive quality deficiencies even when the product meets the required standards (Michelson et al., 2021; Wossen, Abay, and Abdoulaye, 2022).

We investigate some of these issues through a field experiment conducted with both agro-dealers and smallholder farmers in their catchment areas in the nascent market for improved, high-yielding maize varieties in eastern Uganda.[1] We focus partly on agro-dealers because they are an essential marketing channel for inputs and technologies in countries with large smallholder farmer populations living in remote areas with poor infrastructure. A reasonably dense network of semi-formal agro-dealers provides access to seed, fertilizer, agro-chemicals, and tools, and may be combined to provide agricultural advisory services and credit facilities, both formal or informal.

Yet small-scale agro-dealers may also be weak links in the supply chain for quality inputs. For instance, the semi-formal nature and scale of agro-dealers may mean they lack knowledge on proper handling and storage of agro-inputs. Barriga and Fiala (2020) document various issues related to handling and storage that may reduce input quality in the Ugandan seed supply chain. For example, agro-dealers often repack seed from larger bags packed by seed companies into smaller bags in order to offer quantities that are convenient and affordable to smallholders. As a result, important information including variety name, expiry date, or planting instructions are lost, while the material used for re-packaging—air-tight polyethylene bags—affect aeration, moisture, and seed viability. Other agro-dealers sell from open bags, which can similarly lower seed viability (Bold et al., 2017). In a first hypothesis, we thus posit that simply providing information to agro-dealers will increase seed quality and subsequently improve farmers' product experience, ultimately encouraging them to adopt improved maize varieties.

However, we recognize that providing information only to agro-dealers may not necessarily remedy the fact that seed quality cannot easily be observed by farmers. Furthermore, we expect that small scale agro-dealers are subjected to less regulation and oversight than their larger counterparts in manufacturing, import, or wholesale operations that are situated further up the supply chain. This means that agro-dealers may still be incentivized—even with training—to underinvest in quality management and preservation. In a context similar to ours, Hoffmann et al. (2021) examine maize

[1] In the context of this study, high-yielding maize varieties refers to both open-pollinated varieties and hybrids. While the distinction may be lost on some, it is a nuance that is recognizable to many colleagues working in the fields of plant breeding and seed sector development.

(grain, not seed) in rural Kenyan markets and find an absence of incentives for sellers to address food safety problems because they are not observable to their buyers. The same issue carries into seed markets, and in a worst-case scenario, agro-dealers may intentionally sacrifice quality to reduce costs and increase profits, e.g., by mixing improved or fresh seed with local or old seed, or even with grain. There is some evidence that may be consistent with this kind of adulteration and counterfeiting 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.

But even in cases where agro-dealers provide quality inputs, the fact that quality can not be easily assessed by farmers at the time of purchase may be problematic if farmers hold negatively skewed cognitive beliefs about seed quality sold by agro-dealers.[2] Michelson et al. (2021) show that the nutrient content of inorganic fertilizers in Tanzania meets industry standards, but farmers nonetheless persist in their belief that it is adulterated. Wossen, Abay, and Abdoulaye (2022) show that farmers in Nigeria routinely misperceive the cassava variety they are cultivating, and that efforts to address misperceptions could potentially improve farmers' investment choices and productivity outcomes.

In a second hypothesis, we conjecture that making quality observable to both buyers and sellers will increase adoption through various mechanisms. First, buyers may shift from sellers that sell low quality inputs to sellers that provide high quality inputs. Second, sellers may start to compete on quality, either by increasing quality if there is still room for improvement, or by making the quality attribute of their products more salient to buyers. Finally, in light of the new information, farmers may adjust their perceptions of the quality of technologies.

The two hypotheses are tested in a randomized control trial (RCT) among 350 agro-dealers and an associated 3,500 smallholder maize farmers in their catchment areas in eastern Uganda over the course of two agricultural seasons. The first hypothesis involves a fairly standard intervention where we provide a one day training for agro-dealership owners and managers on proper storage and handling of seed. For the second hypothesis, we build on Hasanain, Khan, and Rezaee (2023) and implement a decentralized information clearinghouse that is based on crowd-sourced information on quality provided by agro-dealers which is then aggregated and made public, much like yelp.com or tripadvisor.com. In particular, we ask farmers to provide star ratings to agro-dealers in their vicinity, and use these ratings to construct scores and rank agro-dealers. We then disseminate these scores to farmers. We also provide the score, together with their relative position in the rankings, to the agro-dealers.

We find that the information clearinghouse improves outcomes for both agro-dealers and farmers. Clearinghouse treated agro-dealers receive more customers and have

[2] There are many reasons why these beliefs are likely to be biased downwards, including negativity bias and loss aversion (Rozin and Royzman, 2001; Kahneman and Tversky, 1979).

higher revenues from maize seed than control agro-dealers. Clearinghouse treated farmers are significantly more likely to use improved maize varieties from agro-dealers, and have higher yields than control farmers after two seasons. Impact also seems to stem from treated agro-dealers who increase their efforts and expand the services that they provide to farmers. Treated agro-dealers are also more likely to be registered with the Uganda National Agro-input Dealers Association (UNADA), perhaps to signal quality now that it has been made salient to farmers. Finally, we find that farmers in the treatment group rate maize seed of agro-dealers in their neighborhood better, suggesting that the clearinghouse treatment is also effective in changing perceptions.

The agro-dealer training does not have a clear impact on dealers, nor on farmers in associated catchment areas. Interestingly, we do find that the information clearinghouse increases agro-dealer knowledge about proper seed storage and handling. Upon exploring interaction effects between the training and the clearinghouse treatment, we also find that the training becomes effective for agro-dealers that are also in the clearinghouse treatment group. This is consistent with Bold et al. (2022) who point out the importance of simultaneously addressing demand-side constraints to make training more effective.

Our study contributes to a large literature on the effectiveness of providing training to small businesses in developing countries. Helping entrepreneurs to grow small firms by teaching them business skills has yielded mixed results when subjected to rigorous impact evaluation methods (eg. Karlan and Valdivia, 2011; Drexler, Fischer, and Schoar, 2014; Giné and Mansuri, 2021)}. While these studies often suffer from methodological issues such as low statistical power, it has also been argued that simply providing knowledge may be insufficient to move the needle (McKenzie and Woodruff, 2013). More promising results have emerged recently when the focus shifts from traditional trainings to trainings designed to instill personal initiative(Campos et al., 2017).[3] Our study similarly shows the importance of (external) motivation in making trainings reach their objective.

Our study also contributes to the literature that shows how providing product information to consumers can solve the lemons problem through a variety of economic mechanisms. First, by enabling consumers to screen on quality, they can now shift to better quality products. For instance, Lane, Schonholzer, and Kelley (2022) show that commuters in Nairobi choose for the safe busses after information on safety records of different busses was made publicly available. Second, public disclosure of product information makes it possible for sellers to differentiate on quality, and indeed, start competing on it, in turn lifting the market out of the low quality equilibrium. For example, Bennett and Yin (2019) show that entry of a chain store (with a solid reputation for quality) leads to higher overall drug quality and lower prices in India. For the market for antimalarial drugs in Uganda, Björkman Nyqvist, Svensson, and Yanagizawa-Drott (2022) show that the presence of a non-governmental organization providing a superior product led to a stark reduction in the share of firms selling fake drugs.

[3] Personal initiative is defined as a self-starting, future-oriented, and persistent proactive mindset.

We also contribute to a growing literature on the importance of social comparison, self-image, and social norms in determining behavior. Allcott and Rogers (2014) find that a social comparison-based intervention consisting of mailing reports of home energy use to households reduced their energy consumption dramatically. Gosnell, List, and Metcalfe (2020) report on an experiment with airline pilots where different strategies to increase fuel efficiency (including performance feedback and prosocial incentives) are tested. We suspect that, in addition to the threat of farmers shifting to better rated agro-dealers, psychological factors such as professional identity and a sense of social obligation may even be more important drivers for agro-dealers to improve.

The article further fits into an emerging literature that tests how crowd-sourced information can be used to to reduce information asymmetries. Even though advances in Information and Communications Technology and the rise of e-commerce has led to numerous platforms that allow for consumer feedback and a variety of websites that aggregate crowd-sourced reviews, there is surprisingly little evidence on the effects of these developments. The few rigorous studies that are available report impressive impact. Reimers and Waldfogel (2021) compare the effects of professional critics and Amazon star ratings of books on consumer welfare and find the effect of star ratings on consumer surplus to be more than ten times the effect of traditional (expert) review outlets. In the context of smallholder agriculture, Hasanain, Khan, and Rezaee (2023) implement a crowd-sourced information clearinghouse in the market for artificial insemination of livestock in Punjab, Pakistan, where individual signals of quality are noisy. They find that farmers who receive information enjoy 25% higher insemination success.

2 Experimental design

We designed an experiment with two interventions (detailed in the next section) that aim to induce quality improvements (or perceptions thereof) in the seed market, and evaluate their impact on a set of outcomes related to market performance, technology adoption, and productivity. The interventions are randomized at the agro-dealer catchment area level. These catchment areas are clusters of towns, villages, markets, trading centers, and other key market sheds where agricultural market activity tends to operate, and are typically host to several agro-dealers. Clustering agro-dealers into catchment areas is done on the basis of geographical location.[4]

We randomize at the level of the catchment area (instead of opting for randomization at the less aggregate agro-dealer level) for three reasons. Firstly, randomizing at the level of the individual agro-dealer prompted ethical concerns and was thus ruled out a priori. Specifically, in cases where two or more agro-dealers operate in very close prox-

[4]We use a haversine function to construct an adjacency matrix based on GPS coordinates, and agro-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 a map, the size of an average village in our sample and the reported distance between farmers and agro-dealers in survey data from a previous study of the maize value chain that can be found here.

imity to each other, treating only one of them may lead to a competitive (dis)advantage. Randomizing at the catchment level substantially reduces the risk of (dis)advantaging agro-dealers in this way. Secondly, catchment-level randomization reduces the likelihood of spillovers from treated to control agro-dealers. Thirdly, catchment-level randomization allows us to extend the evaluation to the measurement of treatment effects on farmers (and not just agro-dealers) because all farmers in the catchment area are now exposed to agro-dealers who all received the same treatment.

We used simulations to determine the sample sizes required to detect effects of the treatment on selected outcomes at both farmer and agro-dealer levels.[5] The simulations show that if the number of catchment areas is larger than 112, our experiments will return statistically significant results 80% of the time on a selection of primary outcomes. This corresponds to approximately 318 agro-dealers. Based on further simulations to study impacts at the farm-household level, we decide to collect information on 10 farmers per agro-dealer, leading to a sample size of 3,180 households.[6] The two interventions are combined in a field experiment that takes the form of a 2^2 factorial design. The power simulations focused on the individual treatments, implying that we are likely to be under-powered to estimate interaction effects between the interventions (Lin, 2013; Muralidharan, Romero, and Wüthrich, 2019)

3 Interventions

3.1 Agro-dealer training

Training content and material

To determine the content of the training and to ensure it is sufficiently anchored in the study site and context, we consulted experts from several Ugandan organizations using semi-structured interviews and a workshop to identify problems in the seed sector and in agro-dealer retailing practice, and to discuss effective and realistic solutions and best practices to address seed storage and handling issues. We then developed a training manual to ensure standardization and a simple but visually appealing poster illustrating the most important practices. Participants in the interviews and workshops included individuals from the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF), the National Agricultural Research Organization (NARO) the Uganda Seed Trade Association (USTA), and the Uganda National Agro-Dealers Association (UNADA). The roll-out of the experiment began in 2021 (Figure 1).

[5]Simulation provides a flexible and intuitive way to analyze statistical power. Furthermore, instead of relying on theoretical distributions for the outcome variables that make assumptions and return analytic solutions, we run simulations that (re-)sample from real data that was collected in previous surveys. In particular, we use data from 78 agro-dealers and 1,529 smallholder farmers in the catchment areas of these agro-dealers that were collected in three districts in eastern Uganda in July 2019. The data are publicly accessible here.

[6]More detailed information including the expected treatment effect sizes can be found in the pre-analysis plan which was pre-registered at the AEA RCT registry under RCT ID 0006361.

Training

In each treated catchment area, all agro-dealers were selected for a training, and for each treated agro-dealer, both the owner and shop manager were invited. The owner was invited because several recommended techniques and practices required that new investments were made in the agro-dealership, while the shop manager was invited because many of the recommendations are hands-on practices that would ultimately fall under the manager's purview for day-to-day operations. Of 166 agro-dealers that were invited, 140 sent at least one person, leading to a compliance of 84%.[7]

The trainings took place in May 2021, a time when agro-dealers are not too busy, and early enough to ensure they could apply newly learned practices in the second agricultural season. Trainings were held in locations that were easily reachable by the agro-dealers. Trainings were organized in small groups, with an average of 10-15 agro-dealers participating. To deal with COVID in a responsible manner, participants and trainers were required to keep the proper distance, wear face masks, and frequently disinfect their hands. All attendants were compensated for transport, and both lunch and refreshments were provided. Participants were further incentivized to engage in the training and pay close attention with an offer of a free portable seed moisture meter, subject to passing a short content knowledge tests comprised of a short series of multiple-choice questions at the end of the training.[8] The agro-dealers were also given a copy of an informational poster used in the training to remind them of best practices.

In each training, the trainers explained correct handling and storage practices for improved maize seed and used the poster and an example seed bag for illustration. Participants then rehearsed the more challenging practices like measuring moisture using a moisture meter. The trainings were organized and conducted in collaboration with UNADA.

3.2 Information clearinghouse

Rating collection and computation

At the time of baseline data collection (April 2021), we asked sampled farmers to rate all agro-dealers that operated in the catchment area on multiple characteristics. Enumerators were guided by a tablet-based application that iterated through all agro-dealers in the catchment area. For each agro-dealer, we provided the common names that are used to refer to the agro-dealer, a description of where the store is located, and a picture of the store front (obtained during the agro-dealer census—see Subsection 5.1). If farmers knew the agro-dealer, they were asked to provide ratings using the questions listed in Table 1. For example, we asked farmers to rate the maize seed that an agro-dealer sells on a scale of one to five stars on seed germination. As can be seen

[7]For 80 agro-dealers, both owner and manager attended; for 50 agro-dealers, only the owner attended; for 10 agro-dealers, only the manager attended.

[8]This was just to encourage agro-dealers to pay attention. Every agro-dealer that attended got a moisture meter, regardless of how they scored on the test.

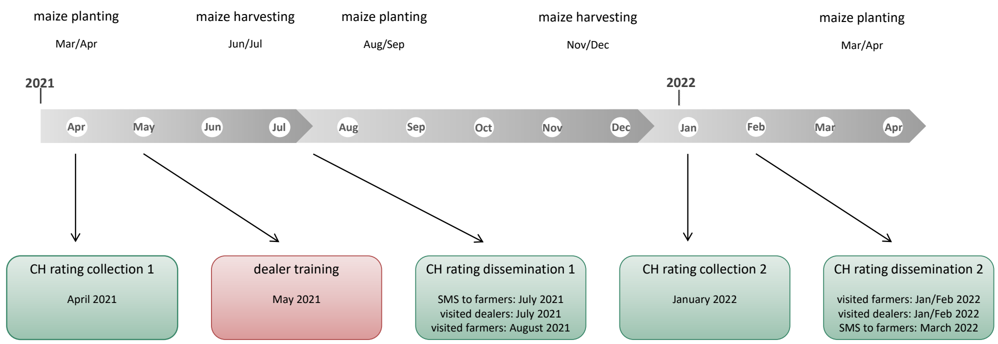

Figure 1: Timeline

in Figure 1 , we implemented the clearinghouse in two consecutive seasons, so ratings were collected again in January 2022. Ratings were always 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 quickly the crop matured (i.e., duration).

A potential concern arises from asking treated farmers to rate agro-dealers because it may increase awareness among farmers of the existence of all agro-dealers in the area, so that this awareness effect could confound the clearinghouse effect. To address this concern, we also iterated through the agro-dealers in the catchment areas with farmers in the the control group to make them similarly aware of the existence of agro-dealers in their vicinity. However, control farmers were not asked to rate agro-dealers as the process of rating an agro-dealer's seed could make quality more salient, which we consider to be a key aspect of the treatment.

Based on the answers of all farmers about all agro-dealers in a catchment area, we computed an average rating for each agro-dealer. These ratings were translated into both words and star ratings to ensure that they were easily comprehensible to farmers and agro-dealers when disseminated. See Appendix A.2 for details on the rating computations..

Rating dissemination to farmers

Our ability to test the effectiveness of the clearinghouse treatment requires precise timing for the dissemination of these agro-dealer ratings. Dissemination occurred before

Table 1: Questions for farmers to rate agro-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-dealer on:		
Quality and authenticity of seed	1 star	5 stars
Please rate the maize seed that this agro-dealer 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

farmers started buying seed for the next agricultural season, allowing treated farmers to use the new rating information when choosing whether and where to purchase inputs (Figure 1). Ratings were disseminated to farmers through short message service (SMS) and in person, as detailed below.

Text messages Farmers were sent one text message per agro-dealer in their proximity by SMS in one of three local languages---Lusoga, Lugwere, or Samia---chosen at the sub-county level to increase specificity. For farmers in the treatment area, the message read:

> Hello from AgroAdvisor! Did you know that customers from [*name of the agro-dealer*] rate the quality of maize seed sold there as [*okay/good/very good/excellent*]?

To isolate the effect of the ratings from more general effects that may arise from sending SMS messages, we also use a placebo for the control group that consisted of an "empty" SMS that only pointed out the existence of the agro-dealers in the control farmer's catchment area. This also makes it more difficult for farmers to identify if they are being treated or not, thus reducing the likelihood of reactivity effects and experimenter bias.

In person The enumerators also re-visited the farmers in our sample. For this purpose, we designed a visually appealing tablet-based application that cycles through all agro-dealers in the catchment area of each farmer and provides their ratings. The application generates the following statement:

Figure 2: SeedAdvisor certificate

> We wanted to let you know that customers from [*name of the agro-dealer*] rate the quality of maize seed sold there as [*okay/good/very good/excellent*]! The quality of the maize seed that this agro-dealer sells received a score of [*score*] out of 5!

The application also displayed the stars associated with the score. Again, for control group farmers, the application cycled through the agro-dealers in the control areas without providing ratings to control for any effect that may arise from simply being reminded of the existence of agro-dealers.

Rating dissemination to agro-dealers

Agro-dealers received their ratings by means of a report on laminated paper that was delivered to their agro-dealerships. The front of the report is a visually appealing certificate with a logo and the agro-dealer's general rating (Figure 2). We encouraged agro-dealers to prominently display the ratings in the agro-dealership, similar to a "certificate of excellence" from TripAdvisor or similar rating apps.

The back of the report provides additional information, including the individual ratings that the seed sold by the agro-dealer received for overall quality, yield, drought and disease resistance, speed of maturing, and germination, and the average (combined) ratings of other agro-dealers in the same catchment area in a table, visualized by stars. This shows agro-dealers their relative position in the area, potentially incentivizing the agro-dealer to improve their ratings.

The entire process of collecting and disseminating ratings was done twice, the first time targeting the second agricultural season of 2021 and the second time targeting the first agricultural season of 2022 (see Figure 1). Repeating the treatment was important to capture different dynamics of particular impact channels on certain outcomes. For instance, if seed quality is good but farmers hold pessimistic beliefs about the quality, disseminating information may already result in increased adoption and yield effects after a single season. However, if agro-dealers engage in counterfeiting, the threat of farmers switching to more honest agro-dealers may lead them to improve quality, which will only be reflected in subsequent ratings. This in turn could increase adoption but the effect of this on yields will only become apparent during harvest in the second season. Repetition may also be important for the effectiveness of certain impact pathways. For instance, agro-dealers may be more likely to change their behavior if they know that they will be scored again in the near future.

4 Empirical strategy

We estimate intention-to-treat effects on outcomes at both the agro-dealer level and the farmer level. To increase power, we condition the estimates on (mean-centered) baseline values of the outcome variables. We estimate the following specification using Ordinary Least-Squares to obtain the average treatment effect for agro-dealer level outcomes:

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

where Y_{ij} is the outcome for agro-dealer 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 controls for the orthogonal treatments in the factorial design (demeaned and interacted with the main treatment effect, see Lin, 2013; Muralidharan, Romero, and Wüthrich, 2019), and ε_{ij} an error term that is potentially correlated within catchment areas. The coefficient β is the estimated average treatment effect. For farmer-level outcomes, a similar equation is estimated, where Y_{ij} is now the outcome variable for farmer i in catchment area j at midline or endline, Y_{0ij} is the corresponding outcome at baseline, and all other terms are defined as in the agro-dealer regression above.

Because we randomize at the catchment-area level, we use cluster-robust variance-covariance matrices that cluster standard errors at this level. For outcomes at the farmer level where we have almost 3,500 observations in 130 clusters, the original form of the sandwich estimator that does not make any small-sample correction, is used. For outcomes at the agro-dealer level where we have almost 350 observations in 130 clusters, we use the Bell–McCaffrey adjustment (Imbens and Kolesár, 2016).

We also follow several pre-registered principles for variable construction. For continuous variables, trimmed values are used to reduce the influence of outliers. In particular, we trim 1% of each side of the distribution for agro-dealer level outcomes and 2.5% of each side of the distribution for farmer level outcomes. Inverse hyperbolic sine transformations are used if variables are skewed, with skewness being defined as the adjusted Fisher-Pearson coefficient of skewness exceeding 1.96. Outcomes for which 95% of observations have the same value within the relevant sample are omitted from the analysis.

We account for multiple hypothesis testing by aggregating different outcomes within a family into summary indices, following Anderson (2008).[9] While these indices are useful to answer the question of overall impact of the intervention on a family of outcomes, it is not straightforward to interpret the effect size. Zooming in on individual outcomes within each family, effect sizes become more meaningful and show which variables drive the results. That is why we also report the treatment effects on individual variables, though we advise care in interpretation.

5 Data

5.1 Sample

he agro-dealer sample was obtained by listing all agro-dealers in 11 districts in southeastern Uganda. After the census, which resulted in a sample of 348 eligible agro-dealers, these agro-dealers were assigned to 130 catchment areas (for details, see Section 2, Footnote 4 in particular). This procedure let to an average of three agro-dealers per catchment area, ranging from a minimum of 1 to a maximum of 18.

To connect agro-dealers to customers, we asked agro-dealers for the names of the villages where most of their customers come from. Then enumerators were instructed to randomly sample ten households that grow maize in these villages. Consequently, about 3,500 smallholder maize farmers were sampled. Allocation of farmers, agro-dealers and catchment areas to the different treatment cells of the factorial design is summarized in Table 2.

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

At the level of the agro-dealer, enumerators were instructed to interview the person who is most knowledgeable about the day-to-day operations, which was usually the shop manager. As part of this initial quality assessment process, a bag of maize seed was also purchased at each agro-dealer, although only 232 of the 348 sampled agro-dealers had seed in stock at the time of the baseline interview. Enumerators were also instructed to note down a series of objectively verifiable quality indicators related to storage. Often, this also meant that enumerators inspected stores at different locations that were separate from the sales outlet.

[9]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.

Table 2: Factorial design

		agro-dealer training	
		1	0
clearinghouse	1	33 areas 96 agro-dealers 960 farmers	32 areas 97 agro-dealers 970 farmers
	0	33 areas 70 agro-dealers 700 farmers	32 areas 85 agro-dealers 850 farmers

At the farm household level, enumerators were instructed to interview the person most knowledgeable about maize farming. However, a set of questions deals with the household head, who could be or could not be the respondent. In addition to general questions about farming and input use, the farmer was asked to enumerate all maize plots, from which a random plot was chosen, and detailed data was collected on that plot.[10]

5.2 Descriptive statistics

This subsection describes the baseline sample. Information about the average agro-dealer can be found in Table 3. 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 also the owner of the agro-dealership.

We see substantial heterogeneity among agro-dealers. Some are small informal stores that are located in rural areas and sell maize seed and other agricultural inputs in addition to consumer items to a small customer base and only during the planting season. Others have many customers, are located in towns and only sell inputs and equipment used in agricultural production. The average agro-dealership was established 5 years prior to the baseline survey date, is located 7 km from the nearest tarmac road, and services an average of 41 customers per day. Among the sampled agro-dealers, 74% only sell farm inputs and equipment. 60% reported that they provide credit and 46% that they offer advisory services.

Information was also collected to provide an initial assessment of the quality of maize seed sold at the sampled agro-dealers. This included specific questions on seed storage and handling. Furthermore, with the shop manager's permission, enumerators—drawing on training provided to them at the outset of the study—inspected the area where seed was stored and noted the conditions. We find that 65% of agro-dealers had

[10] This was mainly done to reduce on data collection costs, time, and burden. As plots were chosen randomly, averages should be representative at the household level.

problems with pests such as rats or insects, while 16% store maize seed in open containers, thus exposing the seed to a range of pests and contaminants. Not surprisingly two thirds of the agro-dealers sampled reported that they had received at least one complaint about seed they sold from a customer during the prior season.

Turning to the seed samples obtained from the agro-dealers, our measurements of moisture content in the bag indicated an average of 13.6%, with a minimum of 10.3% and a maximum of 17.4%. On average, these moisture rates were above the recommended rate of 13%, suggesting potential for the growth of molds and pests that can negatively affect seed quality and performance. In terms of labeling for quality, 68% of the purchased seed bags contained a printed packaging date, only 18% had an expiry date, and only 8% displayed a quality indication label issued by the National Seed Certification Services (NSCS).[11]

Table 4 reports means in the farmer sample. The average household head in our sample is 49 years old; 78% are male and 51% have finished primary education. The average household size is 9 people, and the typical homestead is located 4 kilometers from the nearest agro-dealer and 9 kilometers from the nearest tarmac road. The average farmer has 23 years of experience with maize cultivation and cultivates 3 acres of land for all crop including maize.

Half of the farmers in our sample planted improved maize seed on at least one of their plots during last season, with 1 out of 3 farmers purchasing this seed at an agro-dealer. Only 25% applied inorganic fertilizers such as di-ammonium phosphate (DAP) or nitrogen, phosphorus, and potassium (NPK) on the randomly selected plot. Yields on these plots is about 440 kilograms per acre.

5.3 Orthogonality tests of randomization balance

We include standard orthogonality tables with pre-registered variables for both agro-dealers and farmers to test if treatment and control groups are comparable in terms of a set of baseline characteristics (Tables 3 and 4 respectively). Some of these characteristics are unlikely to be affected by the intervention, while others are drawn from the set of outcome variables that will be used to measure the intervention's impact and explore the underlying mechanisms at play in the next sections.

For outcomes at the agro-dealer level reported in Table 3, we find that from a total of 32 comparisons, only one is significant at the 5% significance level and two are significant at the 10% level. For outcomes at the farmer level reported in (Table 4, out of 32 comparisons, one is significant at the 10% level. In all, we conclude that these results show reasonable balance at baseline.

[11] Typically, maize seed is certified by NSCS, a division of the Department of Crop Inspection and Certification (DCIC) in MAAIF. Certified seed is indicated as such with a blue tag or sticker affixed to the package, and quality declared seed is indicated by a green tag or sticker.

Table 3: Descriptive statistics and orthogonality tests - Agro-dealer

	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)
Agro-dealer's distance to nearest tarmac road in km	6.56	-0.92	-1.58
	(10.39)	(2.21)	(2.24)
Agro-dealer only sells farm inputs	0.74	-0.09	0.03
	(0.44)	(0.07)	(0.06)
Years since Agro-dealer 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)
Quantity of maize seed sold in kg	695.50	201.06	176.31
	(1497.18)	(252.97)	(235.92)
Amount of maize seed lost/wasted last season in kg	3.50	1.99	2.40
	(18.65)	(2.47)	(2.30)
Agro-dealer has problem with pests	0.65	-0.01	-0.03
	(0.48)	(0.06)	(0.06)
Agro-dealer stores maize seed in open containers	0.16	0.00	0.08
	(0.36)	(0.05)	(0.05)
Agro-dealer received seed related complaint from customer	0.64	-0.11*	0.07
	(0.48)	(0.05)	(0.05)
Moisture in bag of maize seed in %	13.56	0.25	-0.18
	(1.44)	(0.25)	(0.26)

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report 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% levels.

Table 4: Descriptive statistics and orthogonality tests - Farmer

	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-dealer 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	443.01	27.15^{+}	-6.14
	(304.99)	(13.71)	(13.52)
Farmer used quality maize seed on any plot	0.49	0.02	0.01
	(0.50)	(0.02)	(0.02)
Farmer bought this seed at agro-dealer	0.32	-0.01	0.01
	(0.47)	(0.02)	(0.02)
Amount of this seed farmer bought at agro-dealer in kg	9.52	0.16	-0.34
	(6.92)	(0.53)	(0.53)
Farmer thinks maize seed at agro-dealer is adulterated	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: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report 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% levels.

Table 5: Attrition

	mean	training	CH
		midline	
Agro-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-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: Column (1) reports sample means at mid- or endline and standard deviations below; columns (2)-(3) report 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% levels.

5.4 Attrition

Table 5 reports attrition levels in the treatment and comparison groups. We failed to collect data from 12% of agro-dealers and 2% of farmers at midline, and from 14% of agro-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 agro-dealers are significantly less likely to leave the sample.

The differential attrition may be due to a larger share of control agro-dealers going out of business, while the clearinghouse treatment cushioned some agro-dealers in the treatment catchment areas against bankruptcy at a time when COVID-19 hit. As in biomedical RCTs where differential attrition rates may be due to excess mortality in the control group, the attritors are likely the ones that would have benefited most from the treatment. As such, the unadjusted selection-contaminated estimates provide lower bounds for the true treatment effect (Angrist, Bettinger, and Kremer, 2006; Duflo, Glennerster, and Kremer, 2007).

6 Results

We now present impact of the two interventions on both agro-dealer level outcomes and farmer level outcomes. We separately report effects one agricultural season after the intervention (referred to as impact at midline) and two seasons after the intervention (referred to as impact at endline).

For reasons of transparency and replicability, all outcome variables are described in the registered pre-analysis plan which can be found in the American Economic Association Randomized Controlled Trial Registry. In addition, before midline data collection, the entire econometric analysis was run on simulated data and also registered in a mock report (Humphreys, De la Sierra, and Van der Windt, 2013).[12] All documents, code, and data were under revision control and are publicly accessible in a GitHub repository which provides time-stamped records of all changes made over the course of the project.[13]

Tables 6 to 15 present results in a common layout. Column (1) provides baseline sample means with standard deviations in parentheses to help gauge effect sizes.[14] In column (2), we provide the average treatment effect of the agro-dealer training at midline, while column (3) reports the average treatment effect of the information clearinghouse treatment at midline. Standard errors are reported in parentheses below the coeffcient estimates. Column (4) reports the number of observations used in the estimations at midline. Columns (5) and (6) report average treatment effects of the training and the clearinghouse treatment respectively at endline, that is, after two seasons. Column (7) reports the number of observations that was used in the endline estimations. As noted in Section 4, we account for multiple hypothesis testing by aggregating different outcomes within families into overall summary indices, following Anderson (2008). Results for these indices are reported at the bottom of the tables.[15]

6.1 Impact on agro-dealers

We start by testing if the interventions affected general business operations of agro-dealers (Table 6). Sales volume and price, revenue, and number of customers and maize varieties in stock are the key outcomes of interest. A measure of sales volume was constructed by asking agro-dealers how much of a specific maize variety they sold in the previous season. We restrict attention to the four most popular improved varieties, two of which are hybrids (Longe 7H and Longe 10H) and two of which are open pollinated varieties (OPVs) (Longe 4 and Longe 5). Total quantity sold is the sum of quantities sold of these four varieties. We also asked agro-dealers about the sales price of the

[12]A mock report is a dynamic report that integrates all code, such that when midline and endline data becomes available, one simply has to replace the simulated data with the real data. We use the knitr engine to integrate R code in LaTeX (Xie, 2017).

[13]The presentation of results in this paper differs somewhat from the way it was pre-registered and presented in the mock report (and midline report, endline report, and previous versions of this manuscript). In particular, we reorganized the presentation of the results to match a structure where we first look at impact on outcomes at the end of the causal chain and then look at impact on intermediate outcomes to explore potential mechanisms. While this change does affect the construction of some of the indices, overall conclusions remain the same. Several pre-registered tables can be found in Appendix A.3. The entire analysis that follows the pre-registered structure can be found through the project history in GitHub, for instance here.

[14]Note that these sample means are reported in levels to allow for this interpretation of effect sizes, even though we may report the difference between treatment and control group after using inverse hyperbolic sine transformations.

[15]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, severely reducing statistical power.

four varieties at the start of the season and then calculated the simple average at the agro-dealer level. We then calculate the revenue (expressed in million UGX) by first multiplying prices with quantities sold and then summing over the four varieties.[16] We also include the number of customers that bought maize seed on an average day at the start of the season, as well as the number of maize varieties that the agro-dealer had in stock.

Table 6 shows that we do not find an impact of training agro-dealers on their business operations. At both midline and endline, the impact on the index is not significantly different from zero. No particular pattern emerges to explain these insignificant results, and there is little significance among any of the outcome variables when estimated separately. At midline, we find a negative impact of the training on the average sales price. At endline, the training seems to have reduced amounts sold, which is also reflected in a lower revenue.

We do find a positive impact of the information clearinghouse intervention on agro-dealer operations. At midline, the overall index is significantly higher among agro-dealers in the clearinghouse treatment group. Among individual outcomes, treated agro-dealers sold more maize seed at a higher price, albeit not significantly so. However, in combination, this lead to revenues that are almost 20% higher (and this difference is significant at the 10% level).[17] At endline, the positive effect of the clearinghouse intervention seems to become stronger, with the overall index now significant at the 1% level. The effect is driven by a 31% increase in the number of customers that a treated agro-dealer attracts, which translates into 6 additional customers per day.

The next set of results focuses on the effect of the interventions on operations related to one particular variety, specifically, the most recently released hybrid (Longe 10H) in Table 7 and the most recently released OPV (Longe 5) in Table 8. In addition to the business operation outcomes reported in Table 6, we also include outcomes related to stock management, given that seed quality decreases with shelf-life. We asked the agro-dealers how much of the particular seed was carried over from the previous season. Many agro-dealers reported that they did not carry over any seed, leading to low baseline means. Furthermore, we asked the agro-dealers to estimate how much they bought from any provider during the same season. For both varieties, this is slightly more than what agro-dealers reported to have sold. We expect our treatments to decrease the amount of seed carried forward and increase the amount of fresh seed procured from providers. We also asked the agro-dealers to estimate how much of the seed stock was lost or wasted during the season, and how often they ran out of stock. We expect the interventions to reduce both losses and stock-outs.

For both varieties, we do not find significant effects of the training nor the clearinghouse treatment at midline. At endline however, all individual coefficient estimates move in the expected direction for the information clearinghouse, and when outcomes

[16] One dollar was about 3600 UGX at the time of the study.

[17] For reasonably large values, coefficients of regressions that involve a dependent variable that has been transformed using the inverse hyperbolic sine can be interpreted as elasticities (Bellemare and Wichman, 2020).

Table 6: Effects on agro-dealer outcomes: Operations

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Quantity of maize seed sold in kg§†	695.503	-0.092	0.284	292	-0.499^{+}	0.239	286
	(1497.183)	(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)	
Revenue from maize seed in mln UGX§†	2.890	-0.069	0.185^{+}	292	-0.227^{+}	0.143	286
	(6.286)	(0.104)	(0.108)		(0.118)	(0.118)	
Number of maize seed customers per day§†	19.764	-0.056	0.127	294	-0.190	0.310**	288
	(20.689)	(0.098)	(0.101)		(0.116)	(0.112)	
Number of maize varieties in stock†	2.834	0.042	0.245	295	-0.216	0.221	292
	(1.589)	(0.266)	(0.245)		(0.234)	(0.220)	
Overall index	0.031	-0.130	0.197*	274	-0.131	0.238**	270
	(0.610)	(0.095)	(0.092)		(0.086)	(0.082)	
Max. number of obs.				306			297

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.
§Due to the skewness of this variable, the regression was run after an Inverse Hyperbolic Sine transformation. Coefficient estimates can therefore be interpreted as percentage changes. The baseline mean column shows the untransformed variable.

are combined in an index, the effect is positive and statistically significant.

Moving one step further up the impact chain, we explore whether reported increases in the number of customers, sales, and revenues are likely driven by an increase in the quality of maize seed sold by these agro-dealers. To do so, we instructed enumerators to buy a random bag of seed from each agro-dealer. This bag was then inspected on a range of attributes (bag integrity, lot number, packaging date, and shelf-life, etc) and moisture was measured. Our quality tests of the seed purchased and collected during the survey did not indicate any effects, although due to the fact that not all agro-dealers had seed in stock, we may be facing statistical power issues. More information can be found in Appendix A.1.

6.2 Impact on smallholder farmers

We first examine harvest-related outcomes for farmers and report the results in Table 9. We start by examining production, plot size, and production scaled by plot size (i.e., yield) on a randomly selected maize plot. We also look at market participation (amount sold, sales price, and revenue from maize sales) and how much grain farmers save to use as seed in the next season. While we expect positive effects on harvest and sales, the amount kept as seed enters the index negatively.

The coefficient estimates for the overall index show no effect of the agro-dealer training, and a positive effect of the information clearinghouse, albeit only after two seasons of implementation. Farmers that live in areas where the clearinghouse was implemented report higher production and productivity at endline than control farmers that live areas where the clearinghouse was not implemented. Yield differences are significant at the 1% level and amount to 10% of the baseline mean. Finally, we look at the amount of maize that farmers retain for seed in the next season. At midline, we see that, in line with expectations, clearinghouse treated farmers save less grain for seed.

To further explore the large and significant effect of the clearinghouse on yields, we investigate whether specific subgroups of farmers experienced yield gains more than others. Rerunning the regression only for farmers who did not adopt at baseline led to a coefficient of 56.44 with a standard error of 17.38 (hence, significance at the 1% level). For farmers that did adopt at baseline, we find a coefficient of 30.79 with a standard error of 20.38 (hence, no significance). This indicates that the effect is plausibly driven by farmers who did not use improved maize seed at baseline, started using improved maize seed due to the clearinghouse and, in turn, realized higher yields.

Moving up on the causal chain, we test if the interventions affect the use of agricultural technology by farmers. In particular, we examine the use of purchased maize seed as a second important family of outcomes at the smallholder level. For the agro-dealer training, we do not find any effect at midline, nor at endline. The effect of the information clearinghouse treatment on overall use (or “adoption” for convenience) as measured by the index is positive and significant at the 5% level at mid- and endline.

Zooming in on individual outcomes, we start with a subjective assessment of seed used by asking farmers if they "...used any quality maize seed (like OPV or hybrid in

Table 7: Effects on agro-dealer outcomes: Operations - Longe 10H

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Quantity sold in kg§†	288.384	0.050	0.236	256	-0.205	0.352	242
	(727.049)	(0.206)	(0.204)		(0.231)	(0.239)	
Sales price in UGX/kg§†	9.417	-0.025	-0.013	194	-0.019	0.010	187
	(0.145)	(0.026)	(0.026)		(0.030)	(0.029)	
Revenue in mln UGX§†	1.625	0.008	0.130	255	-0.106	0.173	241
	(3.839)	(0.119)	(0.123)		(0.130)	(0.136)	
Amount carried over in kg§†	2.679	-0.186	0.090	262	-0.012	-0.034	250
	(12.137)	(0.212)	(0.215)		(0.138)	(0.134)	
Amount shop bought from provider in kg§†	294.672	0.118	0.206	257	-0.022	0.283	243
	(741.810)	(0.218)	(0.213)		(0.250)	(0.253)	
Amount lost/wasted in kg§†	0.036	-0.001	0.019	257	-0.058	-0.038	243
	(0.405)	(0.093)	(0.097)		(0.037)	(0.041)	
Number of times per month shop ran out§†	1.039	-0.236^{+}	-0.045	192	-0.180	-0.205	185
	(1.575)	(0.129)	(0.133)		(0.128)	(0.136)	
Overall index	0.080	0.030	0.029	244	0.021	0.217**	233
	(0.437)	(0.067)	(0.070)		(0.052)	(0.057)	
Max. number of obs.[1]				268			254

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

§Due to the skewness of this variable, the regression was run after an Inverse Hyperbolic Sine transformation. Coefficient estimates can therefore be interpreted as percentage changes. The baseline mean column shows the untransformed variable.

[1]The comparisons were only made for agro-dealers which had Longe 10H in stock at mid- or endline.

Table 8: Effects on agro-dealer outcomes: Operations - Longe 5

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Quantity sold in kg§†	389.492	-0.040	0.304	261	-0.215	0.316	259
	(716.556)	(0.222)	(0.216)		(0.234)	(0.230)	
Sales price in UGX/kg§†	8.730	0.017	-0.015	249	-0.002	0.013	241
	(0.110)	(0.016)	(0.016)		(0.022)	(0.022)	
Revenue in mln UGX§†	1.193	0.019	0.111	261	-0.080	0.114	258
	(2.175)	(0.099)	(0.096)		(0.100)	(0.105)	
Amount carried over in kg§†	4.312	0.247	-0.092	270	-0.095	-0.004	263
	(19.088)	(0.324)	(0.306)		(0.148)	(0.155)	
Amount shop bought from provider in kg§†	431.451	-0.005	0.253	262	-0.179	0.289	260
	(803.696)	(0.221)	(0.215)		(0.232)	(0.235)	
Amount lost/wasted in kg§†	1.756	-0.150	0.031	266	-0.055	-0.033	261
	(10.173)	(0.128)	(0.128)		(0.055)	(0.058)	
Number of times per month shop ran out§†	0.839	0.053	0.086	248	0.094	-0.054	237
	(1.509)	(0.100)	(0.101)		(0.120)	(0.126)	
Overall index	0.039	0.037	0.012	256	-0.038	0.152*	252
	(0.401)	(0.068)	(0.062)		(0.058)	(0.058)	
Max. number of obs.[1]				275			269

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

§Due to the skewness of this variable, the regression was run after an Inverse Hyperbolic Sine transformation. Coefficient estimates can therefore be interpreted as percentage changes. The baseline mean column shows the untransformed variable.

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

Table 9: Effects on farmer outcomes: Harvest on specific maize plot

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Production in kg†	463.203	-0.806	-20.372	2884	16.959	43.937*	2898
	(399.595)	(14.050)	(14.529)		(17.957)	(17.922)	
Area in acres	1.094	-0.013	-0.003	3004	0.000	0.006	3066
	(0.655)	(0.029)	(0.029)		(0.032)	(0.038)	
Yield in kg/acre†	443.222	-12.216	-23.006	2878	5.118	56.436**	2889
	(304.964)	(16.234)	(16.964)		(15.596)	(17.382)	
Amount sold in kg§†	195.295	-0.046	-0.201	3063	-0.147	0.173	3137
	(297.545)	(0.126)	(0.124)		(0.159)	(0.173)	
Sales price in UGX/kg	506.954	-7.787	33.027*	610	-47.215	12.614	639
	(139.389)	(14.395)	(14.244)		(30.547)	(41.238)	
Revenue in UGX§†	97.783	-0.141	-0.393	3058	-0.354	0.355	3109
	(156.538)	(0.260)	(0.257)		(0.341)	(0.363)	
Amount kept as seed in kg§	14.506	-0.098	-0.188*	2931	-0.043	0.036	2861
	(18.530)	(0.092)	(0.092)		(0.108)	(0.104)	
Overall index	-0.020	-0.015	-0.061	2932	0.018	0.097*	2900
	(0.784)	(0.039)	(0.039)		(0.041)	(0.041)	
Max. number of obs.				3407			3441

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.
§Due to the skewness of this variable, the regression was run after an Inverse Hyperbolic Sine transformation. Coefficient estimates can therefore be interpreted as percentage changes. The baseline mean column shows the untransformed variable.

seed) on any of their plots". We see that at midline, farmers that were subjected to the clearinghouse treatment were 3.5 percentage points more likely to answer this question with "yes" than control farmers. After two agricultural seasons, the difference between treatment and control farmers increases to 4.2 percentage points. Related, we ask if farmers bought high-yielding maize varieties at an agro-dealer for any plot. At midline, we find a difference between the clearinghouse treatment and control groups of about 6 percentage points, and this amounts to an almost 20% increase relative to the baseline mean. At endline, the difference is about 3 percentage points, but not significant. We do not find an impact of the clearinghouse on the amount of seed that farmers bought at agro-dealers. However, note that estimates are based on a small sample size (n=599 at midline and 621 at endline) that was conditional on having purchased seed from an agro-dealer.

Next, we turn our attention to the use of purchased maize seed on a randomly selected plot. For the use of seed from either hybrid or open-pollinated maize varieties, we find positive treatment effects of the clearinghouse, although the coefficients are insignificant.[18] As for the more general questions above, we also ask if the seed that was used on the random plot was obtained from an agro-dealer. We find an almost 5 percentage point treatment effect for the clearinghouse at midline and an almost 4 percentage point effect at endline. Conversely, we estimate the clearinghouse effect on the use of farmer-saved seed on the randomly selected plot. Again—and in line with our expectations—we find that farmers that were exposed to the clearinghouse treatment reduced their use of saved seed, albeit only significantly so at midline. Finally, we examine the product of the amount and the price of maize seed, i.e., the total expenditure on seed for the plot. We see that in areas where the clearinghouse was implemented, farmers invest significantly more in seed.

7 Causal chain and mechanisms

For the agro-dealer training, the underlying mechanism is fairly straightforward: it potentially changes agro-dealer knowledge and behavior through learning, which results from exposure to, and uptake of, new and salient information. The information clearinghouse is a multifarious intervention in that it solves a variety of potentially interlinked information problems simultaneously. If the quality of maize seed is sufficient but some farmers believe that agro-dealers provide sub-standard quality, a clearinghouse may correct their perceptions. If the quality of seed differs between agro-dealers, the clearinghouse provides farmers with information that may help them to switch to agro-dealers selling better quality products. Furthermore, the rating system directly incentivizes agro-dealers to stay ahead of immediate competitors. They can do this by

[18] Here, we asked farmers which variety they planted in the previous season. If a farmer used Longe 10H, Longe 7H, Longe 7R/Kayongo-go, Bazooka, Longe 6H, Longe 5/Nalongo, Longe 4, Panner, Wema, KH series, or other hybrid/OPV, and this seed was not recycled or farmer-saved but newly purchased, it counted as hybrid/open-pollinated maize seed.

Table 10: Effects on farmer outcomes: Adoption

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Farmer used quality maize seed on any plot†	0.492	-0.021	0.035^{+}	3206	-0.009	0.042^{*}	3282
	(0.500)	(0.020)	(0.020)		(0.020)	(0.020)	
Farmer bought maize seed at agro-input shop for any plot†	0.325	-0.014	0.059^{**}	3145	0.004	0.031	3225
	(0.468)	(0.021)	(0.021)		(0.019)	(0.020)	
Amount of this maize seed farmer bought at agro-input shop in kg	9.519	0.512	-0.105	599	0.457	0.378	621
	(6.920)	(0.348)	(0.358)		(0.419)	(0.431)	
Farmer used hybrid/open-pollinated maize seed on specific plot^{1†}	0.432	-0.019	0.035	2954	0.009	0.030	3047
	(0.495)	(0.023)	(0.023)		(0.023)	(0.023)	
Farmer bought maize seed at agro-input shop for specific plot†	0.330	-0.010	0.047^{*}	3153	0.012	0.036^{+}	3240
	(0.470)	(0.022)	(0.022)		(0.019)	(0.019)	
Farmer used farmer-saved maize seed on specific plot	0.579	0.020	-0.042^{+}	3153	-0.009	-0.016	3240
	(0.494)	(0.022)	(0.022)		(0.020)	(0.020)	
Cost of maize seed used on specific plot in UGX§†	14078.272	-0.181	0.499^{*}	2848	0.283	0.350^{+}	2942
	(24654.685)	(0.235)	(0.235)		(0.208)	(0.209)	
Overall index	-0.013	-0.030	0.087^{*}	2854	0.015	0.086^{*}	2978
	(0.899)	(0.043)	(0.042)		(0.039)	(0.039)	
Max. number of obs.				3407			3441

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

[1]For this variable, only non-recycled (newly purchased, not farmer-saved) seed counted hybrid/open-pollinated seed.

§Due to the skewness of this variable, the regression was run after an Inverse Hyperbolic Sine transformation. Coefficient estimates can therefore be interpreted as percentage changes. The baseline mean column shows the untransformed variable.

improving the quality of the products they offer, or by signaling that the quality of products they offer is good. In this section, we investigate the relative importance of these different impact pathways.

7.1 Agro-dealer knowledge

The primary mechanism underlying the agro-dealer training is learning, which is in turn expected to increase knowledge of treated agro-dealers. To test if the interventions affect agro-dealer knowledge, we construct two indices that summarize different measures of knowledge. The first index aims to measure knowledge about seed storage and handling and tests if agro-dealers retained the information that was provided during the training. The test is a short multiple choice quiz of five questions related to seed carryover between agricultural seasons, how seed should be stored after repackaging, how seed should be stored in the storeroom, and whether seed should be repackaged. The exact questions, the options presented to farmers, and the correct answers are outlined in Appendix A.4.

The second knowledge index aims to capture knowledge about seed more broadly, and does not focus on seed handling recommendations covered in the training. We again use multiple choice questions to test if agro-dealers know which seed variety to recommend if a farmer complains about poor soil or lack of rain, if a farmer is late for planting, and whether they know what to tell clients who inquire about the yield benefits of hybrid or OPV seed. Again, the questions and (correct) answer options are explained in Appendix A.4.

Table 11 suggests a positive impact of the agro-dealer training on knowledge at midline, but the coefficient is just shy of significance at the 10% level. The (insignificant) effect of the training is strongest at midline, which seems reasonable as the training was organized only once at the start of the study (Figure 1). Interestingly, we find knowledge effects from the clearinghouse treatment, particularly for agro-dealer knowledge related to seed storage seed and handling. This effect becomes stronger over time, which again seems reasonable as this treatment was repeated. This result suggests that the clearinghouse treatment, with its focus on seed quality, prompts agro-dealers to actively search for information on better ways to store and handle seed.

The above suggests that providing only knowledge through training is unlikely to improve outcomes when demand-side constraints are binding, echoing Bold et al. (2022). In our setting, extra knowledge at the agro-dealer level is only useful if farmers are able to appreciate the effect of it (see also Hoffmann et al. (2021)). To examine this further, we exploit the factorial design of the experiment, and focus on the subset of agro-dealers that were assigned to both the training and the clearinghouse treatment. We indeed find a significant positive interaction effect on key outcomes at the agro-dealer level at endline (most notably on the overall operations index, as in Table 6). The positive interaction effect seems to be driven by significant improvements in effort and practices (as in Table 12). We also find a positive interaction effect on the index of agro-dealer knowledge about seed at midline, but the effect is not significant, possibly due to insufficient statistical power to test interactions. Results on these interaction

Table 11: Effects on agro-dealer outcomes: Knowledge

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Index of dealer knowledge about seed storage[1]†	0.000	0.091	0.115	306	0.030	0.124*	297
	(0.482)	(0.076)	(0.075)		(0.053)	(0.055)	
Index of dealer knowledge about seed[2]†	0.000	0.102	0.065	306	-0.009	-0.007	297
	(0.533)	(0.072)	(0.070)		(0.080)	(0.078)	
Overall index	0.000	0.208	0.211^{+}	306	0.038	0.142	297
	(0.729)	(0.125)	(0.119)		(0.107)	(0.102)	
Max. number of obs.				306			297

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

[1]The index of dealer 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.

[2]The index of dealer 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.

effects are available from the authors upon request.

7.2 Agro-dealer efforts, services, and practices

The information clearinghouse provides agro-dealers with an incentive to become better than their direct competitors to attract more farmers (Lane, Schonholzer, and Kelley, 2022). Furthermore, the performance feedback provided through the treatment may motivate agro-dealers to become better and increase quality through behavioral channels such as social comparison and self-image effects (Gosnell, List, and Metcalfe, 2020).

Agro-dealers can attempt to increase quality by changing the way they store and handle seed. Furthermore, and particularly if they already use appropriate storage and handling methods, they may increase effort and start providing more or better services in an attempt to (indirectly) affect ratings.[19]

In Table 12, we provide evidence that agro-dealers who are exposed to the clearinghouse indeed invest more effort than agro-dealers in the control group. The table shows results for one overall index and four individual indices that each capture different dimensions of effort, services, and practices. The first index focuses on effort and service provision as reported by agro-dealers themselves, and is composed of seven variables: whether the agro-dealer (1) offers explanations on how to use the seed they sell to farmers, (2) recommends complementary inputs to get optimal results from improved varieties, (3) provides advisory services or training, (4) offers discounts for large-quantity purchases, (5) offers credit, (6) received a seed-related customer complaint since last season, and (7) accepts mobile money payments. A second index summarizes the perceptions of farmers who purchase from these agro-dealers. This index is also constructed from seven variables: whether a agro-dealer (1) offers refunds or insurance, (2) provides credit, (3) offers training or advice to customers, (4) delivers to the farmgate, (5) provides after-sales service, (6) accepts different payment methods, and (7) sells small quantities. Farmers' answers to these questions are aggregated at the agro-dealer level before the index is computed.

To handle and store seed correctly, a combination of investments and labor-intensive practices are necessary. Also during the agro-dealer training, we recommended a mix of practices that are in reach of different types of agro-dealers, some of which may have excess labor while others may have access to money to invest. A third index groups a set of labor-intensive seed handling and storage practices. It contains six variables: whether seed is stored (1) in a dedicated area, (2) in correct lighting, (3) on appropriate surfaces, and (4) not in open containers; whether the agro-dealer has a pest problem; and whether the agro-dealership looks clean and professional. Data for these variables were collected by enumerators through visual inspection, and none are self-reported

[19]For example, if agro-dealers already provide quality inputs but farmers complain about low yields, agro-dealers may provide training/advice and recommend complementary inputs to get optimal results. This could increase yields, in turn increasing farmer perceptions of seed quality. Or, agro-dealers may provide insurance or cash back guarantees, which may then be interpreted by farmers as a signal that agro-dealers sell high quality.

by agro-dealers. A fourth index summarizes capital-intensive seed-handling practices, based on six variables: whether the roof is (1) leak-proof, (2) insulated; (3) whether the walls are insulated; whether the agro-dealership is (4) ventilated, and (5) displays any official certificate; and (6) whether expired seed is handled correctly. Most of these variables were collected or at least confirmed by enumerators through visual inspection, only one of them (whether expired seed is handled correctly) is self-reported.[20]

We find that the clearinghouse intervention increases agro-dealer effort and services, especially at midline, where the coefficient of the overall index is significant at the 1% level. This effect is driven by treated agro-dealers who significantly raised their effort and services, according to farmers. We see that the impact persists until endline, where the significant effect on the overall index seems to be driven by the self-reported measure of effort. We do not find that the agro-dealer training improves services or practices.

In markets characterized by asymmetric information, signaling is often used to solve the inefficiency problem (Spence, 1973). In our case, as it is difficult to assess seed quality via visual inspection, agro-dealers may use various strategies to signal to customers that their products are of good quality. Becoming a member of professional organizations is one way to do so, as these memberships signal professionalism. Agro-dealers who try to signal quality will also not shy away from inspections. On the contrary, they may actively seek inspection so that they can advertise the result in their agro-dealerships.

Table 13 collects a set of variables related to signaling quality, including memberships in UNADA and other professional associations, trading licenses, the number of inspections in the last season, and warnings or confiscations of seed after inspection. We find that at endline, judging by the overall index, the clearinghouse treatment led to a significant increase in compliance with or participation in quality assurance measures. Looking at the individual outcomes, the overall effect seems to be driven by an increase in registrations with UNADA. We also see that treated agro-dealers were inspected significantly more often.

7.3 Switching

An important potential mechanism underlying the effect of the information clearinghouse at the farmer level is the possibility that farmers switch from lower rated agro-dealers to those with better ratings. To explore this mechanism, we asked farmers if they switched agro-dealers since the previous season. Results (Table 14) indicate that only 17% of farmers reported switching at baseline. However, at midline, a significantly higher share of farmers in the clearinghouse treatment group reported switching agro-dealers. Also at endline, we find a higher propensity for switching among clearinghouse treated farmers.

Increased switching in itself does not necessarily mean that farmers move from

[20]To test whether social desirability affects this result, we exclude the last variable from the index and rerun the analysis, since agro-dealers might report that they handle expired seed correctly but, in reality, choose not to do so for strategic reasons such as cost management. Doing this does not change the coefficients for the index of capital-intensive seed-handling practices in any notable way.

Table 12: Effects on agro-dealer outcomes: Efforts and practices

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Index of dealer efforts and services, self-reported[1†]	0.000	-0.063	0.066	243	-0.031	0.086^{+}	297
	(0.454)	(0.062)	(0.060)		(0.051)	(0.048)	
Index of dealer efforts and services, according to farmers[2†]	-0.027	-0.151^{*}	0.301^{**}	259	0.006	0.086	271
	(0.583)	(0.074)	(0.069)		(0.092)	(0.084)	
Index of labor-intensive seed handling practices[3†]	0.010	0.058	0.099	285	0.083	0.074	274
	(0.484)	(0.070)	(0.065)		(0.067)	(0.068)	
Index of capital-intensive seed handling practices[4†]	0.000	-0.019	0.000	270	-0.087	0.070	265
	(0.508)	(0.063)	(0.072)		(0.092)	(0.081)	
Overall index	0.032	-0.029	0.359^{**}	189	0.006	0.165^{+}	234
	(0.540)	(0.121)	(0.113)		(0.099)	(0.091)	
Max. number of obs.				306			297

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.
[1]The index of dealer efforts and services, self-reported 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.
[2]The index of dealer 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.
[3]The index of labor-intensive seed handling practices contains 6 variables: whether seed is stored in dedicated area, in correct lighting, on correct surface, not in open containers, whether shop has no pest problem, cleanness and professionality rating by enumerator.
[4]The index of capital-intensive seed handling practices contains 6 variables: whether roof is leak-proof, roof is insulated, walls are insulated, shop is ventilated, shop displays official certificate, expired seed is handled correctly.

Table 13: Effects on agro-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 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)	
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)	
Number of shop inspections§†	1.532	0.037	-0.097	293	0.038	0.292^{*}	273
	(1.859)	(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: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.
§Due to the skewness of this variable, the regression was run after an Inverse Hyperbolic Sine transformation. Coefficient estimates can therefore be interpreted as percentage changes. The baseline mean column shows the untransformed variable.

Table 14: Effects on farmer outcomes: Switching behavior

	midline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Farmer switched to different agro-input shop[1]	0.168	-0.013	0.042^{**}	3407	-0.024	0.026^{+}	3441
	(0.374)	(0.014)	(0.014)		(0.015)	(0.015)	
Max. number of obs.				3407			3441

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.
[1]We report the mean and standard deviation at midline because this variable was not collected at baseline.

lower-rated agro-dealers to higher-rated ones. To investigate this, we calculate the difference between the rating of agro-dealer the farmer is switching to and that of the agro-dealer the farmer is switching from. If farmers move to better-rated agro-dealers, this difference is positive. We find that this is indeed the case, and more so during the second season, although the difference is not significantly different from zero at conventional levels (p-value = 0.166).

At the agro-dealer level, we find that the clearinghouse treatment led to a significant increase in the number of customers (Table 6). This can not be explained by farmers switching, since switching involves an increase in customers for some agro-dealers at the expense of others, leaving the average number of customers of agro-dealers in the treatment group unaffected. When we look at changes in customers over time, we actually do not see that the increase in customers is largest for agro-dealers with high ratings. This suggests that the impact of the clearinghouse treatment on perceptions—to which we turn next—may be particularly important for agro-dealers with low ratings, offsetting any potential loss that is due to the switching mechanism.

7.4 Perceptions

Finally, the clearinghouse may change farmer perceptions of the quality of seed sold by agro-dealers. Table 15 provides impact on two measures of farmer perceptions of quality. First, we asked farmers if they think that maize seed that can be bought at agro-dealers is counterfeit or adulterated. At baseline, two in three farmers responded affirmatively to this question, indicating substantial pessimism about quality. Columns (2) to (5) show the impact of the clearinghouse for the full sample. The treatment does not significantly affect farmer perceptions as measured by this variable at midline or endline. However, we expect the effect of the clearinghouse on perceptions to be strongest for farmers who did not use improved maize varieties at baseline. Therefore, we repeat the analysis for this subgroup of farmers in columns (6) to (9). At midline, farmers that did not adopt at baseline and live in areas exposed to the clearinghouse are 12.5 percentage points less likely to think that agro-dealers sell adulterated seed than similar farmers in areas not assigned to the treatment.

Second, we look at rating data to assess farmer perceptions of product quality. In particular, we look at the index of maize seed ratings that combine ratings for general quality, yield, drought tolerance, pest and disease tolerance, time of maturity, and germination of seed obtained from various agro-dealers.[21] These ratings are aggregated at the farmer level (since one farmer generally rates multiple agro-dealers) and then the index is calculated.[22] We see that the index is positively and significantly affected by the clearinghouse treatment, even though the effect is only significant at the 10%

[21] As the act of rating agro-dealers was an essential part of the clearinghouse treatment, we only collect ratings in control areas at endline and so can only test this hypothesis at endline.

[22] To compute this index at the farmer level, we restrict the sample to observations where a farmer needs to have rated at least one agro-dealer in the catchment area on all components of the index. This procedure leads to a sample size reduction, which in turn may affect statistical power.

level. If we restrict the sample to farmers that did not adopt improved maize varieties at baseline, the treatment effect on the ratings is significant at the 5% level. The impact on the overall index that combines the two perception related indicators is also significant for this sub-sample.

The improvement in farmer opinions and ratings may reflect a real increase in the quality of seed, because the clearinghouse improved agro-dealers' seed handling efforts and practices, thus improving seed quality. However, in Appendix A.1 we show that we do not find clear evidence that the clearinghouse treatment affected a set of (imperfect) quality proxies of the seed the agro-dealer sell. Furthermore, looking at Table 12, we find no evidence that agro-dealers change seed handling practices in response to the clearinghouse treatment. As such, it does not seem that the change in perceptions reflects a real change in quality.

An alternative explanation is that the quality of maize seed at most agro-dealers 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 generally good but that farmers' beliefs are often incorrect, so that one simply needs to rectify this misperception to increase adoption. Consistent with this explanation, we find that two in three farmers thought that maize seed at agro-dealers is counterfeit or adulterated at baseline. At the same time, note that the average agro-dealer was rated 3.4 out of 5 at baseline which indicates that perceived seed quality was reasonable. The fact that ratings are relatively high is probably due to the fact that farmers who rate have experience with seed from agro-dealers. Because of the clearinghouse treatment, mostly non-adopting pessimistic farmers notice that adopting peers do not share their pessimism, and they adjust their perceptions. Furthermore, the clearinghouse affects several measures of adoption already at midline. If we assume that changing agro-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.

8 Conclusion

In this study, we hypothesize that seed quality deteriorates because agro-dealers lack knowledge and/or because asymmetric information results in excessive search costs for farmers and reduced incentives for agro-dealers. Our hypothesized solutions to these problems are a training to inform agro-dealers about correct seed handling and storage practices, and an information clearinghouse based on crowd-sourced ratings of the quality of seed that agro-dealers sell to farmers. We explore the impact of these solutions on a range of agro-dealer and farmer outcomes with an experimental design that allows for causal attribution and investigation of several underlying mechanisms.

Results show that training agro-dealers is generally ineffective: our training does not change agro-dealer knowledge about proper storage and handling practices, their day-to-day operations, or the seed they sell to farmers. Nor does the training affect

Table 15: Effects of the clearinghouse on farmer outcomes: Perceptions

		full sample				*sub-sample*			
	baseline	*midline*		*endline*		*midline*		*endline*	
	mean	CH	obs.	CH	obs.	CH	obs.	CH	obs.
Farmer thinks maize seed at agro-dealer is adulterated†	0.685	-0.041	2113	0.020	2167	-0.125**	903	0.010	944
	(0.465)	(0.027)		(0.028)		(0.036)		(0.035)	
Index of farmer's maize seed ratings of agro-dealers within area[1]†	0.000			0.092^{+}	1664			0.141*	693
	(0.637)			(0.054)				(0.063)	
Overall index	0.019			0.104	1462			0.160*	596
	(0.770)			(0.071)				(0.074)	
Max. number of obs.			3407		3441		1719		1741

Note: Column (1) reports baseline means and standard deviations below; columns (2) and (4) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (3) and (5) report number of observations; columns (6) to (9) mirror this structure for the sub-sample of farmers that did not adopt at baseline, **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

[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 agro-dealers), then the index is computed. Note that treatment and control groups can only be compared 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 agro-dealers, so that this variable can be investigated.

farmers' perceptions of seed quality purchased from these agro-dealers or subsequent use of purchased seed. The punchline from these results is that training seems insufficient without additional incentives.

This is where the clearinghouse results come into play. They suggest that if agro-dealers have the right incentives, they may actively seek out knowledge necessary to improve their operations and stay ahead of their competitors. If agro-dealers are exposed to both incentives and information, they handle and store seed better and attract more business.

Recently, Dar et al. (2023) showed that an information intervention targeted at private input suppliers is effective in changing their behavior and in increasing farmer-level adoption, which seems to contradict our null result for the training at first sight. However, their information treatment is very different from ours: instead of training these suppliers in seed handling and storage at the agro-input shop, they give them access to a new seed variety for their own learning, hoping that they will spread this information to their clients who will use it on the farm. Moreover, Dar et al. (2023) find that business incentives and reputational concerns play a key role when dealers share information and give advice, which is in line with our finding that incentives matter.

The information clearinghouse clearly affected the market for maize seed in our study area: sellers and buyers started behaving in line with our theory of change. Agro-dealers reported more business and smallholders reported increased use of purchased maize varieties, in turn increasing production outcomes. This effect seems to partly originate from agro-dealers who expanded service provision and signal quality to farmers to outperform their competitors. We find some evidence that the clearinghouse induced farmers to switch between agro-agro-dealers, but most of the impact on farmer outcomes seems to be driven by the fact that the clearinghouse improved the opinions that farmers held about agro-dealers and their products.

The significant impact of the clearinghouse indicates that farmers cannot judge the quality of maize seed at the time of purchase. If the quality of a product can not be easily assessed at the time of purchase, one solution is to make sure consumers do not have to, through regulation and quality assurance. Most LMICs regulate seed quality in the formal market with codified standards, inspections, and certification systems. However, and particularly in countries that lack institutional capacity to implement and enforce the regulatory framework, the reach of these quality assurance systems—and the seed market in general—is limited. As a result, seed certification provides farmers with a relatively weak and unreliable indication of quality. A decentralized approach that relies on crowd-sourced quality signals such as the clearinghouse may be more effective.

Furthermore, peer ratings are likely to measure the dimensions of seed quality that matter most to smallholders. While it is possible to objectively measure seed quality (e.g., by sending mystery shoppers, followed by DNA fingerprinting) or agro-dealer practices (e.g., by sending objective inspectors incognito), it is plausible that farmers are not concerned about genetic purity (indicating whether the seed embodies the genetic characteristics of a specific variety) but mainly care about seed performance (e.g., germination rate, vigor, and yield). The opinion of peers who are familiar with the heterogeneous conditions farmers face, may be more useful and trustworthy for smallholders than the judgment of an inspector or DNA test.

A key assumption underlying the clearinghouse mechanisms is that, while individual farmers can not assess the quality of seed at the time of purchase, collective experience does provide useful information. This is because farmers can learn from experience, and use this information when making decisions in subsequent seasons. Empirically, however, farmers may have difficulties drawing a causal link between seed quality, on the one hand, and plant emergence, growth, and harvest, on the other hand given the extensive set of confounding variables at play (rainfall, soil quality, pest and disease pressure, inputs, management, and plant genetics), the complexity of genotype-by-environment-by management (G×E×M) interactions, or the stochastic nature of many of these variables. In addition, Bayesian learning takes time, and opportunities to learn are few (even tough in Uganda there are two agricultural seasons). This partly explains the rich body of research on the role of peer effects in technology adoption: the ability to combine own experience with the experience of farmers in a similar location is therefore likely to provide a good signal about the quality of seed (Conley and Udry, 2010; Bandiera and Rasul, 2006; Foster and Rosenzweig, 1995). As farmers are thus unlikely to discover quality of inputs themselves, an information clearinghouse that relies on peer ratings is expected to increase data points that farmers can use when making adoption decisions.

While the crowd-sourced information clearinghouse tested in this study may also be feasible at scale, the clearinghouse idea cannot not be approached naively. There is considerable controversy surrounding the credibility of reviewing platforms and the ability of sellers on these platforms to improve their ratings with payments to consumers to provide favorable ratings, automated bot reviews, and other strategic practices. There are also more practical considerations, such as how long ratings should remain valid, or how to deal with sellers who receive high ratings on one set of attributes—seed quality, in this case—but perform poorly in other categories, for example, by engaging in unfair labor practices, discriminating against certain types of customers, engaging in anti-competitive behavior, or promoting environmentally hazardous products. Rating platforms could potentially amplify these practices and biases rather than address them. While this paper offers both proof of concept and an empirical test of theoretical predictions about the relationship between observable product quality and buyer and seller behavior in a market characterized by asymmetric information, further piloting and testing is needed at increasingly larger scales to test additional hypotheses about market performance, supply and demand responses, and productivity, welfare, and resilience outcomes.

References

Akerlof, G. A. 1970. "The Market for "Lemons": Quality Uncertainty and the Market Mechanism." *The Quarterly Journal of Economics* 84 (3): 488–500.

Allcott, H. and T. Rogers. 2014. "The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation." *American Economic Review* 104 (10): 3003–37.

Anderson, M. L. 2008. "Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects." *Journal of the American Statistical Association* 103 (484): 1481–1495.

Angrist, J., E. Bettinger, and M. Kremer. 2006. "Long-Term Educational Consequences of Secondary School Vouchers: Evidence from Administrative Records in Colombia." *American Economic Review* 96 (3): 847–862.

Ashour, M., D. O. Gilligan, J. B. Hoel, and N. I. Karachiwalla. 2019. "Do Beliefs About Herbicide Quality Correspond with Actual Quality in Local Markets? Evidence from Uganda." *The Journal of Development Studies* 55 (6): 1285–1306.

Ashraf, N., X. Giné, and D. Karlan. 2009. "Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya." *American Journal of Agricultural Economics* 91 (4): 973–990.

Bandiera, O. and I. Rasul. 2006. "Social Networks and Technology Adoption in Northern Mozambique*." *The Economic Journal* 116 (514): 869–902.

Barriga, A. and N. Fiala. 2020. "The supply chain for seed in Uganda: Where does it go wrong?" *World Development* 130: 104928.

Bellemare, M. F. and C. J. Wichman. 2020. "Elasticities and the Inverse Hyperbolic Sine Transformation." *Oxford Bulletin of Economics and Statistics* 82 (1): 50–61.

Bennett, D. and W. Yin. 2019. "The Market for High-Quality Medicine: Retail Chain Entry and Drug Quality in India." *The Review of Economics and Statistics* 101 (1): 76–90.

Björkman Nyqvist, M., J. Svensson, and D. Yanagizawa-Drott. 2022. "Can good products drive out bad? A randomized intervention in the antimalarial medicine market in Uganda." *Journal of the European Economic Association* 20 (3): 957–1000.

Bold, T., K. C. Kaizzi, J. Svensson, and D. Yanagizawa-Drott. 2017. "Lemon technologies and adoption: Measurement, theory and evidence from agricultural markets in Uganda." *The Quarterly Journal of Economics* 132 (3): 1055–1100.

Bold, T., S. Ghisolfi, F. Nsonzi, and J. Svensson. 2022. “Market Access and Quality Upgrading: Evidence from Four Field Experiments.” *American Economic Review* 112 (8): 2518–52.

Borlaug, N. 2007. “Feeding a Hungry World.” *Science* 318 (5849): 359–359.

Campos, F., M. Frese, M. Goldstein, L. Iacovone, H. C. Johnson, D. McKenzie, and M. Mensmann. 2017. “Teaching personal initiative beats traditional training in boosting small business in West Africa.” *Science* 357 (6357): 1287–1290.

Conley, T. G. and C. R. Udry. 2010. “Learning about a New Technology: Pineapple in Ghana.” *American Economic Review* 100 (1): 35–69.

Dar, M., A. De Janvry, E. Sadoulet, K. Emerick, and E. Wiseman. 2023. “Private input suppliers as information agents for technology adoption in agriculture.” *American Economic Review: Applied Economics* forthcoming.

De, A., C. Miehe, and B. Van Campenhout. 2022. “Gender bias in consumer perceptions: The case of agro-input dealers in Uganda.” *IFPRI Discussion Paper* .

Drexler, A., G. Fischer, and A. Schoar. 2014. “Keeping It Simple: Financial Literacy and Rules of Thumb.” *American Economic Journal: Applied Economics* 6 (2): 1–31.

Duflo, E., R. Glennerster, and M. Kremer. 2007. “Using randomization in development economics research: A toolkit.” *Handbook of Development Economics* 4: 3895–3962.

Duflo, E., M. Kremer, and J. Robinson. 2011. “Nudging farmers to use fertilizer: Theory and experimental evidence from Kenya.” *American Economic Review* 101 (6): 2350–90.

Foster, A. D. and M. R. Rosenzweig. 1995. “Learning by doing and learning from others: Human capital and technical change in agriculture.” *Journal of Political Economy* 103 (6): 1176–1209.

Giné, X. and G. Mansuri. 2021. “Money or Management? A Field Experiment on Constraints to Entrepreneurship in Rural Pakistan.” *Economic Development and Cultural Change* 70 (1): 41–86.

Gollin, D., C. W. Hansen, and A. M. Wingender. 2021. “Two Blades of Grass: The Impact of the Green Revolution.” *Journal of Political Economy* 129 (8): 2344–2384.

Gosnell, G. K., J. A. List, and R. D. Metcalfe. 2020. “The Impact of Management Practices on Employee Productivity: A Field Experiment with Airline Captains.” *Journal of Political Economy* 128 (4): 1195–1233.

Hanna, R., S. Mullainathan, and J. Schwartzstein. 2014. “Learning through noticing: Theory and evidence from a field experiment.” *The Quarterly Journal of Economics* 129 (3): 1311–1353.

Hasanain, S. A., M. Y. Khan, and A. Rezaee. 2023. “No bulls: Experimental evidence on the impact of veterinarian ratings in Pakistan.” *Journal of Development Economics* 161: 102999.

Hoffmann, V., S. K. Mutiga, J. W. Harvey, R. J. Nelson, and M. G. Milgroom. 2021. “Observability of food safety losses in maize: Evidence from Kenya.” *Food Policy* 98: 101895.

Humphreys, M., R. S. De la Sierra, and P. Van der Windt. 2013. “Fishing, commitment, and communication: A proposal for comprehensive nonbinding research registration.” *Political Analysis* 1–20.

Imbens, G. W. and M. Kolesár. 2016. “Robust Standard Errors in Small Samples: Some Practical Advice.” *The Review of Economics and Statistics* 98 (4): 701–712.

Kahneman, D. and A. Tversky. 1979. “Prospect Theory: An Analysis of Decision under Risk.” *Econometrica* 47 (2): 263–291.

Karlan, D. and M. Valdivia. 2011. “Teaching Entrepreneurship: Impact of Business Training on Microfinance Clients and Institutions.” *The Review of Economics and Statistics* 93 (2): 510–527.

Karlan, D., R. Osei, I. Osei-Akoto, and C. Udry. 2014. “Agricultural decisions after relaxing credit and risk constraints.” *The Quarterly Journal of Economics* 129 (2): 597–652.

Lane, G., D. Schonholzer, and E. Kelley. 2022. “Information and Strategy in Lemon Markets: Improving Safety in Informal Transit.” *PEDL Research Paper* .

Lin, W. 2013. “Agnostic notes on regression adjustments to experimental data: Reexamining Freedman’s critique.” *Annals of Applied Statistics* 7 (1): 295–318.

McKenzie, D. and C. Woodruff. 2013. “What Are We Learning from Business Training and Entrepreneurship Evaluations around the Developing World?” *The World Bank Research Observer* 29 (1): 48–82.

Michelson, H., A. Fairbairn, B. Ellison, A. Maertens, and V. Manyong. 2021. “Misperceived quality: Fertilizer in Tanzania.” *Journal of Development Economics* 148: 102579.

Muralidharan, K., M. Romero, and K. Wüthrich. 2019. *Factorial designs, model selection, and (incorrect) inference in randomized experiments.* Tech. rep., National Bureau of Economic Research.

Reimers, I. and J. Waldfogel. 2021. “Digitization and pre-purchase information: The causal and welfare impacts of reviews and crowd ratings.” *American Economic Review* 111 (6): 1944–71.

Rozin, P. and E. B. Royzman. 2001. "Negativity Bias, Negativity Dominance, and Contagion." *Personality and Social Psychology Review* 5 (4): 296–320.

Spence, M. 1973. "Job Market Signaling." *The Quarterly Journal of Economics* 87 (3): 355–374.

Suri, T. 2011. "Selection and comparative advantage in technology adoption." *Econometrica* 79 (1): 159–209.

Suri, T. and C. Udry. 2022. "Agricultural Technology in Africa." *Journal of Economic Perspectives* 36 (1): 33–56.

Van Campenhout, B. 2021. "The Role of Information in Agricultural Technology Adoption: Experimental Evidence from Rice Farmers in Uganda." *Economic Development and Cultural Change* 69 (3): 1239–1272.

Wossen, T., K. A. Abay, and T. Abdoulaye. 2022. "Misperceiving and misreporting input quality: Implications for input use and productivity." *Journal of Development Economics* 157: 102869.

Xie, Y. 2017. *Dynamic Documents with R and knitr.* CRC Press.

A Appendix

A.1 Effects on seed quality at agro-dealer

To assess the effect of the training and clearinghouse intervention on the quality of seed sold by agro-dealers, we bought a bag of seed at each agro-dealer and inspected it on a number of attributes. First, we measured the moisture content of the seed. In Table A1, we see that the clearinghouse treatment reduced moisture as expected, but the parameter is estimated imprecisely, perhaps due to the smaller data set as we were not able to source seed from all agro-dealers and the comparisons were only made for agro-dealers from which the enumerator was able to buy a bag of maize seed at mid- or endline. We further look at the integrity of the package and whether it shows important information such as the packaging date, shelf-life and the lot number. We do not find that the clearinghouse treatment nor the agro-dealer training affected quality proxies of the seed that agro-dealers sell. However, because our proxies of seed quality are far from perfect and we rely on a smaller sample, we cannot safely conclude that the treatments did not affect seed quality.[23]

[23] Assessing seed quality is not only challenging for farmers, but also for researchers. Even though investigating moisture is an attempt to test the quality of seeds in a quantitative and objective way, this variable is one-dimensional and only a weak indication of seed quality. Additional ways to capture seed quality include lab testing to measure purity as the rate of extraneous, non-seed material in the bag, germination using a germination chamber, grow-out tests for genetic purity using morphological analysis, and DNA fingerprinting to test for genetic purity using single nucleotide polymorphisms tests.

Table A1: Effects on agro-dealer outcomes: Bag of maize seed

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Moisture in %†	13.564	0.017	-0.122	175	-0.041	-0.220	261
	(1.482)	(0.142)	(0.144)		(0.198)	(0.197)	
Bag shows packaging date†	0.689	0.053	0.050	179	-0.091	0.035	265
	(0.464)	(0.069)	(0.072)		(0.063)	(0.064)	
Shelf-life in days[1] †	60.951	-18.930	-8.272	164	13.091	6.352	240
	(40.960)	(22.091)	(20.869)		(8.243)	(8.289)	
Seed is in original undamaged bag†	0.940	0.025	0.002	179	0.006	0.051	265
	(0.238)	(0.044)	(0.046)		(0.053)	(0.055)	
Bag shows lot number†	0.508	0.025	-0.001	179	-0.138*	0.027	265
	(0.501)	(0.106)	(0.107)		(0.062)	(0.064)	
Overall index	0.065	0.083	0.108	160	-0.067	0.108	236
	(0.364)	(0.103)	(0.103)		(0.094)	(0.090)	
Max. number of obs.[2]				179			265

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

[1] Days since the packaging date or, if the bag does not show the packaging date, days since the expiry date minus 6 months.

[2] The comparisons were only made for agro-dealers in which the enumerator was able to buy a bag of maize seed at mid- or endline. Also, we do not control for the baseline values of the outcome variables in the entire table because only 144 of the 179 dealers who had seed at midline also had seed at baseline and only 183 of the 265 dealers who had seed at endline also had seed at baseline, so that controlling for baseline values would reduce the sample sizes drastically.

A.2 Rating computation: details

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 agro-dealers 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 agro-dealers 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-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.3 Outcome variables and results as they were pre-registered

Table A2: Effects on primary dealer outcomes

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Quantity of maize seed sold in kg§†	695.503	-0.092	0.284	292	-0.499^{+}	0.239	286
	(1497.183)	(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)	
Revenue from maize seed in mln UGX§†	2.890	-0.069	0.185^{+}	292	-0.227^{+}	0.143	286
	(6.286)	(0.104)	(0.108)		(0.118)	(0.118)	
Number of maize seed customers per day§†	19.764	-0.056	0.127	294	-0.190	0.310**	288
	(20.689)	(0.098)	(0.101)		(0.116)	(0.112)	
Moisture in randomly selected seed bag in %	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: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

§Due to the skewness of this variable, the regression was run after an Inverse Hyperbolic Sine transformation. Coefficient estimates can therefore be interpreted as percentage changes. The baseline mean column shows the untransformed variable.

[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 A3: Effects on secondary dealer outcomes: Indices

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

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

[1]The index of dealer's motivation and satisfaction contains 3 variables: whether dealers see themselves working as agro-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 A4: Effects on primary farmer outcomes

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

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

[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 agro-dealers), 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 agro-dealers), then this index is computed.

[3]The index of services of agro-dealers within catchment area 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 within the catchment area 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.

Table A5: Effects on secondary farmer outcomes: Adoption on randomly selected maize plot

	baseline	*midline*			*endline*		
	mean	training	CH	obs.	training	CH	obs.
Farmer planted hybrid seed†	0.264	0.002	0.009	2654	-0.023	0.032	2700
	(0.441)	(0.022)	(0.022)		(0.023)	(0.023)	
Farmer planted open-pollinated seed†	0.260	-0.017	0.002	2654	0.010	-0.007	2700
	(0.439)	(0.022)	(0.022)		(0.020)	(0.021)	
Farmer planted farmer-saved seed†	0.579	0.020	-0.042^{+}	3153	-0.009	-0.016	3240
	(0.494)	(0.022)	(0.022)		(0.020)	(0.020)	
Farmer planted seed bought at agro-input shop†	0.330	-0.010	0.047*	3153	0.012	0.036^{+}	3240
	(0.470)	(0.022)	(0.022)		(0.019)	(0.019)	
Farmer planted hybrid or open-pollinated seed[1]	0.432	-0.019	0.035	2954	0.009	0.030	3047
	(0.495)	(0.023)	(0.023)		(0.023)	(0.023)	
Overall index	-0.003	0.000	0.002	2867	-0.010	0.026	2963
	(0.553)	(0.024)	(0.024)		(0.025)	(0.025)	
Max. number of obs.				3407			3441

Note: Column (1) reports baseline means and standard deviations below; columns (2), (3), (5), and (6) report differences between treatment and control groups and standard errors below; they are clustered at the level of randomization; columns (4) and (7) report number of observations; **, *, and + denote significance at the 1, 5 and 10% levels; † indicates that the variable is included in the overall index; larger indices indicate more desirable outcomes.

[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.

A.4 Multiple choice questions to measure dealer knowledge

Dealer knowledge about seed storage

1. How long can seed be carried over before losing viability?
   (a) Seed can be carried over into the next seasons as you can store seed for 12 months.
   (b) Seed cannot be carried over into the next seasons as 6 months is the longest seed can be stored.
   (c) This depends on the seed: hybrids cannot be carried over, OPVs can be carried over for 5 seasons.
   (d) I don't know.
2. How should seed best be stored after repackaging?
   (a) Airtight in polyethylene bags.
   (b) In paper bags or perforated polyethylene bags.
   (c) In a sealed tin/plastic container.
   (d) I don't know.
3. What is the minimum recommended distance between the floor and where seed is stored?
   (a) 0 inches, seed should be stored directly on the floor for maximum stability.
   (b) Minimum 2 inches from the floor.
   (c) Minimum 6 inches from the floor.
   (d) I don't know.
4. How should seed ideally be stored in your store room?
   (a) In sealed cardboard boxes.
   (b) Stacked on pallets.
   (c) Arranged on shelves with sufficient space between packets.
   (d) I don't know.
5. Which statement do you agree most with?
   (a) You should repackage all your seed to visually verify that you are selling good quality seed.
   (b) You should repackages all your seed so you can sell more to small farmers.
   (c) You should avoid repackaging your seed as much as possible.
   (d) I don't know.

Dealer knowledge about seed

1. If a farmer complains about poor soil, which maize variety do you recommend?
   (a) Longe 5.
   (b) Bazooka.
   (c) Longe 10H.
   (d) I don't know.
2. What do you tell clients who inquire about the yield benefits of hybrid seeds?
   (a) Hybrid seeds double maize yields (increasing yield from about 4 to 8 bags/acre).
   (b) Hybrid seeds triple maize yields (increasing yield from about 4 to 12 bags/acre).
   (c) Hybrid seeds increase yields tenfold (increasing yield from about 4 to 40 bags/acre).
   (d) I don't know.
3. If a farmer misses the rains or lives in an area that receives little rain, which maize variety do you recommend?
   (a) Longe 10H.
   (b) Longe 7H.
   (c) Wema.
   (d) I don't know.
4. If a farmer is late for planting in the short season and needs a fast maturing variety, which maize variety do you recommend?
   (a) Bazooka.
   (b) Longe 10H.
   (c) Myezi mitatu (mm3).
   (d) I don't know.