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Information Barriers to Adoption of Agricultural Technologies: Willingness to Pay for Certified Seed of an Open Pollinated Maize Variety in Northern Uganda

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Abstract

We examine smallholder farmers' willingness to pay for agricultural technology and whether information is a constraint to adoption of certified maize seed in Northern Uganda. The uptake of improved maize varieties by smallholder farmers in Uganda remains persistently low, despite the higher yield potential compared to traditional varieties. A recently growing body of literature identifies information constraints as a potential barrier to adoption of agricultural technologies. We used incentive compatible Becker-DeGroot-Marschak auctions to elicit willingness to pay for quality assured improved maize seed by 1,009 smallholder farmers, and conducted a randomised evaluation to test the effect of an information intervention on farmers' knowledge of seed certification. Our results show that the randomised information treatment enhanced farmers' knowledge of certified seed. However, using the information treatment as an instrumental variable for knowledge, we find no evidence of a causal effect of knowledge on willingness to pay, suggesting that even though farmers are information constrained, this constraint does not affect adoption of certified seed directly. Nevertheless, only 14% of sampled farmers were willing to pay the market price, which corresponds closely with actual observed demand for certified seed in the previous season. This suggests that there are other barriers to adoption than information and awareness.

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1. Introduction

Despite their proven benefits, adoption of many welfare enhancing products and technologies remains puzzlingly low across the developing world (Duflo *et al.*, 2008, 2011; Ashraf *et al.*, 2009; Cohen and Dupas, 2010; Mobarak and Rosenzweig, 2013). This could be, for example, because producers do not have enough information to assess benefits associated with product use, because of liquidity constraints and the consequential high opportunity costs for money, lack of access (Simtowe *et al.*, 2019), or downside risk associated with the investment (Emerick *et al.*, 2016).

When low willingness to pay (WTP) for a new technology and resulting low uptake is due to lack of knowledge about the product, the rate of adoption can be increased by providing relevant information. Such information can help producers understand the advantages associated with product use. A growing body of literature shows that information is an important barrier to adoption (Pan *et al.*, 2015; Shiferaw *et al.*, 2015; Shikuku, 2019). A number of studies show that provision of information has been effective in increasing adoption of welfare enhancing technologies or services (Rogers, 2004; Jensen, 2007, 2010; Jalan and Somanathan, 2008; Meenakshi *et al.*, 2012; De Groote *et al.*, 2016a). On the other hand, there are instances where information interventions did not generate the intended effect (Ashraf *et al.*, 2013; De Groote *et al.*, 2016a).

In sub-Saharan Africa, market imperfections and information asymmetries tend to restrict farmers' ability to appreciate the benefits of welfare enhancing technologies, in particular for agricultural inputs (Jack, 2013; Maredia *et al.*, 2019). For example, germination, seed health and vigour are credence attributes. Farmers only know whether they bought a good quality product after the seed has germinated. In fully functional markets, recognisable brands and price attributes are cues for quality. In the absence of these cues a quality assurance label could provide such signals (Dentoni *et al.*, 2014; Banerji *et al.*, 2016; De Groote *et al.*, 2016a).

Here we explore a government issued 'certified seed' label as a means of signalling quality of an agricultural technology, an improved maize variety. Improved seed varieties refer to varieties that have purposely been bred by breeders and have an improvement, such as higher yields, drought tolerance, pest and disease resistance. Certified seed refers to seed that is produced for the purpose of seed and relates to quality standards of physical purity, germination percentage and seed health.

The uptake of improved maize varieties by smallholder farmers in Uganda is persistently low, this despite the fact that improved varieties have a much higher yield potential than the varieties traditionally grown by farmers. Just over 15% of Ugandan farmers buy improved varieties from the formal seed market, with the rest relying mostly on home-saved seed and low quality products from the local market (ISSD, 2014). Counterfeiting seed is a commonly recognised problem in Uganda (Joughin, 2014) and is widely reported in national media.

Our objective is to measure WTP for certified maize seed of smallholder farmers in Northern Uganda and to assess whether information about seed certification and quality standards can improve WTP for an improved maize variety. Our main hypothesis is that low uptake of improved maize varieties is restricted by low willingness to pay because farmers have limited knowledge of the quality of the product and of the seed certification label. By providing information on seed quality assurance and formal certification we test whether the WTP for the seed increases. We conducted a randomised controlled trial (RCT) where farmers in the treatment group received detailed information about the certified seed label, while the control group did not. We then assessed the effect of the information treatment on farmers' knowledge of certified seed. To test the effect of knowledge of certified seed on WTP, we used the randomised information treatment as an instrumental variable for knowledge, where WTP is obtained using incentive compatible Becker-DeGroot-Marschak (BDM) auctions.

We make several contributions to the literature on adoption of welfare enhancing technologies, and in particular yield enhancing technologies. Our main contribution to the literature is on information barriers to adoption of agricultural technologies and the role certification could play for signalling quality of a credence good (Fuglie *et al.*, 2006; De Groote, 2011; Guei *et al.*, 2011; Banerji *et al.*, 2016; Poku *et al.*, 2018; Channa *et al.*, 2019).

In addition, we expand the discussion on adoption of improved (maize) varieties from valuing individual variety traits to WTP for seed as a quality product. WTP studies for seed have mainly focused on the WTP for individual variety traits such as drought tolerance or higher yields, rather than for the product itself (in our case a 2 kg pack of maize seed), using conjoint or discrete choice experiments (see, for example, Baidu-Forson *et al.*, 1997; Bajari and Benkard, 2001; Dalton, 2004; Horna *et al.*, 2007; Asrat *et al.*, 2010; Enid *et al.*, 2015; Kassie *et al.*, 2017). In addition, Maredia *et al.* (2019) point out that in most of these studies variation in quality of the product is not considered. In their study they address this by eliciting WTP for different seed quality types, using visual inspection of crops in the field to assess quality of the seed. Our study takes an existing known product (a quality assured improved maize variety – Longe 5D) available on the market to elicit WTP for the product containing both quality traits and varietal traits, and to measure the effect of providing information about quality of the product on the adoption of this agricultural technology. To our knowledge no other studies on WTP for quality seed of improved maize varieties as a complete product have been conducted.

Finally, our study contributes to an ongoing debate in seed sector development, where estimating seed demand is becoming more pertinent (Fuglie *et al.*, 2006; Spielman and Kennedy, 2016; Erenstein and Kassie, 2018; Lybbert *et al.*, 2018; Simtowe *et al.*, 2019). Our empirical strategy relies on a Becker-DeGroot-Marschak (BDM) auction to elicit WTP for quality seed and estimates the informational effects on farmers' WTP (e.g. De Groote *et al.*, 2011, 2016b; Banerji *et al.*, 2016; Oparinde *et al.*, 2016; De Steur *et al.*, 2017; Maredia *et al.*, 2019).

The remainder of the paper is organised as follows: the next section highlights key aspects of the seed sector in Uganda to set the context of the study and provides the background to the certified seed label. Section 3 describes the methodology and the design of the experiment. The results are discussed in section 4, while section 5 concludes with key findings and policy implications.

2. Ugandan Seed Sector

In Uganda, agriculture is a core sector of the economy that provides a livelihood for approximately 65% of the population. Improving agricultural productivity in Uganda is therefore a key policy priority (Government of Uganda, 2007). Efforts to expand agricultural productivity in Uganda have, amongst others, focused on technological change and specifically the adoption of yield enhancing seed varieties.

The Ugandan seed sector is characterised by a formal seed system and an informal seed system, where the latter provides about 85% of all seed used (ISSD, 2014). The informal seed system comprises home-saved seed, seed obtained from social networks (family and friends), informal seed multiplication groups and the local grain market. The local grain market typically provides recycled seed of unknown quality (Kansiime and Mastenbroek, 2016). Seed from farmers' own farms, social networks, and informal seed multipliers have social trust as informal quality control mechanisms because of the familiar and short supply lines (Kansiime and Mastenbroek, 2016; Hoogendoorn *et al*., 2018), but quality is not assured.

The formal system is responsible for the dissemination of certified seed of improved varieties through a structured system that includes variety development and release, external quality assurance and formal distribution, and marketing mechanisms through an agro-input dealer network. In Uganda the National Seed Certification Services (NSCS) under the Ministry of Agriculture, Animal Industry and Fisheries is responsible for seed certification in the formal system (Mastenbroek and Ntare, 2016).

Uganda has a mandatory seed inspection system that recognises two seed classes: certified seed and quality declared seed (QDS). Certification is a process which translates unobservable levels of seed quality into observable attributes, allowing farmers to differentiate between different qualities of seed. Certified seed obtained from a formal source should theoretically reduce the risk of seed borne pests and diseases, and guarantee high germination, and physical and genetic purity. Once the seed is certified, the seed company is issued with blue tamperproof Government labels for the seed packs. Certified seed is sold directly by seed companies and is also distributed through agro-input dealer shops. In addition, Government and NGO programmes distribute certified seed for free. Free seed distribution is restricted to a limited sub-set of smallholder farmers in targeted districts and wealth brackets. Though the Ugandan Ministry of Agriculture, Animal Industries and Fisheries formally recognises QDS as a separate seed class, the regulations do not allow maize seed to be produced under this arrangement. Therefore this seed class is not further discussed, though the certification principles are the same.

The seed industry in Uganda was liberalised in the 1990s and involves a relatively high number of seed companies (26) for a relatively small estimated market of 18,000 MT maize seed per year (Mastenbroek and Ntare, 2016), which is the predominant product of these companies. The institutional environment is weak and the level of counterfeit seed and poor quality seed on the market is estimated as high as 40% (Joughin, 2014; Marechera *et al*., 2016; Bold *et al*., 2017; Erenstein and Kassie, 2018).[2] Systematic records on seed sector functioning are scarce and incomplete. It is estimated that 10% of maize seed is marketed through the formal system (Marechera *et al*., 2016) of which about half are hybrids and half are open-pollinated maize variety (OPVs) (Erenstein and Kassie, 2018). One strategy to curb the counterfeit and low quality seed on the market is to improve the paper version of the certified seed label

[2]In this paper we choose not to distinguish between counterfeit and poor quality seed as these two concepts are not easily distinguishable in practice. So far, two studies (Bold *et al.,* 2017; Barriga and Fiala, 2020) report on quality of true-to-type seed (genetically pure seed) in Uganda.

by introducing a tamperproof label with unique identifiers in each seed pack, which was introduced in 2014 for both OPVs and hybrid seed.[3] The use of the certified seed labels is not yet widespread. Approximately 10% of maize seed sold (and none for other crops) is inspected by the NSCS (Mastenbroek and Ntare, 2016). We therefore focused our research on certification for maize seed.

In addition to formal seed sector challenges, smallholder farmers also face major constraints in the maize output market which is undifferentiated and lacks premiums for high quality produce. As such, farmers have little incentive to purchase high quality seed; yet large public investments are made to develop high yielding varieties. Until recently, most seed was sold in larger volumes only. For maize this was 10 kg and above, while 5 and 2 kg packs are becoming more available (Mastenbroek and Ntare, 2016; Erenstein and Kassie, 2018).

3. Methods

3.1. WTP and BDM

Measuring farmers' WTP for certified seed is challenging, as some farmers might not be able to precisely determine the amount they would pay when faced with a real-life purchase while others might provide strategic answers. BDM auctions offer a field experiment technique to offset these pitfalls of WTP measurement (Breidert *et al.*, 2006). The technique has been used among a growing body of applied studies measuring WTP in a rural African setting, providing reliable results (see e.g. Banerji *et al.*, 2016; Oparinde *et al.*, 2016; De Groote *et al.*, 2016b; Maredia *et al.*, 2019; Berry *et al.*, 2020).

During the BDM auction a farmer is asked to place a bid (b) for a *target product*. This bid amount is later compared to a random price (p). If the farmer's bid is lower than a random price ($b < p$), then the farmer loses the chance to obtain the product and no payment has to be made (Oparinde *et al.*, 2016). It is an incentive compatible technique as the bid amount only determines the possibility to make the purchase while the random price is independent of the participant's choice or other participants' bids. Lusk and Shogren (2007) show that a rational participant's utility function would optimally lead to a bid equivalent to the true valuation, the maximum WTP.[4] We did not provide an endowment to the farmers to buy the product at the end of the auction, as the empirical literature shows mixed results using endowments (e.g. Lusk and Shogren, 2007; Ihli *et al.*, 2013). Moreover, we do not want to eliminate cash constraints as a barrier for farmers to make on the spot purchases in our BDM auction.

[3]Bold *et al.* (2017) relate low quality to low returns of maize seed, and argue that farmers are willing to pay a premium for quality seed. In line with this, Gharib (2018) analyses farmers' perceptions of packaging of seed and finds a WTP premium for untampered seed packets of seed companies.

[4]We should emphasise that while we interpret WTP as a proxy for potential adoption of certified OPV seed, we should also be cautious to interpret actual purchase behaviour of farmers directly as adoption or non-adoption, since adoption also depends on recommended replacement practices of purchasing fresh (certified) OPVs seed every 3 to 4 seasons (and hybrids every season).

Following BDM rules, we established an experimental auction design where research assistants privately led individual farmers through the purchasing process. No price menu was provided in order to avoid anchoring effects on the reference price and to elicit a more individual-specific WTP (Breidert *et al.*, 2006).[5] First, general rules of the auction were introduced and the farmer was given an opportunity to ask questions. Then we moved to the purchasing round, which included several stages: (i) asking for the maximum bid; (ii) confirming that participants understood the auction rules well; (iii) requesting confirmation that the bid amount could be paid 'out-of-pocket'; (iv) confirming the final bid amount; (v) revealing the price (referred to as the *envelope price*); and (vi) finalising the purchase through money exchange.

We established two purchasing rounds: a mock trial with a piece of regular soap (well known to all farmers and inexpensive at a market price at 500 UGX; approximately 0.15 USD at the 2016 average exchange rate) and later our target product, a 2 kg pack of labelled certified maize seed. We offered an open-pollinated maize variety (OPV), Longe 5D, with a market price around 6,000 UGX (1.75 USD) per 2 kg pack. This is an existing product on the market, sold by a number of seed companies. We opted for this variety because in the research area it was the most common OPV variety sold by seed companies and had been distributed through targeted government programmes. Considering our target population, one important benefit of choosing this particular variety was affordability, as the market price was relatively low compared to hybrid seed and there were no strict requirements for additional high cost inputs such as fertiliser.

To ensure that the respondents understood the procedures well, the mock trial followed all steps we just described for the BDM procedure, with an envelope price of 400 UGX. To strengthen the farmer's incentive compatibility, we asked him/her to pay the envelope price for the soap. Out of the 1,009 respondents, 733 bought the soap and 60 refused the offer. After the practice round was completed successfully, the farmer was asked to place a bid for the target product. The envelope price was randomised at alternative amounts of 4,000, 4,500, 5,000 and 5,500 UGX, that were previously unknown to the research assistants. This double blinding strategy aimed to reduce the research assistants' involvement in the bidding process. If a stated bid was lower than the amount in the envelope ($b < p$), the farmer would lose the chance to make the purchase. If the bid was greater than or equal to the envelope price ($b \geq p$), the farmer qualified and was allowed to make the purchase at the envelope price.[6]

3.2. *Information treatment*

The information session content was developed in collaboration with Integrated Seed Sector Development (ISSD) Uganda project field officers and covered all primary aspects of certified seed benefits. The information session was designed based on the

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[5]Since all BDM participants were experienced maize farmers that are familiar with using maize seed and making informed decisions on choosing farm inputs, we can assume that they can independently form expectations on the potential benefits of the OVP maize seed on auction.

[6]The range for the envelope price of 4,000–5,500 UGX (67–92% of the market price) was to verify that participants were indeed willing to pay the amount they bid and did not overbid or underbid. In addition, since we did not provide an endowment, we felt it unethical to have envelope prices above the market price.

principles of information relevance and neutrality towards farmers' choice, as we did not want to be associated with commercial marketing campaigns or seed companies.

The information session on certification benefits took approximately 15 minutes and was provided only to the individual farmers in the treatment group, just before the auction procedure. In addition, both groups were briefly introduced to the characteristics of the improved maize variety offered on sale. This introduction took approximately one minute and included standard information for the product that is offered by seed companies. It was important that both the treatment and control group received the one minute session on characteristics of the variety to allow both groups to have the same product information before making a bid. This also implies that the counterfactual to the experiment can be interpreted as the typical exposure to product knowledge that we may expect farmers to experience when purchasing certified seed from a formal supplier.

In the treatment group, the information session script included explanations about the differences between certified seed and grain, seed quality standards (e.g. high germination, purity, uniform seed sizes), benefits of using certified seed and expected returns under recommended agronomic practices. Additionally, each research assistant carried a sample of seed certification labels provided by the Ugandan Ministry of Agriculture which ensured that the seed offered was tested and met quality standards.

3.3. Estimating the effect of knowledge on WTP

The objectives of the empirical analysis are twofold. First, we estimate the effect of providing an information treatment on farmers' knowledge of certified seed. Second, we aim to identify the effect of knowledge of certified seed on WTP for this seed.

To estimate the effects of an information treatment we rely on a randomised controlled trial, where a randomly selected group of farmers was provided with an information treatment and a random control group was not. The experimental design helps us overcome potential selection bias, as unobserved heterogeneity could influence farmers' willingness and ability to seek information on certified seed; for example, if such unobserved heterogeneity is driven by entrepreneurial and cognitive skills, risk preference or socio-economic factors.

Randomisation allows us to estimate the effect of the information treatment (T) by taking mean differences in the outcome variables between the treatment and control groups. We also use an OLS specification to add control variables (X) and region fixed effects (D) in order to improve precision, when estimating the immediate effect of the information treatment on farmers' knowledge and awareness (K).

$$K_i = \alpha + \beta T_i + \gamma X_i + D_i + \varepsilon_i \quad (1)$$

The outcome K includes various aspects of knowledge and awareness of the benefits and sources of certified seed.

The second step of the analysis is to estimate the causal effect of knowledge of certified seed on the WTP. Since knowledge is likely to be endogenous to WTP, we can identify the causal effect by exploiting the randomised design and use the information treatment as an instrumental variable (IV) for knowledge. We then estimate the second stage regression.

$$WTP_i = \delta + \pi K_i + \theta X_i + D_i + \nu_i \quad (2)$$

Randomisation of the instrument lends credibility to the identifying assumption that the information treatment affects WTP only through its effect on knowledge. The drawback of this IV setup is that the estimated causal effect needs to be interpreted as the local average treatment effect: the effect of knowledge on WTP for those farmers who saw an increase in their knowledge from the information treatment. On the other hand, from a policy perspective this does reflect the actual target group of the intervention and therefore offers a policy relevant treatment effect.

3.4. Sampling and data collection

The study, consisting of the BDM auction and survey, was conducted in Northern Uganda where the OPV Longe 5D is a well-known maize variety. The two target districts were Nwoya and Dokolo, which are both maize growing areas. The final sample included 1,009 farmers, of which 400 are from Dokolo and 609 from Nwoya. The auction and survey took place in the first half of April 2016, over a period of 2 weeks, which coincided with the late start of the first planting season when demand for maize seed is relatively high.

We interacted with farmers at their homes or in a few cases at their farmland. First, we stratified at district level and randomly selected 100 villages: 60 in Nwoya and 40 in Dokolo. We then sampled farm households from a sampling frame which was drafted by a team of mobilisers that was sent ahead to the villages. Our target population consisted of all rural households in the villages, assuming most of them grow maize. We selected approximately 10 households within each village. If the household appeared not to grow maize, it was replaced by another random household within the same village. The final sample consisted of 1,009 households, of which 532 were in the control group and 477 in the treatment group.

Depending on availability, we interviewed the household head, the spouse or the child above 18 years old. The survey was adapted to different sub-regions and translated into two dialects of the Luo language: Lango and Achioli. To avoid spill-over of the information session, we first interviewed households in the central location and later moved towards outer parts of the village. This strategy prevented possible meetings with neighbouring farmers between the visits. The households in a village were interviewed strictly on the same day.

All households were surveyed after the BDM auction, including those that were not interested in the purchase of seed during the auction. The household survey relied on a questionnaire with modules on household demographics and socio-economic characteristics, maize production details, certified seed knowledge, access to credit and poverty. The purpose of the questionnaire was to capture farmers' characteristics related to seed purchasing behaviour. Household poverty levels were measured using the poverty scorecard method designed by Schreiner (2015), yielding a poverty score that can theoretically range from 0 (poorest) to 100 (richest). The technology score was composed of four procedures that are considered to be good agronomic practices and that provide an indication of the level of investment by farmers. These are using a string for planting (row planting), hiring of labour during planting, use of fertiliser and use of pest control.

Summary statistics for the control variables in the analysis are given in Table 1. Descriptive information regarding the seed, knowledge and WTP variables are presented in the next section. Note that all but one of the control variables in

Table 1
Descriptive statistics

	N	Mean	Std. dev	Min	Max
Age	958	40.33	13.45	18	90
Female	1,007	0.43	0.49	0	1
Head of household	1,005	0.76	0.43	0	1
Education					
None	1,005	0.22	0.41	0	1
Did not complete primary	1,005	0.43	0.50	0	1
Completed primary	1,005	0.23	0.42	0	1
Completed O-Level	1,005	0.07	0.25	0	1
Completed A-Level	1,005	0.02	0.15	0	1
Completed tertiary	1,005	0.03	0.18	0	1
Social network advice	987	0.52	0.50	0	1
Land cultivated (acres)	988	2.92	1.80	0	10
Received free handout	966	0.18	0.39	0	1
Poverty score	989	29.91	11.59	0	64
Technology score	887	1.13	1.04	0	4
Purpose for growing maize					
Predominantly food	934	0.38	0.48	0	1
Predominantly cash	934	0.34	0.47	0	1
Food and cash	934	0.28	0.45	0	1
Dokolo district	1,009	0.40	0.49	0	1
Nwoya district	1,009	0.60	0.49	0	1

Table 1 are balanced for the treatment and control groups (for details see Appendix Table A1).

4. Results

4.1. Maize seed varieties in Northern Uganda

A commonly referred example in the seed systems literature is that farmers access maize seed through the formal sector, while for other crops they mainly use informal seed systems (e.g. Almekinders *et al.*, 1994; Louwaars *et al.*, 2013). However, our data covering the two seasons in 2015 shows that local maize varieties (Table 2) were still very common in Northern Uganda, comprising 66% of all seed varieties. Out of the improved varieties, OPVs (25%) were more widely used than hybrids (12%). Longe 5 (D) was the most common OPV, representing 93% of the OPVs mentioned. Farmers in Nwoya planted more local varieties (76%) compared to farmers in Dokolo (51%), while the latter planted more OPVs (36% compared to 18%).

About 81% of maize seed came from informal sources (Table 3) with home saved seed as the most common source (37%), followed by local grain markets (28%), social networks (10%) and informal seed multiplication groups (6%). The 19% of the seed that came from the formal market (and constitute the 'certified seed' category) was mainly purchased from agro-dealers and seed companies (12%), while 7% of seed acquired by farmers were free handouts by the Government and NGOs. About 63%

Table 2
Maize seed varieties planted in the last two seasons (percentages)

	All	Nwoya	Dokolo
Local varieties	65.99	75.71	51.21
OPV (Longe 1–5, 5D)	25.03	18.09	35.58
Hybrids	11.76	9.57	15.09
Other	1.50	0.71	2.70
Observations	935	564	371

Note: Farmer responses include multiple variety types, so the percentages by column can cumulate to more than 100%.

Table 3
Maize seed source in the last two seasons (percentages)

		By seed variety used		
	All	Local varieties	OPVs	Hybrids
Home saved seed	36.62	46.27	22.32	9.09
Social network	9.85	10.23	11.15	10.91
Local grain market	27.84	36.20	11.59	8.18
Informal seed multipliers	6.42	4.22	11.16	9.09
Agro-dealer/seed company	12.10	1.62	27.04	43.64
Government/NGO	6.85	0.97	16.74	19.09
Observations	934	616	233	110

Note: We left out the ‘other type’ (see Table 2), hence not all columns add up to 100%.

of hybrid seed and 44% of the OPVs reached farmers through the formal market. It should be noted that most hybrids in Uganda are 3-way crosses of which seed could be recycled for one or two seasons, although this is not recommended for yield stability and uniformity. Hybrids therefore also appeared at informal seed sources.[7]

Before the planting season, farmers have a choice between varieties (products) with different traits, seed source and quality aspects. The main attribute reported by farmers for selecting a particular variety was yield potential (34%), followed by availability at home (32%) and the price of seed (10%). Less prominent reasons for selecting a particular maize variety were grain appearance (6%), maturity (5%) and distance to the sales point (4%). Thus, farmers seem to mix variety specific traits (grain appearance, maturity, yield potential) and access characteristics (distance, price and availability at home) in their decision making.

The reported seed sources indicated that less than half of the farmers actually purchased seed the year prior to the survey. However, except for seed from the agro-dealer, the quality of seed from other seed sources is uncertain, as it is not certified. Despite the apparent benefits of certified seed, many farmers are reluctant to move

[7]Note that 1.62% of local variety seed is reported as sourced from agro-dealers and seed companies, and 0.97% from free handouts. Given that the formal sector should not be providing local varieties, this might be due to misclassification, for example if farmers may not have known the variety name.

Table 4
Barriers to adopting certified maize seed (percentages)

	All	Nwoya	Dokolo
Lack of money to buy certified seed	63.94	58.37	72.61
Lack of information about benefits	25.56	28.69	20.67
Don't know where to buy them	23.94	24.05	23.77
Distance to certified seed supplier	15.66	18.41	11.37
Lack of adequate amount of land	15.45	10.78	22.74
Lack of credit to buy certified seed	11.72	14.93	6.72
Lack of labour to plant certified seed	9.80	11.61	6.98
Seed not available at time of planting	8.59	8.62	8.53
Distrust related to certification label	2.53	1.82	3.62
Low quality of the soil	1.41	1.49	1.29
Certified seed is not worth the price	1.11	0.83	1.55
Certified seed cannot be replanted	1.11	1.82	0.00
Inadequate package size	1.01	1.16	0.78
Striga weed	0.40	0.17	0.78
Observations	990	603	387

Note: Multiple responses were possible, so the percentages by column can cumulate to more than 100%.

away from local varieties towards higher yielding improved varieties and continue to rely on home saved seed or products from the local grain market. Yet, at the same time, yield potential was reported to be a major contributing factor for selecting a variety by smallholder farmers. Several potential barriers could explain this apparent inconsistency. Table 4 shows self-reported barriers to adoption of certified seed among our sample of farmers, and their responses seem to correspond with the literature. Affordability was the most prominent response (64%), followed by lacking information about the benefits (26%) and the source (24%) of certified seed, distance to suppliers (16%), and a lack of land (15%) and credit (12%). There were some differences between the two districts: information, distance and credit were more prominent in Nwoya than in Dokolo, while we see the opposite for affordability and available land, as Nwoya is relatively more sparsely populated and farmers have more land available for agriculture.

4.2. Farmers' knowledge of certified seed

Table 5 reflects the farmers' knowledge on the benefits and sources of certified seed (control group only). Farmers related the benefits of certified seed mainly to higher yields (79%), which results from high germination, uniform appearance and indirectly pest and disease resistance. These determinants of yield potential were recognised by far fewer farmers than yield potential itself. Since certified seed is quality assured and tested, the likelihood of seed borne diseases is much lower than seed from informal sources. About 20% of the control group knew that this seed is quality assured and that the produced grain may get a better price.

Over half of the farmers were able to correctly identify at least one formal source of certified seed and improved varieties (57%), mostly by recognising agro-dealers as a formal source (47%). Just over a fifth of the farmers mentioned government handouts

Table 5
Knowledge of certified maize seed benefits and sources (percentages for the control group)

Benefits of certified seed	All	Nwoya	Dokolo
High yield	78.57	74.38	84.91
High germination	43.05	45.94	38.68
Resistant to disease and pest	21.99	27.50	13.68
Quality assurance	21.05	19.38	23.58
Higher grain price	20.11	20.94	18.87
Uniform maturity	14.69	13.79	16.04
Uniform appearance	14.47	15.63	12.74
Tested by Government	6.95	4.06	11.32
Possibility to return	0.56	0.63	0.47
Certified seed source			
Formal source[a]	56.95	64.38	45.75
Agro-dealer	46.43	53.75	35.38
Government	19.55	20.94	17.45
Project/NGO	12.22	15.63	7.08
Informal source	23.12	15.31	34.91
Informal seed multipliers	13.91	8.44	22.17
Local grain market	7.89	5.94	10.85
Neighbour	3.20	2.19	4.72
Own seed	2.26	0.63	4.72
Don't know	32.14	28.75	37.26
Fully correct knowledge	4.51	5.94	2.36
Observations	532	320	212

Note: Responses on benefits and seed sources were not mutually exclusive; [a]at least one formal source correctly identified.

as a formal source, while 12% mentioned a project or NGO. On the other hand, almost a third incorrectly answered that certified seed can be obtained from an informal source and a third reported they didn't know the source. Only 5% of the farmers identified all correct formal sources and did not mention any informal sources, suggesting that accurate information may be a barrier to adoption.

We also quizzed our respondents on their knowledge of the going market price for 1 kg of Longe 5 certified seed, the product tested in the BDM auction. More than half of the sampled farmers did not make any estimate because they did not know the price. Of those that did give a price estimate only 13% of the farmers mentioned a price that falls in the range that would be realistic during the study period (between 2,500 and 3,500 UGX per 1 kg). The remaining 30% stated a price either below or above this range. Overall, this shows that, even though more than half the farmers were familiar with certified seed and knew where to purchase it, they were less aware of the seed market price.

4.3. WTP for Longe 5D and the demand for certified seed (BDM results)

Out of the sample of 1,009 farmers, 116 farmers indicated that they were not interested in purchasing certified maize and did not place a bid in the auction. Of those that did participate in the auction, a further 43 farmers were dropped from the sample because they eventually refused the purchase even though their bid qualified (i.e., $b \geq p$). This leaves a sample of 850 farmers for the WTP analysis. The distribution of the 850 BDM auction bids is shown in the Online Supplementary Appendix. The restricted sample has an average WTP of 3,259 UGX for a 2 kg pack of Longe 5D certified maize seed, with a median of 2,700 UGX and a mode of 2,000 UGX.[8] These results suggest that the WTP for Longe 5D certified seed is well below market price, which in 2016 fluctuated around 6,000 UGX for a 2 kg pack.

Interestingly, the BDM auction bids correspond well with the actual purchase at outlets for Longe 5D certified seed. As we show in Table 3, 12% of the farmers in our sample reported purchasing seed from agro-dealers and seed companies, while our BDM auction results suggest that 14% of farmers are willing to purchase the target product at the going market price in 2015.[9]

The BDM results also suggests that the price elasticity is relatively high at the going market price, with an arc elasticity of −3.4 for the range 5,500–6,500 UGX per 2 kg pack.[10] The arc elasticity gradually reduces as the price decreases, to near unity around the average WTP. This suggests that at the current market prices, farmers are relatively sensitive to price reductions.

4.4. *Effect of knowledge and awareness on WTP (RCT results)*

Turning to the RCT results, we first assess whether the information treatment increased knowledge, and then whether farmers' knowledge itself is a binding constraint for the WTP of Longe 5D certified seed.

The impact of the information treatment on farmers' knowledge of the benefits of certified seed are shown in Table 6 and the sources for obtaining these seed varieties in Table 7. These variables are similar to those reported and discussed in Table 5. For all knowledge outcome variables we report the results without control variables. The specifications with control variables yield very similar results and are included in the Online Supplementary Appendix (Table A2 and Table A3). Since knowledge of each seed source and benefit reported by an individual farmer are unlikely to be independent from each other, we allow the error terms to be correlated by estimating a seemingly unrelated regression (SUR) system for both the sources and the benefits.

The results in Table 6 suggest that the information treatment increased farmers' knowledge of the certified seed benefits. However, we find no evidence of an effect for farmers' knowledge of certified seed sources: the coefficients are small and not statistically significant for all formal and informal seed sources (Table 7).

The strongest effects are found for knowledge regarding certified seed quality assurance, resistance to disease and pests, and the possibility to return seed if problems occurred. Relative to the control group mean (captured by the constant), the information treatment increased knowledge of quality assurance and pest resistance by about

[8]Figures A1 and A2 in the Online Appendix show the full distribution of the farmers' WTP for certified OPV seed. Note that we repeated the analysis for the full sample, taking the actual bids of the refusers and setting WTP = 0 for the non-participants. The average WTP for the full sample is slightly lower, at 3,031 UGX, but the impact analysis provides very similar results.

[9]If we include the non-participants with a WTP of 0, about 12% is willing to purchase at the market price.

[10]With 8% and 15% farmers willing to purchase at prices 6,500 and 5,500 respectively.

Table 6
Impact of the information treatment on knowledge on the benefits of certified seed (SUR)

	(1) Quality	(2) Tested	(3) High yield	(4) Germination	(5) Uniform	(6) Resistant	(7) Mature	(8) Price	(9) Return
Treatment	0.07**	0.03+	0.03	0.06+	0.03	0.06*	-0.00	0.04+	0.02**
	[0.027]	[0.017]	[0.025]	[0.031]	[0.023]	[0.027]	[0.022]	[0.026]	[0.008]
Constant	0.21**	0.07**	0.79**	0.43**	0.15**	0.22**	0.15**	0.20**	0.01
	[0.019]	[0.012]	[0.017]	[0.022]	[0.016]	[0.019]	[0.015]	[0.018]	[0.005]
R-squared	0.007	0.003	0.001	0.004	0.002	0.005	0.000	0.003	0.007

Note: Number of observations: 1,008. Standard errors clustered at village level in brackets. Statistical significance: **1%, *5%, +10%.

Table 7
Impact of the information treatment on knowledge on the certified seed source (SUR)

	(1) Agro dealer	(2) Government	(3) Project/NGO	(4) Own seed	(5) Neighbour	(6) Local market	(7) Local business
Treatment	0.04	0.02	−0.02	0.00	0.00	−0.00	−0.00
	[0.031]	[0.025]	[0.020]	[0.009]	[0.011]	[0.017]	[0.022]
Constant	0.46**	0.20**	0.12**	0.02**	0.03**	0.08**	0.14**
	[0.022]	[0.018]	[0.014]	[0.006]	[0.008]	[0.012]	[0.015]
R-squared	0.002	0.001	0.001	0.000	0.000	0.000	0.000

Note: Number of observations 1,009. Standard errors clustered at village level in brackets. Statistical significance: **1%, *5%, +10%.

a third. The effect on awareness of higher grain prices (increasing by 20% relative to the control group) is also statistically significant, but at the 10% level. The same holds for knowledge of certified seed enjoying higher germination rates and certified seed being tested and approved by the Ministry of Agriculture, but these effects lose statistical significance when we add control variables.

Before we can estimate the effect of knowledge on WTP using the IV setup, we first need to capture the knowledge and awareness variables in a single amalgamated knowledge score. We construct the variable using Principle Components Analysis (PCA) where we include all the variables reported in Table 5 on the source and benefits of certified seed. The PCA results and factor loadings are reported in the Online Supplementary Appendix (Table A4).[11]

The IV results are presented in Table 8. Column 1 shows the first stage regression, where the information treatment is used as the instrumental variable for the amalgamated knowledge score (equation (1)). Column 2 shows the second stage regressions, with the local average treatment effect of the knowledge score on WTP (equation (2)). Columns 3 and 4 repeat the IV analysis including the full set of control variables. By adding the control variables, we lose some observations due to missing values with some of the variables. The *R*-squared statistic increases marginally, to 0.06, as only very few of the controls show a statistically significant association with WTP.

The first stage regressions show that the information treatment does improve the knowledge score, confirming it is a relevant instrumental variable. The results in Table 6 and Table 7 suggest that this effect is driven mainly by the impact of the treatment on awareness and knowledge of certified seed. Turning to the control variables, column (3) shows that land size, previous free handouts of certified seeds, and having received advice on certified seed from members in their social networks is associated with increased knowledge of certified seed, while female farmers have a lower knowledge score. We also see that the purpose for growing maize matters, with a relatively higher knowledge score for farmers who grow maize for both own consumption and the market.

Despite the effect of the information treatment on knowledge of certified seed, we find no effect of the knowledge score on the WTP. These results are not sensitive to including control variables.[12] Among the control variables we find very little statistically significant correlation, except for the technology scores, suggesting that affinity and experience with agricultural technology is associated with increased WTP and with it the likelihood that farmers will use certified seed. We also see that WTP in Nwoya is about 600 UGX higher than in Dokolo.

Consistent with the IV results, the reduced form results of the randomised experiment show little impact of providing additional information on the WTP for certified seed. Table 9 reports the average WTP for farmers in the control and treatment

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[11]The Kaiser-Meyer-Olkin measure of sampling adequacy is 0.614, and the Bartlett test of sphericity rejects the null hypothesis that the variables are not correlated at the 1% significance level.

[12]We also estimated the IV model without covariates but restricting the sample to the 642 observations in columns 3 and 4. The coefficients are comparable. The effect of knowledge on WTP remains small and is not statistically significant, while the coefficient of the information treatment reduces to 0.18 but is less precise. Hence, adding the controls for the restricted sample seems to improve precision somewhat for the first stage, but for the second stage the conclusion remains unchanged.

Table 8
Instrumental variable (IV) estimates of the impact of knowledge on willingness to pay (WTP)

	(1) Knowledge score	(2) WTP	(3) Knowledge score	(4) WTP
Knowledge score		390.53		51.44
		[899.26]		[1,026.28]
Treatment	0.23*		0.23+	
	[0.11]		[0.12]	
Age			0.00	−15.42+
			[0.01]	[9.26]
Female			−0.27+	0.60
			[0.16]	[380.35]
Head of household			0.05	−220.66
			[0.16]	[365.37]
Education (ref: none)				
Did not complete primary			−0.30*	−330.82
			[0.15]	[401.90]
Completed primary			−0.38*	−22.15
			[0.18]	[523.40]
Completed O−Level			−0.23	614.12
			[0.25]	[685.00]
Completed A−Level			−0.01	1,561.07
			[0.38]	[1,751.02]
Completed tertiary level			0.04	425.67
			[0.30]	[863.59]
Social network			0.40**	99.12
			[0.12]	[416.07]
Land cultivated			0.10**	31.68
			[0.03]	[108.32]
Received free handout			0.58**	−345.01
			[0.16]	[612.52]
Poverty score			−0.00	19.39
			[0.01]	[12.04]
Technology score			0.09	290.85*
			[0.06]	[147.43]
Purpose for growing maize (ref: predominantly food)				
Predominantly cash			−0.23+	−68.57
			[0.13]	[346.86]
Food and cash			0.47*	−178.39
			[0.20]	[577.47]
Dokolo			0.05	−607.79*
			[0.19]	[255.22]
Constant	−0.09	3,252.37**	−0.42	3,499.40**
	[0.087]	[118.28]	[0.31]	[751.13]
Observations	850	850	642	642
R-squared	0.007	0.007	0.148	0.064

Note: Standard errors clustered at village level in brackets. Statistical significance: **1%, *5%, +10%.

Table 9
Willingness to pay for treatment and control group (Ugandan shilling)

	All	Nwoya	Dokolo
All	3,259	3,496	2,925
Treatment	3,307	3,564	2,962
Control	3,217	3,437	2,890
Difference	90	127	72
Observations	850	498	352

groups. In both Nwoya and Dokolo district the WTP is slightly higher for the group that received the information treatment, ranging from 72 to 127 UGX. These differences are small (2.5% to 3.7% of control group WTP, respectively) and not statistically significant. Controlling for the variables that are also included in the IV regression does not increase precision of the experiment's impact estimates by purging the error term of noise.

5. Discussion and Conclusions

Our objective was to elicit WTP for certified maize seed of an improved open-pollinated variety of smallholder farmers in Uganda, and test whether information about seed certification as a mechanism of communicating seed quality affects WTP for certified seed of this variety under prevailing market conditions. Our key findings are that WTP is approximately half of the commercially sold maize seed price and that randomised information sessions did increase knowledge and awareness of the benefits of certified seed, but increased knowledge did not translate into a higher willingness to pay.

The study extends the body of evidence suggesting that information is not the key constraint in the adoption process of yield enhancing products (Ashraf *et al.*, 2013; De Groote *et al.*, 2016a). When exploiting the randomisation of the information treatment to construct an instrumental variable for knowledge, we find no evidence of a causal effect of knowledge and farmers' WTP for certified seed of the tested variety. That is, enhanced knowledge on seed certification and benefits of using certified seed did not change farmers' purchasing behaviour.

The WTP elicited through the BDM auctions seems to match actual purchasing behaviour and seed demand. Consistent with earlier studies, this confirms that BDM auction mechanisms can yield WTP estimates that resemble actual market outcomes and farmers' purchasing behaviour in a developing country context (e.g. Berry *et al.*, 2020). The percentage of farmers that state a WTP for the seed price similar to that of the commercially sold seed is about 14%, which is close to the percentage of farmers that bought seed at agro-dealer shops in the season before the BDM auction. This suggests either that a government issued certification label may not be an appropriate mechanism to signal quality and address information asymmetries, or that there are other barriers to adoption than knowledge and awareness of seed certification.

Our study implies that, in Uganda, scaling up adoption of certified OPV maize seed is not realistic under prevailing market conditions and constraints faced by farmers. The BDM results further imply that at current market price levels the price elasticity of demand for certified seed is relatively high. In addition, more than 60% of smallholder farmers stated affordability as a major barrier to uptake of certified seed of this variety. This would suggest that interventions targeting budget constraints, such as price subsidies for certified OPV maize seed or credit programmes might be effective to achieve initial gains in scaling certified OPV maize seed. Alternatively, Karlan *et al*. (2014) suggest that risk could be frustrating farmers' investment decisions.

In contrast to information, prior experience with agricultural technology is likely to affect the purchase of certified seed in Uganda. It is possible that technologically advanced farmers had positive experiences with using certified seed in the past, although this correlation can also be driven by unobserved heterogeneity due to farmers' personal characteristics. This is in line with findings by Simtowe *et al*. (2019), who find that adoption of drought tolerant maize varieties in Uganda could increase by 8% if the whole population would be exposed to the varieties. Maredia *et al*. (2019) find that visual evidence through field demonstration works as a cue for quality and attracts a price premium for bean seed in Tanzania and cow pea seed in Ghana. This could suggest that there is scope for other, more hands-on, forms of knowledge provision, such as extension services where farmers are actively involved in the planting process, or training within farmer groups where social networks are engaged in the learning process.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Annex A. Tables and Figures.
Annex B. Auction procedure and script.

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