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Certification and Credibility: Do Seed Certification Systems in Uganda Help Signal Quality to Farmers?

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ABSTRACT

The value of purchased seed is a product of its underlying genetic information. However, farmers purchasing seed face a classic information asymmetry problem, as varietal identity is not directly observable. In this article we investigate the effectiveness of two certification systems in addressing this issue in the context of Uganda: the formal certification system (predominantly private sector) and the FAO's quality declared system (certification for seed produced mainly by farmers' groups). Using a large, nationally representative panel dataset spanning thirteen growing seasons, and controlling for time-invariant household and plot-level unobservables, we find that cultivating purchased quality declared improved seed results in measurable yield increases relative to saved seed. Surprisingly, however, certified improved seed is shown to provide no yield benefits over seed saved from previous seasons, despite its higher cost. Our findings suggest that input heterogeneity and information asymmetry in seed markets may be key constraints to the successful diffusion of improved maize varieties in Uganda, and that the formal seed certification system may not have provided an adequate signal of seed quality to farmers during the time period covered by the panel.

JEL Classification: O33, O34, Q12, Q16

1 | Introduction

A growing body of literature has focused on the heterogenous quality of agricultural inputs as an important driver of low adoption rates of improved seeds and other productivity-enhancing technologies across the developing world, particularly in sub-Saharan Africa. For example, in Uganda, Ashour et al. (2019) report that low-quality herbicide is prevalent in the marketplace, while Bold et al. (2017) find that fertiliser and maize seed quality are quite heterogeneous. Their findings indicate that fertiliser samples were missing 30% of the active ingredient, and hybrid maize seed samples contained less than 50% authentic seed. Other studies, such as Michelson et al. (2021), find little evidence of low-quality fertiliser in Tanzanian markets but show that farmer beliefs about heterogeneity in fertiliser quality are likely to be lowering adoption rates, while Hoel et al. (2024) argue that even incorrect beliefs about inputs that are in fact high quality can inhibit learning. Experimental evidence further shows that uncertainty about seed quality in sub-Saharan Africa reduces farmers' willingness to pay (WTP) for improved maize seed (Gharib et al. 2021), and farmer uncertainty about seed type has been experimentally shown to reduce yields of high-quality improved seeds (Bulte et al. 2025).

One proposed solution to help mitigate the market failures caused by information asymmetry in under-regulated input markets is the development of quality assurance programs (certification systems) that regulate and certify product quality (Hoel et al. 2024), informing consumers of the unobservable quality level of products (Auriol and Schilizzi 2015). When buyers cannot directly observe product quality, certification systems by which an independent certifier ensures that a

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product meets a specified standard can provide buyers with valuable information about quality, potentially incentivising producers to sell higher quality products (Zapechelnyuk 2020) and helping to increase demand for products with unobservable quality attributes such as bio-fortified grain (Banerji et al. 2016). Certification aims to identify high-quality seed, enabling purchasers to rely on certification labels rather than undertaking their own costly efforts to test the quality of seed available in the marketplace. This approach has been proposed as a solution to the challenges associated with quality heterogeneity in Uganda's seed market (Mastenbroek, Sirutyte, and Sparrow 2021) and elsewhere in sub-Saharan Africa (Maredia et al. 2019) and Asia (Win et al. 2023), although producer WTP for certified seed may not always be sufficient to match the market price (Mastenbroek, Sirutyte, and Sparrow 2021; Maredia and Bartle 2023). Recent work by Wossen et al. (2024) has shown through experimental work in Nigeria focused on cassava that most purchasers are prone to quality misperception but revise their bids upwards in response to positive quality signals for certified cassava stems.

Poorly-designed and under-resourced certification systems may fail to achieve their intended purpose; however, certification systems may fail in a number of ways. The certification regime itself may be poorly implemented, with inadequate monitoring of quality. This governance failure results in certificates conveying little or no meaningful information. Alternatively, the certification regime may function properly, but the certification itself may be counterfeited, leading to the presence of counterfeit certified products in the market. Producers may also capture (or mislead) the regulator and produce certified seed that does not meet the minimum quality requirements set by the certification system. Finally, even if certification systems work well, mishandling and poor storage of seeds may result in certified seeds being low quality by the time they are planted (Barriga and Fiala 2020).

In this article, we investigate whether two co-existing seed certification systems effectively mitigate information asymmetry problems in markets for goods of uncertain quality by providing a credible signal of seed quality[1] in the context of Uganda: the formal seed certification system and the de-centralised, FAO-designed quality declared seed system. We empirically test the hypothesis that improved maize seed bearing some form of certification will be superior (in terms of yield) to improved maize seed of unknown provenance (i.e., declared 'improved' by the farmer). We use a plot-level panel dataset from Uganda spanning thirteen growing seasons to analyse whether either form of certification provides a yield advantage over maize seed that is declared 'improved'.

Employing plot-level fixed effects analysis to control for time-invariant unobservables, we find that the form of regulation matters: the cultivation of purchased improved seed certified through the quality declared system leads to substantial yield increases relative to non-purchased seed, while in contrast, purchased certified improved seed provides no advantage over saved seed—providing suggestive evidence of a poorly functioning formal certification system during the period covered by the dataset.

2 | Seed Certification Systems in Uganda

In Uganda, two seed certification systems co-exist: the formal, certified seed system as well as the quality declared certification mechanism. Improved maize seed sold in the country may be certified through either of these systems (certified or quality declared) or sold without certification (declared improved but no certification label specified).

2.1 | Certified Seed

According to Uganda's 2018 National Seed Policy, certified seed refers to a class of seed produced from registered seed within the formal seed system, which is predominantly managed by private firms (Ugandan Ministry of Agriculture, Animal Industry and Fisheries 2018a). While the majority of agriculture in Uganda takes place within the informal seed system, characterised by home-saved seed, social networks and local markets, certified seed is exclusive to the formal seed system. According to Uganda's 2018 National Seed Strategy (formulated to operationalise the National Seed Policy), hybrid maize seed is only certified through the formal certification system, and Uganda's Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) estimates that the majority of certified maize seed is hybrid, though some open-pollinated varieties also bear the formal certification label (Ugandan Ministry of Agriculture, Animal Industry and Fisheries 2018b). Certification is carried out by the National Seed Certification Services (NSCS), a public organisation that is part of MAAIF. The NSCS regulates the formal seed sector from variety registration through to seed certification.

The 2018 National Seed Policy states that the formal system contributes only 10%–15% of the estimated national certified seed requirements. It also highlights the need to strengthen the NSCS to meet growing demand. Uganda's 2018 National Seed Strategy envisions the development of a 'transformed and integrated seed system' in which farmer-saved seed and quality declared seed are replaced by certified seed.

2.2 | Quality Declared Seed

The quality declared seed (QDS) system is a certification mechanism specifically designed for the informal seed sector. It indicates seed produced by a registered seed producer, in Uganda typically an individual or group of farmers, using basic seed that meets the required minimum field inspection and certification standards for purity and germination. The QDS System was introduced by the United Nations Food and Agriculture Organization in 1993 and later revised in 2006.

In collaboration with Uganda's National Agricultural Research Organization (NARO), the Integrated Seed Sector Development (ISSD) Uganda Programme trained farmers and farmer groups in the production of quality declared seed and the establishment of entrepreneurial local seed businesses. Similar to formal certification, QDS seed production involves inspection and certification by the MAAIF, which has also supported the creation of district agricultural officers to carry out field inspections; this occurs at the district level as opposed to the more centralised formal certification system. The QDS system is used to certify strictly the seed of open-pollinated maize varieties, not hybrid maize varieties, according to the MAAIF's 2018 National Seed Strategy. In addition, while formal certified seed is marketed directly by seed companies and through agro-dealer networks, QDS is sold within the communities where seed is produced and is typically not stocked by agro-dealers (Mastenbroek, Otim, and Ntare 2021).

The quality declared seed system—consisting of local seed businesses—was incorporated into Uganda's seed policy after the collection of evidence that the model could produce and market quality seed of open-pollinated varieties, and the development of a regulatory framework by which inspection services were decentralised to District Agricultural Offices. Local seed businesses pay a fee of about 15 USD as a cost for each inspection, which is carried out by local inspectors.

QDS has thus been developed as an alternative seed quality assurance system that complements the formal certification process managed by the National Seed Certification Services (Mastenbroek, Otim, and Ntare 2021). However, whereas formal certified seed (identified with a blue label) can be sold nationwide, the sale of quality-declared seed (identified with a green label) is limited to specific geographic areas.

3 | Empirical Approach

In this section, we first state our hypothesis; followed by a description of the plot-level dataset used in our analysis, and conclude with an explanation of our econometric approach and identification strategy.

3.1 | Hypothesis

We hypothesise that the two certification mechanisms available in Uganda's seed marketplace—if effective—will provide sufficient information for a farmer purchasing improved maize seed to substitute certification for their own experience testing different seed types. Specifically, we propose that improved maize seed bearing some form of certification will be superior to improved maize seed bearing no specified certification label.[2]

Our empirical approach aims to test this hypothesis using a key variable: the observed level of certification of the improved maize seed purchased by farmers (both QDS and formally certified seed in Uganda bear an easily recognisable label).

We employ plot- and household-level fixed effects to help address endogeneity concerns related to time-invariant unobserved factors, such as plot-level (e.g., soil quality) and household-level variables (e.g., farming knowledge). We also take several steps to reduce the impact of measurement error. We discuss our approach to endogeneity in the discussion section, where we explore the possible consequences of time-varying unobservables, such as the level of farmer effort, on our results.

The key variable in our dataset is the level of certification of purchased maize seed cultivated by a farmer in a given plot. Importantly, while the varietal identity and quality of purchased seed are not directly observable by farmers, its certification status is, as certified and quality declared seeds are labelled with easily recognisable labels provided by the Ugandan government. If the given certification system is functioning properly, we would expect the certification label to serve as an effective signal of the high quality and authenticity of purchased improved seed.

3.2 | Data

We use household data for rural agricultural households from the 2009/10, 2010/11, 2011/12, 2013/14, 2015/16, 2018/19, and 2019/20 waves of the Uganda National Panel Survey (UNPS),[3] together constituting fourteen waves of panel data, including both the main and secondary agricultural seasons (although we only include 13 growing seasons in our analysis due to the absence of a key variable in one of the seasons). The UNPS includes a nationally representative sample of households and provides detailed information on rural households' economic activities, their income, and other socio-economic variables.

Essential for our analysis, plot-level information is collected regarding the type of seed used (improved versus traditional),[4] whether the seed was purchased or retained from previous growing seasons, the type of certification[5] of the improved seed (certified, quality declared or unknown[6]) and the source of seed. Figure 1 illustrates the decision set concerning seed input use for the farmers in our sample.

Data were collected on crops planted by the household during both the first cropping season (January–June) and the second cropping season (July–December) on each plot accessed by the household through ownership or user rights. We focus on maize, one of the most important crops in Uganda and the main crop for which farmers use improved seed in our representative sample of Ugandan farmers. This crop is the most important crop in terms of household income and one of the most important crops for food security in Uganda. In absolute terms, maize occupies the largest area of all crops and is grown by the largest number of households in Uganda. The area planted to maize in the country has also been increasing over recent decades (Ahmed 2012). The total area planted to maize in 2012/13 was about 23% of the total crop area, and 63% of the cereals area (UBOS 2014).

For each plot and season, farmers were asked if they purchased seed, the type of seed purchased (traditional or improved, along with the level of certification), and whether other inputs, such as fertiliser or pesticides, were used (Table 1). Our analysis focuses on purchased seed. Farmers in our sample purchase seed for only about one quarter of plots, suggesting a strong tendency to save seed from previous cropping seasons.

For plots where multiple types of maize were cultivated, we use only the observation corresponding to the type planted on the largest area. In addition, maize harvests were recorded in various conditions ('dry grain', 'fresh/raw', etc.) and these values were adjusted to ensure comparability.[7] In addition,

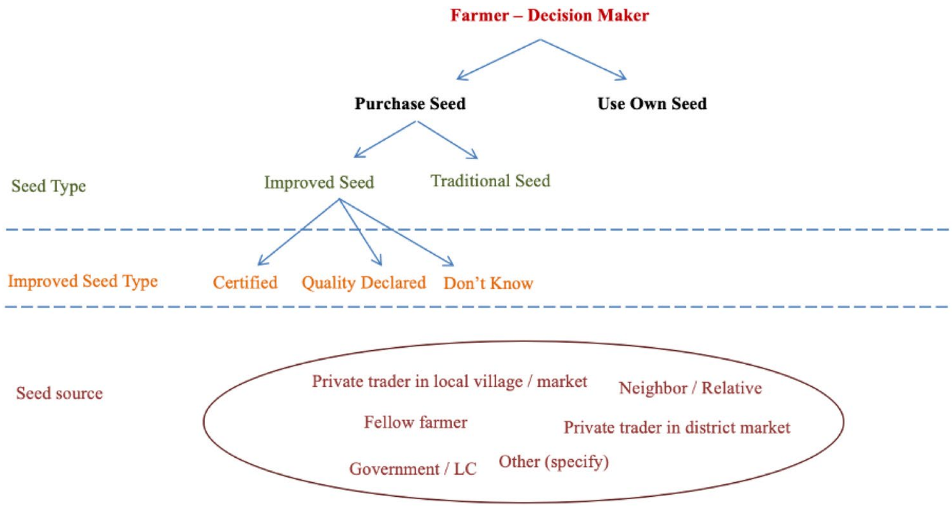

FIGURE 1 | Farmer decision set—seed inputs. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 | Key input variables by plot.

Variable	No. of plots (1)	Percent of sample (2)
Seed type		
Non-purchased seed	15,222	73.6
Purchased seed, of which	5463	26.4
Improved (declared)	372	1.8
Improved, certified	980	4.7
Improved, quality declared	652	3.2
Traditional	3459	16.7
Other inputs		
Inorganic fertiliser	590	2.9
Organic fertiliser	643	3.1
Pesticide	1454	7.0
Total number of plot observations	20,685	100

Note: Pooled dataset. Observations are at plot (area planted to a variety) level, by season.

some extreme yield values and inconsistent purchased seed type combinations (suggesting data recording errors) were dropped.[8]

The vast majority of the sample, nearly 74% of the plot-season observations, is characterised by the use of local, non-purchased seed during the seasons covered by the survey. This finding aligns with other studies, which indicate that Uganda is characterised by extremely low adoption rates of improved seeds and that the informal seed supply system accounts for the majority of the country's seed supply (Lwakuba 2012). Of the approximately 26% of plots that were cultivated with purchased seeds, about 63% were cultivated with purchased traditional varieties, while only 37% were cultivated with improved varieties. Similarly, rates of inorganic fertiliser use are also low, only being reported on about 3% of the total plots in the sample (with a similar percentage of plots reporting organic fertiliser use), consistent with findings from other analyses in East Africa (see e.g., Ogada et al. 2014).

Our summary statistics (Table 1) show that about 4.7% of total plots are cultivated with purchased improved seed certified through Uganda's formal seed sector; 3.2% of plots are cultivated with purchased improved seed certified through the UN FAO's QDS certification system; and 1.8% of plots were cultivated with purchased 'declared' improved seed with no specified certification. Most improved seed is bought in local and district markets (around 90% for certified and quality declared seed, and 80% for improved seed with no certification), though seed is also purchased to a smaller degree from other sources[9].

The detailed information provided on the different types of improved seed used is essential for our analysis, as it enables us to test our hypothesis that purchased certified and quality declared improved seed will perform significantly better (in terms of yield) than purchased improved seed without any form of certification. These variables are central to the estimation strategy we use in our empirical analysis.

In Table S1, we present the percentage of different purchased certified improved seed types cultivated by year. Cultivation of purchased certified seed ranged from 2.7% to 8% of plots per year across the period of the panel dataset, while cultivation of quality declared seed ranged from 2.1% to 4.3%.

We also present a summary of complementary inputs by seed type (including inorganic fertiliser and pesticide use, as well as the cost of hired labour). These results are shown in Table S4 in the Appendix S1. We find that inorganic fertiliser is applied jointly for more than twice as many plots cultivated with certified seed as with those cultivated by 'declared' improved seed (without any specified certification), and just under twice as many for purchased quality declared seed (relative to 'declared' improved seed), indicating that many farmers are more willing to apply complementary inputs to certified and QDS seeds relative to 'declared' improved seeds. Pesticide use and the average cost of hired labour, while not very different between the three improved maize seed types, are quite a bit higher than for purchased traditional and saved seed (about twice as high), suggesting that producers distinguish between improved and non-improved seed types as well.

3.3 | Estimation Strategy

Our estimation strategy employs fixed effects methods to mitigate endogeneity concerns by controlling for unobserved time-invariant variables at the plot level (and, by extension, the household) exploiting the panel nature of our dataset. This approach allows us to identify how changes in the type of seed cultivated on the same plot by the same farm household affect plot-level yield outcomes, in order to test our hypothesis that higher quality seeds with some form of certification (QDS or 'certified' seeds) will provide a significantly higher yield advantage over saved seed and that of seed that is declared improved (without any form of certification specified).

By relying on household and plot-level fixed effects estimation, we account for time-invariant characteristics at both the household and plot levels that can have a substantial impact on yield. These fixed effects help address the challenge of demonstrating that a given seed type has led to better yield outcomes, independent of unobservable farmer and plot-level characteristics that may simultaneously make a farmer more likely to adopt improved seeds and also be inherently more productive, regardless of seed choice.

The core of our empirical analysis is captured by the following fixed effects equation (Equation 1), which estimates how the choice of seed k (and the level of certification of the purchased seed) cultivated on plot i during season t impacts plot-level yields:

$$\mathrm{Ln}\left(\mathrm{Yield}_{it}\right) = X_{it}{'} \times \alpha + \sum\nolimits_{k=1}^{4} \beta_k \times \text{Seed Choice}_{i,k,t} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In this equation, we measure how choosing to cultivate different purchased seed types—traditional, certified improved, quality declared improved, or declared improved seeds—affects yield outcomes, with representing the natural log transformation of yields at the level of plot i and during season t.[10]

Here, represents a vector of other time-varying input variables and cultivation practices at the plot level. These include whether inorganic fertiliser was used, whether the plot was intercropped with other crops, the area of plot cultivated, and the cost of hired labour used at the plot (in Ugandan shillings). We also include (plot-level fixed effects) and (season fixed effects), while ε_{it} represents time-varying unobservables that remain after the within transformation.

In addition, we also estimate a second equation (Equation 2) that interacts inorganic fertiliser use ('F') with seed type, given that different types of seed may be more or less sensitive to fertiliser inputs:

$$\mathrm{Ln}\left(\mathrm{Yield}_{it}\right) = X_{it}{'} \times \alpha + \sum\nolimits_{k=1}^{4} \beta_k \times \text{Seed Choice}_{i,k,t} + \sum\nolimits_{k=1}^{4} \theta_k \times \text{Seed Choice}_{i,k,t} \times \mathrm{F}_{i,k,t} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

A detailed description of all explanatory variables included in our fixed effects estimates, along with their summary statistics, is provided in Tables S1 and S2 in the Appendix S1. We use robust standard errors clustered at the plot level, as the individual plot is the primary level of our analysis.

4 | Results

In this section, we present the results of our empirical analysis, which focuses on the impact of certified and quality declared seed use on maize yield; before moving to Section 5, which presents the results of several robustness checks.

4.1 | Certified Seed Use and Maize Yield

In Table 2, we present the results of the estimation of Equation (1), a plot-level fixed effects equation examining the impact of different types of purchased maize seed on yield, measured as the natural logarithm of plot-level output. The reference category is non-purchased (saved) seed.

In Equation (1), we find that purchasing quality declared seed led to a significant increase in yield, but that cultivating all other types of purchased seed did not lead to detectable yield increases relative to saved seed. This result is in line with the findings of previous research in Uganda (Bold et al. 2017), and suggests that the formal seed certification system has not been able to successfully limit the sale of low quality seed that carries the certified label (at least during the period covered by the dataset). The results also indicate that the farmer-led, FAO-designed QDS system is likely to be functioning better than the private sector certification system.

In Equation (2), we include interaction terms between the type of purchased seed used and the use of inorganic fertiliser, none of which are found to be significant. These results suggest that a lack of fertiliser use concurrently with purchased certified seed was not responsible for the lack of yield increase.

5 | Robustness Checks

In this section we examine the impact of three other potential confounding factors that could affect our results: the role of extension information, the joint use of organic fertiliser, and concurrent increases in hired labour jointly with the cultivation of different types of purchased seed.

TABLE 2 | Seed type and plot-level yield outcomes.

Explanatory variable	Ln (yield) (1)	Ln (yield) (2)
Seed type		
Purchased seed (declared improved)	−0.054 (0.125)	−0.052 (0.129)
Purchased improved seed (certified)	0.039 (0.095)	0.003 (0.098)
Purchased improved seed (QDS)	0.195* (0.106)	0.206* (0.109)
Purchased traditional seed	−0.029 (0.055)	−0.029 (0.055)
Other inputs		
Inorganic fertiliser used	0.097 (0.116)	0.034 (0.138)
Purchased seed (declared improved) × inorganic fertiliser		0.032 (0.554)
Purchased improved seed (certified) × inorganic fertiliser		0.410 (0.289)
Purchased improved seed (quality declared) × inorganic fertiliser		−0.077 (0.365)
Cost of hired labour (10,000 s Ug. Sh.)	0.002 (0.003)	0.002 (0.003)
Other variables		
Intercropped	0.475*** (0.047)	0.477*** (0.047)
Area of plot planted	−0.072*** (0.006)	−0.072*** (0.006)
Constant	5.463*** (0.039)	5.463*** (0.039)
Plot-level fixed effects	Yes	Yes
Season fixed effects	Yes	Yes
R^2	0.54	0.54
N	12,212	12,212

Note: Robust standard errors in parentheses, clustered at the plot-level. Yield is transformed using the natural log.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

5.1 | Information as a Complementary Input

We begin by exploring whether extension programs—which have been shown to increase yields in Uganda (Pan et al. 2018)—might impact the yield outcomes for different seed types. For example, if information about using new technologies (such as improved maize varieties) is key to successful adoption, then our primary finding—that certified improved seed provided no yield advantage over local seeds—could be driven by a lack of extension information provided on how to cultivate these varieties.

To investigate this question, we re-estimate our main Equation with an additional variable indicating whether the farm household had received agriculture-related information from an agent from Uganda's National Agricultural Advisory Services (NAADS) in the past 12 months. The results are provided in Table S5 in the Appendix S1.

In Equation (1), we include just the variable 'Extension information received', while in Equation (2) we also include interactions between whether or not the farm household had received extension information in the past 12 months and the type of purchased seed cultivated. Our main result from Section 4 holds in both the first and second equations—that purchased certified seed provides no yield advantage over local, saved seed.

5.2 | Organic Fertiliser

Second, we include an additional analysis investigating whether the use of organic fertiliser may have impacted the results. In Table S6, we present the results of two equations that investigate whether organic fertiliser positively impacts maize yield, both in general and when interacted with purchased certified seed (and other seed types) alongside inorganic fertiliser. We do not find that organic fertiliser has a positive impact on maize yield; the interaction between organic fertiliser use and certified seed is insignificant.

5.3 | Hired Labour

Last, we present in Table S7 an analysis in which the cost of hired labour is interacted with seed type to see if cultivation of purchased certified seed led to higher yields in cases where more labour had been hired in as a complementary input. We do not find any of the interactions between the cost of hired labour and purchased seed type to be significant.

6 | Discussion

One of the strengths of our analysis is its focus on specific plot-level seed type and application of fixed-effects methods to a larger and longer panel dataset (spanning thirteen growing seasons) than those used in previous related literature (e.g., Coromaldi et al. 2015). This approach enables us to control for time-invariant variables at both the plot and household levels, thereby reducing potential biases. However, it is important to acknowledge the limitations of our empirical approach. While fixed-effects methods address time-invariant unobserved heterogeneity, they do not fully account for certain forms of measurement error (Abay et al. 2023) or unobserved time-varying heterogeneity across plots and households. This limitation introduces potential concerns related to omitted variable bias and endogeneity.

For example, consider a scenario where a farmer decides in one season to prioritise increasing maize yields by experimenting with new, improved maize varieties. This decision might coincide with the farmer becoming more motivated and exerting greater effort—behaviour that may not be fully captured by our labour variables. In this case, higher yields might result not from the inherent genetic advantages of the maize variety but from the farmer's increased effort. Such behavioural effects have been documented in the literature (Bulte et al. 2014, 2025).[11]

Despite these limitations, we believe that the main findings of our analysis remain robust to this potential issue of farmer behaviour. Notably, the direction of this bias would likely increase the measured yield of improved varieties, particularly certified improved varieties. Farmers purchasing certified seeds may expect them to be of higher quality and, as a result, invest more effort in their cultivation, consistent with the findings of Bulte et al. (2014) and Bulte et al. (2025). This bias, while potentially leading to an over-estimation of the yield gains from purchasing improved maize seeds, does not undermine our primary result that certified improved seeds provided no yield advantage at all over non-purchased, local seeds.

7 | Conclusions and Policy Implications

In this article we investigate the role of input heterogeneity—specifically in terms of purchased improved maize seed—in determining plot-level yield outcomes; and whether two coexisting certification systems can help to mitigate market failures associated with information asymmetry present in seed markets. Our analysis provides suggestive evidence that seed quality (which is found to be different between certification systems) is essential for productivity outcomes resulting from farmer experimentation with purchased maize seed in Uganda. While much of the literature has emphasised farmer heterogeneity as a key factor in yield variations and adoption decisions (e.g., Suri 2011), our findings highlight the significant role of input heterogeneity, particularly seed type, in driving productivity gains.

In particular, we explore the effectiveness of two certification systems in signalling seed quality, and find that the form of certification matters. While the cultivation of quality declared improved seeds led to higher yields in our analysis, we provide suggestive evidence that certified improved seeds provide no yield benefits over non-purchased seeds, in spite of their higher cost. Thus, certified improved seeds seemed to have performed at the same level as local seeds saved from previous seasons, supporting the hypothesis that they may have potentially been mixed or diluted with local seeds, and suggesting that the FAO quality declared seed certification system seems to have performed better during the period of the panel than the formal certification system in terms of providing a signal of quality to farmers.

However, it is important to note that it is not exactly clear what is causing the poor performance of certified seeds suggested by our results: this could be a result of the certification system not functioning properly on the supply side (seed multiplication operations are not adequate to ensure the production of high quality improved maize seed, a problem cited by Uganda's 2018 National Seed Plan); at the seed dealer level (e.g., through dilution or counterfeiting of certified improved seeds, as suggested by Bold et al. 2017); or, alternatively, at the genetic level (the predominantly hybrid varieties sold as certified through the formal seed sector may simply not be well-suited to the Ugandan context, as suggested by Coromaldi et al. 2015). More analysis is needed to identify more precisely what is driving this result. For example, Barriga and Fiala (2020) carry out an important analysis of the maize seed supply chain, and suggest that lower performing seed farther down the supply chain may be driven by mishandling and poor seed storage practices. Further experimental investigations of the quality of both certified and quality declared maize seed present in the Ugandan seed market would be useful to provide a more rigorous analysis of how well the two certification systems have been performing in more recent years.

Regardless of which factors are behind this finding, however, the poor quality of certified seeds is significant in that it may have the effect of discouraging farmers who are experimenting with new seed types (indeed, we find in the data multiple instances where farmers first purchase certified maize seed and then switch to another purchased seed type), and lead them to not adopt improved maize seed in general, an example of the classic lemons problem. This dynamic may contribute to the 'low productivity trap' Uganda finds itself in with regards to agriculture, keeping the number of farmers cultivating improved varieties low and reducing the benefits of knowledge spillovers and social learning that are observed as more (authentic) productive technologies such as improved maize varieties or fertiliser spreads. Our results thus both highlight the value of experimenting with new varieties and emphasise the need to focus on the systems (such as certification) supporting the transfer of innovations to farmers' fields.

Some economists have proposed that governments in Sub-Saharan Africa subsidise the provision of improved maize varieties to farmers, in the case of both Malawi (Denning et al. 2009; Katengeza et al. 2019) and Uganda (Matsumoto et al. 2013), arguing that such subsidies can render households more likely to purchase new technologies such as improved maize seed in the future and also lead to spillover effects among their neighbours (Omotilewa et al. 2019). However, our results instead highlight that even if such a subsidy programme is successful initially, it will not lead to lasting change if it does not solve the essential problem of information asymmetry posed by markets for seed of uncertain quality and the corresponding opportunities for market failures at multiple levels (on the genetic level; on the level of the certification system; and on the level of the seed traders). A solution to this problem could be to stimulate more competition by helping to support the entry of seed suppliers providing high-quality inputs, an intervention that has been shown to lead to an overall higher quality of product in the case of the antimalarial drug market in Uganda (Nyqvist et al. 2018); indeed, recent experimental work has shown that private input suppliers can be effective agents for spreading information about new crop varieties (Dar et al. 2024). However, the core of the problem is one of regulation—the question of how the government can ensure that the certification systems in place work appropriately, testing of seed quality functions properly, and that traders that 'cheat' are punished properly.

The market for improved maize seed in Uganda can be characterised as a 'market for lemons', where the quality of the seed may be represented or misrepresented (Akerlof 1970). An effective seed certification system offers one potential solution to the challenges posed by information asymmetry and quality heterogeneity in such a setting. Interestingly, we find in our analysis that one system of certification—the FAO-designed quality declared system—seems to be outperforming the private sector certification system substantially. This finding may be a result of the challenges of implementing a formal certification system in the Ugandan context, where the formal seed system is underdeveloped and there are limited resources available for the development of the national seed certification services and implementation of systematic seed testing across the country. On the other hand, the quality declared certification system may function more effectively through its focus on decentralised, local seed production, the development of local seed businesses and training of farmers in quality seed production, and the maintenance of seed diffusion processes based on trust between farmers. Regardless, further work is needed to strengthen both systems of certification to ensure that Ugandan farmers are able to access high-quality seed that is suitable to local growing conditions, and to determine whether efforts to improve the effectiveness of these certification systems have succeeded in more recent years.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Endnotes

[1] We approximate seed quality using the productivity gains associated with the adoption of certified seed experienced in farmers' fields, relative to yield outcomes for saved seed.

[2] We thus use yield (relative to saved seed) as our measure of quality.

[3] This dataset was collected by the Ugandan Bureau of Statistics (UBOS) (www.ubos.org) as part of the World Bank Integrated Surveys on Agriculture project. For more detail regarding the survey instruments and sampling strategy, see: https://microdata.worldbank.org/index.php/catalog/1001/related-materials. Last accessed: October 2nd, 2023.

[4] 'Improved' varieties are those developed using modern plant breeding techniques, such as those released during the Green Revolution, while 'traditional' crop varieties are local varieties that have been developed through farmer selection.

[5] The survey questionnaire specified that the interviewed farmer should be asked if the improved seed they had purchased was certified, quality-declared, or 'unknown' (recorded as 'don't know').

[6] Improved but non-certified seed indicates seed that is thought or believed by the farmer to be of an improved nature but without any further information on its provenance or character.

[7] For example, to standardise harvest weights to 'dry grain' equivalents, the following adjustments were applied: weights recorded as 'dry at harvest in cob' were multiplied by 0.95; by 0.9 for 'dry at harvest with cob and stalk'; by 0.8 for 'green harvested with cob'; and by 0.75 for 'green harvested with cob and stalk'.

[8] We exclude all extreme values above the U.S. national corn yield record from 2017 of about 13.5 metric tons per acre, held by David Hula (https://www.ncga.com/file/1540/2017-National-Winners-12.18.17.pdf). We also drop 0 values, given that the causes of crop failure can be unrelated to seed type (e.g., hail, flooding, damage from animals), as well as observations with irregular harvest units.

[9] These figures are based on the 2009 and 2010 waves of data collection, the only years in which farmers were asked where they bought the seed.

[10] We use the natural log transformation of yield.

[11] For example, Bulte et al. (2014) conducted a double-blind trial in Tanzania, where farmers were given traditional or improved cowpea varieties, with only half of them informed of what seed type they had received. Their finding showed that farmers who were aware they had received improved cowpea seeds achieved significantly higher yields than those who had improved cowpea seeds but were unaware of the seed type, demonstrating the importance of expectations and unobserved inputs, such as labour quality and effort. Bulte et al. (2025) find similar results from a field experiment with traditional and improved maize varieties in Tanzania.

References

Abay, K. A., T. Wossen, G. T. Abate, J. R. Stevenson, H. Michelson, and C. B. Barrett. 2023. "Inferential and Behavioral Implications of Measurement Error in Agricultural Data." *Annual Review of Resource Economics* 15: 63–83.

Ahmed, M. 2012. "Analysis of Incentives and Disincentives for Maize in Uganda. Technical Notes Series, MAFAP, FAO, Rome."

Akerlof, G. A. 1970. "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics* 84, no. 3: 488–500.

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." *Journal of Development Studies* 55: 1285–1306.

Auriol, E., and S. G. Schilizzi. 2015. "Quality Signaling Through Certification in Developing Countries." *Journal of Development Economics* 116: 105–121.

Banerji, A., E. Birol, B. Karandikar, and J. Rampal. 2016. "Information, Branding, Certification, and Consumer Willingness to Pay for High-Iron Pearl Millet: Evidence From Experimental Auctions in Maharashtra, India." *Food Policy* 62: 133–141.

Barriga and Fiala. 2020. "The Supply Chain for Seed in Uganda: Where Does It Go Wrong?" *World Development* 130: 104928.

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." *Quarterly Journal of Economics* 132, no. 3: 1055–1100.

Bulte, E., G. Beekman, S. Di Falco, J. Hella, and P. Lei. 2014. "Behavioral Responses and the Impact of New Agricultural Technologies: Evidence From a Double-Blind Field Experiment in Tanzania." *American Journal of Agricultural Economics* 96, no. 3: 813–830.

Bulte, E., S. Di Falco, M. Kassie, and X. Vollenweider. 2025. "Low-Quality Seeds, Labor Supply and Economics Returns: Experimental Evidence From Tanzania." *Review of Economics and Statistics* 107, no. 3: 845–852.

Coromaldi, M., G. Pallante, and S. Savastano. 2015. "Adoption of Modern Varieties, Farmers' Welfare and Crop Biodiversity: Evidence From Uganda." *Ecological Economics* 119: 346–358.

Dar, M. H., A. De Janvry, K. Emerick, E. Sadoulet, and E. Wiseman. 2024. "Private Input Suppliers as Information Agents for Technology Adoption in Agriculture." *American Economic Journal: Applied Economics* 16, no. 2: 219–248.

Denning, G., P. Kabambe, P. Sanchez, et al. 2009. "Input Subsidies to Improve Smallholder Maize Productivity in Malawi: Toward an African Green Revolution." *PLoS Biology* 7, no. 1: e1000023.

Gharib, M. H., L. H. Palm-Forster, T. J. Lybbert, and K. D. Messer. 2021. "Fear of Fraud and Willingness to Pay for Hybrid Maize Seed in Kenya." *Food Policy* 102: 102040.

Hoel, J. B., H. Michelson, B. Norton, and V. Manyong. 2024. "Misattribution Prevents Learning." *American Journal of Agricultural Economics* 106: 1571–1594.

Katengeza, S., S. Holden, and R. Lunduka. 2019. "Adoption of Drought Tolerant Maize Varieties Under Rainfall Stress in Malawi." *Journal of Agricultural Economics* 70, no. 1: 198–214.

Lwakuba, A. 2012. "'The Seed Sector of Uganda; Is the Future of Small Scale Farmer Bleak or Bright'. PELUM Association, MISEREOR."

Maredia, M. K., and B. Bartle. 2023. "Excess Demand Amid Quality Misperceptions: The Case for Low-Cost Seed Quality Signalling Strategies." *European Review of Agricultural Economics* 50, no. 2: 360–394.

Maredia, M. K., R. Shupp, E. Opoku, et al. 2019. "Farmer Perception and Valuation of Seed Quality: Evidence From Bean and Cowpea Seed Auctions in Tanzania and Ghana." *Agricultural Economics* 50: 495–507.

Mastenbroek, A., G. Otim, and B. R. Ntare. 2021. "Institutionalizing Quality Declared Seed in Uganda." *Agronomy* 11, no. 8: 1475.

Mastenbroek, A., I. Sirutyte, and R. Sparrow. 2021. "Information Barriers to Adoption of Agricultural Technologies: Willingness to Pay for Certified Seed of an Open Pollinated Maize Variety in Northern Uganda." *Journal of Agricultural Economics* 72, no. 1: 180–201.

Matsumoto, T., T. Yamano, and D. Sserunkuuma. 2013. "Technology Adoption in Agriculture: Evidence From Experimental Intervention in Maize Production in Uganda." In *An African Green Revolution*, edited by K. Otsuka and D. Larson. Springer.

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

Nyqvist, M. B., J. Svensson, and D. Yanagizawa-Drott. 2018. "Can Competition Reduce Lemons? A Randomized Intervention in the Antimalarial Medicine Market in Uganda," Working Paper.

Ogada, J. M., G. Mwabu, and D. Muchai. 2014. "Farm Technology Adoption in Kenya: A Simultaneous Estimation of Inorganic Fertilizer and Improved Maize Variety Adoption Decisions." *Agricultural and Food Economics* 2: 12.

Omotilewa, O. J., J. Ricker-Gilbert, and J. H. Ainembabazi. 2019. "Subsidies for Agricultural Technology Adoption: Evidence From a Randomized Experiment With Improved Grain Storage Bags in Uganda." *American Journal of Agricultural Economics* 101, no. 3: 753–772.

Pan, Y., S. C. Smith, and M. Sulaiman. 2018. "Agricultural Extension and Technology Adoption for Food Security: Evidence From Uganda." *American Journal of Agricultural Economics* 100, no. 4: 1012–1031.

Suri, T. 2011. "Selection and Comparative Advantage in Technology Adoption." *Econometrica* 79, no. 1: 159–209.

UBOS. 2014. "Statistical Abstract 2014. Kampala, Uganda."

Ugandan Ministry of Agriculture, Animal Industry and Fisheries. 2018a. "National Seed Policy."

Ugandan Ministry of Agriculture, Animal Industry and Fisheries. 2018b. "National Seed Strategy—2018/2019–2022–23."

Win, M. T., M. K. Maredia, and D. Boughton. 2023. "Farmer Demand for Certified Legume Seeds and the Viability of Farmer Seed Enterprises: Evidence From Myanmar." *Food Security* 15, no. 2: 555–569.

Wossen, T., D. J. Spielman, A. D. Alene, and T. Abdoulaye. 2024. "Estimating Seed Demand in the Presence of Market Frictions: Evidence From an Auction Experiment in Nigeria." *Journal of Development Economics* 167: 103242.

Zapechelnyuk, A. 2020. "Optimal Quality Certification." *American Economic Review: Insights* 2, no. 2: 161–176.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** jage70002-sup-0001-Supinfo01.pdf.