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Farmer perception and valuation of seed quality: Evidence from bean and cowpea seed auctions in Tanzania and Ghana

By

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Data Appendix Available Online

A data appendix to replicate main results is available in the online version of this article. Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

Abstract

Double blind field experiments and experimental auctions were conducted with bean and cowpea farmers in Tanzania and Ghana to gauge the relative demand for three types of seed products that differ in price and quality: certified, quality declared, and recycled. Whether the cost differential makes these seeds qualitatively different products as reflected in their perceived performance, and whether that translates into farmers' willingness to pay price premiums, are the research questions addressed by this study. Results indicate that, all else equal, there were significant differences in the perceived quality of the seed products evaluated. Farmers were willing to pay significantly more for their higher rated seed relative to their lower rated seeds. However, for a majority of farmers the magnitude of the premium they are willing to pay for a higher quality seed is less than the current price differential between certified seed and grain. Research and policy implications of these results for legume seed system are discussed.

Key words: *willingness to pay, auction experiments, seed demand, seed quality, Tanzania, Ghana, legume seed*

JEL codes: *O33 Technological Change: Choices and Consequences; Q12 Micro Analysis of Farm Firms, Farm Households, and Farm Input Markets; Q18 Agricultural Policy; C90 Design of Experiments: General; C93 Field Experiments*

1. Introduction

A significant portion of the global agricultural research and development spending is devoted to developing improved varieties of staple crops. Farmers can reap the benefits of such research only if they plant good quality seeds of improved varieties, where quality is defined by the ability of seed to germinate, and establish seedlings rapidly, uniformly, and robustly (Finch-Savage and Bassel, 2016). The availability of good quality seed at affordable prices can raise agricultural productivity and contribute to poverty reduction (Awotide et al., 2013). Thus, returns to investments in crop improvement research depend critically on the existence and performance of market-driven seed systems that can deliver this improved genetics to farmers in the form of quality seed.

One of the factors that determines the existence of a market-driven seed system is the 'effective demand' for fresh seed. Low volume and frequency of purchase of improved varieties are often cited as major reasons for the lack of private sector involvement in seed provision. In the case of open-pollinated crops such as maize, hybridization technique (which requires repeated purchase of seeds to maintain crop yield) has made private sector involvement possible in the seed system. However, this is not the case for self-pollinated legume crops like beans, groundnuts, cowpeas, and pigeon peas, since hybridization is not an option. Also, since self-pollination produces progenies that are more uniform than those that result from outcrossing, it is easier for farmers to save some grain from their own harvest to use as seed in following season. As such, unless there are effective plant breeders' rights or contract laws that prohibit farmers from recycling seeds, which is rarely the case, incentives for private sector involvement in the seed system for legume crops are low.

Other factors undermining a market-driven seed system are transaction costs, which can be high for both buyers and sellers. For example, farmers (as buyers) incur the costs of acquiring reliable information about new varieties. They also face the moral hazard of being sold poor quality seed, which can become apparent only after the seeds are planted and it is too late to rectify the damage or to seek redress from the seed vendor. Suppliers, on the other hand, encounter high costs of information in discovering farmers' preferences, face the risk of potentially unsold inventory, and need to carry stocks to meet uncertain and fluctuating demand (Wiggins and Cromwell, 1995). As a result, the market for improved seed varieties is markedly imperfect, and leads to low effective demand, low availability of seeds, and high prices. The end result is that farmers in developing countries continue to grow crops using low quality planting material. According to the nationally representative data from Integrated Surveys on Agriculture (ISA) available online for Ethiopia, Nigeria, Niger, Tanzania, Uganda, and Malawi, the use of purchased seed for key legume crops (common bean, cowpea, pigeon pea, and fava bean) produced in these countries is less than five percent.[1] More than 95% of legume seeds planted by smallholder farmers in these countries are recycled seeds saved from their own harvest (60-70%) or purchased as grain from other farmers or grain vendors (25-35%).

[1] This is authors' estimation based on the response to the question in the LSMS-ISA surveys on the source of seed planted by the household in the previous seasons. More information about these surveys and the online dataset is available at: http://surveys.worldbank.org/lsms/programs/integrated-surveys-agriculture-ISA.

A market-driven seed system requires the coexistence of several demand and supply side conditions. A necessary condition on the demand side is that farmers should be able to perceive the 'seed' product as a higher quality planting material than grain, and that they are willing to pay a premium for this higher quality product. On the supply side, the required conditions are that the price farmers are willing to pay is high enough to cover the cost of producing quality seed, and the quantity and frequency of seed demanded (i.e., seed replacement) at that price is large enough to attract suppliers to produce and sell seeds. This study is an attempt to understand these conditions from the demand side by conducting experimental auctions to assess farmers' willingness-to-pay (WTP) for quality cowpea seeds in Ghana and bean seeds in Tanzania. Quality seed products of a given variety are differentiated based on observed agronomic performance of plants in farmer-managed blind demonstration plots. Participating farmers expressed their WTP for these seed products based on their subjective assessment of perceived quality.

This paper makes several important contributions to the literature. First, we measure consumer (i.e., farmer) demand for seed with a focus on quality traits rather than genetic traits. While the literature is replete with studies on varietal adoption, varietal preferences, and WTP for seed varieties, there are few studies that examine the preference and demand issues for seed quality per se. For example, the study by Horna et al. (2007) examined farmers' preferences for seed of new rice varieties and their WTP for seed-related information in Nigeria and Benin. Similarly, Waldman, Kerr, and Isaacs (2014) estimated preferences of Rwandan farmers for common bean varieties and found small differences in producer WTP based on farmer participation in an on-farm trial. Fuglie et al. (2006) surveyed potato farmers in Indonesia to elicit their perceptions of seed quality from different sources and derived farmers' WTP for quality potato seed using a non-experimental approach. There are several studies that have also focused on farmer WTP for crop varieties with specific traits. For example, Kassie et al. (2017) and Ward et al. (2014), respectively, measured farmer preferences for drought tolerant maize in Zimbabwe and drought tolerant rice in India. Waldman et al. (2017) evaluated Malawian farmers' preferences for perennial pigeon pea to assess the tradeoffs involved in annual versus perennial pigeon pea production. Similarly, Birol et al. (2012) estimated Filipino farmers' WTP for Bt (*Bacillus thuringiensis*) maize seed, and Birol et al. (2015) investigated Indian farmers' preferences for and trade-offs among various production and consumption attributes of pearl millet seed with a focus on the hypothetical introduction of a high-iron pearl millet variety. These prior studies have mostly focused on farmers' preferences and WTP for varietal attributes or specific genetic trait of a seed to help understand farmers' willingness to adopt a new crop variety. In most of these experiments, seed quality is either implicitly held constant, not mentioned, or not included as an attribute. In this study seed quality is the explicit focus of the auction experiments. We add to this literature on seed demand by evaluating farmers' WTP for seed quality as reflected in their agronomic performance, while keeping the varietal attributes constant.

A second contribution of this study is to the literature on seed systems in developing countries. There is a vast literature that critically examines the social, economic, regulatory, and policy aspects of making quality seeds available, accessible, and affordable to smallholder farmers in developing countries (Tripp and Rohrbach, 2001; Spielman and Kennedy, 2016; Louwaars, de Boef, and Edeme, 2013). Research has focused on understanding the role of different channels of seed access (i.e., formal, semi-formal, formal) (McGuire and Sperling, 2016; Nagarajan, Smale, and Gleww, 2007), constraints along the seed value chain (Maredia et al. 1999), the role of public, private and NGO sectors in increasing the efficiency of the seed system, and regulatory frameworks to promote seed R&D, cross-border trade, and private sector investments in the seed system (Jaffee and Srivastava, 1992; Tripp and Rohrbach, 2001). A major focus of practitioners and policy makers has been on the debate and discussions regarding how to promote a market driven seed system by encouraging diverse business models ranging from small scale seed enterprises and farmer seed cooperatives to medium and large-scale national and multi-national seed companies (Sisay, Verhees, and Trijp, 2017; David, 2004). Major investments have been made by donor agencies to promote these approaches and to relieve supply side constraints (Bloomberg, 2016). However, few studies have examined the basic question of how much farmers are WTP for purchased seed and the margins farmers will pay for different qualities of seed to sustain a market driven seed system. This study attempts to address this question via case studies of two legume crops that exemplify the challenges of transforming into market driven seed systems.

2. Rationale for this study and research questions

Bean farmers in Tanzania and cowpea farmers in Ghana potentially have access to three types of planting materials (hereafter referred to as 'seed types'): certified seeds, quality declared seeds (QDS), and recycled seeds (i.e., grain from previous harvest). These three types of seeds differ in seed input (i.e., the generation of seed used to produce them), the regulatory supervision they receive (or not), and the technical conditions under which they are produced. Certified seed is produced from basic (or foundation) seed, which is a higher cost input, and is grown using more stringent agronomic and post-harvest practices to meet the quality standards required by the country's seed certification agencies. QDS is also produced from basic, foundation or certified seed using production standards similar to certified seed, but without the 'certification' from the government. In Ghana, QDS is not a legally recognized seed product. It refers to the seed produced by farmers under the supervision of researchers with an objective of training farmers to become registered seed growers or out-growers for registered seed companies. The QDS produced by these farmers can only be 'sold' within the communities. In Tanzania, QDS is legally recognized and produced by a group of farmers under close surveillance of the seed certifying organization in collaboration with a researcher. Sale or distribution of the QDS is restricted to the district where it is produced. In both the countries QDS was introduced to circumvent the stringent and costly mandatory certification system, and to increase the availability of quality seed for smallholder farmers. Recycled seed is produced by farmers as grain for consumption or sale in the market, and represents seed saved from a previous harvest or procured from a market or other farmers as grain. These three seed types vary in quality and cost of production. Specifically, seeds that are sold as certified or QDS, cost more to produce and come with some assurance of genetic quality (i.e., variety name and identity) and seed quality in terms of germination, purity, disease-free, etc. Grain or recycled seed is 'produced' with no regulatory or technical supervision and thus has lower production costs than certified or QDS, but also comes with no quality assurance and is typically considered to be lower quality than certified or QDS. Recycled seeds are typically lower quality because farmers lack appropriate training, technology, and facilities required to produce, clean, treat, and store seeds. Such knowledge and material resources are needed to ensure good quality seeds are harvested, and those harvested seeds remain healthy (i.e., free from seed borne diseases and pests), pure (i.e., are not contaminated with inert or other seed materials), and vigorous until the next planting season.

These cost and quality differences among different seed products are reflected in their price differentials. In most developing countries, certified seeds are sold at prices 1.5 to 2 times the price of grain (Katungi et al., 2011; Hanif and Sperling, 2016). Depending on demand and seed scarcity, the price of QDS is often the same or just below that of certified seed as was the case in this study for Tanzania and Ghana. Moreover, in most developing countries, the significant buyers of certified and QDS are government- and donor-supported non-governmental organizations (NGOs) who then distribute these seeds to farmers for free or at subsidized prices (Tripp and Rohrbach, 2001). Recognizing that this is not a sustainable strategy, efforts have intensified in recent years to promote the growth of a private sector-led seed market.[2] The success of this market-driven approach depends on understanding consumer (i.e., farmer) demand for the seed products.

This study specifically focuses on the following two research questions rarely addressed in the literature. First, for a given improved variety (i.e., keeping the genetics constant), what is the perceived difference in the performance of the crop across three seed types – certified, QDS and recycled grain, when the seeds are planted and managed by farmers under their own conditions in a blind experiment? Second, how does the observed differential performance measured by indicators such as filling of pods, plant health, and vigor translate into farmers' WTP for these different seed types?

[2] For example, from 2006 to 2016 the Alliance for a Green Revolution in Africa had reportedly spent $100 million in seed companies. In 2016 they announced intensifying their investment by $500 million over the next five years to promote the efforts by agricultural seed companies and governments in seed production (Bloomberg, 2016).

As a preview of our results, we find significant differences in the perceived quality of the seed products based solely on observed performance at the flowering stage and prior to harvesting, and the corresponding differences in farmers' WTP for their higher rated seed relative to their lower rated seed product. However, for a majority of farmers the magnitude of the premium they are willing to pay for a higher quality seed is less than the current price differential between the highest quality seed available in the market (i.e., certified seed) and grain. Moreover, the magnitude of the premium farmers are willing to pay depends on the higher rated seed product performing significantly better than the lower rated seed on quality indicators such as perceived yield, plant health, and vigor.

The rest of this article is organized as follow. We first describe the methodology and data used to address the research questions in the two case study countries and crops. Following that, we present the results, and discuss the implications and need for further research.

3. Methodology

Double-blind field experiments (FE) were established in 12 villages in the Hai and Karatu districts (northern Tanzania) and in 10 villages in Binduri district in Upper East Region of Ghana (see Online Appendix A for more details regarding the design of FEs). These districts were selected based on the importance of beans and cowpea production in the country. In the case of Ghana, villages within the districts were selected randomly from a list of villages that were in the size range of 80-120 households, and were *striga* hotspot areas, since the cowpea variety used in the experiment was a *striga* resistant variety. In Tanzania, villages were selected in consultation with the local agricultural extension agents. They were purposively selected based on prior participation in a bean project.

The fields were used to demonstrate the characteristics of the three types of seed quality of a bean variety (*Jesca*) in Tanzania and a cowpea variety (*Songotra*) in Ghana, both improved varieties commonly grown by farmers in the study areas. For the given variety, the seed types included in the FEs were certified, quality declared and recycled seeds. In Tanzania, two categories of certified seeds representing seeds produced in the most recent season (certified 1) and certified seeds carried over from the previous season (certified 2) were included in the field experiments. Ghana did not have a similar differentiation and thus we include only one type of certified seed—i.e., those produced in the most recent season.

Certified seeds were procured from agro-dealers or directly from certified seed producers, QDS from community seed growers, and recycled seed from farmers who had previously purchased seeds of a given variety or from the market. For all three types of seeds, the variety was confirmed by the breeder based on visual characteristics (i.e., seed color, size, texture).[3] The recycled cowpea seed used in the experiments in Ghana was recycled for three seasons. However, in the case of Tanzania, it is unknown for how many years the 'recycled' bean seed was recycled, as these seeds were procured from the bean vendors in the market.

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[3] Recent studies on varietal identification using DNA fingerprinting have highlighted the biases of methods that rely on farmer or expert opinion to identify a variety (Yigezu et al., 2018; Wossen et al., 2019; Floro et al., 2017; Maredia et al., 2016) and also point to adulteration of seed by agro-dealers in many developing countries (Bold et al. 2017). Such biases pose challenges for estimating varietal adoption, understanding determinants of adoption, or estimating productivity impacts of varietal technology. In this study, the purpose of the field experiments was to demonstrate the performance of different types of seeds of a given variety available in the market, and to get farmers' subjective ratings of the quality of seeds as marketed to them. Thus, two things were important and were taken in to consideration when designing the field experiments. First was to simulate the seed quality options available to farmers in the actual market, and second was to make sure farmers believed that all the plots had the same variety, and the only difference was the seed product in terms of quality. On both these fronts, it was determined that verifying the variety through DNA fingerprinting was not necessary and thus not undertaken.

One farmer per village was selected to host the FE using their own management practices. They received equal quantities of seeds of each type, which were planted in plots next to each other. These plots were labeled by letters (e.g., A, B, C and D in the case of Tanzania for certified 1, certified 2, recycled and QDS seed, respectively; and G, L, and M in the case of Ghana for certified, QDS and recycled seed, respectively) (see Online Appendix A for other details). Two field days were held in 12 villages in Tanzania and a subset of 8 villages in Ghana where other farmers from those villages were invited to observe the demonstration plots around flowering stage (Field Day 1) and around harvest stage (Field Day 2). During the field days, each farmer attendee was asked to evaluate the performance of the seed plots based on visual characteristics they considered important, and rate one plot (i.e., seed type) as the best (both field days) and one as the worst (Field Day 2 only).

Once farmers had observed how different types of seeds performed in the field, WTP auctions were carried out during Field Day 2 to elicit information about how much they were willing to pay for these seeds based on the observed differences in their performance. We followed the Becker-DeGroot-Marschak (BDM) (Becker, DeGroot and Marschak, 1964) method, where participants do not bid against other people, but only against themselves. The WTP elicitation mechanism is typically performed using one of two methods – a full bidding or an endow-upgrade method. In both these auctions each participant receives a cash endowment at the beginning with which to either pay for a product (i.e., full bidding method) or to upgrade (i.e., endow-upgrade method). Each method has its advantages, but the literature (e.g., Lusk and Shogren, 2007; Alfnes, 2009) appears to lean towards using the full bidding method, especially if very similar products are readily available in the market place. Thus, in this study we used the full bidding method, whereby farmers participated in three auctions in the case of Ghana (i.e., one each for seed types G, L, and M) or four auctions in the case of Tanzania (i.e., one each for seed types A, B, C and D). Farmers were asked to "bid" their maximum WTP for one kilo[4] of seed for a given type of seed (referred to by the letter labels) knowing that only one of the three or four auctions would be chosen randomly and the bid for that seed would then be compared to a randomly drawn price from a given revealed range equivalent to their endowment. This revealed price range was 0 to 3,950 Shillings in Tanzania, and 0 to 9.90 Cedis in Ghana. If the bid was greater than or equal to the randomly drawn price, then the farmer purchased that seed for the randomly drawn price (not their bid). The difference in the bids between the three/four auctions reveals the premium (or discount) due to the different quality attributes as perceived by the farmer.

Approximately 20-40 farmers from each village participated in the auctions. In Ghana, these farmers were randomly selected from the cowpea growing farmers in a given village. In Tanzania, all the bean growing farmers who attended the field days (who represented close to 80% of bean growing households in a village) participated in the auctions. Farmers were given 4000 Shillings (TSH) equivalent to $1.85 in Tanzania and 10 Cedis (GHC) equivalent to $2.6 in Ghana as their initial endowment so they didn't have to bid using their own money.[5] These amounts for the initial endowments were equivalent to about 20% more than the market price of one kg of certified (i.e., highest quality) seed in Ghana, and about 33% more than the market price of one kg of certified seed in Tanzania. Prior to the seed BDM auction, a practice BDM auction was conducted with a bar of soap (a product that has a readily apparent valuation) to make sure farmers understood the

[4] Kilo is a common unit in which farmers purchase seeds in Tanzania and Ghana.

[5] The exchange rate from 1 $US to local currency at the time of these experiments was about 2100 Tanzanian Shillings (TSH) and 3.8 Ghanaian Cedi (GHC).

auction mechanism. An additional small amount of cash (i.e., TSH 400 in Tanzania and GHC 2 in Ghana) equivalent to $0.25-0.50 was given to farmers for this practice BDM auction.

4. Data

A total of 247 bean farmers in Tanzania and 269 cowpea farmers in Ghana participated in both the field days and the WTP experiments. Data from the two field days (i.e., flowering and harvesting stages) where farmers ranked the seed plots based on visual characteristics were used to gauge the perception of seed quality differential across the seed types. Data from the WTP auctions on field day 2 were used to estimate the relative WTP for each type of seed.

Data were also collected from all the participating farmers using a structured questionnaire to understand the household and farmer characteristics, and agricultural practices, including their use and experience with different types of seeds. The participants were majority men (60%) in Tanzania and majority women (60%) in Ghana. Summary statistics of farmer characteristics is provided in Online Appendix B. For many of the farm characteristics, the participants represent typical smallholder farmers in these countries.

Next, we present the results of the field experiments and the WTP auctions. Given that the experiments were blind, the seed types in all the tables and figures are referenced by their plot IDs (i.e., A, B, C, D for Tanzania, and G, L, M for Ghana) as a reminder of what farmers were actually bidding for or rating.

5. Results

5.1 Results of the field experiments

In both countries, the plots planted with certified seeds (i.e., plot A in Tanzania and plot G in Ghana) received the highest rating by a majority of farmer participants in Field Day 1 (flowering stage) and Field Day 2 (harvest stage) (Table 1). At flowering stage, close to 60% of farmers in Tanzania and 90% of farmers in Ghana rated these plots (A and G) as the best, whereas at the harvest stage there was an even clearer distinction between the plots planted with different quality seeds, resulting in more farmers rating these same plots (A for Tanzania and G for Ghana) as the best. The relative ranking of other seed types (i.e., QDS, recycled) remained the same at the harvest stage as it was at the flowering stage. At the harvest stage, farmers were also asked to rate the worst plot. Less than 1% of participants in Ghana and less than 5% of participants in Tanzania rated the certified seed plot as the worst plot. Clearly, in both the countries farmers were confident about rating certified seed (plot A and plot G) as the best and least worst. The main reasons reported by farmers for rating a plot as the best include, potential yield, grain quality, seed density in the pods, and how healthy the plants looked. Unhealthy appearance of plants and lower potential yields were the major reasons given by famers for rating a plot as worst.[6] We use the subjective best and worst rating on seed quality at the harvest stage to explain how much the perceived seed quality influenced farmers' WTP for the respective seeds.

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[6] Plots were harvested a few days after the auction experiments and yields were recorded by the agricultural extension agent. In Ghana, average harvested yield (kg/ha) for Plot G (certified) was 1534, for Plot L (QDS) was 975, and for Plot M (recycled) was 445. In Tanzania, average harvested yield (kg/ha) for Plot A (certified 1) was 1485, for Plot B (certified 2) was 1475, for Plot C (recycled) was 1321, and for Plot D (QDS) was 1345. These yield data confirm farmers' perception of superior performance of plots planted with certified seed compared to other seed plots. However, yields across plots were statistically significantly different in the case of Ghana but not in Tanzania.

{Table 1 here}

5.2 Results of WTP experimental auctions

On average, farmers in Tanzania indicated their willingness to pay TSH 2,093/kg for the seeds used in plot A (certified 1), TSH 1,804/kg for plot B (certified 2), TSH 1,594/kg for plot D (QDS), and TSH 1,605/kg for plot C seeds (recycled) (Table 2). The WTP for these different types of seeds are all statistically significantly different (at p<0.01), except for plots C and D. To put these expressed WTP values in context, the mean bean grain price per kg reported by farmers at the time of the survey was TSH 1,577. The mean price for bean 'seed' paid by the farmer participants was TSH 1,761/kg. In terms of comparison, the average bid price for the lowest rated seed (plot D) is very similar to the average grain price reported by farmers. Moreover, the average bid price for the highest rated seed (plot A) is statistically significantly higher (at p<0.01) than the price of bean 'seed' paid by farmers in their last purchase. Such seed was typically purchased in bulk without any packaging or label, and is thus not equivalent to certified seed.

{Table 2 here}

In Ghana, participants' bids indicated an average willingness to pay GHC 7.19 for one kg seed of type G (certified seed), which was higher than their WTP for seed type L (QDS) (GHC 5.27) and seed type M (recycled seeds) (GHC 4.90). Differences in the WTP between seed type G, type L, and type M are statistically significant at p<0.05. Again, to put these values in context, the mean cowpea grain price per kg reported by farmers in the study area was GHC 2.80. The mean cowpea seed price per kg paid by the participant farmers in their last seed purchase was GHC 4.66. Like Tanzania, most of these seed products were purchased from seed vendors in the market and came with no label and were not packaged. The average bids for all three seed types expressed by the farmers in the case of Ghana are significantly higher ($p<0.01$) than the farmer reported grain price. Also, the average bid price for the highest rated seed (type G) was significantly higher than the reported price of bulk 'seed' paid by farmers in their last seed purchase.

For both Tanzania and Ghana, the WTP for different quality seeds were positively correlated with the rank order in which participants had rated the seed plots. The correlation coefficients between the rank order of farmers' WTP and seed quality rating for Ghana is 0.69 and for Tanzania is 0.53. The WTP for seeds planted on plots A and G (i.e., certified seed) was highest, which on average was ranked the best plot by a majority of participants in each country. Similarly, the WTP for seed type C and M (i.e., recycled seed) was the lowest in case of Ghana, and second lowest, but not significantly different from the lowest bid price, in the case of Tanzania, with the corresponding lowest percentage of participants rating it as the best seed plot in each country.

The distribution of WTP for different quality seeds, cumulative across all the farmers is depicted in Figure 1. The WTP line graph for a given seed type can be interpreted as a demand curve showing the inverse relationship between price and quantity demanded. The vertical distance between the 'demand' curves for any two seed type denotes farmers' willingness to pay a premium or a discount for different quality seeds (Figure 1). The experimental auctions were in fact designed to estimate this vertical distance between the demand curves of different seed types. For Tanzania, relative to the overall lowest rated seed type (i.e., recycled), on average farmers were willing to pay (per kg) an additional TSH 490 or about 30% more for the highest rated seed plot (i.e., certified 1).

In relative terms, the premium for the highest rated seed type in Ghana was significantly more than the same premium in Tanzania (Figure 1). On average Ghanaian farmers were willing to pay an additional GHC 2.3 or 73% more for one kg of the overall highest rated seed type (i.e., certified seed) compared to the overall lowest rated seed type (i.e., recycled). Why the difference in the size of the premium? While farmers did not know the yield results when bidding, the actual yield difference between the highest and lowest rated seed was significantly more in Ghana than in Tanzania and perhaps this may explain the differential in premiums. However, it is important to reiterate that the farmer did not know the yield results when bidding. They were placing their bids solely based on observation of the plots and their perceptions of quality differences. As reported in Table 1, in both Ghana and Tanzania there was a clear perception that the plots with certified seeds were best and thus rated higher than other plots. This perception is what matters in explaining the observed premiums for certified seeds. That said, if the yields over time do not meet expectations (i.e., if certified seeds do not outperform recycled or QD seed), then the WTP a 30-73% premium may disappear. What the results of this paper indicate is that if seed quality is perceived to be better (and presumably is), then farmers are willing to pay more for it.

{Figure 1 here}

5.3 Farmers' willingness to pay for different quality seed relative to perceived quality

The average bids for different seed types noted above are confounded by farmer characteristics that could give biased estimates of the premium for seed quality. We address this potential issue by estimating the mean WTP for different seed type using the farmer fixed effect model noted in equation 1.

$$WTP_{ij} = a + bS_j + \delta_i + e_{ij} \quad (1)$$

Where, WTP_{ij} represents farmer i's willingness to pay (or bid) for seed type j; S_j represents seed type j, δ_i is the fixed effect for farmer *i,* and e_{ij} are idiosyncratic error terms. Coefficient b is the regression equivalent of the average WTP reported in Table 2, measured as the price premium farmers are willing to pay for seed type *j* relative to a base category.

However, since the field experiments were blind and farmers didn't know the identity of seed types, one could argue that a true measure of the average WTP for quality seed should be the mean of the premium each farmer is willing to pay for his/her highest rated seed relative to his/her lowest rated seed type. One would expect a positive association between farmers' perception of seed quality (based on observations of plant performance in the experimental plots) and their WTP for a seed type. Of course, there could be other factors that can also influence farmers' WTP, such as income, prior use and experience with non-recycled seeds, farm characteristics, and personal characteristics such as education, age, gender, innovativeness, risk attitudes, etc. This relationship between WTP for different types of seed (of a given variety) and other factors can be specified as,

$$WTP_{ij} = \alpha + \beta Q_{ij} + \gamma Z_i + \varepsilon_{ij} \qquad (2)$$

where, WTP_{ij} represents farmer i's willingness to pay (or bid) for seed type j; Q_{ij} represents the perceived seed quality rating for seed type j by farmer i, Z_i is a vector representing farmer and household characteristics such as demographic, socio-economic, and behavioral variables, and ε_{ij}

are idiosyncratic error terms. Given that for each farmer who participated in the auctions, we have the WTP for different seed types, we can use the farmer fixed effect to control for the farmer and household characteristics, including the unobservable confounding factors. Thus, we use Ordinary Least Square (OLS) estimation method with farmer/household fixed effects to explore the relationship between perceived seed quality and WTP for quality seed as specified in equation 3.

$$WTP_{ij} = \alpha + \beta Q_{ij} + \delta_i + \varepsilon_{ij} \quad (3)$$

Where, δ_i is the fixed effect for farmer *i*. In this model, the coefficient of interest is β, which measures the average price premium farmers are willing to pay for each unit increase in the perceived seed quality rating (i.e., when seed quality rating changes from worst to neutral to best).

Arguably, the main variable of interest in model 3, Q_{ij} (i.e., perceived quality of seed) may itself be endogenous and influenced by some unobservable factors that cannot be completely captured by the farmer level fixed effects, δ_i. Thus, to address this potential endogeneity issue we use two stage least square regression where perceived quality is regressed on seed type (equation 4), and then the predicted values for perceived quality ($\hat{Q}_{ij}$) are used in the second stage regression of WTP on perceived quality (equation 5).

$$Q_{ij} = x + wS_j + \delta_i + r_{ij} \quad (4)$$

$$WTP_{ij} = c + d\hat{Q}_{ij} + \delta_i + h_{ij} \quad (5)$$

The model estimations from equations 1, 3 and 5 are presented in Tables 3 and 4 for two sub-sample of participants. Sub-sample 1 includes all the observations, and sub-sample 2 excludes observations where the farmer's bid for the best rated plot was lower than his/her bid for the worst rated plot. In other words, sub-sample 2 excludes 31 and 29 observations of farmers in Tanzania and Ghana, respectively with bids that seem unreasonable and perhaps reflect their inabilities to understand the BDM exercise. Equation 3 is estimated using seed quality as a categorical variable (columns 2 and 6 in Tables 3 and 4) and as a scale variable (columns 3 and 7).

{Tables 4 and 5 here}

The estimated premiums for different types of seed quality (i.e., certified and QDS) relative to recycled seed (model 1, Tables 3 and 4) are similar in magnitudes as shown in Table 2. For example, on average bean farmers in Tanzania and Ghana are, respectively, willing to pay 487 TSH/kg and 2.29 GHC/kg more than the recycled seed. However, since these were blind experiments, farmers were not actually bidding for 'certified', 'QDS', or 'recycled' seeds, but for seeds they perceived to be of high, medium or low quality. Thus, in models 2-4 and 6-7 in Tables 3 and 4, we present the estimated premium for perceived seed quality, which was the main motivation for doing the blind experiments. The statistically significant values for the perceived seed quality variables confirm that after controlling for other potentially confounding factors (including unobservable factors), there is a positive correlation between perceived quality of seed and farmer's WTP for one kg seed of that seed type. Relative to seed plots that were rated worst, bean farmers in Tanzania were willing to pay on average TSH 630 more for one kg seed of their highest rated seed and on average TSH 156 more for one kg of the seed type they rated neither best nor worst (referred as medium quality in Table 4). The average value of this premium goes up as the sub-sample is restricted (specifications 2). Similarly, the average premium per kg for a one unit increase in seed quality rating goes up from 315 to 471 TSH in sample 1 and from 405 to 583 TSH in sample 2, under the two-stage regression models 4 and 8, respectively. Thus, for Tanzania the results are robust and statistically significant across both sub-samples and across different models.

In the case of Ghana, results suggest that on average, cowpea farmers were willing to pay between GHC 2.3 to 2.7 per kg for the highest rated seed quality relative to the lowest rated seed type, depending on the sub-sample used for model estimation. For the medium quality rated seed, farmers were willing to pay an average GHC 0.43 to 0.61 per kg across the three sub-samples (Table 4). The results for Ghana are robust and statistically significant across all sub-samples for the premium estimated for the highest quality seed, and for sub-sample 2 estimates are also statistically significant for medium quality rated seed (Table 4). Similar to Tanzania, the estimated average premium for one unit increase in seed quality rating also goes up under the two-stage regression models, further supporting the robustness of the results.

To put these estimated premiums in context and to illustrate the cross-country differences in the magnitudes of WTP premiums relative to a common yardstick of grain price, in Figure 2 we show the distribution of the predicted values from model 6 of farmers' WTP for the best and worst rated plot relative to the grain price. In Ghana, all farmers in sample 2 were at least willing to pay for the best rated seed type a price greater than the grain price; although for about 15% of farmers the WTP for their worst rated seed type was below the grain price. In Tanzania, there is a substantially greater proportion of participants (about 30%) with a maximum WTP price for the best rated seed below the grain price. Since the cost of producing good quality seed is likely to be significantly more than producing grain, the supply curve for the best rated seed type will certainly be above the grain price. Using the existing market price of certified seed as a proxy for the supply curve for quality seed, we show that in both the countries, only about 35% of sample 2 farmers' WTP for highest quality seed is above the market price of certified seed (Figure 2). In other words, for about 65% of farmers in the study area, the current market price of certified seeds, which is supposedly the best quality seed, is above their WTP.

{Figure 2 here}

6. Discussion of results and implications

Overall, the experiments conducted in Tanzania and Ghana point to several interesting results. First, at least in Ghana, quality seeds available in the market did perform differently in terms of important agronomic and plant growth characteristics relative to recycled grain. This finding that seed quality matters, challenges the long-held notion that for self-pollinated crops, farmers don't lose much if they recycle seeds for multiple generations. Surprisingly, there are very few studies that evaluate the performance of different generations of legume seeds of the same variety under farmers' conditions as was done in this study.[7] There is a need for more experimental evidence on productivity differences in seed types across legume crops under different conditions to confirm or challenge the notion that self-pollinated crops do not suffer significant yield loss as a result of

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[7] Few examples we found in the literature in the context of developing countries all relate to potato (e.g., Rahman *et al.*, 2010; Crissman *et al*., 1990; Demo *et al.*, 2015). In developed countries with matured seed industry, such experiments are more common; see for example studies by Clayton et al. (2009) that compared Canadian farmers' saved seed of hybrid canola with certified canola seed of the same variety and study by Dunphy and Ferguson (1991) in the U.S. comparing farmer saved and professionally grown soybean seed.

recycling seeds for multiple generations. Such research should guide more clear recommendations on seed replenishment practices by farmers under different conditions.

In the Tanzanian experiments, although in absolute terms the yield difference between the perceived high quality (certified 1) and low quality seed (recycled) was about 117 kg, which for smallholder farmers is not trivial, this difference was not statistically significant. This could be because of the small sample size (i.e., 12 sites), implying low statistical power to detect significant difference. Another possibility could be that for the sample of certified and QDS seeds procured for this study, the procedures followed by seed growers were somehow compromised and thus did not generate any additional quality boost compared to farmer produced grain. In the market driven system, this possibility generates uncertainty, which dampens the demand for quality seed. The implication of this possibility is that in order to promote the use of certified or QDS seeds, the formal seed system must have all the processes and procedures in place (i.e., availability of quality foundation seeds, field inspection and monitoring, seed quality tests, etc.) to assure high quality seed products are available to farmers.

A second important finding of this study is that it shows that farmers are willing to pay a premium for their perceived higher quality seed. In the case of Ghana, the average premium farmers were willing to pay for one kg of higher quality seed was equivalent to the price of grain prevalent at the time of harvest. This WTP such a significant premium for quality legume seed by smallholder farmers is encouraging and indicative of an effective demand. However, it is worth noting that the quality rating of the seed was done at the flowering and harvesting stages, when the seed quality was actually observed and experienced. In practice, farmers' face the issue of quality uncertainty and lack of trust in seed quality at the time of seed purchase. The design of this study does not assess whether a farmer can perceive quality differences at the time of seed purchase, and how that impacts their WTP. Addressing this issue of trust in seed quality at the time of purchase would require an experimental design in which seed types are identified and then asking for bids. This is something future research should explore.

A third finding of this study is that although the auction experiments reveal that about a third of the farmers' WTP for quality seed in Ghana, and about a quarter of the farmers' WTP for quality seed in Tanzania were above the price of certified seed, in practice farmers' use of purchased certified seeds or QDS is much lower. In fact, a majority of farmers reported buying 'seed' every year or every 2 to 5 years, but from specialized vendors who have no credentials and sell bulk 'seed' with no label or quality assurance (i.e., from those that represent the so called 'informal' seed system). Further research is needed to investigate whether the low (actual) use by farmers of quality seed products like certified seed from the formal sector is a trust and perception issue (i.e., counterfeit or inferior seed sold in the name of certified and QDS), or an availability issue (i.e., supply side constraint),[8] or both. If most farmers are acquiring seeds from the informal system, there is also a need for more research and systematic investigation on what the true quality is of these seeds acquired from the informal system and how much the quality varies from vendor to vendor. Given the role these vendors play in the current system, it may be worth investigating how to link them to the formal system to increase farmers' access to legitimate quality seed products (McGuire and Sperling, 2016).

[8] The high cost of seed multiplication and the limited capacity of the public sector to produce early generation seeds are often cited as major constraints for the formal sector to produce and supply certified seeds to meet the demand. Recent estimates suggest that the formal seed system has the capacity to produce certified seeds for at most 1% of cowpea area in Ghana (AGRA/USAID, 2017), and about 1-5% of total bean area in Tanzania (AGRA/USAID, 2016).

The fourth finding is that across both the crop-country case studies, there are a significant proportion of legume growing farmers (about 65%) whose willingness to pay a premium for quality seed is much lower than the existing certified seed to grain price ratio in the study area. For a sub-set of these farmers (about 30% in Tanzania), the WTP for quality seed is even lower than the grain price. This may imply that a multi-pronged approach is needed to get high quality seed into the hands of all the farmers across this spectrum of WTP. Current efforts to entice the private sector to produce and supply certified seeds through agro-dealers can potentially meet the seed needs of at most 35% of farmers if the quality of those seeds is substantially superior to recycled grain. More research and discussion is warranted to address the seed needs of those farmers whose WTP for quality seed is below the price at which certified seeds are sold in the market. For example, research is needed on how to lower the cost of quality assurance systems and the cost of producing quality seed so that per unit cost can be brought closer to grain price, while still providing a sufficient profit margin for seed producers. Training and capacity building of seed producers to reduce the rejection of seeds can increase the seed yield, and thus lower the cost per unit of seed produced. In the case of Ghana, the high price elasticity of demand for quality seed observed in this study implies that lowering the price of good quality seed can substantially increase the revenues for seed producers. Thus, from a policy perspective it makes economic sense for governments to invest in programs that lower the cost of seed production and increase the supply of quality seeds.

Finally, the results are indicative of the important role that perceived quality advantages of different seed products play in influencing the magnitude of the price premium farmers are willing to pay. For crops and in settings where the significant advantage of planting good quality seed compared to recycled seed can be demonstrated (i.e., where one can really show product quality differentiation between grain and seed), it is possible to see a higher WTP, and thus a higher demand for fresh seed, which can stimulate more private sector investments in the seed system. However, we note that the demand implied from the estimated premiums farmers are willing to pay in this study is from a single measure. In the long-run, the market potential for the seed that is perceived to have higher quality in these experiments will depend on actual yields and farmer experience. Moreover, to determine the potential for a market-driven seed system for self-pollinated crops such as beans and cowpeas, it is also important to know more about the quantity of seed and the frequency with which farmers would purchase seed at these premiums. More research into these dimensions is needed to determine if there is sufficient seed demand to sustain a successful market-driven seed system.

7. Conclusion

This study was designed to explore the impact of perceived seed quality on farmers' willingness to pay a premium for different types of bean and cowpea seed. The results of this study are based on small scale experiments conducted in two districts of the country and the sample of farmers who participated in the auctions are not nationally representative in a statistical sense. This limits the scope of extrapolating the results to a broader geographic scale. However, the evidence from two countries for two different crops does lead to some generalizable conclusions and policy implications.

Results indicate that the relative difference in farmers' WTP for different seed products is highly correlated with the relative difference in their perceived quality. Policies and programs are needed to increase the availability of qualitatively better performing (i.e., higher germinating, disease-free, and non-mixtures) seed products to smallholder farmers that are within the range of price premium farmers are willing to pay. Lowering the cost of producing higher quality certified seed to no more than 1.5 times the cost of grain production is key to getting quality seed products for crops like beans and cowpeas into the hands of more farmers, and thus increasing their effective demand and sustaining a more vibrant seed system. While cost-reducing strategies through policy, programmatic and technological options should remain a high priority for governments and donor-supported programs, this study also indicates the need for continued support for innovative and smart subsidy-based approaches to meet the needs of 15-30% of farmers who's WTP for seed is so low that for-profit seed production/marketing models will not work.

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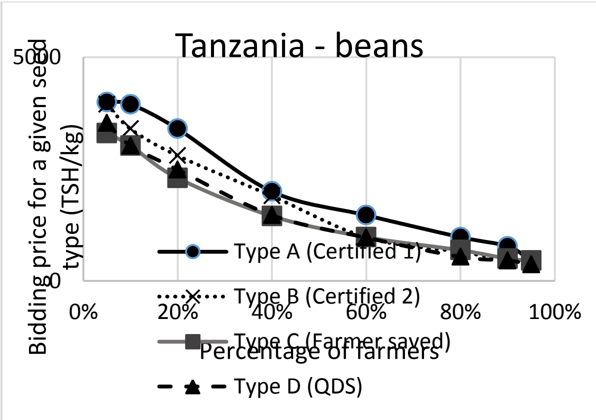
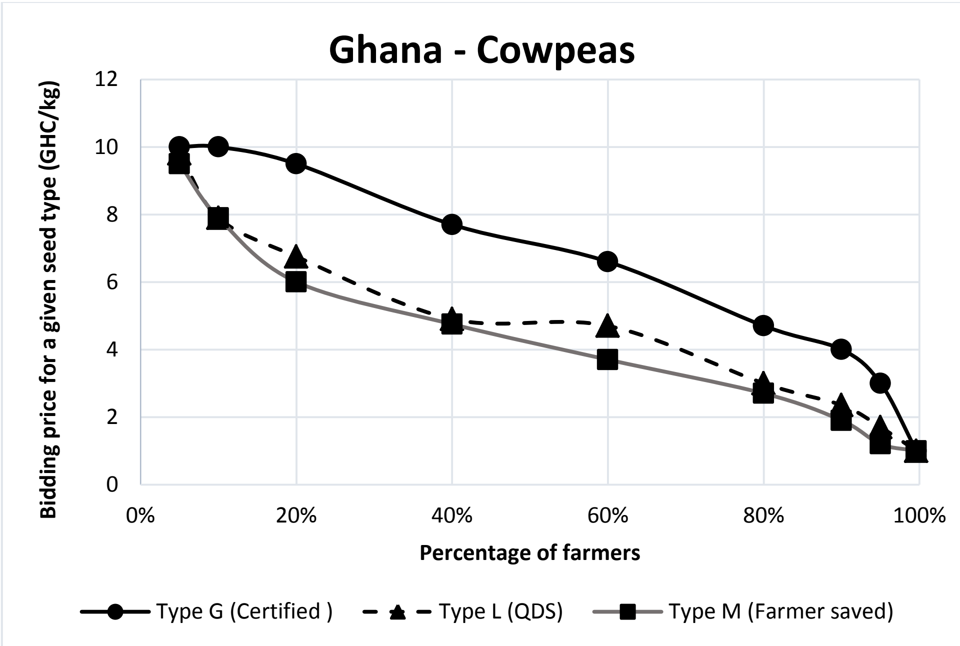
Figure 1. Farmers' WTP for seeds of different quality types: Results of the bidding auction experiments from Tanzania for beans and Ghana for cowpeas

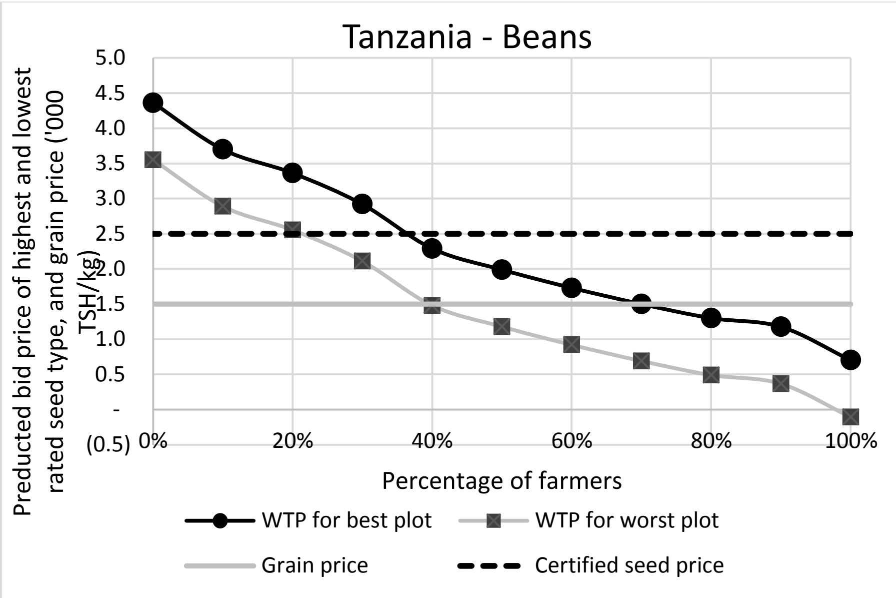


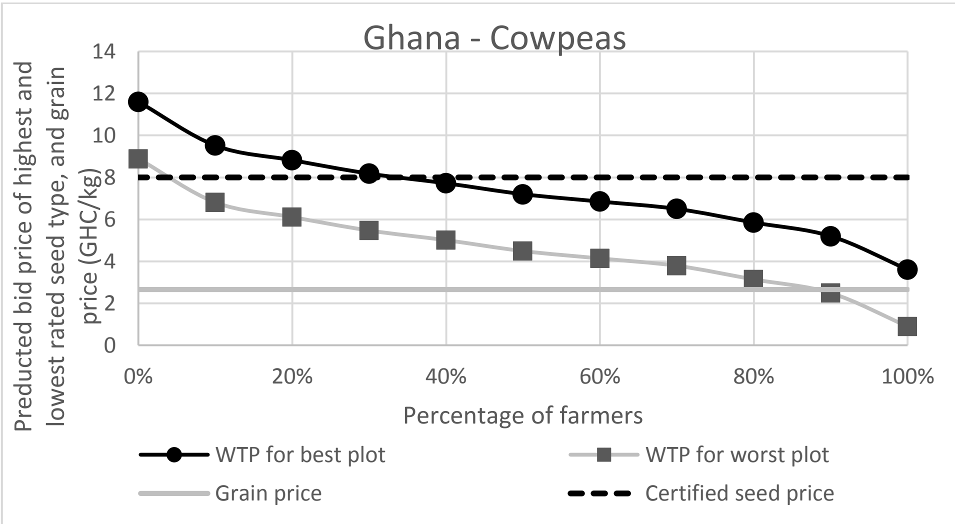
Source: Authors' estimation from experimental auctions, Tanzania (2015-16)



Source: Authors' estimation from experimental auctions, Ghana (2016)

Figure 2. Farmers' WTP for best and worst rated seed relative to grain and certified seed price: Predicted values from model 4 for Tanzania and Ghana





Source: Authors' estimation based on Model 6 results

Table 1. Farmers' perception of quality differences: Ratings of best plots at Flowering stage, and best and worst plot at harvest stage--Results from Tanzania and Ghana field experiments

Plot (Seed type)	Flowering stage	Harvest stage	
	Best plot	**Best plot**	**Worst plot**
	Percentage of farmers		
Tanzania (beans)	**N=282**	**N=245**	**N=245**
Plot A: Certified 1	59.22	73.06	4.49
Plot B: Certified 2	26.60	15.51	34.69
Plot D: Quality Declared	7.80	7.76	33.47
Plot C: Recycled	6.38	3.67	27.35
Ghana (cowpeas)	**N=268**	**N=269**	**N=269**
Plot G: Certified	89.93	95.17	0.37
Plot L: Quality Declared	7.84	4.09	21.93
Plot M: Recycled	2.24	0.74	77.70

Source: Field experiment data, Tanzania 2015-16; Ghana 2016

Table 2. Farmers' WTP for different seed types: Results of the bidding auction experiments

Seed type \a	**Mean WTP**	**Std.dev.**
Tanzania-beans (TSH/kg) (N=247) \b		
Plot A: Certified 1	2,092.51 [a]	1,165.68
Plot B: Certified 2	1,803.65 [b]	1,149.49
Plot D: Quality Declared	1,594.13 [c]	1,087.91
Plot C: Recycled	1,605.06 [c]	987.55
Ghana-cowpeas (GHC/kg) (N=269) \c		
Plot G: Certified	7.19 [x]	2.16
Plot L: Quality Declared	5.27 [y]	2.11
Plot M: Recycled	4.90 [z]	2.19

Source: Authors' estimation from experimental auctions, Tanzania (2015-16) and Ghana (2016)

\a Note that seed types planted on different plots were not known to farmers at the time of bidding experiments. Average grain price reported by Tanzanian bean farmers at the time of experiment was TSH 1577/kg (median was 1500/kg) and by Ghanaian cowpea farmers was GHC 2.80/kg (median was 2.66/kg).

\b Numbers with different letters denotes that differences in WTP are statistically significant at $p<0.01$.

\c Numbers with different letters denotes that differences in WTP are statistically significant at $p<0.05$.

Table 3. WTP for different seed types and influence of perceived seed quality on farmers' WTP: Results of different model estimates for bean seed in Tanzania

	Sample 1				Sample 2			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		(based on observed values)	(based on observed values)	(based on predicted values)		(based on observed values)	(based on observed values)	(based on predicted values)
Seed type:								
Plot A: Certified 1	487.45***	--	--	--	573.86***	--	--	--
	(82.40)				(80.73)			
Plot B: Certified 2	198.79*	--	--	--	172.27	--	--	--
	(109.22)				(128.14)			
Plot D: QDS	-10.53	--	--	--	-33.18	--	--	--
	(105.33)				(110.59)			
Perceived seed quality rating (1 to 3)	--	--	314.80***	471.32***	--	--	405.05***	583.42***
			(50.60)	(76.74)			(44.15)	(80.74)
Perceived seed quality categories:								
Highest=3	--	629.59***	--	--	--	810.09***	--	--
		(101.26)				(88.37)		
Medium=2	--	156.42***	--	--	--	237.72***	--	--
		(46.98)				(45.32)		
Farmer fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-square	0.812	0.823	0.818	0.807	0.832	0.857	0.851	0.828
N	988	980	980	980	880	872	872	872
Mean (SD) of the omitted variable	1605.06	1533.47	--	--	1600.91	1452.29	--	--
	(987.55)	(1031.67)			(973.95)	(979.10)		

Source: Authors' estimation from field experiment and experimental auction data, Tanzania (2015-16)

Standard errors are in the parenthesis. Robust SE are clustered at the village (or field experiment level). ***=p<0.01, **=<0.05, *=<0.1.

Sample 1 includes all the observations. Sample 2 excludes farmers with bid price for the best rated seed type less than the bid price for the worst rated seed type.

Table 4. WTP for different seed types and influence of perceived seed quality on farmers' WTP: Results of different model estimates for cowpea seed in Ghana

	Sample 1				Sample 2			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		(based on observed values)	(based on observed values)	(based on predicted values)		(based on observed values)	(based on observed values)	(based on predicted values)
Seed type:								
Plot G: Certified	2.29***	--	--	--	2.67***	--	--	--
	(0.31)				(0.19)			
Plot L: QDS	0.36	--	--	--	0.50**	--	--	--
	(0.26)				(0.19)			
Perceived seed quality rating (1 to 3)	--	--	1.15***	1.38***	--	--	1.36***	1.60***
			(0.14)	(0.17)			(0.10)	(0.11)
Perceived seed quality categories:								
Highest=3	--	2.30***	--	--	--	2.71***	--	--
		(0.287)				(0.193)		
Medium=2	--	0.43	--	--	--	0.61**	--	--
		(0.259)				(0.243)		
Farmer fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-square	0.712	0.710	0.689	0.705	0.763	0.765	0.742	0.756
N	807	807	807	807	738	738	738	738
Mean (SD) of the omitted variable	4.90	4.88	--	--	4.78	4.73	--	--
	(2.19)	(2.05)			(2.13)	(1.96)		

Source: Authors' estimation from field experiment and experimental auction data, Tanzania (2015-16)

Standard errors are in the parenthesis. Robust SE are clustered at the village (or field experiment level). ***=p<0.01, **=<0.05.

Sample 1 includes all the observations. Sample 2 excludes farmers with bid price for the best rated seed type less than the bid price for the worst rated seed type.