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Estimating Price Discounts for Low-Quality Maize in sub-Saharan Africa: Evidence from Benin

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Summary. — This article uses household data from Benin to estimate the extent that markets in sub-Saharan Africa discount damaged maize. Stated preference methods indicate that a 10% increase in insect damage results in a 9% maize price discount. However, revealed preference methods indicate that this discount is only 3%. Discounts are larger immediately after harvest than they are in the lean period when maize is scarce. Our results help explain why many smallholder farmers sell maize at harvest rather than making the effort to preserve grain of good quality for later in the season when it may fetch a higher price.

Key words — maize quality, price discounts, post-harvest, market participation, sub-Saharan Africa

1. INTRODUCTION

Smallholder farmers in sub-Saharan Africa (SSA) face many obstacles that make it difficult for them to increase their income and improve their food security. One major problem is that many smallholder farmers sell their maize immediately after harvest, rather than making the effort to preserve grain of good quality for later in the season when it may fetch a higher price. One reason why this occurs is because many smallholders must deal with a binding liquidity constraint at harvest to pay for immediate needs like school fees that makes the need for cash at harvest imperative (Renkow, 1990; Saha & Stroud, 1994; Stephens & Barrett, 2011). The second reason for early sale is that without access to effective and affordable storage technology, grain placed in storage may experience substantial damage from post-harvest pests, such as insects, rodents, and mold.

Pests are major impediments to grain storage and household food security that create two problems. First, pest damage reduces the quantity available for households to sell and consume later in the year. Second, farmers potentially receive a price discount for lower quality damaged grain that is marketed. Markets in developed countries have explicit standards for maize quality and discount schedules that give price penalties to visibly damaged maize. However, formal quality standards do not exist in most rural maize markets in SSA, which is where most of the maize transactions in the region take place.

Despite its importance, the issue of possible quality premiums or damage discounts for maize in informal rural markets has received limited attention in the literature. In a recent meta-analysis of post-harvest loss in SSA, Affognon, Mutungi, Sanginga, and Borgemeister (2015) cite quality loss in the post-harvest as one of the major problems that has yet to be fully understood or quantified. This is an important issue because as noted in Hodges, Buzby, and Bennett (2011, p. 43), "successful markets depend on a consistent supply of better-quality produce." Furthermore, Jones, Alexander, and Lowenberg-Deboer (2014) develop a financial model for measuring profitability of storage that includes quality loss. They conclude that when quality losses are considered in an economic analysis of the returns to storing maize, the "total value loss" can far exceed traditional estimates that only consider quantity of maize lost in storage.

With these considerations in mind, the objective of this article is to estimate the extent to which insect damage affects the price that smallholder farm households in SSA receive and pay for maize in rural markets. We test two main hypotheses that to our knowledge remain largely unanswered to date. The first (null) hypothesis is: *there is no statistically significant price discount for maize that has been damaged by insects*. If markets in SSA do not place a premium on high quality maize (discount damaged maize), this can help explain why poor quality maize exists, which has negative implications for household food security and health.

The second (null) hypothesis is: *the average price discount is the same in the early post-harvest period and lean period for maize with the same level of damage*. Markets may value quality and thus discount damaged maize in the period immediately following harvest, when quantity is plentiful and is generally of high quality. However, in the lean period maize becomes scarce and quality may become less important as people must eat what is available regardless of insect damage.

This article uses data from a random sample of 360 smallholder maize farmers conducted across Benin after the 2011–12 harvest. We conduct a straightforward experiment showing farmers maize with different levels of insect damage to test the two hypotheses presented above. We first ask farmers the price per kilogram and level of insect damage for the maize that constituted their largest maize sale and purchase in the past post-harvest season. Second, we ask farmers to value maize at each damage level for purchase and sale. Our estimates include a parsimonious specification that includes only the level of insect damage as a control, and a full specification that incorporates other household-level, and market-level factors, along with information about transaction partners as control variables. Since some farmers do not sell (buy) maize because they price they receive (pay) is below (above) their reservation value, we have a number of missing values for maize price in our experiment. We deal with this potential selection bias issue caused by farmers not buying

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or selling maize using the Heckman sample selection correction method, following Heckman (1979).

To our knowledge this article is the first study to empirically quantify price discounts for damaged maize using revealed preference data from smallholder farmers in SSA. In doing so, it makes three contributions to the literature. First, we obtain quantitative estimates of maize damage discounts for a representative sample of smallholder maize farmers regardless of how long they store their maize. Many of these farmers are both producers and consumers of maize so we ask them how they value damaged maize when they operate on each side of the market. Second, we compare the results from past-transactions (revealed preference) with those from farmers' perceptions (stated preference) about the effects of insect damage on maize prices. We use these two methods to compare the accuracy of each estimation approach. Third, for sale and purchase transactions, we test whether the price discounts for damaged maize are significantly different between the time period immediately after harvest and the lean season.

Previous literature suggests that there may be unofficial price discounts for insect damage in West African cowpea markets (Langyintuo, Ntoukam, Murdock, Lowenberg-DeBoer, & Miller, 2004). However, there is limited information on possible insect damage discounts for maize, and virtually no information at the farmer-level. To our knowledge the only published study in Africa by Compton *et al.* (1998) uses trader focus groups in Ghana to construct a maize discount schedule based on stated preferences. Hoffmann and Gatobu (2014) survey a population of Kenyan farmers who store maize for longer than six months. The authors use an experimental auction and conclude that asymmetric information about unobservable maize attributes such as the existence of aflatoxins may also contribute to the prevalence of smallholder autarky in staple grains.

Our study complements and extends the work by Hoffman and Gatobu, as we believe maize prices should reflect observable quality during market transactions. We focus on potential discounts for maize with different levels of insect damage and how those discounts may be different between the early post-harvest period and the lean period.

The rest of this article is organized as follows. The next section describes how data collection and the experiment were conducted in the selected areas. Subsequent sections present the empirical estimation, results, and conclusions.

2. MAIZE MARKETING IN BENIN

Private sector trading among farmers and traders dominates the maize marketing system in Benin. However, the government still intervenes in cereal markets. The national office for food security called "Office National d'Appui a la Securite Alimentaire (ONASA)" buys and stores maize and other cereals to resell between harvests to smooth out market supplies and limit price surges.

Smallholder farmers buy and sell maize in local rural markets, and occasionally in larger district markets. There is no formal quality control mechanism in these markets, so market participants implement their own practices to verify maize quality. Most traders prefer to purchase maize during the harvest season and the early post-harvest period, when prices are lowest and good quality grain is abundant. They build up their stocks to take advantage of spatial and temporal price arbitrage that occurs later in the season. Wholesale traders assemble maize from different rural and district markets to resell it in regional or urban markets.

During harvest and early post-harvest period, maize is fresh and of good quality so the risk of damaged grain being concealed in bags is low. Indeed, many wholesale traders often only sample a certain portion of the maize they purchase to check for quality. They may also hire middlemen in rural areas to collect and ensure that good quality maize is being purchased.

Wholesale traders buy maize during the lean period only when there is acute demand in the consumer markets. However, retail traders represent more constant market partners for farmers, since they operate in local and district markets throughout the seasons. Women are the main retail maize traders across rural markets in Benin, just as in other West African countries. Retail traders buy different amounts of maize from farmers and resell it out of their small shops or kiosks to other rural dwellers and farm households who run out of their own produced maize stocks.

Quality control is less of a challenge for market participants when small quantities of maize are traded, as is often the case when smallholders buy and sell maize in the lean period. When the traded quantity is small, it is relatively easy for farmers and traders to determine observable maize characteristics through visual controls and touching maize contained in bags and baskets. It is important to note that market participants can only judge maize quality based on its observable characteristics and do not have the means to test for unobservable characteristics that could be harmful to them, such as the maize being contaminated with aflatoxin.

3. DATA

Data used in this study come from a random survey conducted from July to August 2012 in Benin. We selected six departments out of 12 in Benin using multiple criteria of agricultural productivity, food security, and geographical repartition. Two counties called "Sous-Prefecture" were then randomly chosen in each department, followed by the random selection of one district in each identified county. The villages for farmer interviews were also randomly chosen in each district. In a final step we randomly selected 30 farmers from a census of maize farmers from each village. In total 360 farmers were interviewed, but we retain 357 observations because two farmers did not store maize and one farmer was an outlier with a quantity produced far above (51 times) the average production of other farmers, and thus cannot be considered a smallholder.

The number of respondents differs depending on the evaluation method that is used. Only farmers who were involved in market transactions during the past post-harvest season were interviewed for the revealed preference (RP) evaluation. There were 246 farmers who sold maize (69% of the sample) and 134 (37% of the sample) who purchased maize. All 357 farmers were asked to elicit their preferences for a range of maize qualities for the stated preference (SP) evaluation.

In each sampled village the survey started with a focus group discussion. These focus groups were composed of 10–15 male and female maize farmers from the selected villages. The enumerators explained the purpose of the study to participants, and participants helped to evaluate how realistic the damage levels that we presented were for marketed maize in the village. In addition, the focus group participants were asked to differentiate the major periods in the season when price and quality vary, to capture local market conditions. In summary, shortly after the harvest, maize prices are relatively low and the quality and quantity are generally high.

Later in the post-harvest season, the lean period occurs where maize becomes scarce, and the available maize is likely of lower quality than just after harvest, while at the same time prices are high. For the purpose of the analysis, we distinguish between an early post-harvest (PH) period and a lean period during the post-harvest season, which is the season after final storage on the farm has been made (see Figure 1).

We set up the experiment by filling clear plastic boxes with maize that represented five different levels of insect damage: 0%, 10%, 20%, 30%, and 50%. Only insect damage was examined among maize attributes, and was allowed to vary by these five levels. Other attributes such as mold content, color, and variety were identical and held constant across samples. Each enumerator had five boxes of the different levels of damage that they showed to farmers. The farmers were not told what level of damage they were looking at, and the boxes of different damage levels were placed in a random order that was known to the enumerator for recording purposes, but not to the responding farmer.

In the revealed preference approach, farmers were asked to choose among the maize samples and pick the one box out of the five possible options that was closest in level of damage to the maize that constituted their largest sale and/or purchase transaction during the past post-harvest season. Farmers were then asked to report the transaction price in F CFA/kg for the chosen maize quality. Other characteristics of the household such as demographic information, annual income, and savings were also recorded during the interview.

In the stated preference experiment, farmers were asked to state how much they would pay and accept for each level of maize quality that they were shown. Each respondent was shown all five samples in random order, so five responses were recorded for each person interviewed. [1]

We designed the SP survey to minimize measurement error and insure validity of the estimates by following recommendations in Carson (2000) for implementing contingent valuation interviews. First, interviews were made in one-on-one settings with only the enumerator and the farmer. Second, identical boxes of different maize damage levels were shown to each respondent and they were allowed to touch the maize to evaluate the quality. Third, the respondent elicited his or her preference by stating a price for a given quality in the experimental transaction. In addition, the respondent was free to state a zero value as price when he or she was not willing to purchase the good. Fourth, respondents were asked about their willingness-to-pay (WTP) and willingness-to-accept (WTA) during the lean period, as it is the most realistic period for poor quality maize. [2]

4. EMPIRICAL ESTIMATION

(a) *Empirical specification of the revealed preference models*

We build our empirical model upon a hedonic price from Lancaster (1966) and Rosen (1974). Rosen (1974) states that under competitive market conditions, implicit prices will normally be related to product attributes alone, without accounting for producer or supplier attributes. However, rural markets from SSA are rarely competitive, and several empirical studies have shown that prices are also related to the attributes of buyers, sellers, and markets (Dury & Meuriot, 2010; Langyintuo *et al*., 2004; Parker & Zilberman, 1993).

Hence, we define an implicit form of the empirical model for factors affecting maize price for a household (i) as follows:

$$P_i = f(\boldsymbol{D}_i, \boldsymbol{M}_i, \boldsymbol{F}_i, \boldsymbol{T}_i, \mu_i) \quad (1)$$

where the dependent variable P denotes the market price, which is the sale price when a farmer sells maize and the purchase price when he or she buys maize.

The main covariate of interest is measured through $\boldsymbol{D}$, which denotes the levels of the visible characteristic, insect damage. Through focus group discussions in Ghana, Compton *et al.* (1998) reveal that insect damage has an impact on maize price. In the present application, the vector $\boldsymbol{D}$ is treated under two forms. First, it is a set of dummy variables that correspond to the level of insect damage. These dummy variables are 10%, 20%, 30% and 50% with base 0% damage. The first four levels of damage follow Compton *et al.* (1998) who indicate the categories called undamaged, slightly damaged, and badly damaged. By adding 50% damage, we extend Compton *et al.* (1998) with an additional level of insect damage to identify a probable rejection value for maize quality in the market. Second, in an alternative specification, $\boldsymbol{D}$ also represents a continuous variable that takes as values the level of insect damage. The marginal effect of $\boldsymbol{D}$ on price tests hypothesis one: *there is no statistically significant price discount for maize that has been damaged by insects*.

The vector $\boldsymbol{M}$ corresponds to market variables, which allows us to differentiate how maize quality may be valued in different market settings. For instance, normally there is a much higher prevalence of insect-damaged maize during the lean period compared to the early post-harvest period. Therefore we include a dummy variable = 1 when the market transaction occurs in the lean period, so that we can compare price discounts between that period and the early post-harvest period. We also include an interaction between level of insect damage, $\boldsymbol{D}$, and the lean period dummy. The joint statistical

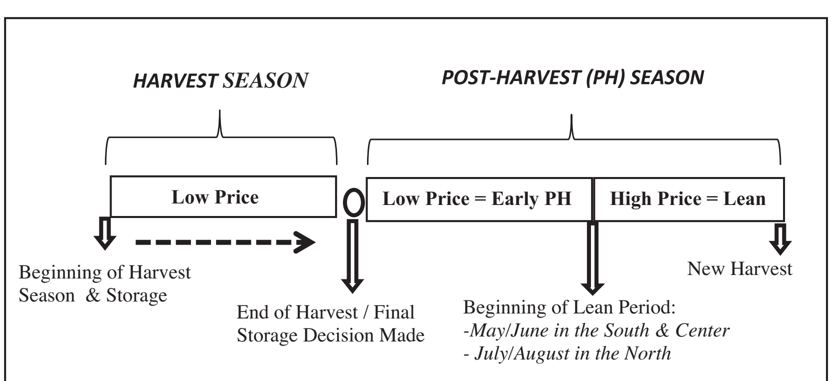

Figure 1. *Maize consumption cycle in Benin.*

significance of this interaction effect and the coefficient on $\boldsymbol{D}$ tests the second hypothesis in this study: *the average price discount is the same in the early post-harvest period and lean period for maize with the same level of damage*.

In addition, we incorporate the distance from market in kilometers within the vector $\boldsymbol{M}$. Farmers farther from the market might place a lower valuation on maize quality than farmers closer to the market due to transaction and storage costs, and constraints to access market information. We also introduce the department dummies to control for regional differences in insect infestation and price patterns.

The vector $\boldsymbol{F}$ represents a set of household characteristics. We include demographic variables along with determinants of a farmer's market participation. We consider determinants such as (i) age of household head, (ii) education of household head, and (iii) household size. We then add (iv) a farmer's full income from activities other than maize production and (v) saving at the beginning of the harvest season. These two variables capture a household's liquidity constraints that may hinder market participation (Stephens & Barrett, 2011). We also assume that better information about market prices and the quality of maize traded depend on the degree to which a farmer participates in markets either as a seller or a buyer. Thus, we consider the variables (vi) total quantity of maize traded by the household in the post-harvest period, (vii) the share of production that is sold to measure the household's propensity to sell maize, and (viii) the share of maize purchased for consumption relative to quantity of maize produced by the household to infer their propensity to buy maize.

The vector $\boldsymbol{T}$ denotes a household's trading partner during the transaction, namely maize buyers for sales, and maize sellers for purchases. For the sale model the vector comprises the following set of dummy variables: (1) farmers in the village, (2) traders from the market, (3) governmental grain marketing agency called ONASA, and (4) "other buyers" which serves as the base in the sales transaction. For the purchase model, we use "traders" as the base.

(b) *Dealing with potential omitted variable bias in the revealed preference models*

It is possible that unobserved factors in the error term of Eqn. (1) of the RP models, denoted by μ_i, that affect the dependent variable maize price, also affect maize quality. If this is the case then omitted variables could lead to biased estimates of the maize damage coefficients. To indirectly test and deal with the impacts of omitted variable bias, we present a parsimonious specification for each of our estimated models that only includes level of insect damage, department dummies, and a constant as covariates. Results of the parsimonious specification are presented next to results where a full set of observable household, season, and market characteristics are in the model, as explained in Eqn. (1). There is little change in the insect damage coefficient estimates between the parsimonious and fully specified specifications. This lends validity to the notion that omitted variables are not biasing the insect damage coefficient estimates in this study.

(c) *Functional form in the revealed preference models*

Most hedonic price models rely on the Box–Cox transformation to identify the correct functional form, as there is no theoretical background to support the functional form of the dependent variable. The Box–Cox transformation of the dependent variable confirms the semi-log form for the sale model, but it indicates a simple linear form for the purchase model. To test the robustness of the estimates, we use a log-linear specification for the dependent variable along with a simple linear regression. The log-linear regression is applied only when the covariate $\boldsymbol{D}$ is treated as a continuous variable representing the level of insect damage.

(d) *Dealing with potential sample selection issues in the revealed preference models*

Since only a sub-sample of households in our full sample actually purchase and/or sell maize, we may encounter selection bias in our estimation of factors affecting maize price. This occurs because some households do not sell (purchase) maize because the price they would receive (pay) is below (above) their reservation value for that maize. Therefore, the value of that maize is unobservable to us (it is not equal to zero), and failure to accurately correct for this problem can lead to biased coefficient estimates (see Wooldridge (2010) for discussion of this problem, which he calls incidental truncation).

Our problem is analogous to the common empirical situation where one needs to correct for labor market participation when estimating a wage equation. We test and correct for this concern using a two-step estimation of Heckman selection model, following Heckman (1979). In this context, the first step is the selection equation that corresponds to the household's decision to participate in markets for each type of transaction (sale or purchase). We then derive the inverse mills ratio (IMR) from the selection equation and include it as an additional covariate in the maize price equation as shown in Eqn. (1). The statistical significance of the IMR in the second step tells us if selection bias is an issue under the null hypothesis that there is no selection bias.

We use total area cultivated to crops other than maize as our exclusion variable in the participation equation. This variable is appropriate because households with larger non-maize areas may be more likely to sell and less likely to purchase maize. However, this variable would not be expected to directly affect maize price.

Table 8 in the Appendix presents the results when the Heckman selection model is used to estimate the revealed preference maize price equation. The exclusion variable is significant in the first stage participation models for both purchases and sales (p-value <0.05), indicating that it is suitable to identify the equation. In the second stage, the IMR is insignificant in the maize price model for sales (p-value $= 0.94$), suggesting that selection bias is not an issue. The IMR is statistically significant in the maize price models for purchases (p-value $= 0.00$). However, the statistical significance of the coefficients on insect damage and lean season variables do not change when the IMR is included compared to the main results when it is not. This suggests that selection bias is not a major empirical concern in this setting.

(e) *Empirical specification of the stated preference models*

The stated preference model in our study uses a contingent valuation (CV) method. The CV method is very straightforward, and since we are interested in only one characteristic of the good, its level of insect damage, this method is widely accepted as valid (Bateman *et al.*, 2002). In this application, we measure the respondent's purchase decision as the maximum WTP in a situation where he or she wants to acquire the good. We measure the sales decision as the minimum WTA, which represents the compensation value for which the respondent is being asked to voluntarily give up a good (Carson, 2000).

From an econometric perspective there are no special issues involved in estimating the WTP equation beyond those normally experienced with survey data (Carson, 2000). Thus, we specify the CV models as follows:

$$WTA_i = g(D_i, Q_i, F_i, M_i, e_i) \quad (2)$$

$$WTP_i = h(D_i, Q_i, F_i, M_{i,} a_i) \quad (3)$$

where WTP represents a farmer's willingness-to-pay for the maize characteristics in the purchase model, whereas WTA represents a farmers' willingness-to-accept in the sale model. The covariates in Eqns (2) and (3) are defined as before, with e_i and a_i as the respective error terms. We exclude the time seasonal variable from the vector M, since the SP assumes an experimental market that occurs only during the lean season.

(f) *Estimation strategy for the stated preference models*

Testing the validity of the CV requires including variables that can help verify the conformity with economic theory (Mitchell & Carson, 1989) and knowledge of concerned goods (Carson & Hanemann, 2005). We follow these principles by including income and saving as covariates in the model. Similarly, we verify farmers' knowledge of the good by including variables that measure their propensity to sell and to purchase maize, measured by the ratio of sold/produced maize, and the ratio of purchased/produced maize.

Furthermore, the combined use of WTA and WTP tests the convergent validity criteria as proposed by Carson (2000) and Venkatachalam (2004). Theoretically the difference between WTP and WTA should be small and unimportant as long as income effects and transactions cost are not large (Carson, 2000).

Some households state that they would not purchase or sell maize with particular levels of insect damage at any price in the state preference experiment. In this situation the zero price elicitation is a true measure of a household's willingness to pay or accept, and such a response suggests that farmers place a value of zero on maize of that damage level. Therefore, while our main models are estimated via OLS, for robustness we compare the OLS estimates with estimates from a tobit and a double hurdle. The latter two models explicitly deal with a non-trivial number of zero responses in the dependent variable. Tables 9 and 10 in Appendix present the results when the stated preference modes are estimated via tobit and double hurdle. We find that there is no substantive difference in the coefficient estimates and standard errors between OLS and these two alternative estimators, suggesting that OLS generates reliable coefficient estimates in this context.

Since we ask each farmer to elicit his or her price preferences for five categories of maize damage in the state preference experiment, we end up with five observations for each respondent household. We cluster the standard errors at the individual-level to make them robust to potential serial correlation and heteroskedasticity.

5. RESULTS

(a) *Descriptive statistics for revealed preference models*

Table 1 presents the descriptive statistics for the variables used in the RP analysis. The table shows that only 20% of farmers participate in sale transactions during the lean period compared to 44% who purchase maize during the lean period, which is not surprising. Given the mean purchase price is nearly 50% higher than the mean sale price, it is likely that farmers pay a higher price for purchased maize than they receive for maize they sell. Traders represent the main market partners in both sale and purchase transactions. Wholesale traders buy maize from farmers mainly during the early post-harvest period, whereas retail traders operate throughout the entire post-harvest season. However, retailers are normally the only traders from whom farmers buy maize in local and district markets.

Table 2 shows the percentage of observed maize sales and purchases made by smallholders in our sample that falls into each of the five levels of damage (0%, 10%, 20%, 30%, and 50%). The table suggests that high quality maize (0% damage) is the most commonly traded damage level for both sale and purchase transactions during the early post-harvest period, as expected. Indeed, maize with 0% damage level represents 53% of 197 sale transactions during the early post-harvest period and 55% of 75 purchase transactions.

Table 1. *Descriptive statistics for the sample*

Variables	Full sample		Sale		Purchase	
	Mean	Sd.	Mean	Sd.	Mean	Sd.
=1 if HH participates in lean period (%)	–	–	20	–	44	–
Maize price (F CFA/kg)	–	–	163	56	220	90
=1 if HH buys from/sells to a trader (%)	–	–	87	–	77	–
=1 If HH buys from/sells to a farmer (%)	–	–	4	–	18	–
=1 if HH buys from/sells to government (%)	–	–	2	–	5	–
=1 if HH buys from/sells to other partner (%)	–	–	7	–	–	–
Age	42	13	42	13	45	14
Household size	10	6	10	6	9	5
Full income (× 10,000 F CFA)	79	294	69	141	102	456
Saving (× 10,000 F CFA)	8	23	10	27	5	13
Quantity sold (kg)	1,417	7,180	2,056	4,262	480	1,111
Quantity purchased (kg)	78	160	65	145	183	196
Distance (km)	6	5	6	5	6	4
Ration sale/production (%)	41	53	60	55	24	28
Ratio purchase/consumption (%)	21	2	12	22	52	2
=1 if HH head attended school (%)	37	–	35	–	36	–
=1 if HH head is female (%)	10	–	9	–	12	

Note: The symbol (–) indicates Not Applicable; 1 US $ = 512 F CFA at the time of the survey.

Table 2. *Level of insect damage in marketed maize for RP transactions*

Maize quality	% of Observed sales		% of Observed purchases	
	Early PH	Lean	Early PH	Lean
0% Damage	53	31	54	49
10% Damage	23	49	28	29
20% Damage	11	4	5	10
30% Damage	7	14	5	7
50% Damage	6	2	8	5
Number of observations	197	49	75	59

Note: All columns sum to 100%.

Conversely, maize with a higher damage level (10% damage and above) is somewhat more prevalent during the lean period. Maize with damage levels greater than zero accounts for nearly 70% of sale transactions in the lean period, but only 51% of purchase transactions during the same period. However, there are very few recorded transactions for extremely damaged maize (50% damage), which suggests that extremely damaged maize is less marketable.

(b) *Descriptive statistics for stated preference models*

Table 3 presents the mean price for each level of insect-damaged maize in the SP and RP models. These results suggest that as insect damage increases there is a decrease in farmers' WTP for purchasing maize, and WTA for selling maize. Farmers' price elicitation is also consistent with theory. The ratio between SP and RP is shown on the far right column of Table 3. It shows that higher mean value of the WTA relative to the mean sale price of the RP confirms that the owner overestimates the value of the maize that he or she will hypothetically sell. Instead, the mean value of the WTP is close to or lower than the RP mean price for purchases, as expected (Carson, Flores, Martin, & Wright, 1996).

These results could also indicate that the presence of high insect damage provides information about unobservable maize quality that is not accounted for in market transactions. The ratio SP/RP is above 1 for good maize quality (0% and 10% damage) for sale transactions. Thus, farmers may believe that markets do not reward their efforts to preserve maize quality during the lean season. In this sense when they are asked to purchase maize in the SP, farmers are willing to pay a fair price for high maize quality (0% damage) since the ratio SP/RP is close to 1. However, when insect damage accumulates they are willing to pay substantially less than what they actually pay in the RP. These results may suggest that farmers believe market prices do not reflect the true value of maize quality.[3] The ratio SP/RP for high damage maize is consistent with this interpretation in sale transactions, as it reveals that farmers are willing to accept lower prices than what the markets pay in the RP.

Table 3. *Price (in F CFA/kg) for different levels of insect damage in revealed preference (RP) and stated preference (SP) models*

Maize damage	SP		RP				Mean ratio*
	Lean Period		Early PH Period		Lean Period		SP/RP
	Mean	SD	Mean	SD	Mean	SD	
	WTA		Sale				
0% Damage	214	91	160	54	172	20	1.24
10% Damage	192	88	174	75	171	32	1.12
20% Damage	163	90	164	69	200	00	0.82
30% Damage	154	85	140	43	175	56	0.88
50% Damage	123	81	133	32	167	00	0.74
	WTP		Purchase				
0% Damage	213	83	257	118	206	48	1.03
10% Damage	191	78	217	89	228	91	0.84
20% Damage	165	73	164	55	173	41	0.95
30% Damage	160	73	193	33	204	34	0.78
50% Damage	128	70	158	63	190	69	0.67

Note: SD = Standard deviation; 1 US $ = 512 F CFA at the time of the survey.
* The ratio considers the lean season value for the RP.

(c) *Estimation results for the revealed preference sale model*

Table 4 presents the results for the model of factors affecting prices that farmers receive when selling their maize. Columns 1, 3, and 5 show the parsimonious results where only level of insect damage and a constant are included in the model, while columns 2, 4, and 6 show the results with a full set of controls. The results are generally consistent across specifications, and indicate that farmers receive price discounts when they sell insect-damaged maize.

In columns 1 and 2, the dependent variable is the maize price in F CFA/kg, and the impact of insect damage on maize price is estimated using a set of 4 dummy variables with 0% insect damage as the base. The parsimonious regression in column 1 shows that only the variable for 50% insect damage is statically significant (p value = 0.04). In column 2 the price discount for maize with insect damage becomes statically significant when insect damage reaches 30% of the sample. These results suggest that maize buyers tolerate insect damage as low as 20% during sale transactions without requiring the maize to be discounted. Farmers whose marketed maize contains 30% insect damage receive about 15 F CFA/kg ($ 0.029/kg) less than farmers selling high quality maize (0% damage). When insect damage reaches 50% of maize sold, the discount increases to 25 F CFA/kg ($ 0.05) and this effect is also statistically significant (p-value = 0.04).

In column 3 through column 6 of Table 4 we treat the level of insect damage as a continuous variable to generate a linear damage slope. The dependent variable is also converted to log of maize price. The coefficient on the damage slope in columns 3 and 4 suggests that a 10% increase in damage level entails a 3.3–3.4% price discount on average that is statistically significant in both specifications (p-value < 0.05).

Columns 5 and 6 of Table 4 show the results where insect damage is interacted with the lean period dummy variable, which allows the damage effects on maize price to vary between early PH and lean periods. In column 5 the results indicate that in the early PH period a 10% increase in insect damage lowers maize price by 4.1% (p-value = 0.01). However, in the lean period the price discount for insect damage is minimal as a 10% increase in insect damage reduces the maize price by just 0.2%, as the joint F-test between the level of damage coefficient, and the interaction term between the level of damage and the lean season dummy is statistically significant at the 5% level (p-value = 0.03). This finding provides evidence to reject hypothesis 2, as the average price discount is not the same in the early post-harvest period as it is in the lean period for maize with the same level of damage.

In column 6 the results are very similar as a 10% increase in insect damage during the early PH period reduces maize price by 3.7% (p-value = 0.01). But in the lean period a 10%

Table 4. *Factors affecting price of sold maize (F CFA/Kg) in the reveled preference model*

Dependent variable	(1) Price			(2) Price			(3) Log (Price)			(4) Log (Price)			(5) Log (Price)			(6) Log (Price)		
	Coef		$P > t$	Coef		$P > t$	Coef		$P > t$	Coef.		$P > t$	Coef.		$P > t$	Coef.		$P > t$
Damage slope							−0.34	**	(0.02)	−0.33	***	(0.01)	−0.41	**	(0.01)	−0.37	***	(0.01)
Damage slope * lean period													0.39		(0.16)	0.29		(0.26)
10% Damage	1.35		(0.83)	0.89		(0.88)												
20% Damage	−13.95		(0.15)	−10.91		(0.27)												
30% Damage	−11.14		(0.28)	−14.93	*	(0.07)												
50% Damage	−25.35	**	(0.04)	−25.12	**	(0.04)												
= 1 if transaction is in lean period				11.03	**	(0.05)				0.10	***	(0.01)	0.10	**	(0.06)	0.07		(0.16)
=1 if HH head attended school				12.81	**	(0.02)				0.07	*	(0.07)				0.07	*	(0.07)
Age				2.65	*	(0.06)				0.02	*	(0.07)				0.02	*	(0.08)
age square				−0.03	*	(0.08)				−2E−04	*	(0.10)				−2E−04		(0.11)
= 1 if HH head is female				−7.59		(0.35)				−0.02		(0.68)				−0.02		(0.68)
Household size				−1.32	***	(0.00)				−0.01	**	(0.02)				−0.01	**	(0.02)
Income (× 10,000 F CFA)				0.04	**	(0.03)				2.E−04	***	(0.00)				2.E−04	***	(0.01)
Saving (× 10,000 F CFA)				0.26	***	(0.00)				2.E−03	***	(0.00)				2.E−03		(0.00)
Quantity sold				0.00		(0.80)				4.E−06		(0.41)				4E−06		(0.41)
Ratio sale/consumption				−2.66		(0.68)				−0.03		(0.47)				−0.03		(0.45)
Ratio purchase/production				0.47		(0.98)				−0.03		(0.76)				−0.03		(0.82)
Distance from market (Km)				0.97		(0.13)				2.E−03		(0.52)				2.E−03		(0.51)
= 1 if sold to traders				−13.72		(0.31)				−0.04		(0.60)				−0.03		(0.63)
= 1 if sold to government				−14.99		(0.45)				−0.07		(0.54)				−0.10		(0.36)
= 1 if sold to farmers				−24.23		(0.24)				−0.14		(0.27)				−0.14		(0.28)
Constant	175.53	***	(0.00)	117.40	***	(0.00)	5.17		(0.00)	4.78	***	(0.00)	5.11	***	(0.00)	4.80	***	(0.00)
N		246			246			246			246			246			246	
R^2		0.43			0.55			0.38			0.51			0.42			0.51	

Note: *, **, ***, indicate that corresponding coefficients are statistically significant at the 10%, 5%, and 1% level, respectively; 1 US $ = 512 F CFA at the time of the survey; Department dummies are not shown in the table; the t-test for difference between the estimates of the damage levels in column 1 and 2 is statistically significant between 10% and 30% damage level and between 10% and 50%.

increase in insect damage only reduces maize price by 0.8%, as the joint F-test between the level of damage coefficient, and the interaction term between the level of damage and the lean season dummy is statistically significant at the 5% level (p-value = 0.04). These results indicate that the price discount for lower quality maize is substantial in the early post-harvest period, but is much smaller in the lean season. This finding makes sense as scarcity in the lean season makes people desperate, which in turn pushes prices up and makes them care less about quality. Our results are consistent with Compton *et al.*'s (1998) findings in Ghana that traders tolerate higher levels of insect damage later in the year when maize became scarce.

(d) *Estimation results for the stated preference sale model*

Subsequent tables are presented in the same format as Table 4, with the specifications showing a full set of variables following the corresponding parsimonious specifications.

The results for the stated preference for sale estimates in Table 5 suggest that farmers are willing-to-accept a discounted price for every level of insect damage. Column 1 presents the parsimonious regression with the dependent variable, price in F CFA/kg. Results in column 1 indicate that the discount is statistically significant for every level of damage (p value = 0.00). The price discount is nearly 0.9% for 1% insect damage, as shown in column 3 where the dependent variable is log price. In addition, households' characteristics have no effect on the discount, since the results of the discount slope are the same when the full set of variables are introduced in columns 2 and 4.[4, 5]

We also find other drivers of farmers' WTA that can serve the internal validity test for the SP. For instance, household size has a negative and statistically significant effect on price (p-value < 0.05) in column 2 of Table 5. One possible explanation might be that larger households interact more frequently in the market for cash needs to the extent that they provide more realistic estimation of sale prices.

(e) *Estimation results for the revealed preference purchase model*

Table 6 indicates that farmers discount prices depending on the maize quality purchased in markets. In the parsimonious regression in column 1, the negative signs of the coefficients are generally what we would expect for a consumer purchasing low quality maize. But the discount coefficients are marginally statistically significant for 50% damage level (p-value = 0.11). Controlling for other transaction characteristics in column 2 does not modify substantially the magnitude of the discount coefficients, but does modify the level of the statistical significance. The price discount is no longer significant at any level of insect damage. These results could mean farmers are not concerned about the quality of purchased maize because they have little choice but to pay what the market offers when they run out of stock, regardless of quality.

In columns 3 and 4, we use the log price to determine the damage slope during purchase transactions. In column 3, the results indicate that a 10% increase in maize damage lowers the average price farmers are willing-to-pay by 2.4%, but this damage slope remains marginally significant (p-value = 0.11). When we account for transaction characteristics in column 4 the discount for a 10% increase in maize damage is 2.6%, and the statistical significance remains marginally significant (p-value = 0.12).

Results from columns 5 and 6 in Table 6 reveal that when the damage slope is interacted with the lean season dummy, the discount for purchases in the early post-harvest period is higher than it is in the lean period. In column 5, a 10% increase in insect damage translates to a 4.4% reduction in maize price during the early post-harvest period, but the joint effect suggests that during the lean period, a 10% increase in insect damage translates to just a 0.5% decrease on average.

Table 5. *Factors affecting price of sold maize (F CFA/kg) in the stated preference model*

Dependent variable	(1) Price			(2) Price			(3) Log (Price)			(4) Log (Price)		
	Coef.		$P > t$	Coef		$P > t$	Coef		$P > t$	Coef.		$P > t$
Damage slope							−0.88	***	(0.00)	−0.88	***	(0.00)
10% Damage	−20.65	***	(0.00)	−20.65	***	(0.00)						
20% Damage	−46.52	***	(0.00)	−46.52	***	(0.00)						
30% Damage	−51.14	***	(0.00)	−51.15	***	(0.00)						
50% Damage	−78.77	***	(0.00)	−78.46	***	(0.00)						
=1 if HH head attended school				3.69		(0.44)				0.03		(0.16)
Age				1.74		(0.12)				0.01	*	(0.07)
age square				−0.02		(0.13)				0.00	*	(0.10)
=1 if HH head is female				−6.64		(0.46)				0.01		(0.66)
Household size				−1.24	**	(0.03)				−3E−03		(0.16)
Income (× 10,000 F CFA)				0.01		(0.15)				3E−05		(0.45)
Saving (× 10,000 F CFA)				0.09		(0.17)				4E−04		(0.22)
Quantity sold				−5E−04		(0.46)				−4E−06		(0.18)
Ratio sale/consumption				−5.64		(0.23)				−0.02		(0.48)
Ratio purchase/production				1.25	*	(0.07)				0.01	**	(0.03)
Distance from market (km)				1.18	*	(0.06)				3E−03		(0.38)
Constant	206.79	***	(0.00)	163.06	***	(0.00)	5.27	***	(0.00)	5.05	***	(0.00)
N	1756			1756			1698			1698		
R^2	0.43			0.45			0.47			0.48		

Note: *, **, ***, indicate that corresponding coefficients are statistically significant at the 15%, 5%, and 1% level, respectively; 1 US $ = 512 F CFA at the time of the survey; Department dummies are not shown in the table; the t-test for difference between the estimates of the damage levels in columns 1 and 2 is statistically significant between each pair comparison.

Table 6. *Factors affecting price of purchased maize (F CFA/kg) in the revealed preference model*

Dependent variable	(1) Price			(2) Price			(3) Log (Price)		(4) Log (Price)			(5) Log (Price)			(6) Log (Price)		
	Coef		$P > t$	Coef		$P > t$	Coef.	$P > t$	Coef.		$P > t$	Coef.		$P > t$	Coef.		$P > t$
Damage slope							−0.24	(0.11)	−0.26		(0.12)	−0.44	*	(0.06)	−0.45	*	(0.06)
Damage slope * lean period												0.39		(0.19)	0.35		(0.23)
10% Damage	−0.41		(0.97)	7.42		(0.50)											
20% Damage	−5.88		(0.65)	−15.27		(0.31)											
30% Damage	−20.48		(0.24)	−26.26		(0.20)											
50% Damage	−22.75		(0.11)	−24.95		(0.20)											
=1 if transaction is in lean period				−5.76		(0.56)			−0.01		(0.75)	−0.03	(0.56)		−0.05	(0.31)	
=1 if HH attended school				12.66		(0.20)			0.05		(0.21)				0.05		(0.24)
Age				0.70		(0.70)			0.00		(0.88)				0.00		(0.88)
age square				−0.01		(0.69)			0.00		(0.91)				0.00		(0.91)
=1 if HH head is female				39.27	*	(0.09)			0.11		(0.12)				0.11		(0.13)
Household size				−1.36		(0.11)			−5E−03		(0.15)				−5E−03		(0.17)
Income (× 10,000 F CFA)				−0.01		(0.35)			−7E−05	*	(0.10)				−8E−05	*	(0.07)
Saving (× 10,000 F CFA)				−0.60	***	(0.01)			−4E−03	***	(0.00)				−4E−03	***	(0.00)
Quantity purchased (kg)				−0.04		(0.23)			−2E−04		(0.19)				−2E−04		(0.19)
Ratio sale/production				1.78		(0.92)			0.02		(0.75)				0.03		(0.69)
Ratio purchase/production				1.34		(0.36)			0.01		(0.43)				0.01		(0.38)
Distance from market (km)				3.21	*	(0.08)			0.01		(0.12)				0.01		(0.12)
=1 if purchased from other farmers				−15.42		(0.24)			−0.05		(0.45)				−0.05		(0.42)
=1 if purchased from government				−140.79	***	(0.00)			−0.65	***	(0.00)				−0.66	***	(0.00)
Constant	209.76	***	(0.00)	195.11		(0.00)	5.33	(0.00)	5.39	***	(0.00)	(5.34)	***	(0.00)	5.41	***	(0.00)
N	134			134			134		134			134			134		
R^2	0.45			0.63			0.51		0.70			0.52			0.71		

Note: *, **, ***, indicate that corresponding coefficients are statistically significant at the 10%, 5%, and 1% level, respectively; 1 US $ = 512 F CFA at the time of the survey; Department dummies are not shown in the table; the t-test for difference between the estimates of the damage levels in columns 1 and 2 is statistically significant between 10% and 30% damage level and between 10% and 50%.

Table 7. *Factors affecting price of purchased maize (F CFA/kg) in the stated preference model.*

Dependent variable	(1) Price			(2) Price			(3) Log (Price)			(4) Log (Price)		
	Coef		P > t	Coef		P > t	Coef.		P > t	Coef.		P > t
Damage slope							−0.90	***	(0.00)	−0.90	***	(0.00)
10% Damage	−23.02	***	(0.00)	−23.02	***	(0.00)						
20% Damage	−51.70	***	(0.00)	−51.70	***	(0.00)						
30% Damage	−58.60	***	(0.00)	−58.61	***	(0.00)						
50% Damage	−90.63	***	(0.00)	−90.59	***	(0.00)						
=1 if HH head attended school				4.37		(0.46)				0.01		(0.73)
Age				1.79		(0.14)				−6E−05		(0.99)
Age square				−0.02		(0.19)				−6E−08		(1.00)
=1 if HH head is female				−7.58		(0.43)				−0.01		(0.74)
Household size				−1.12	**	(0.03)				−4E−03	**	(0.04)
Income(× 10,000 F CFA)				0.02	**	(0.02)				7E−05	**	(0.04)
Saving (× 10,000 F CFA)				−0.03		(0.69)				1E−04		(0.76)
Quantity purchased				0.01		(0.65)				−4E−05		(0.65)
Ratio sale/production				−7.95		(0.16)				−0.07	***	(0.01)
Ratio purchase/production				−1.11		(0.24)				0.02	*	(0.06)
Distance from market (km)				0.42		(0.59)				5E−04		(0.88)
Constant	180.77	***	(0.00)	152.17	***	(0.00)	5.12	***	(0.00)	5.21	***	(0.00)
N		1756			1756			1620			1620	
R^2		0.38			0.39			0.51			0.52	

Note: *, **, ***, indicate that corresponding coefficients are statistically significant at the 10%, 5%, and 1% level, respectively.
1 US $ = 512 F CFA at the time of the survey; Department dummies are not shown in the table; the t-test for difference between the estimates of the damage levels in columns 1 and 2 is statistically significant between each pair comparison.

In column 6, a 10% increase in insect damage in the early post-harvest season, reduces maize price by 4.5% on average, but during the lean period a 10% increase in insect damage reduces maize price by 1.0% on average. However, we cannot make strong statistical inference for the price discount during the lean season in this specification because the joint F-test for the level of damage and the interaction term between level of damage and the lean season dummy is not statically significant in columns 5 and 6 (p value = 0.17).

Table 6 also provides insights about the effects on purchase prices of some household and market characteristics. The effect of household savings is highly significant across all columns of the table, whereas households' income effect is significant only in the log-linear estimation in columns 4 and 6. The sign of these coefficients shows that wealthier households pay less for maize quality, but the magnitude of the effect is small. Farmers who purchase maize from the government pay a much lower purchase price and this effect is highly statistically significant. Farmers who have access to the government market are able to purchase maize at a 65% discount or on average 140 F CFA lower than the market average. However, few farmers buy from this market channel mainly because there are high transport and transaction costs to access government shops, which are generally located far from rural villages.

(f) *Estimation results for the stated preference purchase model*

Results in Table 7 show that farmers are willing-to-pay less for maize that has more damage. In the parsimonious specification shown in column 1, the discount is statistically significant for every level of insect damage (p-value = 0.00). Likewise, the quality slope estimation in column 3 shows that a 10% increase in insect damage generates 9.0% price discount. We find little effect if any of household characteristics on the quality valuation in the WTP model. Indeed, when we control for households' characteristics in columns 2 and 4, the coefficient on the damage dummies and the damage slope are almost unchanged compared to their parsimonious regressions in columns 1 and 3, respectively.[6,7]

Table 7 also provides evidence of the internal validity of the WTP estimation. First, the results are consistent with economic theory. Wealthier households are likely to elicit a higher willingness-to-pay for maize quality, even though the income effect is small. Income elasticity for demand is indeed positive for maize which is a normal good (Carson & Hanemann, 2005). In contrast, households with more members are willing to pay less for identical maize quality suggesting that farmers with higher family expenses might be more price-cautions. Second, the positive coefficient for the purchase/production ratio indicates that the more the household depends on purchases for food consumption, the more the household head is willing-to-pay for maize. Conversely, a household with a larger propensity-to-sell (denoted by a higher ratio of sales/production) is less willing-to-pay a high price to consume maize. We also observe a similar effect for the saving variable most likely because farmers with larger savings are more likely to be maize sellers than buyers.

6. CONCLUSION

This article uses data from a random sample of 360 maize farmers from Benin to estimate the extent to which insect damage affects the price that farmers' in SSA receive when they sell maize and the price that they pay when they purchase maize. We also test whether or not there is a price discount in the early post-harvest period when maize is plentiful, compared to the lean period when maize is scare. This study builds upon a recent meta-analysis by Affognon *et al.* (2015) that describes quality loss as one of the major post-harvest challenges that farmers in SSA face. The findings from this study add to the existing literature by helping to explain why many smallholders in SSA sell maize at harvest and do not invest in modern storage technology that can preserve maize quality for later in the post-harvest season.

The main results of this article suggest that there is a price discount for insect-damaged maize in Benin. The size of the price discount varies depending on the evaluation method (revealed preference *vs*. stated preference) and side of the market transaction (sales *vs*. purchases). Farmers provide the same magnitude of price discounts for the WTA and WTP, but the SP estimates are almost three times those of the RP.

Our RP results for maize sales also provide some evidence to support the idea that the average price discount is not the same in the early post-harvest period as it is in the lean period for maize with the same level of damage. This suggests that when there is sufficient maize on the market immediately after harvest, people have quality maize available to them and subsequently discount maize that has been damaged by insects. Conversely, in the lean season people become desperate and do not have the luxury to select their maize based on quality. This result is intuitive and it reflects the dire food security situation that many farm households who do not produce enough food to meet their consumption needs face in the lean season. Our results are consistent with an earlier stated preference focus group study of maize traders in Ghana (Compton *et al*., 1998). However, to our knowledge the present study is the first study to empirically quantify this discount using revealed preference data from smallholder farmers in SSA.

The results of our study also add to other recent studies that estimate how unobservable maize quality attributes such as aflatoxins affect a farmer's market participation decision. Hoffmann and Gatobu (2014) infer that unobservable maize quality attributes might help explain why many farmers in SSA remain semi-subsistence, and only purchase maize from the market when necessary. We find larger discounts for visibly damaged grain in the SP compared to the RP models when farmers buy and sell maize. This suggests that in a hypothetical SP context, farmers are concerned about visible insect damage and the effect it has on price, but their observed behavior in the RP experiment suggests that these discounts may in fact be smaller. We also find that the difference between SP and RP results is larger at higher levels of insect damage. This may mean that in a SP situation farmers associate higher levels of observable insect damage with unobservable quality measures such as aflatoxins. However, the smaller relative damage slope in our RP model indicates that in situations of food scarcity, such as in the lean period, even visible characteristics like insect damage matter less in a household's decision making process.

Our results also indicate that farmers who might otherwise want to store maize with the intention of selling it in the lean period, currently have little incentive to invest in effective storage technologies to preserve quality. Rural maize markets in Benin seem to have a higher tolerance for lower quality maize in the lean period, as reported by Affognon *et al.* (2015). Therefore, farmers have less incentive to preserve good quality maize to get a higher price when they sell it. This creates a vicious circle where farmers do not protect their stored maize from insects, resulting in large post-harvest losses that further exacerbate maize scarcity. In turn, the scarcity of maize and prevalence of insect damage in the lean period means that farmers who must purchase maize in the lean season for food security will purchase maize of whatever quality is available in the market.

The results of our study lead to two main recommendations. First, since price discounts exist in the early post-harvest period when maize is plentiful, it is important to help farmers increase productivity and output that will extend the plentiful season further into the marketing year. Doing so requires promoting the adoption of modern fertilizers and improved seeds to smallholder farmers along with providing them with better information on production estimates and prices.

Second, promoting the adoption of improved storage technology can enhance farmers' ability to store more good quality maize at harvest to consume and sell in the lean season. With an increase in the quantity and quality of maize available in the lean period, we hypothesize that the price discounts observed in the early post-harvest period would also become present in the lean period. As a result, farmers who sell good quality maize in the lean season will experience an income gain, which may incentivize them to invest in modern inputs such as inorganic fertilizer and improved seed the next year. This relationship has been observed in a recent study in Malawi (Ricker-Gilbert & Jones, 2015). Adoption of better storage technology leading to adoption of better production technology can help break the low maize productivity, and low maize quality cycle that exists for many smallholder farmers in SSA. In addition, with more maize produced and better storage technology households are less likely to be forced into purchasing poor quality maize during the lean season when food security concerns become acute.

NOTES

1. The SP approach used in the present study is an open-ended questionnaire about only one characteristic of a private good that respondents are very familiar with. Carson and Hanemann (2005) contend that incentives for strategic behavior, such as cheap talk and free-riding, are absent for private goods and therefore do not have a differential effect on CV for stated preference experiments. Kealy and Turner (1993) find that there is no difference in WTP with open-ended contingent valuation and closed-ended contingent valuation for private goods. Mitchell and Carson (1989) contend that the open-ended CV may work in cases where the respondents are familiar with the concept of paying for the good.

2. Insect damage takes times to develop, and only becomes apparent one or two months after harvest (Boxall, 2002).

3. The true value of maize quality corresponds not only to observable but also unobservable characteristics such as aflatoxin. The level of insect damage can be informative of storage practices from which farmers may assume there are other unobservable quality issues. Hell, Cardwell, Setamou, and Poehling (2000) find that the mean aflatoxin content of maize infested with pests was significantly higher than maize free of pests. Diener *et al*. (1987) indicate that the presence of insect damage increases the risk of aflatoxin development.

4. The estimation with the sample restricted only to maize sellers and non-sellers does not yield substantial difference in the magnitude and the statistical significance of the coefficient estimates. These results are available upon request.

5. There is no substantial change in the magnitude and the statistical significance of the coefficient estimates when individual-level fixed effects and random effects are used as estimation procedures. Results using these estimators are available upon request.

6. The estimation with the sample restricted only to maize buyers and non-buyers does not yield substantial difference in the magnitude and the statistical significance of the coefficient estimates. These results are available upon request.

7. There is no substantial change in the magnitude and the statistical significance of the coefficient estimates when individual-level fixed effects and random effects are used as estimation procedures. Results using these estimators are available upon request.

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APPENDIX

Table 8. *Heckman selection correction for the revealed preference models*

Dependent variable	Revealed preference for sales						Revealed preference for purchases					
	Selection equation (Probit) (1 = HH sold Maize)			Structural equation (OLS) (Price F CFA/kg)			Selection equation (Probit) (1 = HH bougt Maize)			Structural equation (OLS) (Price F CFA/ kg)		
	Coef.		$P > t$	Coef.		$P > t$	Coef.		$P > t$	Coef.		$P > t$
10% Damage				1.79		(0.76)				8.01		(0.51)
20% Damage				−11.95		(0.16)				−33.63		(0.11)
30% Damage				−20.83	**	(0.02)				−26.10		(0.24)
50% Damage				−18.80	*	(0.09)				−1.48		(0.95)
=1 if transaction is in lean period				5.63		(0.39)				6.12		(0.60)
=1 if HH head attended school	−0.20		(0.23)	18.04	***	(0.00)	−0.14		(0.41)	22.65	*	(0.09)
Age	−0.04		(0.29)	3.16	***	(0.01)	−0.03		(0.37)	5.67	**	(0.05)
Age square	3.40E−04		(0.36)	−0.03	***	(0.01)	3.90E−04		(0.30)	−0.06	**	(0.05)
=1 if HH head is female	−0.33		(0.21)	−9.50		(0.33)	−0.07		(0.81)	56.53	***	(0.01)
Household size	−0.03	**	(0.04)	−1.49	***	(0.01)	0.01		(0.69)	−1.48		(0.22)
Income(× 10,000 F CFA)	−2.86E−04		(0.37)	0.05	***	(0.00)	2.13E−04		(0.55)	−0.02		(0.26)
Saving (× 10,000 F CFA)	0.01	*	(0.08)	0.22	*	(0.09)	−3.19E−03		(0.43)	−0.97	**	(0.03)
Distance from market (km)	0.01		(0.42)	1.19	*	(0.08)	−0.03	*	(0.07)	−15.69		(0.49)
Quantity traded (sold/purchased)				−9.86E−05		(0.90)				−0.03		(0.41)
Ratio sale/production				−4.07		(0.47)				−15.69		(0.49)
Ratio purchase/production				1.77		(0.91)				0.74		(0.71)
=1 if market partner is a traders				−28.59	***	(0.00)						
=1 if market partner is government				−27.34		(0.17)				−17.10		(0.23)
=1 if market partner is a farmer				−23.85		(0.12)				−134.41	***	(0.00)
Exclusion Var. : Area other than maize	0.13	**	(0.05)				−0.21	***	(0.00)			
Inverse Mills Ratio				2.08		(0.94)				−0.21	***	(0.00)
Constant	1.00		(0.26)	124.78	***	(0.00)	1.10		(0.21)	102.81		(0.15)
N				357.00						356.00		
Rho				0.06						−0.86		
Wald-Chi2				280.63						118.42		

Note: *, **, ***, indicate that corresponding coefficients are statistically significant at the 10%, 5%, and 1% level, respectively; 1 US $ = 512 F CFA at the time of the survey; Department dummies are not shown in the table.

Table 9. *Robustness check: Alternative estimators used to estimate factors affecting price of sold maize (F CFA/kg) in stated preference model*

	OLS (main results, as shown in Table 5)			Tobit			Double Hurdle					
							Hurdle 1: Probit			Hurdle 2: Truncated Regression		
	Coef.		$P > t$	Coef.		$P > t$	Coef.		$P > t$	Coef.		$P > t$
10% Damage	−20.65	***	(0.00)	−20.75	***	(0.00)	−0.01		(0.24)	−19.47	***	(0.00)
20% Damage	−46.52	***	(0.00)	−46.80	***	(0.00)	−0.02	**	(0.05)	−44.98	***	(0.00)
30% Damage	−51.15	***	(0.00)	−51.51	***	(0.00)	−0.03	**	(0.02)	−48.78	***	(0.00)
50% Damage	−78.46	***	(0.00)	−79.58	***	(0.00)	−0.05	***	(0.00)	−71.52	***	(0.00)
=1 if HH head attended school	3.69		(0.44)	3.42		(0.48)	−0.03	*	(0.06)	8.58	**	(0.03)
Age	1.74		(0.12)	1.78		(0.12)	0.00		(0.79)	1.72	**	(0.04)
Age square	−0.02		(0.13)	-0.02		(0.14)	0.00		(0.74)	−0.02	*	(0.06)
= 1 if HH head is female	−6.64		(0.46)	−6.97		(0.45)	−0.03		(0.17)	0.74		(0.91)
Household size	−1.24	**	(0.03)	−1.32	**	(0.04)	0.00	**	(0.04)	−0.80	**	(0.04)
Income(× 10,000 F CFA)	0.01		(0.15)	0.01		(0.15)	3E−06		(0.85)	0.01	*	(0.08)
Saving (× 10,000 F CFA)	0.09		(0.17)	0.09		(0.16)	4E−04		(0.22)	0.05		(0.37)
Quantity purchased	−5E−04		(0.46)	−4E−04		(0.56)	1E−05	*	(0.07)	−9E−04		(0.12)
Ratio sale/production	−5.64		(0.23)	−6.09		(0.22)	−0.03		(0.15)	−3.86		(0.30)
Ratio purchase/production	1.25	*	(0.07)	1.25	*	(0.07)	6E−04		(0.86)	1.25	**	(0.05)
Distance from market (Km)	1.18	*	(0.06)	1.20	*	(0.06)	9E−04		(0.69)	1.12	**	(0.05)
Constant	163.06	***	(0.00)	162.62	***	(0.00)						
N	1,756			1756			1756			1698		
R^2 or Pseudo R^2	0.45			0.05			0.17			1042.5[a]		

Note: *, **, ***, indicate that corresponding coefficients are statistically significant at the 10%, 5%, and 1% level respectively; [a]indicates the value for Wald Chi2; 1 US $ = 512 F CFA at the time of the survey; Department dummies are not shown in the table.

Table 10. *Robustness check: Alternative estimators used to estimate factors affecting price of purchased maize (F CFA/kg) in stated preference model*

	OLS (main results, as shown in Table 7)			Tobit			Double Hurdle: Hurdle 1: Probit			Double Hurdle: Hurdle 2: Truncated Regression		
	Coef.		*P* > *t*	Coef.		*P* > *t*	Coef.		*P* > *t*	Coef.		*P* > *t*
10% Damage	−23.02	***	(0.00)	−23.50	***	(0.00)	−0.04	***	(0.02)	−21.27	***	(0.00)
20% Damage	−51.70	***	(0.00)	−53.47	***	(0.00)	−0.10	***	(0.00)	−47.78	***	(0.00)
30% Damage	−58.61	***	(0.00)	−60.46	***	(0.00)	−0.10	***	(0.00)	−54.15	***	(0.00)
50% Damage	−90.59	***	(0.00)	−94.76	***	(0.00)	−0.15	***	(0.00)	−83.71	***	(0.00)
=1 if HH head attended school	4.37		(0.46)	5.01		(0.44)	0.02		(0.52)	4.04		(0.46)
Age	1.79		(0.14)	2.02		(0.12)	0.01		(0.14)	1.65		(0.13)
Age square	−0.02		(0.19)	−0.02		(0.17)	−6E−05		(0.21)	−0.01		(0.18)
=1 if HH head is female	−7.58		(0.43)	−7.60		(0.45)	−4E−03		(0.92)	−7.00		(0.42)
Household size	−1.12	**	(0.03)	−1.21	**	(0.03)	−3E−03		(0.27)	−1.03	**	(0.02)
Income(× 10,000 F CFA)	0.02	**	(0.02)	0.02	**	(0.02)	−2E−06		(0.94)	0.02	**	(0.02)
Saving (× 10,000 F CFA)	−0.03		(0.69)	−0.04		(0.69)	−2E−05		(0.96)	−0.03		(0.69)
Quantity purchased	0.01		(0.65)	0.01		(0.56)	2E−04		(0.19)	0.01		(0.65)
Ratio sale/production	−7.95		(0.16)	−7.62		(0.21)	0.02		(0.61)	−7.34		(0.16)
Ratio purchase/production	−1.11		(0.24)	−1.79	*	(0.10)	−0.01	***	(0.00)	−1.03		(0.24)
Distance from market (km)	0.42		(0.59)	0.35		(0.67)	−2E−03		(0.36)	0.39		(0.59)
Constant	152.17		(0.00)	147.64		(0.00)						
N		1,756			1756			1756			1756	
R^2 or Pseudo R^2		0.39			0.04			0.12			651.05[a]	

*Note:**, **, ***, indicate that corresponding coefficients are statistically significant at the 10%, 5%, and 1% level respectively; [a]indicates the value for Wald Chi2; 1 US $ = 512 F CFA at the time of the survey; Department dummies are not shown in the table.