Asymmetric Information and Food Safety: Maize in Kenya

Vivian Hoffmann
University of Maryland, College Park
vhoffmann@arec.umd.edu

Samuel Mutiga
Cornell University
skm88@cornell.edu

Jagger Harvey
Biosciences eastern and central Africa – International Livestock Research Institute Hub
J.Harvey@cgiar.org

Rebecca Nelson
Cornell University
rjn7@cornell.edu

Michael Milgroom
Cornell University
mgm5@cornell.edu

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mgm5@cornell.edu

When quality is not observable by prospective buyers, theory predicts that the quality of marketed goods will suffer, and the volume of trade will be depressed. Using data from more than 2,000 maize samples collected in four Kenyan provinces, we show that the presence of aflatoxin, an invisible and dangerous fungal contaminant, is not reflected in maize prices but does affect how maize is used. This apparent market failure reduces the quality of maize available on the market. In addition, we show that self-produced maize is a normal good. *JEL* codes: O12, O13, O15

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1. Introduction

Informal food markets in developing countries are characterized by limited information and an absence of regulation. While consumers are able to observe certain quality attributes at the time of purchase, information on taste and safety is generally unavailable. Contamination of agricultural produce with the fungal byproduct aflatoxin is caused by both environmental conditions and storage practices. The toxin is invisible and tasteless, though likely correlated with the unpleasant taste of mold. Consumption of high concentrations of aflatoxin can cause illness and even death, while low-level, chronic exposure is carcinogenic and has been linked to growth retardation in children. In Kenya, maize is generally sold as dried kernels, which must be cooked before they can be tasted. The presence or absence of aflatoxin contamination is thus both a credence attribute (unobservable by the consumer) and serves as a proxy for the experience attributes of illness and taste and (observable only through consumption)[1]. In this paper, we develop a model in which asymmetric information affects the quality of produce that is marketed versus retained for own consumption. We test the model's predictions with data from the informal maize market in Kenya, using aflatoxin contamination as a measure of quality.

The study of asymmetric information and its consequences in this market is motivated by two welfare concerns. First, aflatoxin is highly toxic to humans. Consumption of high levels can be fatal, and chronic exposure at lower levels increases the risk of liver cancer and is associated with impaired immune system function and growth faltering in children (Strosnider et al. 2006; Khlangwiset et al., 2011). Aflatoxin is produced by several species of fungi in the genus *Aspergillus*, particularly *A. flavus*. Growth of *A. flavus* and production of aflatoxin are facilitated by excessive heat, drought stress and pest attacks during crop development, and inadequate drying and poor storage conditions after harvest (Wilson and Payne, 1994; Hell et al., 2008). While it is not known whether *A. flavus* has a particularly unpleasant taste among molds, the presence of mold is generally associated with unpleasant taste. Once fungal growth has occurred, taste and safety are compromised even after subsequent drying and removal of visibly

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[1] Offering cooked samples prior to sale would be costly and logistically difficult, and has never been observed by the authors.

moldy kernels. Immediate post-harvest practices are therefore an important determinant of aflatoxin contamination, while the observable properties of maize once it reaches the market may tell consumers little about its taste or contamination with toxins.

The average volume of storage losses reported by small-scale farmers in Kenya is less than 1 percent (Stephens and Barrett, 2011). Maintaining volume is thus unlikely to be a strong driver of post-harvest practices. Preserving quality, on the other hand, may be an important consideration affecting the handling of maize intended for home consumption as food. To the extent that quality is rewarded by the market, one would expect care also to be taken with maize destined for sale. However, if there are aspects of quality that do not affect price, then rational farmers and downstream market actors will underinvest in the maintenance or improvement of these. In other words, to the extent that the cost of toxic contamination in the food supply is not borne by those whose practices influence its level, such contamination is an externality that will be oversupplied.

A second welfare concern is that low average quality among traded goods reduces the volume of transactions. In the context of developing country food markets, the low average quality of produce available on the market could lead farmers to grow food for their own needs rather than specializing in those crops in which they have a comparative advantage. According to a nationally representative household survey conducted in Kenya in 2005-2006, maize is grown by 93 percent of households engaged in agriculture (KNBS, 2006). This is despite the fact that other crops generally provide higher net returns (Tegemeo Institute, 1996). Heterogeneity in the quality of self-grown versus purchased commodities is one reason among several that the shadow price of self-grown food may diverge from the market price.[2]

The effects of information asymmetries could potentially be mitigated through repeated interactions and reputation effects. However, the structure of the Kenyan maize market does not lend itself to the development of strong reputation effects. Smallholder maize is generally purchased by small-scale assemblers or brokers, who aggregate maize

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[2] This point was made by Singh, Squire and Strauss (1986, p. 52). Other explanations for such a divergence include marketing transaction costs (de Janvry, Fafchamps, and Sadoulet 1991), and food price volatility (Fafchamps, 1992).

for sale on to wholesalers. Wholesalers then transport maize from surplus to deficit regions, exploiting spatial arbitrage opportunities. Finally, disassemblers in destination regions disaggregate this maize into smaller quantities for sale to consumers (Kirimi et al., 2011).

Even in the formal sector, maize in Kenya is not subject to aflatoxin testing, and maize sold in supermarkets has been found to exhibit contamination levels well above the current regulatory limit of 10 parts per billion (ppb) (Muriuki and Siboe, 1995).[3] Much higher levels of contamination have been detected in maize sold in informal markets. In 2004, a year in which 317 hospitalizations and 125 deaths due to acute aflatoxin poisoning were recorded in Kenya, 55 percent of samples purchased from informal markets in Eastern Province contained more than 20 ppb aflatoxin, 35 percent contained more than 100 ppb, and 7 percent had levels exceeding 1,000 ppb (Lewis et al., 2005). Given that maize is the primary staple grain for Kenyans, accounting for 65 percent of total staple food caloric intake and 36% of total food caloric intake (Kirimi et al., 2011), even relatively low levels of exposure may have significant negative health effects (Shephard, 2008).

Maize quality can vary greatly not only across farms, but also among cobs originating from a single farm, and even among kernels from a single cob (Whitaker, 2003). Heterogeneity in maize quality generally, and of aflatoxin contamination in particular, may arise due to variation in the nutrient content and water retention capacity of soil on a given farm (Blandino et al., 2008), in the extent to which the crop is affected by pests pre- and post-harvest, and in storage practices and conditions, for example drying time, removal of visibly moldy kernels, and whether a particular bag of maize is stored directly on a damp floor.

The consequences of asymmetric information in markets have been investigated in a number of empirical settings, including the market for used vehicles (Bond, 1982, 1984; Pratt and Hoffer, 1984; Lacko, 1986; Genesove, 1993; Sultan, 2008; Emons and Sheldon, 2009), slaves (Greenwald and Glasspiegel, 1983; Pritchett and Chamberlain, 1993), workers (Gibbons and Katz, 1991), baseball players (Lehn 1984), and livestock

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[3] Moisture content is regulated in the formal sector, and since moisture is correlated with fungal growth, this serves to reduce the level of aflatoxin in the formal maize market.

(Anagol, 2011). A common approach used in this literature is to compare the quality of assets that are traded with those that are retained by those initially holding them. For example, frequency or cost of repairs may be compared between vehicles purchased new and those purchased used. Lower average quality among traded goods, controlling for characteristics observable at the time of sale, is taken as evidence of a "lemons" market, as described in Akerlof's (1970) classic treatment of the subject.[4]

Our empirical approach is to first show that there is a dimension of quality, proxied by the presence of aflatoxin, which is not reflected in market prices, but which is observed by those holding the maize and thus determines the use to which grain is put. This suggests an information asymmetry, which, according to the model, should result in the quality of maize sold on the market being lower than that of maize retained by producer-consumers. We tested this prediction using more than 2,000 maize samples collected from consumers at 176 maize mills across Kenya. In addition, we used 2007 data from the Research on Poverty, Environment, and Agricultural Technologies (REPEAT) survey to test the model's implication that self-grown food is a normal good and thus more likely to be consumed by those with greater resources.

The remainder of the paper proceeds as follows. We begin by outlining a simple model of a farmer's decision over how to use the maize in her possession. We then describe the survey and maize quality data in Section 3. Section 4 describes the empirical strategy used and the results, and Section 5 concludes with a summary of findings and prospects for overcoming information asymmetries in this market.

2. Theoretical Framework

The quality of maize, some dimension of which is unobservable during a typical market transaction, is determined during the cultivation, harvest, and post-harvest stages of production. Farmers learn about the quality of their harvest by observing environmental conditions such as drought, excessive rains, and pest infestation during cultivation. In addition, farmers both influence and learn about the quality of their

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[4] This is the approach taken by Bond (1982, 1984), Sultan (2008) and Emons and Sheldon (2009) to study the market for used vehicles. Lehn (1984) uses a similar approach to analyze trades of professional baseball players.

produce through the practices they employ, particularly drying, sorting, and storage methods. Once maize is ready for consumption, perhaps the most important quality attribute—taste—can also be observed. Purveyors of maize thus have access to important information about the quality of the grain in their possession that is not available to potential buyers.

Consider a market for a food crop, characterized by a quality attribute q, which is not observable at the point of sale. The food crop is produced by an infinite number of farm households who also consume the crop. Households may be net buyers or net sellers of the food crop, and may in addition grow a cash crop, *c*. The model described below relies on two critical assumptions:

Assumption 1: Farmers have private information about the quality of food in their possession.

Assumption 2: Farmers have rational expectations about the quality of food available on the market.

Farmers maximize, over production and storage inputs, food sales, and purchases, the expected value of a linear utility function, which takes as its arguments the average quality of the food crop consumed, $\bar{q}$, and consumption of a numeraire good *x*,

$$Max_{\{A_{m,i}, m_{s,i}, m_{p,i}, s_i\}} \; EU = E[\bar{q}_i] + x_i \tag{1}$$

subject to

$$p_m \cdot m_{p,i} + x_i + p_s \cdot s_i \leq p_c \cdot c_i + p_m \cdot m_{s,i} \tag{2}$$

$$M_i \leq m_{h,i} + m_{p,i} - m_{s,i} \tag{3}$$

$$E[\bar{q}_i] = \frac{m_{h,i} - m_{s,i}}{M_i} \cdot \bar{q}_{r,i} + \frac{m_{p,i}}{M_i} \cdot E[q_p] \tag{4}$$

$$m_{h,i} = g_m(A_{m,i}) \cdot \varepsilon_{m,i} \tag{5}$$

$$c_i = g_c(A_i - A_{m,i}) \cdot \varepsilon_{c,i} \tag{6}$$

$$q_{h,i,k} = q(s_i, \varepsilon_{m,i}) + \varepsilon_{q,i,k} \tag{7}$$

The budget constraint described by equation (2) limits the total value of expenditures on purchased food $m_{p,i}$, the numeraire good x_i, and food crop storage costs s_i at price p_s, to be less than or equal to farm income. Income is derived from sales, c_i, of a quality-invariant cash crop at price p_c, and from sale of the food crop, $m_{s,i}$. Since the quality of the food crop is not observable by potential buyers, a single market price for the food crop, p_m, prevails.

As stated in equation (3), the sum of $m_{h,i}$, the amount harvested, and the amount purchased, $m_{p,i}$, less that which is sold, $m_{s,i}$, must equal at least the pre-determined, farmer-specific consumption requirement M_i. All farmers are assumed to meet their consumption requirement. Since utility is strictly increasing in both arguments, equations (2) and (3) bind with equality.

Equation (4) states that the expected average quality of food consumed, $\overline{q}_i$, is equal to the average of the quality retained for producer consumption, $\overline{q}_{r,i}$, and the expected quality of that purchased on the market, $E[q_p]$, weighted by the shares of total consumption constituted by food from each source.

The production functions of the food and cash crops are described by equations (5) and (6) respectively. Production of each crop $j \in \{m, c\}$ is an increasing concave function of the amount of land, A_j, on which it is planted, and is affected by a multiplicative, crop-specific disturbance term with a mean of one.[5]

The food crop is divisible into an arbitrarily large number of units, indexed by the subscript k. The quality of a given unit k of farmer i's harvest, denoted $q_{h,i,k}$, is heterogeneous within a single year and is described by the probability density function $f_{harvest,i}$. The same disturbance term that affects the quantity of the food crop also affects the quality of that farmer's harvest (equation 7). In addition, quality is positively influenced by the level of post-harvest inputs s, as well as by a unit-specific stochastic term, $\varepsilon_{q,i,k}$.

Since quality is not rewarded in the market, a farmer will retain under-invest in post-harvest practices, s, for maize which she plans to sell. She will retain that portion of the harvest which, after the application of post-harvest inputs, is above her expectation of

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[5] Pre-harvest inputs, such as the use of fertilizer and pesticides, could affect both output quantity and quality. These are omitted for the sake of simplicity; including them does not change the testable predictions of the model. Since we do not have data on production inputs, these are absorbed in the empirical models in the disturbance term. The stochastic element is included in the cash crop production function for consistency across the two crops; with a linear utility function, the relative risk of production processes does not affect farmer decisions.

the average quality available for purchase, up to the amount required for household consumption, M_i, and will sell that portion of the harvest for which quality is below this threshold.[6] This results in an average quality of farmer *i*'s retained food crop of

$$\overline{q}_{r,i} = \int_{q_{T,i}}^{q_{max,i}} f_{harvest,i}(q_{h,i,j}) dq_{h,i}, \tag{8}$$

where $q_{max,i}$ is the highest quality of the food crop produced by the farmer, and $q_{T,i}$ is the quality threshold below which she sells, which is equal to whichever is greater: the expected quality of maize available for purchase, $E[q_p]$, or the quality of the $(m_{h,i} - M_i)^{th}$ best unit in the farmer’s possession.

Equation (8) implies that, holding the quality distribution constant across farmers, the quality of the food crop retained by farmers with a larger harvest will be higher than that retained by smaller-scale producers. By equation (6), this implies that farmers with a greater land area devoted to food production will retain higher-quality food. In addition, yield is correlated with quality through the stochastic term $\varepsilon_{m,i}$.

Proposition 1: The quality of retained food is increasing in both area planted under the food crop and the yield.

The stock of food available for purchase on the market is constituted by the aggregate, over all producers, of that portion of the harvest below the quality threshold $q_{T,i}$ of each producer. This results in mean marketed food quality of

$$\overline{q}_p = \sum_i \frac{m_{s_i}}{\sum_i m_{s_i}} \int_{q_{min,i}}^{q_{T,i}} f_{harvest,i}\left(q_{h,i,j}\right) dq_{h,i}, \tag{10}$$

where $q_{min,i}$ is the minimum quality of food produced by farmer i, and m_{s_i} is the quantity of grain sold by farmer i.

By rational expectations,

$$E[q_p] = \overline{q}_p \quad . \tag{11}$$

The fact that the quality threshold above which maize is retained, $q_{T,i}$, is always at least as high as the expected quality of food available on the market, implies the following:

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[6] If agents are risk averse, the quality threshold below which maize is sold will be below the expected quality of maize found in the market, strengthening the predictions of the model.

Proposition 2: The quality of retained food is higher than that which is available for purchase.

Given propositions 1 and 2, and since expected utility is increasing in $\overline{q}$, differences in how household food needs are met can be explained by heterogeneity in productive capacity. Farmers who are able to produce more food due to a larger land endowment, or more resources generally, are more likely to meet their consumption requirements through their own harvest without turning to the market. The proof for the following proposition is provided in the Appendix.

Proposition 3: The proportion of food consumed that is self-grown is increasing household wealth.

Note that the market for maize does not completely unravel (as in the standard Akerlof model) because of the stochasticity of both the quantity and quality of maize produced. Households sell higher quality maize than the market average when they stochastically produce more than required for their household consumption requirement. Without this assumption, households would only sell maize that was lower than average quality, and the market would unravel.[7]

After describing the study methods and resulting data in the following section, we test Assumption 1 and hypotheses based on Propositions 1 through 3 in Section 4.

3. Methods and Data

Approximately 75 percent of the maize grown in Kenya is produced by small-scale growers on farms of five acres (just over two hectares) or less, and most of these producers retain part of their produce for home consumption (Guantai and Seward, 2010). Whether rural households grow or purchase maize, they typically store it either on cobs or as shelled grain (removed from the cob). The most common way of preparing maize is as porridge from meal.[8] Sixty percent of the total maize meal processed in the country is ground in small-scale hammer mills, with the rest presumably milled in larger facilities (Kenya Maize Development Program, 2009, cited in Kirimi et al, 2011).[9] When desired

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[7] We thank an anonymous reviewer for this point.

[8] Maize kernels may also be boiled without grinding, and fresh maize may be boiled or roasted on the cob.

[9] Authors' observations suggest that grinding at home by consumers is extremely rare in Kenya.

for consumption as porridge, maize kernels are taken to a small-scale hammer mill, where they are ground into flour. In addition to providing grinding services, some millers also sell maize flour from their own stock.

We collected survey data and maize samples from more than 2,000 clients at 176 small-scale hammer mills across 138 villages in the Kenyan provinces of Western, Rift Valley, and Nyanza in 2009, and in Eastern Province in 2010. Each province was stratified by agroecological zone to ensure a broad representation of maize-growing conditions. Districts, and then towns, were subsequently selected in each of these zones from a database of market centers using two-stage random sampling. The largest mill in a selected town was generally used as the sampling point, though in areas where market centers were sparse, samples were collected from up to four mills in a single town in order to better represent the geographical diversity of growing conditions.

Survey staff spent between one and three days at each hammer mill interviewing customers aged 18 and above, and procuring samples of maize brought by customers for milling. After the flour had been milled, the entire batch of flour belonging to a particular consumer was mixed to achieve homogeneity and then a sample of this was randomly selected by the enumerator for laboratory analysis. In Eastern Province, enumerators performed visual inspection of maize grains for discolored and broken kernels prior to milling. Similar to the flour sampling procedure, the entire batch of unmilled maize was mixed to achieve homogeneity, and then a sample was randomly selected by the enumerator.

Maize flour samples were sent to the Biosciences eastern and central Africa (BecA) laboratory in Nairobi for quantification of aflatoxin using enzyme-linked immunosorbent assay (ELISA) following manufacturer's instructions.[10] This test is sensitive up to 20 parts per billion. For higher levels of contamination, samples were diluted and reanalyzed, with some loss of precision.

A second, much smaller survey was conducted in 2012 at five of the originally sampled mills in each region, to collect additional data on clients’ perceptions of maize

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[10] Test kits were purchased from Helica Biosystems, Inc., Fullerton, CA.

quality and marketing behavior.[11] Findings from this second survey of 100 mill customers, which provide qualitative support for the model, are discussed in Section 4.

Respondent characteristics

Table 1 provides summary statistics on the demographic characteristics and assets of the individuals interviewed during the main survey, and on the origin, intended use, processing, and quality characteristics of the maize samples collected.[12] The majority of respondents were female, reflecting the traditional female responsibility of milling grain. Seventy percent of the sample had completed eight years of primary school, and 19 percent had completed secondary school. Comparing these figures with those from two nationally representative household surveys conducted between 2008 and 2010[13], respondents were above the national average primary completion rate of 63 percent, but below the 35 percent secondary completion rate. For the subset of the data for which asset and housing quality data were collected, the proportion of households with electricity, at 13 percent, was between the rural average of 6-8 percent and the overall national average of 19 percent. The proportion of respondents living in houses with permanent roofs, at 95 percent, exceeded the nationally representative average of 81 percent, while the proportion with permanent walls, at 52 percent, was below the national average of 60 percent. Household-level mobile phone ownership, at 81 percent, was much closer to the national urban average of 86 percent than the representative rural average of 53 percent. Overall, the educational attainment and asset position of respondents, intermediate between the rural and urban averages for Kenya, is in line with what one would expect of a population drawn from rural market towns, whose inhabitants enjoy better access to both government services and market infrastructure than those residing in smaller villages.

[TABLE 1 ABOUT HERE]

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[11] Five districts in each region were selected to represent geographical diversity, and one village within each of these was randomly selected. In two districts, villages had to be replaced due to missing location data. Data were collected at the main mill in each selected village.

[12] Due to differences in the survey instruments and procedures used in Eastern Province and the western provinces, data on prices of purchased maize, assets, and housing quality are available only for the Eastern sample.

[13] Kenya Demographic and Health Survey, 2008-2009, (KNBS, 2010); 2010 Kenya Malaria Indicator Survey (Division of Malaria Control et al., 2011).

Maize sample characteristics

Just over half of maize samples collected were grown on the respondent's own farm, 4 percent were purchased from the maize miller, and 38 percent were purchased elsewhere. Gifts from friends and family account for 6 percent of samples, with food aid making up less than 0.5 percent.

Almost all of the maize samples collected in the western provinces, and 73 percent overall, were destined for household consumption as food. Production of alcohol was the next most common use, at 23 percent. One percent of grain was intended for use as livestock feed, and 3 percent of respondents reported an intention to sell the grain they were milling. Since farmers generally sell maize as kernels rather than flour, it is not surprising that we observe such a low proportion of planned sales. Similarly, maize is normally fed to livestock as intact grain or ears rather than as milled flour.

Among those milling maize they had grown themselves, more than 82 percent reported using hybrid seed, and the average land area under maize was 0.77 hectares. The average yield per hectare was 1,692 kg, with a very large spread, and maize had been harvested an average of 4.3 months prior to the collection of samples. Most farmers had allowed their maize to dry in the field before harvesting, a practice that may increase the risk of post-harvest damage by pests and fungal contamination (Hell and Mutegi, 2011). A majority of farmers, and all of those in the western region, had dried their maize on a plastic sheet or drying platform after harvest, with the rest drying it directly on bare soil. Contact with soil could expose the kernels to a higher level of toxigenic fungi endemic in the soil.[14] Almost all farmers had removed kernels from the cob (shelled the grain) before storage, and yet a greater proportion had sorted out visibly moldy kernels. Pesticides were added to stored grain by two-thirds of farmers.

Approximately 30 percent of samples collected contained between 1 and 10 percent broken kernels, and a similar proportion contained this share of discolored kernels. Samples with more than 10 percent broken or discolored kernels were relatively

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[14] Some fungal spores from nearby soil are likely to come in contact via dust with maize regardless of where it is dried.

rare, constituting 5 and 8 percent of samples respectively.[15] The mean price paid for purchased maize in Eastern Province was 14 Kenyan shillings per kilogram, approximately 0.175 USD.

Twenty ppb is the allowable limit of aflatoxin contamination for human consumption according to both the US Food and Drug Administration (FDA) and the World Food Program (WFP). The allowable limit in Kenya was recently decreased from 20 to 10 parts per billion (Daniel et al., 2011), which is also the European Union standard for unprocessed maize. The mean aflatoxin content across the sample was three times the legal limit, at 30 ppb. The data echo previous findings of much higher aflatoxin prevalence in Eastern Province than in the western part of the country (Ibid.), with mean and median contamination levels in the western region of 3.5 and 1.1 ppb respectively, compared to 47 and 5.2 ppb in Eastern Province.

Figure 1 shows the distribution of contamination levels in each region on a log scale. Less than 12 percent of samples collected in the western region in 2009 had aflatoxin contamination above the current allowable limit of 10 ppb, whereas 39 percent of those collected in Eastern Province in 2010 were over the limit, and 21 percent contained more than double this level.

[FIGURE 1 ABOUT HERE]

4. Empirical approach and results

Maize attributes and pricing

We began by testing Assumption 1 in the model above, namely that farmers have private information about the quality of food in their possession. To do so, we examined which characteristics determined the price of maize and which determined its use. If a particular quality did not affect price but did affect the use of grain, we conclude that it was observed by those in possession of maize but not by prospective buyers.

Determinants of price could only be analyzed among the subset of maize samples from Eastern Province that had been obtained by respondents through purchase, since

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[15] We report data on visible attributes before sorting. Sorting significantly reduced the proportion of samples in the lower-quality categories, but coefficients of correlation across the sorted and unsorted measures of quality are above 0.9.

price data were not collected in the western region. For these observations, price per kilogram was regressed on the proportion of discolored and broken kernels, as well as the level of aflatoxin contamination, using a linear model. Market center fixed effects and clustered standard errors were used to capture both market-specific variation in the average price and variation in the predictive power of the model across markets. Results are presented in Table 2.

[TABLE 2 ABOUT HERE]

As shown in column 1 of Table 2, maize containing a large proportion of broken or discolored grains carried a price penalty of between 7 and 13 percent. The negative effect of discolored grains is present even when these are relatively few, while broken grains negatively impact price only when these constitute at least 10 percent of all grains.

Columns 2 through 9 of the same table show the impact of aflatoxin contamination on price under various specifications. In this and subsequent analysis, our primary approach is to classify samples by where they fall relative to the following thresholds of aflatoxin contamination: detectable, 10 parts per billion (ppb), and 20 ppb. This focuses attention on the two regulatory standards described above and overcomes the challenge of heteroskedasticity due to reduced precision of the test above 20 ppb. Column 5 shows results with aflatoxin entered as a linear term, top-coded at 20 ppb. While aflatoxin contamination is negatively associated with price in three of four specifications when controls for visible quality are included, none of these associations are statistically significant. When visible quality characteristics are included as controls in columns 6 through 9, the marginal effect of aflatoxin contamination becomes even less insignificant and is positive in all specifications. This result suggests that aflatoxin contamination is unobservable to buyers beyond its visible correlates.

Analysis of the relationship between observable grain qualities and aflatoxin, shown in Table A1 of the Appendix, reveals that maize samples containing a large proportion of broken kernels had a higher likelihood of aflatoxin contamination. While the direction of the association between discolored kernels and aflatoxin contamination mirrors that seen for broken kernels, the magnitude of the correlation is much smaller and the relationship is not statistically significant. The power of either attribute to predict aflatoxin is low, with pseudo R-squared values of both models below 3 percent.[16] It appears, then, that consumers are discerning about the observable characteristics of the maize they purchase, but that the level of aflatoxin contamination is either unobserved at the time of purchase or not valued by consumers. Given that two thirds of respondents claimed to have sorted their grain for health reasons, the first explanation seems more likely.

Determinants of use

Our next step was to investigate the determinants of how maize was used. There are four uses to which maize is typically put in rural Kenya: it can be consumed by the household as food, used to produce alcoholic beverages, fed to livestock, or sold. Aflatoxin content is not affected by cooking, but between 73 and 82 percent of the toxin is removed during fermentation in the production of beer (Chu et al., 1975). The negative health effects of human consumption of aflatoxin include impaired growth among children, depressed immunity, and increased cancer risk (Strosnider et al., 2006). The effects of consuming aflatoxin-contaminated feed on livestock are similar to those on humans, including negative effects on growth and impaired milk production. Milk from animals consuming aflatoxin-contaminated feed also contains the toxin (Robens and Richard, 1992).

Aflatoxin contamination levels at various points in the distribution of maize destined for household consumption, brewing, livestock feed, and sale are shown in Table 3. Maize destined for consumption as food by the household had the lowest level of aflatoxin over most of the distribution, but also the greatest variance. Contamination was generally highest in maize destined for sale, which had more than twice the mean aflatoxin level as that destined for household food consumption.

[TABLE 3 ABOUT HERE]

Figure 2 plots the cumulative distribution function of aflatoxin contamination for maize intended to be used for each purpose. For ease of visualization, this graph is

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[16] We report the adjusted count pseudo R-squared value. This statistic indicates the proportion of observations for which the category of aflatoxin contamination is correctly predicted by the model, excluding those in the most common category. A naïve model would assign all observations to the most common category; the adjusted count statistic thus describes the improvement in predictive power compared to the naïve model.

truncated at 100 ppb. This omits 5.4 percent of the data, which is disproportionately used for brewing (35 percent, compared to 23 percent of samples below 100 ppb),[17] sale (5.6 compared to 3.1 percent), and livestock feed (3.2 compared to 0.9 percent). Household consumption remains the primary use of this maize, accounting for 56 percent of those samples with contamination levels higher than 100 ppb, and 74 percent of those below this level.

[FIGURE 2 ABOUT HERE]

Results from multinomial logit regressions, presented in Table 4, confirm what the summary statistics and graphical analysis suggest. A categorical variable indicating the intended use of maize was regressed on three binary variables, each representing a different level of contamination. The excluded category is no detectable aflatoxin contamination. The shares of observations with no detectable aflatoxin put to each use are reported at the bottom of the table.

[TABLE 4 ABOUT HERE]

The first four columns of Table 4 report results from a model that uses the entire sample for which data on aflatoxin and intended use are available. Columns 5 through 8 show results from the same model, restricting the sample to those observations for which we also have data on the observable qualities of kernel integrity and discoloration. All of these observations are from Eastern Province, where aflatoxin contamination is both more common and severe. Columns 9 through 12 include the observable quality variables as controls.

The basic pattern is consistent across specifications. Grain contaminated with aflatoxin was less likely to be used for household consumption, more likely to be used for alcohol production, and more likely to be sold. All of these effects are driven by the Eastern Province subsample, and are not affected by including controls for visible quality. In the specification that includes controls, the likelihood of using maize as food for the household is 23 percentage points lower when aflatoxin contamination exceeds the regulatory standard of 10 parts per billion compared to when aflatoxin is undetectable (column 9). The most highly contaminated grain (more than 20 ppb aflatoxin) is

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[17] Data on the use of fermented beverages (own consumption versus sale) is not available.

approximately twice as likely as uncontaminated grain to be used for brewing and four times more likely to be sold (columns 10 and 12).

Given that price data are only available for a subset of the data, our observation of an association between contamination and use, but not contamination and price, could potentially be due to a lack of power to detect the second relationship. To investigate this possibility, we randomly select a subset of observations equal in number to those for which price data are available, and re-run the models presented in Table 4 on this smaller sample. This procedure is repeated 500 times per specification, and the mean estimated marginal effects are presented in Table A2. The negative association between aflatoxin contamination and likelihood of use for consumption as food by the household remains statistically significant in two of the three specifications. Further, for samples with aflatoxin at or below 20 ppb, maize which has been purchased exhibits greater variance in aflatoxin contamination than that which has been grown by the consumer, suggesting that the inability to detect a relationship between contamination and price is not due to a lack of variation in the level of contamination within the purchased sample.

While we observe that more contaminated maize was more likely to be sold, a limitation of our data is that only 3 percent of maize samples were destined for sale. Since most grain is sold in the form of whole kernels rather than flour, our main sample is unlikely to be representative of maize sales. In the subsequent survey of 100 mill clients, respondents were asked whether they ever sold any maize from their farm, and if so, whether the maize sold differed in any way from that which was retained for household use. Of the 38 respondents who sold maize, 32 percent reported that the maize they sold differed from that which they retained. The differences reported by this group were how thoroughly sorted or ‘clean’ the maize was (83 percent of those reporting a difference), the extent of drying or care taken in storage (50 percent), addition of pesticides (50 percent), and variety or size of kernels (25 percent). All of those who mentioned sorting, drying, or storage had retained the more carefully sorted, dried, or stored grain. In cases where addition of pesticides was the difference, these were only added to the maize destined for sale.[18] Finally, smaller grains grown from local varieties were retained, while

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[18] Pesticides are primarily used against weevils, and are not expected to directly impact fungal growth.

those of larger size grown from hybrid seed were sold. For 58% of the reported differences between retained versus marketed maize, farmers believed that the attribute would be unobservable to the buyer. Even differences that are observable at farm gate may be rendered unobservable by the time maize reaches the ultimate consumer. A 2011 survey of 370 maize traders carried out in the same provinces as the present study showed that traders often sort and dry maize after purchasing it from farmers, thus improving its observable attributes (Ordoñez and Hoffmann, in progress). While drying can slow or halt fungal growth, and removal of visibly moldy kernels may eliminate the most contaminated grain and stop the spread of fungus from these to other kernels, the effects of poor initial storage conditions on taste and food safety are irreversible, and often invisible. A study in which broken and discolored kernels were removed from samples of aflatoxin-contaminated maize found that between 20 and 60 percent of the aflatoxin remained after sorting (Park, 2002).

A quality that is unobservable at the time of purchase, but which is correlated with aflatoxin contamination and could influence consumers' use of grain (as well as drive the careful drying and storage of maize destined for own use), is the taste of mold. Presence of the fungus *A. flavus* is a necessary, though insufficient, condition for the accumulation of aflatoxin, which is not produced by all strains of the fungus and is more likely to be produced when the fungus is under physiological stress (Payne and Brown, 1998). Hoffmann and Gatobu (2012) experimentally varied whether participants in an auction for maize conducted in rural Kenya were allowed to taste porridge made from maize prior to bidding, in addition to visually inspecting the kernels. Providing information on taste significantly increased bids, suggesting that the taste of maize is an important attribute to consumers, and is not discernible through visual inspection alone. Data from the 2012 survey of mill clients supports the hypothesis that those holding maize have an information advantage about the taste of their maize relative to potential buyers: 74 percent of respondents reported that the taste of maize grown on a particular plot of land is informative about the taste of other maize grown on the same plot, and 67 percent reported that the taste of maize stored in a particular bag is informative about the taste of other maize in the same bag.

Determinants of aflatoxin contamination

We next turn our attention to the effect of farm practices on aflatoxin contamination. The first four columns of Table 5 present results of an ordered probit regression in which the dependent variable is the category of aflatoxin contamination. Farm practices generally influenced aflatoxin contamination in the expected direction. Use of improved drying methods, defined as laying maize on a plastic sheet or other material rather than directly on bare ground during sun drying, reduced the likelihood of contamination. The duration of drying had a positive but statistically insignificant impact on probability that maize was contaminated, possibly due to increased risk of contamination from blown dust over time. Removing grain from the cob (shelling) prior to storage reduced the aflatoxin level, probably because fungus is present in the cobs and serves as a source of inoculum (Zummo, and Scott, 1990; Jaime-Garcia and Cotty, 2004). Aflatoxin contamination increased significantly with time in storage: every month after harvest increased the probability of detectable contamination by 1.7 percent. Leaving maize to dry in the field before harvest had no statistically significant impact on aflatoxin contamination, nor did removing discolored and damaged grain prior to storage, though the mean impacts of both practices are in the expected direction.[19]

[TABLE 5 ABOUT HERE]

The results shown in Table 5 also provide evidence for the hypothesis that the quality of maize retained is increasing in both area planted and yield (Proposition 1). Generally, yield is correlated with plant health, and thus the quality of grain at time of harvest. This is due to both farm management practices, such as weeding and application of fertilizer and pesticides, and stochastic influences, such as weather and pest attacks. Since we do not have data on inputs aside from the land area planted in maize, it is not possible to separate the deterministic and stochastic components of yield. The estimated relationship between yield and aflatoxin thus captures both the impact of stochastic environmental conditions and that of farming practices. The association is positive, as expected, though not large in magnitude: with every incremental 100 kg per hectare, the probability of detectable aflatoxin contamination was reduced by 0.1 percent.

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[19] Since 95 percent of respondents reported sorting maize prior to storage, power to detect an effect of this practice is low.

The size of the area planted with maize clearly determines the quantity harvested, but after controlling for yield, should not affect its quality. However, according to Proposition 1, holding the quality distribution constant, the quality of maize retained is increasing in the quantity harvested, since the proportion of the total required to satisfy household food needs is smaller. This prediction is borne out in the results: an additional hectare under maize reduces the probability of aflatoxin contamination by 2.8 percent (column 1).

Because both yield and area planted under maize may be correlated with geographical factors such as climate and soil type, which also influence aflatoxin contamination, we also estimated a linear model with community level fixed effects (column 6), as well as an OLS model for comparison (column 5). Because of the highly skewed distribution, as well as concern about the accuracy of readings above 20 parts per billion, observations of aflatoxin above this level were top-coded. The effects of yield and area under maize are robust to the change in specification, as is the effect of time since harvest, but the impacts of other farm management practices are reduced in statistical significance in the OLS model and undetectable when fixed effects are included. A Hausman test comparing coefficients in the OLS and fixed effect models shows no systematic difference between the two (p = 0.315).

If farm practices that influence aflatoxin contamination are the same as those leading to more readily observable characteristics that affect the market price, then incentives to improve observable qualities would incidentally lead farmers to adopt practices that reduce aflatoxin contamination. Unfortunately, this does not appear to be the case. Data on both aflatoxin contamination and visible grain qualities are available for a subset of observations from Eastern Province. Comparing the determinants of aflatoxin and discolored grain using this sample in Table 6 suggests differences in the determinants of these outcomes. While the effects of shelling before storage and of the duration of storage on aflatoxin remain statistically significant in this smaller sample, neither of these variables had a detectable effect on the proportion of discolored kernels. Further, the estimated effects of certain practices, such as drying in the field and drying on a plastic sheet or other material as opposed to on the bare soil, are opposite in sign for aflatoxin and discoloration.[20]

[TABLE 6 ABOUT HERE]

While only the impacts of land area under maize and use of improved drying methods differ across the two outcomes at conventional levels of statistical significance, and these only at $p<0.1$, the results are suggestive that the determinants of aflatoxin contamination are different from those of a more easily observable dimension of quality. Farmers' ability to learn about best practices for reducing aflatoxin contamination are thus limited, and the incentives they face to implement such practices, muted.

Source of maize and aflatoxin contamination

We next consider the evidence for Proposition 2, that purchased maize is of lower quality than that which has been stored for household consumption. Figures 3 and 4 present cumulative distribution functions of aflatoxin contamination in the western region and Eastern Province respectively. In both areas, maize produced on the consumer's own farm has a higher probability of zero or low aflatoxin contamination than that which has been purchased.[21]

[FIGURES 3 AND 4 ABOUT HERE]

Results from an ordered probit model in which the category of contamination (0 parts per billion, detectable but below 10 ppb, between 10 and 20 ppb, and >20 ppb) is regressed on variables indicating how the maize was obtained are shown in Table 7. Similar to Table 4, Table 7 presents results using the entire sample for which data on aflatoxin and maize source are available in the first four columns. Columns 5 through 8 show results from the same model, applied to the subset of the data for which information on observable maize characteristics is also available, and columns 9 through 12 include these observable characteristics as controls. Results are qualitatively similar across samples and specifications, though again larger in magnitude in the sub-sample from

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[20] The difference in effect of drying methods across the two outcomes may be a result of competition among various types of fungi. For example, when maize is dried on the bare soil, it may be more likely to be colonized by fungi that happen not to cause discoloration of kernels (including aflatoxin); these fungi may outcompete the more colorful fungi, causing the latter to be positively associated with "improved" drying practices.

[21] Maize purchased from the miller is excluded due to the possibility that reputation effects improve the quality of maize offered in this sub-market.

Eastern Province for which we have data on observables. Focusing on the third specification, which includes these controls, the probability of zero detectable aflatoxin is 5.3 percentage points, or 14 percent, lower in maize that has been purchased on the market relative to that grown by farmers for their own household consumption, for which the probability of zero contamination is 38 percent. The probability of purchased maize exceeding the FDA regulatory standard of 20 parts per billion is 4 percentage points, or 22 percent higher than maize grown by the consumer. These effects are significant at the 10 percent level. Maize purchased from the maize mill, which, unlike most maize traders, has a fixed location and could thus be subject to stronger reputation effects, was no better or worse in quality than grain produced by consumers themselves. Grain received as a gift or as food aid likewise had levels of contamination similar to that grown by farmers and retained for their own household consumption. Given the small number of observations in the latter two categories, however, these estimated effects are very imprecisely measured.

The difference in maize quality by origin is not as stark as the difference in quality by intended use of the grain. This is likely due to the positive correlation between the quality and quantity of maize grown by a particular producer, as observed in the negative association between yield and aflatoxin shown in Table 5. The majority of maize exchanged on the market originates from relatively productive farms and regions, from which average quality is relatively high, dampening the difference in quality between self-grown and purchased maize.

[TABLE 7 ABOUT HERE]

While the results presented above are consistent with an information asymmetry between buyers and sellers causing lower quality maize to enter the market, an alternative explanation could be that quality is perfectly observable, but that the attributes valued by consumers who choose to self-provision are different from those valued by consumers who acquire maize through the market. To investigate this possibility, we compare sorting practices and perceptions about the health effects of consuming low quality maize between those respondents milling self-produced grain and those milling purchased grain. Because both practices and perceptions differ across the two study regions, we conduct these tests within-region. If anything, the comparison suggests that those milling purchased maize are more concerned about its quality and the potential health consequences of consuming contaminated grain than those milling their own.

[TABLE 8 ABOUT HERE]

As shown in Table 8, the proportion of respondents observed to sort discolored or broken grains and debris from their maize at the mill was higher among those milling purchased grain in the Eastern Province sample. This is despite the fact that prior to sorting, purchased maize is of higher visible quality than self-produced maize (significant at p=0.028 using a Mann-Whitney rank-sum test). In the western region, those who had purchased maize were more likely to report sorting maize for heath purposes than those milling self-produced grain, and in Eastern Province those with self-produced grain were more likely to say that eating bad maize could cause health problems. The proportion who believed serious health consequences could result did not differ by the source of maize.[22]

Additional evidence that those who have purchased maize are no less concerned about its quality than those who have grown it is provided by a comparison of maize usage by aflatoxin contamination level within each of these groups.[23] Panel A of Appendix Table A3 shows the number and percentage of grain samples grown on the consumer's own farm in each quality category intended for each of the four possible uses. Panel B presents the same data for maize that was purchased from a source other than the miller. The pattern of use by quality is similar across the two sources of grain, with lower likelihood of consumption as food and increased probability of sale at higher levels of aflatoxin contamination, suggesting that differences in the preferences of buyers and sellers do not account for the lack of a relationship between price and aflatoxin contamination.

A second alternative explanation for the difference in quality between self-grown and purchased maize is that at farm gate, the quality of maize sold is equivalent to that which is retained, but that marketed maize deteriorates during transport and storage by

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[22] Health consequences classified as serious were the following: cancer, fungal disease, weakness, toxin or poison, impaired growth, eye discoloration, liver problems, typhoid, cholera, ulcers, kidney problems, generally worsening health, and death. Health consequences classified as non-serious were nausea, stomach pain, gas, diarrhea, vomiting, headache, sore throat, fever, and heartburn.

[23] The number of observations within these sub-samples is insufficient for reliable econometric estimation.

traders before reaching the ultimate consumer. This seems unlikely, given differences in timing of the harvest across regions of Kenya, and the resultant nature of the maize trade, through which grain is typically transported from areas of recent harvest to areas in which stocks have been depleted (Kirimi et al., 2011). Purchased maize is thus likely to have been harvested more recently than that stored by farmers for own consumption. According to a recent survey of maize traders, the mean and median period for which a given trader typically stored maize were 7 and 14 days respectively, with fewer than 10 percent of traders reporting typical storage times greater than a month (Ordoñez and Hoffmann, in progress). In comparison, the average time since harvest of self-grown maize in our sample is much longer, at over 4 months.

Wealth and consumption of self-grown maize

Given the lower average quality of maize available on the market, we expect self-grown maize to be a normal good. Consumption of self-grown maize is thus expected to be increasing in household wealth (Proposition 3). Since our survey of mill clients did not collect extensive data on household assets, we used data from the 2007 REPEAT agricultural household survey conducted by the Tegemeo Institute to investigate this hypothesis. This is the second round of a multi-year panel dataset and comprises 772 households of the 934 originally interviewed in 2004, which had been randomly selected from within 86 communities representing a diversity of agro-ecological zones and agricultural potential across five Kenyan provinces.[24]

The data include details of agricultural production and household consumption, including ownership of agricultural land and livestock; the value of household assets such as vehicles, farm implements, and consumer durables; and consumption of self-grown and purchased grain. All of the households that completed the consumption section reported consuming maize during the past week, and 86 percent of these reported consuming maize they had produced themselves.

Productive capacity is captured in our empirical model by agricultural landholdings at the time of the survey and the log value of non-land assets one year ago.

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[24] Details of the sampling procedure can be found in Yamano et al., 2004.

Non-land assets include livestock, consumer durables, and farm equipment, excluding those which could be specific to maize production.[25]

A linear regression of maize harvest on land holdings and non-land asset value, presented in column 1 of Table 9, shows that both types of asset positively affect maize production. The next two models estimate the effects of these same asset variables on the probability of consuming self-grown maize. We employ a linear probability specification with community fixed effects, since location may simultaneously affect landholdings, non-land wealth, crop choice, and consumption patterns. Column 2 shows that non-land asset wealth is a statistically significant predictor of self-grown maize consumption. The magnitude of the effect is modest: a 10 percent increase in wealth increases the probability of consuming self-grown maize by approximately 0.25 percent. The effect of landholdings is also positive in sign but not significant at conventional levels. In the final column, we control for maize harvest. The estimated effect of non-land asset value remains similar in magnitude in this model, though it is only significant at the 10 percent level. This suggests that part of the effect of asset wealth on consumption choice is due to greater capacity for maize production, but that greater wealth may also afford households the flexibility to retain maize rather than sell it to cover cash needs.

[TABLE 9 ABOUT HERE]

Data from the 2012 survey of mill clients confirm a widespread preference for maize grown on one's own farm, with 89 percent of respondents preferring their self-produced maize, 4 percent preferring to purchase, and 6 percent expressing no preference. This stated preference result echoes a recent experimental finding by Hoffmann and Gatobu (2012), who show that farmers in Kenya's Western Province were willing to pay an average of 23 percent more for maize they had grown themselves relative to maize of visibly comparable quality purchased at a local market. While all of the respondents interviewed in the 2012 survey grew some maize, only 19 percent grew enough to meet their household's needs. The primary reasons cited by farmers for not growing more maize were lack of land or capital for other inputs (63 percent), followed

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[25] Excluded assets are sickles, chaff cutters, and grinders; included farm equipment items are tractors, trailers, vehicles, carts, donkeys, wheelbarrows, ploughs, borehole, well, hand hoes, spray pumps, diesel pumps, water tanks, and beehives.

by production shocks (48 percent). Only 5 percent of respondents cited low profitability of maize as a reason for not growing more of it.

5. Conclusion

We have shown in this article that contamination with the toxic fungal byproduct aflatoxin is not reflected in prices in the informal Kenyan market for maize. Holders of maize, however, appear to possess information about its level of contamination or correlates thereof. More highly contaminated maize is more likely to be sold or used for brewing than for household consumption as food. Further, maize that has been purchased is more likely to be contaminated than that which has been grown on the consumer's own farm. Our findings are consistent with the interpretation that an information asymmetry between buyers and sellers results in selection of low-quality grain into the market.

We note that our results contrast with those of a recent study by Daniel et al. (2011), which showed higher levels of aflatoxin in maize produced and stored by households relative to maize which had been purchased. Daniel et al. selected both villages and households based partially on reported cases of aflatoxin poisoning. Their finding of higher aflatoxin could therefore be explained by their sampling strategy and is not likely to be representative of the relative rates of contamination in self-grown and purchased maize outside of their sample.

While consumers are able to mitigate their own exposure to aflatoxin by converting contaminated maize into alcoholic beverages, selling it, or feeding it to livestock,[26] 70 percent of the contaminated maize observed in this study was destined for use as food by the person milling it. Farmers are able to reduce aflatoxin contamination through use of improved drying and storage practices. However, the effects of individual farm practices on aflatoxin contamination and more easily observable fungal damage are not always aligned, making learning difficult and leading to a mismatch between practices that are rewarded in the market and those that improve food safety.

Low-cost technologies for reducing aflatoxin contamination, such as the introduction of competitive atoxigenic strains of *A. Flavus* as biological control agents,

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[26] While reduced, aflatoxin remains present in fermented beverages and livestock, so human exposure is reduced, but not avoided, through these strategies.

hold promise for improving the safety of the food supply in Kenya and other low-income countries. However, adoption of such technologies will only be commercially viable if the asymmetric information problem documented in this paper can be overcome. While the cost of testing for aflatoxin and other contaminants at point of sale is prohibitive at present, new technologies that eliminate sample processing are being developed that could make end-user assessment of contamination feasible. A certification system for food quality or safety would reduce testing costs regardless of the technology used, but whether such a system would be credible to consumers is an open question.

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Appendix: Proof of Proposition 3

Constraints (2) through (6) can be written as a single equality (omitting the i subscript for simplicity):

$$x = p_c g_c(A - A_m) - p_m\big(M - g_m(A_m)\big) - p_s s,$$

Substituting for x, $m_p = M - g_m(A_m) + m_s$, and $m_h = g_m(A_m)$ in the utility function:

$$EU = \frac{g_m(A_m) - m_s}{M}\bar{q}_r + \frac{(M - g_m(A_m) + m_s)}{M}E[\bar{q}_p] + p_c g_c(A - A_{mi}) \\ - p_m(M - g_m(A_m)) - p_s s$$

We want to show that the share of food consumed out of own produce, $\frac{m_h - m_s}{M}$, is increasing in the total land endowment, A.

We have two possible cases for the optimal value of the food crop harvested, ${m_h}^*$:

1) ${m_h}^* < M$

and

2) ${m_h}^* \geq M$

In case (1), the farmer will not sell any of the food crop, since she is able to use all food harvested for own consumption, and the quality of this produce is higher than that which could be purchased on the market for the same price at which she would be able to sell. Therefore, ${m_s}^* = 0$, and ${m_p}^* = \mathrm{M} - {m_h}^* > 0$. The share of the household's consumption requirement met through self-production is thus $\frac{{m_h}^* - {m_s}^*}{M} = \frac{{m_h}^*}{M} \in [0,1)$.

In case (2), ${m_s}^* = {m_h}^* - M \geq 0$, and ${m_p}^* = 0$, since no additional maize beyond what has been grown is required for own consumption. The household's entire consumption requirement is then met by self-produced food: $\frac{{m_h}^* - {m_s}^*}{M} = 1$.

The share of food consumed out of own production is thus entirely determined by the amount of food produced, which in turn is determined in expectation by the amount of land allocated to food production through the production function ${m_h}^* = g_m({A_m}^*) \cdot \varepsilon$.

It remains to show the impact of the total land endowment, A, on the land area allocated to the food crop, A_m.

The first order condition of expected utility with respect to A_m equates the marginal utility values of land allocated to each crop:

$$p_c \cdot \frac{\partial g_c}{\partial A_c} = \left(p_m + \frac{q_r - q_p}{M_i}\right) \cdot \frac{\partial g_m}{\partial A_m} \tag{A1}$$

As an aside, we note that since $q_r - q_p$ is positive by Proposition 2, the greater the divergence in quality between self-produced food and that available on the market, the lower $\frac{\partial g_m}{\partial A_m}$ must be for equation (A1) to hold, and thus the more land is allocated to the food crop.

The optimal value of A_m is thus:

$${A_m}^* = \begin{cases} f\left(p_c, p_m, \bar{q}_{r,i} - \bar{q}_{p,i}, M_i, A\right) & \text{if equation A1 holds for some value } A_m \in (0, A) \\ A & \text{if } p_c \cdot \frac{\partial g_c}{\partial A_c} < \left(p_m + \frac{q_p - q_r}{M_i}\right) \cdot \frac{\partial g_m}{\partial A_m} \\ 0 & \text{if } p_c \cdot \frac{\partial g_c}{\partial A_c} > \left(p_m + \frac{q_p - q_r}{M_i}\right) \cdot \frac{\partial g_m}{\partial A_m} \end{cases} \tag{A2}$$

We next consider how ${A_m}^*$ is affected by A in each case of equation A2, and how $\frac{{m_h}^*-{m_s}^*}{M}$ is subsequently affected for each case of the relative magnitudes of ${m_h}^*$ and M.

First, suppose $A_m \in (0, A)$.

Since all land must be allocated to either the cash or food crop, an increase in the total land endowment implies that at either A_m or A_c (or both) must increase. The concave production functions of both crops imply that the marginal utility value of land to the crop to which additional land has been allocated decreases. This implies that the land allocated to the other crop must also increase, if the equality in equation (A2) is to be maintained.

Note that an increase in A never results in moving from an interior solution to a corner solution for the following reason. Increasing the land devoted to crop k from ${A_k}^0$ to ${A_k}^1$ reduces the marginal expected utility value of A_k from $\left.\frac{\partial EU}{\partial A_k}\right|_{{A_k}^0}$ to $\left.\frac{\partial EU}{\partial A_k}\right|_{{A_k}^1}$. For the corner solution $A_k = A$ to hold, it must be that $\left.\frac{\partial EU}{\partial A_k}\right|_{{A_k}^1} > \frac{\partial EU}{\partial A_l}$, where the subscript l denotes the other crop. This cannot be the case unless A_l has also increased, in which case $A_l > 0$ and thus $A_k < A$. The same argument holds for the impossibility of moving to the other corner solution, $A_k = 0$.

Thus, in the case of an initial interior solution, an increase in total land area also increases A_m. Consequently, $E\left[\frac{{m_h}^*}{M}\right]$ is increasing in A, which implies that $\frac{{m_h}^*-{m_s}^*}{M}$ is increasing under case (1) above, in which ${m_h}^* < M$, and does not change under case (2), ${m_h}^* \geq M$, since ${m_s}^*$ adjusts to maintain $\frac{{m_h}^*-{m_s}^*}{M} = 1$.

Next, suppose ${A_c}^* = A$ and ${A_m}^* = 0$.

$E[{m_h}^*] = g_m({A_m}^*) = 0$, and case (1), ${m_h}^* < M$, necessarily holds.

Relaxing the land constraint may increase $E[{m_h}^*]$, but (trivially) cannot decrease it, since m_h is already equal to 0 and cannot be negative.

Finally, suppose ${A_m}^* = A$ and ${A_c}^* = 0$.

Then, $E[{m_h}^*] = g(A)$

If the optimal value ${A_m}^*$ remains A, then, relaxing the land constraint must increase $E[{m_h}^*]$, since the function $E[{m_h}^*] = g_m(A)$ is increasing in A. The expected proportion of food consumed out of own production under case (1), $E[\frac{{m_h}^*}{M}]$, also increases. Under case (2), ${m_h}^* \geq M$, increasing ${m_h}^*$ has no effect on the proportion consumed out of own production since as above ${m_s}^*$ adjusts to maintain $\frac{{m_h}^* - {m_s}^*}{M} = 1$

Finally, an increase in A cannot cause ${A_m}^*$ to decrease, even if it results in ${A_m}^* < A$ by the same argument made for the interior solution case above.

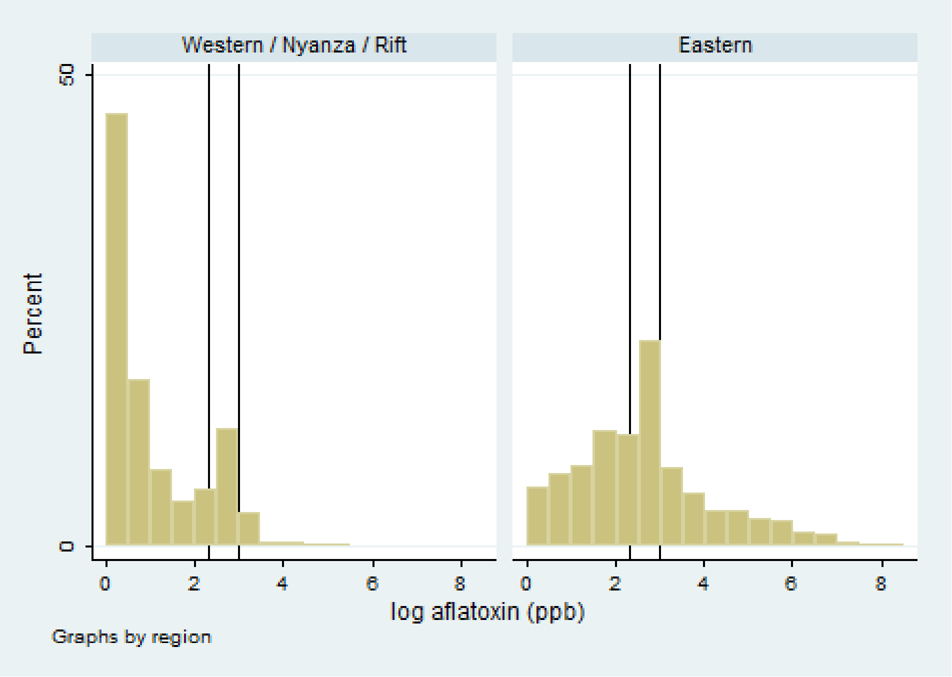

Figure 1: Histogram of log aflatoxin contamination by region. Observations with no detectable aflatoxin contamination are excluded. In Western, Rift Valley, and Nyanza Provinces, 43 percent of observations contain no detectable aflatoxin; in Eastern Province, 33 percent contain no detectable aflatoxin. Vertical lines indicate 10 ppb and 20 ppb aflatoxin.

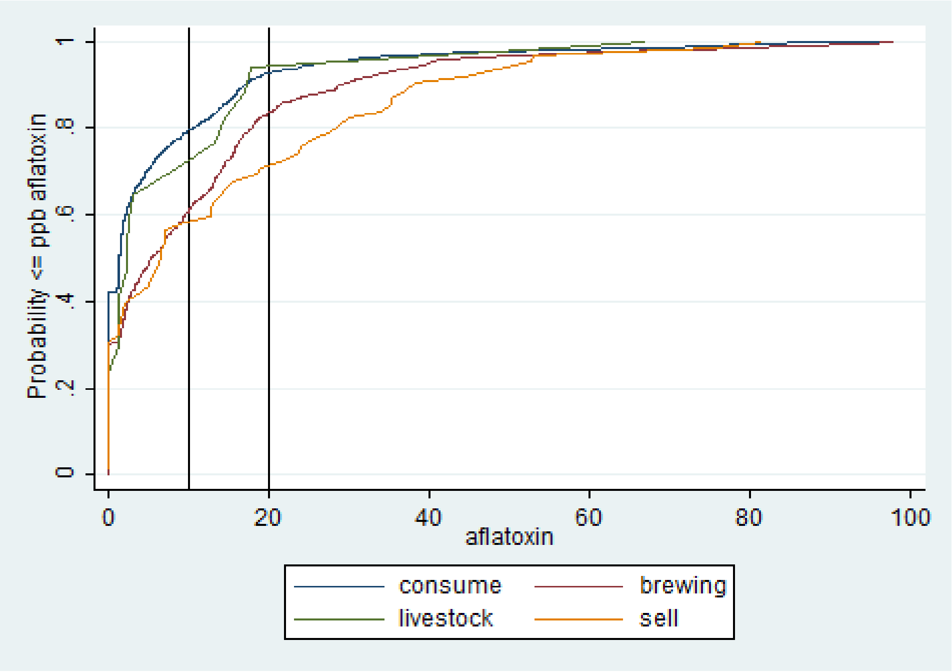

Figure 2: Aflatoxin contamination by stated use of grain. Excludes 5.4% of the sample with greater than 100 ppb aflatoxin contamination. Black vertical lines indicate the 10 ppb and 20 ppb regulatory limits.

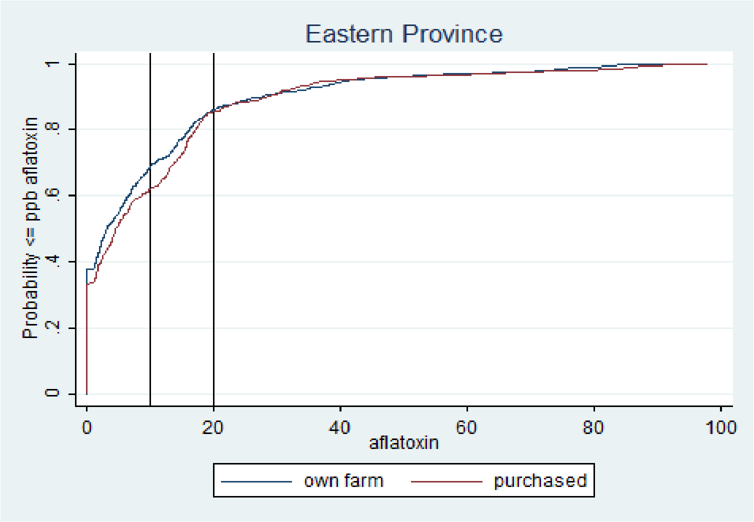

Figure 3: Cumulative distribution of aflatoxin contamination by origin of grain, Eastern Province. Black vertical lines indicated the 10 ppb and 20 ppb regulatory limits.

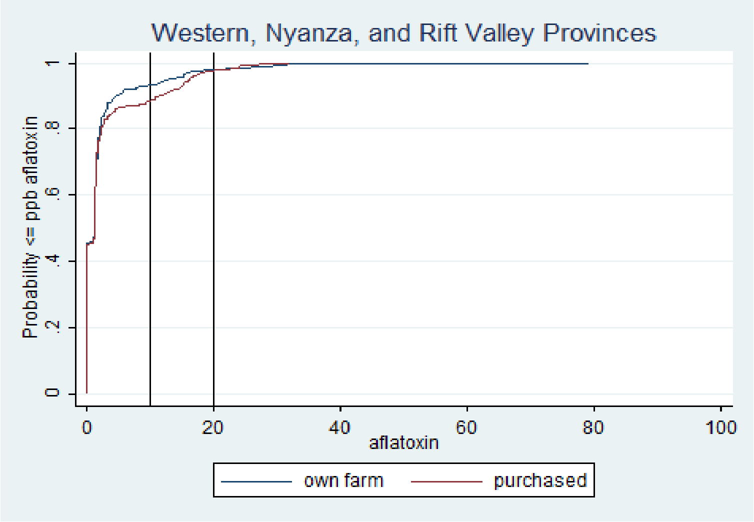

Figure 4: Cumulative distribution of aflatoxin contamination by origin of grain, Western, Nyanza and Rift Valley Provinces. Black vertical lines indicated the 10 ppb and 20 ppb regulatory limits.

Table 1
Summary Statistics

	Overall			Western / Nyanza / Rift			Eastern		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N
demographic & assets									
female	0.75	0.43	2082	0.79	0.411	635	0.74	0.439	1447
age	36.3	12.6	2088	34.5	13.5	658	37.1	12.1	1430
completed primary	0.70	0.46	2077	0.681	0.467	626	0.701	0.458	1451
completed secondary	0.19	0.39	2077	0.238	0.426	626	0.165	0.371	1451
own radio	-	-	-	-	-	-	0.88	0.33	1442
own television	-	-	-	-	-	-	0.24	0.43	1442
house: electricity	-	-	-	-	-	-	0.13	0.34	1441
house: permanent roof	-	-	-	-	-	-	0.95	0.22	1429
house: permanent walls	-	-	-	-	-	-	0.52	0.50	1369
own cell phone	-	-	-	-	-	-	0.81	0.40	1441
maize origin									
own farm	0.52	0.50	1983	0.33	0.47	655	0.61	0.49	1328
posho miller	0.04	0.19	1983	0.07	0.26	655	0.02	0.13	1328
purchased elsewhere	0.38	0.49	1983	0.53	0.50	655	0.30	0.46	1328
gift	0.06	0.24	1983	0.05	0.22	655	0.07	0.25	1328
food aid	0.00	0.06	1983	0.01	0.10	655	0.00	0.03	1328
intended use									
household food	0.73	0.45	2124	0.97	0.18	671	0.61	0.49	1453
brewing	0.23	0.42	2124	0.02	0.14	671	0.33	0.47	1453
livestock feed	0.01	0.10	2124	0.01	0.10	671	0.01	0.10	1453
sell	0.03	0.18	2124	0.00	0.05	671	0.05	0.21	1453
maize inputs and output									
hybrid seed	0.82	0.39	1663	0.83	0.37	210	0.82	0.39	1453
hectares under maize	0.77	1.53	1088	1.12	1.48	182	0.70	1.53	906
yield (kg per hectare)	1692	2178	1062	2220	2257	173	1589	2149	889
months since harvest	4.28	2.76	1076	6.64	6.64	202	3.74	2.19	874
dry in the field before harvest	0.88	0.33	1115	0.68	0.68	215	0.92	0.26	900
improved drying after harvest	0.71	0.46	1071	1.00	1.00	201	0.64	0.48	870
improved drying time	11.50	12.60	1051	8.38	8.38	189	12.20	13.50	862
shell before storing	0.93	0.26	1113	0.88	0.88	218	0.94	0.24	895
sort before storing	0.94	0.23	1114	0.95	0.95	217	0.94	0.23	897
added pesticide to stored maize	0.67	0.47	876	0.83	0.83	213	0.61	0.49	663
maize characteristics									
1-10% discolored	-	-	-	-	-	-	0.32	0.47	1019
> 10% discolored	-	-	-	-	-	-	0.08	0.27	1019
1-10% broken	-	-	-	-	-	-	0.28	0.45	1019
> 10% broken	-	-	-	-	-	-	0.05	0.22	1019
price per kg if purchased (KSH)	-	-	-	-	-	-	-	-	-
aflatoxin (ppb)	30.4	164	2430	3.48	10.1	930	47	207	1500

Notes: Due to variations in questionnaires across regions, data on grain prices and observable characteristics are only available for Eastern Province.

Table 2
Effect of Quality on Price

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1-10% discolored	-1.077**					-1.071**	-1.076**	-1.107**	-1.053**
	(0.502)					(0.497)	(0.508)	(0.514)	(0.499)
>10% discolored	-1.547**					-1.559**	-1.627**	-1.564**	-1.617**
	(0.736)					(0.750)	(0.735)	(0.724)	(0.746)
1-10% broken	-0.030					-0.018	-0.107	-0.105	-0.090
	(0.382)					(0.385)	(0.395)	(0.391)	(0.391)
>10% broken	-1.959*					-2.015*	-2.262*	-2.312*	-2.226*
	(1.112)					(1.144)	(1.195)	(1.226)	(1.195)
detectable aflatoxin		-0.449				0.275			
		(0.408)				(0.435)			
>10 ppb aflatoxin			-0.229				0.545		
			(0.367)				(0.629)		
>20 ppb aflatoxin				0.095				0.889	
				(0.465)				(0.836)	
ppb aflatoxin (top-coded)					-0.018				0.035
					(0.024)				(0.041)
Constant	14.540***	14.393***	14.177***	14.056***	14.240***	14.349***	14.348***	14.399***	14.269***
	(0.208)	(0.286)	(0.159)	(0.104)	(0.215)	(0.334)	(0.275)	(0.223)	(0.352)
Observations	294	390	390	390	390	294	294	294	294
Communities	94	107	107	107	107	94	94	94	94
R-squared	0.044	0.005	0.001	0.000	0.002	0.046	0.051	0.056	0.051

Notes: Coefficients are from linear regressions of price per kg on quality attributes with community fixed effects and standard errors clustered at the community level in parentheses. Data are from the Eastern Province sample only as price data were not collected in the western region. * p<0.10, ** p<0.05, *** p<0.01

Table 3

Aflatoxin Contamination by Intended Use

	mean	SD	min	25th percentile	median	75th percentile	90th percentile	95th percentile	max
Food for HH	28.7	182.5	0.0	0.0	1.4	9.3	24.2	83.6	4839.3
Brewing	41.5	143.3	0.0	0.0	7.2	18.9	82.7	172.4	1658.1
Livestock Feed	48.1	86.6	0.0	1.1	2.8	17.6	200.0	201.3	288.8
Sale	64.6	163.7	0.0	0.0	7.0	33.9	220.3	476.3	806.7

Notes : Pooled data for both regions.

Table 4

Use of Maize as a Function of Aflatoxin Contamination

	HH Food	Brewing	Livestock Feed	Sale	HH Food	Brewing	Livestock Feed	Sale	HH Food	Brewing	Livestock Feed	Sale
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0 < ppb < 10	-0.042*	0.031	0.009	0.001	-0.114**	0.090**	0.028	-0.004	-0.112**	0.088**	0.027	-0.002
	(0.024)	(0.022)	(0.010)	(0.007)	(0.047)	(0.041)	(0.030)	(0.015)	(0.046)	(0.040)	(0.027)	(0.015)
10 < ppb < 20	-0.093**	0.080**	0.016	-0.002	-0.223***	0.192***	0.019	0.011	-0.232***	0.207***	0.015	0.009
	(0.037)	(0.034)	(0.012)	(0.010)	(0.048)	(0.049)	(0.027)	(0.021)	(0.048)	(0.050)	(0.023)	(0.020)
ppb > 20	-0.129***	0.082**	0.021	0.026*	-0.256***	0.151**	0.036	0.069**	-0.258***	0.163***	0.032	0.064**
	(0.044)	(0.038)	(0.016)	(0.014)	(0.058)	(0.060)	(0.036)	(0.031)	(0.059)	(0.062)	(0.032)	(0.030)
1-10% discolored									0.079*	-0.085*	0.007	-0.001
									(0.046)	(0.044)	(0.007)	(0.012)
>10% discolored									0.160***	-0.135***	-0.002	-0.023**
									(0.054)	(0.051)	(0.007)	(0.010)
1-10% broken									-0.071	0.058	-0.002	0.015
									(0.048)	(0.046)	(0.006)	(0.014)
>10% broken									0.076	-0.171***	0.017	0.078
									(0.082)	(0.049)	(0.021)	(0.065)
Eastern	-0.336***	0.300***	-0.003	0.039***								
	(0.032)	(0.029)	(0.008)	(0.008)								
Proportion used for X at ppb = 0	0.796	0.174	0.005	0.024	0.785	0.189	0.003	0.023	0.785	0.189	0.003	0.023
Observations	2124				984				984			
Communities	138				107				107			
Pseudo R-squared	0.000				0.000				0.032			

Notes: Marginal effects from logit regressions, with standard errors clustered at the community level shown in parentheses. The omitted category is no detectable aflatoxin contamination. Columns 1 thorugh 4 show results from a model using the entire sample for which data on aflatoxin and intended use of maize are available. Columns 5 through 12 use data only from those observations from Eastern Province for which data on observable maize characteristics are also available. Pseudo R-squared statistics are calculated using the adjusted count method. * p<0.10, ** p<0.05, *** p<0.01

Table 5

Effect of Farm Practices on Aflatoxin

	Ordered Probit				OLS	FE
					aflatoxin truncated at 20 ppb	
	ppb = 0	0 <ppb < 10	10 < ppb < 20	ppb > 20		
	(1)	(2)	(3)	(4)	(5)	(6)
Quality and quantity of harvest						
Hectares under maize	0.028***	0.001	-0.009***	-0.020***	-0.492***	-0.449***
	(0.009)	(0.002)	(0.003)	(0.006)	(0.087)	(0.116)
Yield (100 kg / ha)	0.001**	0.000	-0.000**	-0.001**	-0.020***	-0.026***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.006)	(0.005)
Post-harvest practices						
Dry maize in field	-0.048	0.001	0.015	0.032	0.540	0.300
	(0.064)	(0.005)	(0.020)	(0.039)	(1.035)	(1.048)
Improved drying	0.130**	0.012	-0.040**	-0.102**	-2.150*	-1.524
	(0.058)	(0.011)	(0.018)	(0.049)	(1.207)	(1.201)
Days improved drying	-0.003	-0.000	0.001	0.002	0.051	0.035
	(0.002)	(0.000)	(0.001)	(0.001)	(0.038)	(0.040)
Sorted before storing	0.090	0.014	-0.027	-0.077	-1.962	-0.875
	(0.068)	(0.021)	(0.018)	(0.071)	(1.577)	(1.607)
Shelled before storing	0.110*	0.020	-0.032**	-0.097	-2.136	-2.465
	(0.060)	(0.021)	(0.016)	(0.065)	(1.581)	(1.577)
Added pesticide		-0.000	0.005	0.011	-0.053	0.074
	(0.039)	(0.001)	(0.012)	(0.027)	(0.712)	(0.669)
Months since harvest	-0.017***	-0.000	0.005***	0.012***	0.421***	0.402***
	(0.006)	(0.001)	(0.002)	(0.004)	(0.098)	(0.105)
Eastern	-0.175***	0.018	0.056***	0.101***	6.061***	6.550***
	(0.066)	(0.015)	(0.021)	(0.033)	(1.001)	(1.151)
Observations	761				761	761
Communities	106				106	106
(Pseudo) R-squared	0.228				0.140	0.030

Notes : Coefficients in columns (1) through (4) are marginal effects calculated from ordered probit

Table 6

Determinants of Alfatoxin and Discoloration

	Aflatoxin				Discolored kernels			OLS	FE	p-value of test for equality of coefficients across models
	ppb = 0	0 <ppb < 10	10 < ppb < 20	ppb > 20	0	0-10%	>10%	aflatoxin truncated at 20 ppb		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(8)
Quality and quantity of harvest										
Hectares under maize	0.056**	0.007	-0.017**	-0.046**	0.026	-0.018	-0.007	-0.790***	-0.799***	0.064*
	(0.025)	(0.005)	(0.008)	(0.022)	(0.026)	(0.019)	(0.007)	(0.192)	(0.217)	
Yield (100 kg / ha)	0.002**	0.000	-0.000**	-0.001**	0.001	-0.001	-0.000	-0.021***	-0.026***	0.485
	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.006)	(0.005)	
Post-harvest practices										
Dry maize in field	0.042	0.007	-0.012	-0.037	-0.295**	0.244**	0.051**	0.116	-0.161	0.140
	(0.132)	(0.005)	(0.035)	(0.128)	(0.126)	(0.114)	(0.024)	(3.073)	(2.995)	
Improved drying	0.020	0.000	-0.006	-0.016	-0.236**	0.175**	0.061**	-0.767	-0.413	0.056*
	(0.069)	(0.000)	(0.020)	(0.058)	(0.092)	(0.071)	(0.031)	(1.431)	(1.311)	
Days improved drying	-0.000	0.007	0.000	0.000	0.007*	-0.005*	-0.002	0.027	0.014	0.208
	(0.003)	(0.030)	(0.001)	(0.002)	(0.004)	(0.003)	(0.001)	(0.049)	(0.044)	
Sorted before storing	0.034	0.003	-0.010	-0.030	-0.126	0.097	0.029	-0.452	1.056	0.505
	(0.126)	(0.009)	(0.033)	(0.119)	(0.170)	(0.145)	(0.026)	(2.601)	(2.436)	
Shelled before storing	0.175***	-0.000	-0.031***	-0.210**	0.362**	-0.156***	-0.206	-4.051*	-4.476**	0.600
	(0.061)	(0.000)	(0.011)	(0.104)	(0.160)	(0.051)	(0.179)	(2.371)	(1.945)	
Added pesticide	0.046	0.006	-0.014	-0.039	-0.064	0.047	0.018	-1.512	-1.356	0.200
	(0.057)	(0.026)	(0.017)	(0.048)	(0.058)	(0.041)	(0.018)	(1.152)	(1.065)	
Months since harvest	-0.048***	0.067	0.014***	0.040***	-0.022	0.016	0.006	0.991***	0.861***	0.207
	(0.013)	(0.045)	(0.005)	(0.010)	(0.020)	(0.014)	(0.006)	(0.249)	(0.244)	
Observations	361				361			361	361	
Communities	74				74			74	74	
(Pseudo) R-squared	0.225				0.144			0.082	0.053	

Notes : Coefficients in columns (1) through (7) are marginal effects calculated from ordered probit regressions of the categorical proportion of discolored kernels (1 through 3), and aflatoxin contamination (4 through 7). Column (8) indicates the significance level of differences between coefficient values in the ordered probit models for discolored kernels and aflatoxin. Standard errors, shown in parentheses, are clustered at the community level for all models and tests. * p<0.10, ** p<0.05, *** p<0.01

Table 7
Aflatoxin as a Function of Maize Source

	ppb = 0	0 > ppb > 10	10 > ppb > 20	ppb > 20	ppb = 0	0 > ppb > 10	10 > ppb > 20	ppb > 20	ppb = 0	0 > ppb > 10	10 > ppb > 20	ppb > 20
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Miller	0.004	-0.000	-0.001	-0.002	-0.010	-0.000	0.003	0.008	0.024	-0.000	-0.007	-0.017
	(0.061)	(0.007)	(0.020)	(0.035)	(0.103)	(0.004)	(0.029)	(0.078)	(0.106)	(0.003)	(0.032)	(0.072)
Other purchase	-0.036*	0.003	0.012*	0.021*	-0.052*	-0.002	0.014*	0.039*	-0.053*	-0.002	0.015*	0.040*
	(0.021)	(0.002)	(0.007)	(0.013)	(0.029)	(0.003)	(0.008)	(0.023)	(0.030)	(0.003)	(0.009)	(0.023)
Gift or aid	-0.029	0.002	0.009	0.018	-0.056	-0.004	0.015	0.044	-0.058	-0.004	0.016	0.047
	(0.035)	(0.002)	(0.011)	(0.022)	(0.051)	(0.007)	(0.013)	(0.044)	(0.051)	(0.007)	(0.013)	(0.045)
Eastern Province	-0.227***	0.038***	0.072***	0.117***								
	(0.037)	(0.013)	(0.011)	(0.019)								
1-10% broken									-0.056*	-0.003	0.016*	0.043
									(0.034)	(0.004)	(0.009)	(0.027)
>10% broken									-0.126**	-0.018	0.030***	0.114
									(0.063)	(0.021)	(0.012)	(0.072)
1-10% discolored									0.030	0.000	-0.009	-0.021
									(0.038)	(0.001)	(0.011)	(0.027)
>10% discolored									-0.034	-0.002	0.009	0.026
									(0.057)	(0.004)	(0.015)	(0.045)
Share of Own-Grown Maize in Category	0.376	0.329	0.133	0.165	0.377	0.280	0.159	0.185	0.377	0.280	0.159	0.185
Observations	2082				931				931			
Communities	138				106				106			
Pseudo R-squared	0.295				0.002				0.018			

Notes: Marginal effects on the likelihood of observing each outcome, derived from an ordered probit regression, with standard errors clustered at the community level shown in parentheses. The omitted category is maize grown on the consumer's farm. Columns 1 through 4 show results from a model using the entire sample for which data on aflatoxin and source of maize are available. Columns 5 through 12 use data only from those observations from Eastern Province for which data on observable maize characteristics are also available. Pseudo R-squared statistics are calculated using the adjusted count method. * p<0.10, ** p<0.05, *** p<0.01

Table 8

Sorting practices and health perceptions by those milling own versus purchased maize

	Western			Eastern		
	own maize	purchased maize	p-value of difference	own maize	purchased maize	p-value of difference
Grain quality (pre-sorting)						
No discolored kernels				0.57	0.64	0.03
No broken kernels				0.69	0.68	0.79
Observed behavior						
Sorted maize at mill	0.79	0.80	0.614	0.58	0.66	0.013
Health perceptions						
Sorted maize for healt	0.43	0.53	0.009	0.75	0.75	0.862
Sorted maize for taste	0.30	0.26	0.278	0.24	0.24	0.923
Bad maize causes heal	0.93	0.96	0.113	0.95	0.99	0.001
Causes major health p	0.03	0.04	0.503	0.12	0.12	0.829

Notes : Data on maize quality is only available for the Eastern Province sample.

Table 9
Effect of Assets on Consumption of Self-produced Maize

	Harvested maize (100 kg)	Consumed maize produced on own farm past 7 days	
	(1)	(2)	(3)
Log asset value	2.502***	0.025**	0.021*
	(0.479)	(0.011)	(0.012)
Agricultural land (ha)	1.873**	0.013	0.013
	(0.892)	(0.009)	(0.009)
Land squared (ha sqr)	-0.034	-0.000	-0.000
	(0.043)	(0.000)	(0.000)
Harvested maize (100kg)			0.001
			(0.001)
Obsevations	679	695	677
Communities	86	86	86
R squared	0.144	0.017	0.018

Notes: Results are from linear regressions with community fixed effects. Standard errors, shown in parentheses, are clustered at the community level . * p<0.10, ** p<0.05, *** p<0.01

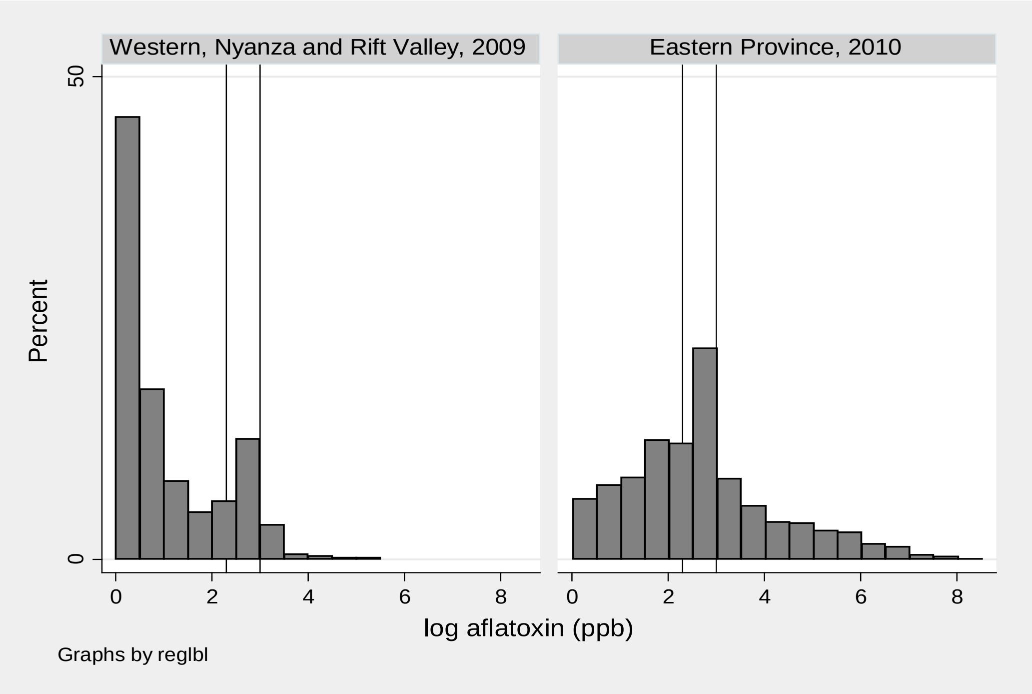

Figure 1
Log Aflatoxin Contamination by Region and Year

Notes : Observations with no detectable aflatoxin contamination are excluded. In Western, Rift Valley, and Nyanza Provinces, 43 percent of observations contain no detectable aflatoxin; in Eastern Province, 33 percent contain no detectable aflatoxin. Vertical lines indicate 10 ppb and 20 ppb aflatoxin.

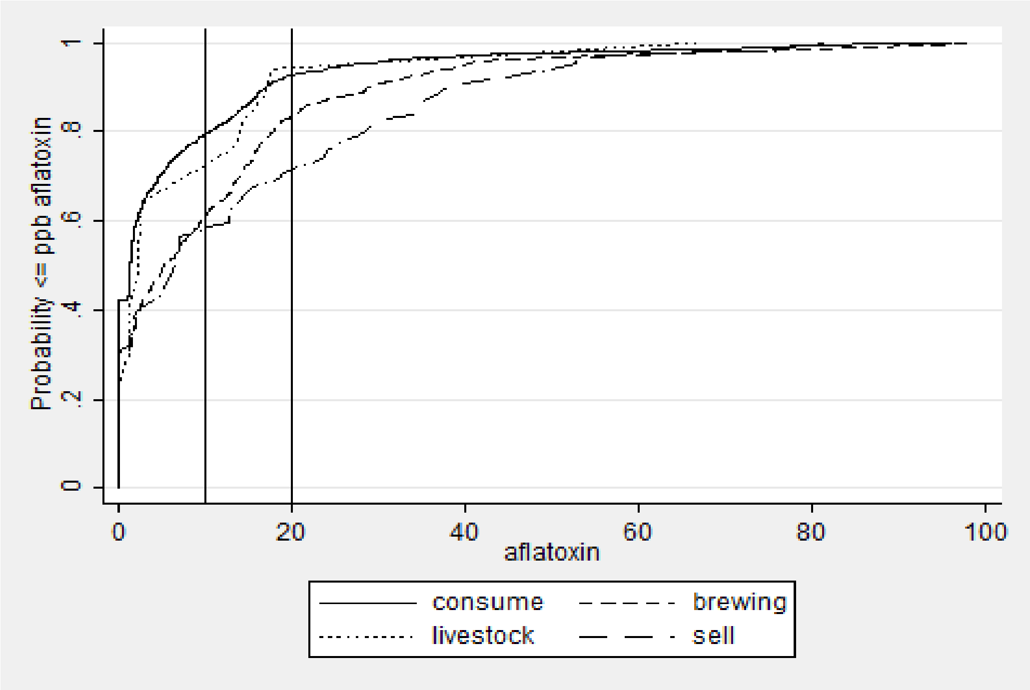

Figure 2
Aflatoxin Contamination by Stated Use of Grain

Notes :Excludes 5.4% of the sample with greater than 100 ppb aflatoxin contamination. Vertical lines indicate 10 ppb and 20 ppb aflatoxin.

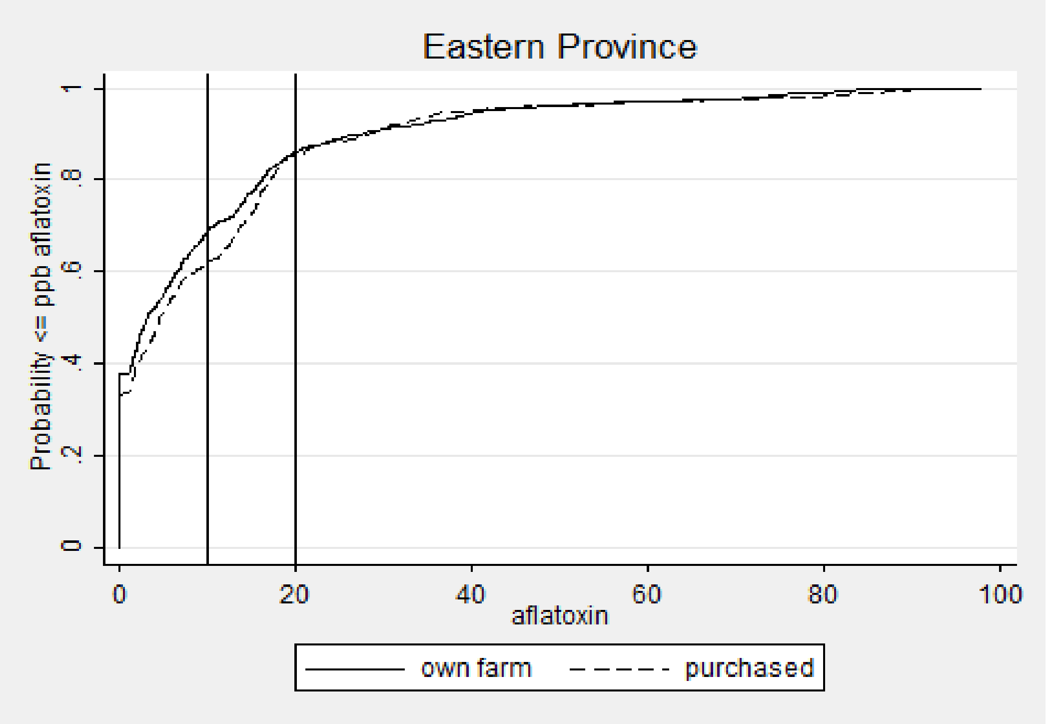

Figure 3

Cumulative Distribution of Aflatoxin by Source of Grain, Eastern Province

Notes : Black vertical lines indicated the 10 ppb and 20 ppb regulatory limits.

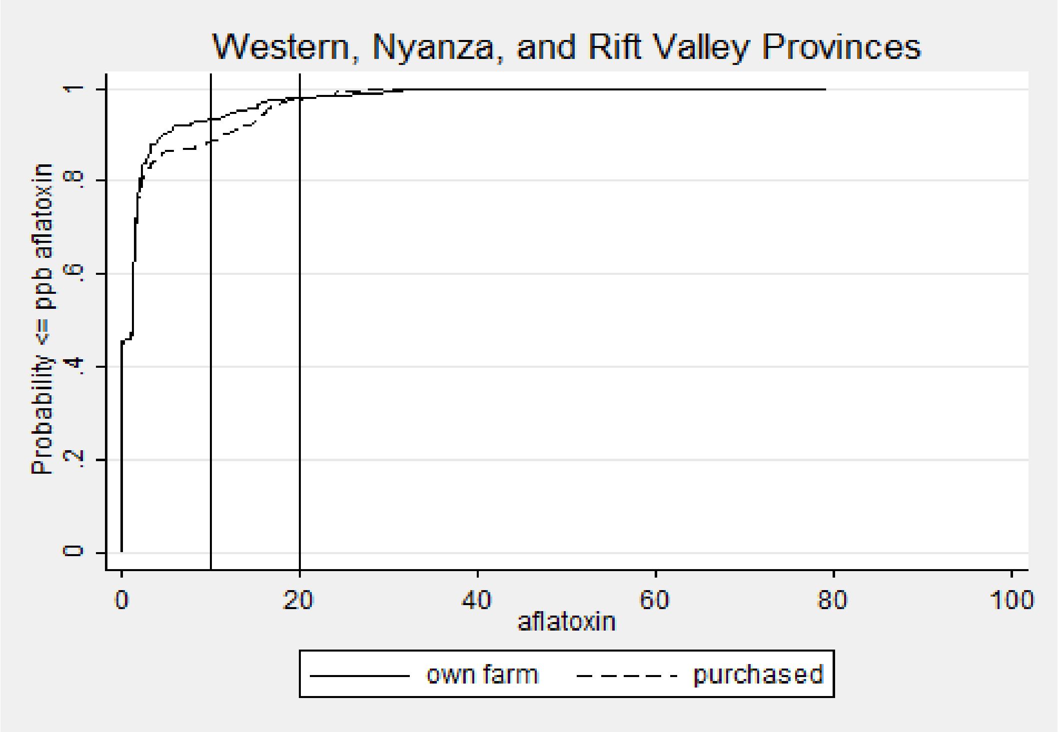

Figure 4

Cumulative Distribution of Aflatoxin by Source of Grain, Western Region

Notes : Black vertical lines indicated the 10 ppb and 20 ppb regulatory limits.

Table A.1

Aflatoxin as a Function of Observable Quality

Panel A

	ppb = 0	0 > ppb > 10	10 > ppb > 20	ppb > 20
1-10% broken kernels	-0.035	-0.002	0.012	0.024
	(0.038)	(0.003)	(0.013)	(0.028)
>10% broken kernels	-0.144***	-0.031	0.043***	0.132*
	(0.053)	(0.028)	(0.013)	(0.068)
Proportion of zero unbroken in aflatoxin category	0.362	0.295	0.172	0.175
Observations		1019		
Communities		108		
Pseudo R-squared		0.024		

Panel B

	ppb = 0	0 > ppb > 10	10 > ppb > 20	ppb > 20
1-10% discolored kernels	-0.001	-0.000	0.000	0.001
	(0.040)	(0.001)	(0.013)	(0.027)
>10% discolored kernels	-0.074	-0.008	0.024	0.058
	(0.050)	(0.011)	(0.016)	(0.044)
Proportion of zero discolored in aflatoxin category	0.351	0.278	0.178	0.193
Observations		1019		
Communities				
Pseudo R-squared		0.029		

Notes: Marginal effects on the likelihood of observing each outcome, derived from ordered probit regressions, with standard errors clustered at the community level shown in parentheses. Pseudo R-squared statistics are calculated using the adjusted count method. Data are from Eastern Province only. * p<0.10, ** p<0.05, *** p<0.01

Table A.2

Use of Maize as a Function of Aflatoxin Contamination - Bootstrapped Estimates

	HH Food	Brewing	Livestock Feed	Sale	HH Food	Brewing	Livestock Feed	Sale	HH Food	Brewing	Livestock Feed	Sale
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0 < ppb < 10	-0.120	0.015	0.097	0.008	-0.319	-0.015	0.287	0.047	-0.229	0.037	0.166	0.026
	(0.209)	(0.066)	(0.220)	(0.076)	(0.224)	(0.138)	(0.317)	(0.205)	(0.214)	(0.105)	(0.266)	(0.151)
10 < ppb < 20	0.213	0.037	0.158	0.018	-0.403*	0.048	0.293	0.061	-0.350	0.112	0.198	0.040
	(0.295)	(0.103)	(0.334)	(0.119)	(0.234)	(0.208)	(0.401)	(0.227)	(0.226)	(0.167)	(0.345)	(0.176)
ppb > 20	-0.254	0.040	0.181	0.032	-0.474**	-0.012	0.390	0.096	-0.385*	0.074	0.247	0.065
	(0.306)	(0.105)	(0.351)	(0.145)	(0.215)	(0.188)	(0.395)	(0.240)	(0.221)	(0.158)	(0.347)	(0.180)
1-10% discolored									-0.065	0.057	-0.001	0.009
									(0.058)	(0.057)	(0.004)	(0.017)
>10% discolored									0.092	-0.167*	0.006	0.069
									(0.133)	(0.093)	(0.024)	(0.110)
1-10% broken									0.078	-0.078	0.001	0.000
									(0.053)	(0.050)	(0.005)	(0.015)
>10% broken									0.136*	-0.124	0.000	-0.013
									(0.078)	(0.076)	(0.007)	(0.021)
Eastern	-0.327***	0.309***	-0.001	0.020								
	(0.046)	(0.044)	(0.009)	(0.023)								
Observations	390				294				294			

Notes: Bootstrapped (500 iterations) marginal effects from multinomial logit regressions, with standard errors clustered at the community level shown in parentheses. The omitted category is no detectable aflatoxin contamination. Columns 1 thorugh 4 show results from a model using the entire sample for which data on aflatoxin and intended use of maize are available. Columns 5 through 12 use data only from those observations from Eastern Province for which data on observable maize characteristics are also available. * p<0.10, ** p<0.05, *** p<0.01

Table A.3
Use of Maize by Source and Contamination Level

Panel A: Maize grown on own farm

		ppb = 0	0 > ppb > 10	10 > ppb > 20	ppb > 20
Food for HH	N	296	262	84	99
	%	77.9	76.8	60.9	57.6
Brewing	N	68	66	47	51
	%	17.9	19.4	34.1	29.7
Livestock Feed	N	2	4	3	4
	%	0.5	1.2	2.2	2.3
Sale	N	14	9	4	18
	%	3.7	2.6	2.9	10.5
	% total	100	100	100	100

Panel B: Purchased maize

		ppb = 0	0 > ppb > 10	10 > ppb > 20	ppb > 20
Food for HH	N	241	206	75	46
	%	86.1	79.2	66.4	46.5
Brewing	N	35	45	36	47
	%	12.5	17.3	31.9	47.5
Livestock Feed	N	1	4	1	1
	%	0.4	1.5	0.9	1
Sale	N	3	5	1	
	%	1.1	1.9	0.9	5.1
	% total	100	100	100	100