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Firm Heterogeneity in Food Safety Provision

Evidence from Aflatoxin Tests in Kenya

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Contents

Tables

Figures

.

ABSTRACT

The lack of a reliably safe food supply in developing countries imposes major costs on both public health and market performance. This paper addresses the question of whether and why food processing firms voluntarily invest in food safety in the absence of effective regulatory enforcement. Using data from more than 900 maize flour samples representing 23 distinct brands in eastern and central Kenya, we explore the relationship between price, brand, and aflatoxin contamination. Aflatoxin is a toxin common in maize, groundnuts, and other crops around the world; and although it is unobservable to the consumer, it may be correlated with other quality characteristics. We find a strong negative correlation between price and contamination rates, which is consistent with certain brands investing more in quality to avoid loss of reputational capital.

Keywords: food safety, firm strategy, voluntary compliance, brand capital

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1. INTRODUCTION

Ensuring food safety in developing countries with poor public-sector regulatory enforcement is a challenge. This is particularly true when the contaminant is unobservable to the consumer and the health concerns are primarily regarding chronic exposure that cannot be linked to the product, giving producers little incentive to self-regulate. This is the case with aflatoxin—a by-product of fungal growth in a range of crops and a global problem. While routine testing and modern processing, handling, and storage have largely eliminated the risk to consumers in the developed world, millions are exposed in developing countries (Strosnider et al. 2006). An additional risk factor for large parts of Africa is the important role of maize or groundnuts, two particularly susceptible foods, in the diet. In this paper, we use data on aflatoxin test results from processed maize flour in Kenya to demonstrate that, despite a lack of public-sector enforcement, higher-priced flours are more likely to meet the official regulatory standard.

Aflatoxin is a toxin produced by the *Aspergillus* species of fungus. Although consumption of high levels of aflatoxin can be fatal, the high rate of chronic exposure in the developing world is of greater public health significance. A link between aflatoxin exposure and liver cancer has been well documented (Strosnider et al. 2006). In addition, evidence is emerging from longitudinal studies of a negative impact on linear growth in children (Gong et al. 2004; Turner et al. 2007). Children can be exposed in utero, through breast milk, and postweaning. Detectable levels of aflatoxin have been found in the cord blood of babies in a range of countries, including the United Arab Emirates (in 67 percent of samples), Kenya (37 percent), and Nigeria (22–82 percent). The levels detected in blood and urine are generally much higher in samples from developing countries (Khlangwiset, Shephard, and Wu 2011).

Crop stress, such as drought or pest infestation, as well as inadequate drying or poor storage makes maize more vulnerable to *Aspergillus* fungal infection (Gnonlonfin et al. 2013). Aflatoxins can be produced by the fungus both in the field and during storage. While visible mold may be an indication that contamination is present, high levels of aflatoxin can be present in foods with no noticeable impurity, and contamination can increase during storage. It is found in a variety of crops and animal products, but the consumption of maize and groundnuts is the most common source of exposure worldwide (Khlangwiset, Shephard, and Wu 2011).

Parts of Kenya have among the highest rates of aflatoxin exposure globally and have experienced some of the most severe recorded outbreaks (Daniel et al. 2011). The proportion of maize exceeding the allowable limit of aflatoxin in Kenya varies by region and year because of differences in climate and yearly rainfall patterns that may favor fungal growth. One study led by researchers from the US Centers for Disease Control and Prevention tested maize grain samples in eastern Kenya for three years. In 2005 and 2006, two years considered outbreak years, 41 and 51 percent, respectively, of maize grain samples tested above the regulatory limit, but in 2007 this fell to 16 percent (Daniel et al. 2011).

The legally allowable level of aflatoxin contamination in food for human consumption set by the Kenyan regulatory authority is no more than 10 parts per billion.[1] However, enforcement of this standard is weak, even in the formal market where the relatively small number of large millers makes testing and enforcement feasible.[2] Some, though not all, mills test maize for aflatoxin prior to purchase, rejecting lots that exceed the legally allowable limit. However, previous work has found evidence of poor testing protocols and corruption at some mills that allow poor-quality maize to pass through the gates (Kirimi et al. 2011). In Kenya, regulators obtain samples both directly from mills and from store shelves for aflatoxin testing. Three millers who were interviewed reported being visited by the regulatory authority

[1] No single international standard exists for allowable levels of aflatoxin. The standard in the United States varies by use and by crop but for human consumption is generally 20 parts per billion (ppb). The EU standards also vary but are more stringent. For example, 2 ppb is the allowable level set for cereal crops meant for human consumption. Animals are also susceptible to aflatoxins, but standards typically allow for higher levels of the contaminant in animal feeds (Dohlman 2003). The Kenya Bureau of Standards had initially set the allowable limit at 20 ppb, but in recognition of the high proportion of maize in the Kenyan diet, the standard was later changed to 10 ppb (Daniel et al. 2011); the level used in Daniel et al.'s analysis is 20 ppb.

[2] A 2009 report estimated that small-scale informal mills processed 60 percent of maize meal in Kenya, with the remainder presumably processed in larger, formal-sector mills (Kenya Maize Development Program 2009, cited in Kirimi et al. 2011).

for sampling; however, none had ever been informed of a violation of the standard. In contrast, a previous independent study obtained and publicized by the Kenyan popular press (Gathura 2011) found that 65 percent of samples from formal-sector millers were contaminated, suggesting that enforcement of Kenya’s *de jure* aflatoxin regulation is not achieving its objective in practice.

In this context, consumers have no way to ensure that they are purchasing uncontaminated maize, whether purchasing whole maize kernels in the informal market or packaged maize flour produced by large mills in supermarkets. At least one study suggests that Kenyan consumers recognize the problem of unobservable quality in maize. In an experimental auction, Hoffmann and Gatobu (2014) find that consumers place a large premium on self-produced maize and provide evidence that this is due to unobservable quality (not specifically related to aflatoxin) in maize purchased in the market. When participants in the study were told that maize had been tested for aflatoxin, bids on market maize increased by approximately 7 percent.

This paper develops a simple model based on brand reputation to explain heterogeneous investment in food safety by producers when this attribute is unobservable to the consumer. We then provide evidence for the model using data from more than 900 aflatoxin tests of maize flour samples in Kenya for 23 distinct brands and show a strong negative correlation between price and samples not meeting the regulatory standard. The three possible explanations for the observed negative relationship are as follows: First, millers with established brands fear an outbreak of illness linked to their product and are more careful to scrutinize the maize they purchase. Second, millers might expect strengthened government regulation or inspection in the near future. Third, aflatoxin contamination may be correlated with other quality characteristics, such as moisture content at the time of purchase by the miller and refining during processing, and lower contamination is an unintended benefit.

This paper is organized as follows: The next section outlines a basic model of investment in improved food safety. Section 3 describes the study and data used in this paper, and Section 4 presents the results. The final section provides a discussion of the implications for approaches to improving food safety in developing countries.

2. MODEL OF INVESTMENT IN UNOBSERVABLE QUALITY

In developing a model of voluntary investment in unobservable food quality, we can draw from a rich theoretical literature, including models of voluntary compliance with regulation and quality investments linked to brand reputation and differentiation. The frequently cited model of d'Aspremot, Gabszewicz, and Thisse (1979) proposes "maximum differentiation" based on quality in a highly competitive market with a homogenous product. However, Bester (1998) shows that when consumers have imperfect information on quality, firms have lower incentives to differentiate their products.

Orosel and Zauner (2011) develop a model that has several features that are relevant to our study of millers in Kenya. First, they assume that the quality of the good is unobservable to the customer before purchase. Second, a competitive fringe will always produce low-cost product with zero investment in quality. According to shop owners and millers in Kenya, many small, regional mills compete on price and offer the cheapest flour available on the market. One difference, however, is the objective of the two models: Orosel and Zauner's is to show how brands and pricing strategies emerge when quality is revealed to consumers after purchase, but ours is to show how established brands might react to emerging food safety threats when quality is not revealed to consumers unless an outbreak occurs.

Among the models examining voluntary versus mandatory standards, that of Segerson (1999) suggests that when consumers are able to observe safety attributes, voluntary provision of food safety is more likely than when food safety is unobservable. However, for both observables and unobservables, the threat of mandatory standards can induce voluntary compliance. Fares and Rouviere (2010) build on the Segerson model by comparing the effects on firm behavior of (1) the threat of mandatory enforcement and (2) low versus high risk of contamination. In their model, the firms can earn additional net benefits from increasing consumer demand as a result of improved food safety. In both the Segerson (1999) and Fares and Rouviere (2010) models, firms are homogenous and make a binary choice to either comply or not comply with a standard, rather than choosing the level of investment in food safety.

Our model begins with firms that are already established and assume that the market is in equilibrium with a continuum of producers from low-priced with no brand capital to high-priced with high brand capital. Following Orosel and Zauner (2011), the price, p, a firm is able to charge, and its marginal cost of production, c_B, are functions of established brand capital, B_i, and a competitive fringe of "no-names" lack brand capital and must sell at the market equilibrium price, $p(B_0)$. Firms with brand capital earn positive rents such that $p(B_i) - c_B(B_i) > p(B_0) - c_B(B_0) = 0$. We abstract from quantities and assume constant marginal costs with respect to quantity.

Now suppose that firms and consumers become aware of a food safety issue, but consumers cannot observe contamination (such as with aflatoxin or pesticide residues). In the absence of regulatory enforcement, the incentive for firms to invest in food safety arises from the potential cost to the firm in the case of an outbreak resulting in illness or death linked to their product, or from information becoming public that their product is contaminated.3 This cost could be legal liability for harm or from loss of brand capital; we focus on the latter. Let *r* be the probability of an outbreak or information about a bad test result that would cost the firm its expected profits, and let *r* be a function of investment in food safety, s. The cost of investment per unit of sale in food safety, c_S, is assumed to be linear and an increasing function of s. Let $r'(s) < 0$, and $r''(s) > 0$.

The firm's expected profit per unit of sale can be described by

$$\left(1 - r(s)\right)\left(p(B_i) - c_B(B_i)\right) - c_s \cdot s. \tag{1}$$

The profit-maximizing firm chooses the level of investment in food safety such that the marginal cost of food safety investments equals the expected gain from continued existence of brand capital, $c_s =$

[3] The study publicized by Gathura (2011), writing for the *Daily Nation*, did not name specific millers but reported that 65 percent of maize flour was contaminated, which caused a stir among maize millers and prompted several of them to invest in improved aflatoxin safety equipment.

$-r'(s) \cdot [(p(B_i) - c_B(B_i)]$. Thus, both greater brand capital and higher perceived returns to food safety investments (for example, when the probability of food safety problems in the absence of preventive action is believed to be high) will lead to higher investment in food safety.

Furthermore, if the probability of contamination is reduced by selection on or improvements in other dimensions of quality, firms that already sell high-quality products may not need to invest as much specifically in food safety to reduce risk as those that sell low-quality products. This is relevant in a study of aflatoxin because certain quality characteristics, for example, consistently low moisture content from the time of harvest to milling, and higher levels of refining are associated with lower levels of contamination (Bennet and Anderson 1978).

The regulatory standard of aflatoxin is set to minimize the effects of chronic exposure—a level much lower than what would be necessary to cause immediate sickness or death. In the absence of reliable and systematic testing, chronic exposure would continue to go undetected. Therefore, if firms perceive the risk of an outbreak of acute aflatoxicosis or of information about the true aflatoxin level of their product to be very small, they may continue to provide a product that exposes the public to chronic risks, absent the threat of regulatory enforcement. On the other hand, as our discussions with millers suggests, fear of publication of test results may be sufficient to spur investment in food safety for some firms.

3. DATA

This paper uses a record of more than 900 aflatoxin test result, brand, price, and package size (1 or 2 kilograms [kg]) observations to study the correlation between price and contamination rates. These data were collected as part of a pilot study in 2013 conducted to gauge consumers' willingness to pay for aflatoxin-tested maize. This study was conducted over several months in 11 shops and small supermarkets in eight different towns in eastern and central Kenya. These areas were chosen because of the relatively high levels of aflatoxin contamination and consumer awareness compared with other areas of Kenya (de Groote et al. 2014).

The study was structured as follows: The team tested packages of maize flour stocked on the shelves of shops using rapid binary tests that indicated whether the aflatoxin level in a given sample exceeded the official Kenyan regulatory limit of 10 parts per billion (ppb). The sample of brands was selected to represent the sales volume of each brand at each store, according to the store manager. Flour that tested negative was labeled as having been tested for aflatoxin and put back on shelves; maize that tested positive was disposed of. Tested maize flour was then offered to customers at prices ranging from 0 to 20 percent above the price of untested flour of the same brand, and consumers were asked to participate in a short exit survey. Because the study design required meeting expected demand for aflatoxin-tested maize of each brand at a particular store, the number of tests conducted per brand varies widely.

We have 23 different brands in our dataset. Prices ranged from 43 to 86 Kenyan shillings (Ksh) per kg. We found that 26 percent of maize flour did not meet the national standard for aflatoxin contamination. Among the brands with more than five observations, contamination rates range from 5 to 83 percent; Table 3.1 summarizes these data. Figure 3.1 shows the percentage of samples that did not meet the regulatory standard by brand and price per kilogram for both 1 and 2 kg packages. This figure provides the first indication of a correlation between aflatoxin test results and price.

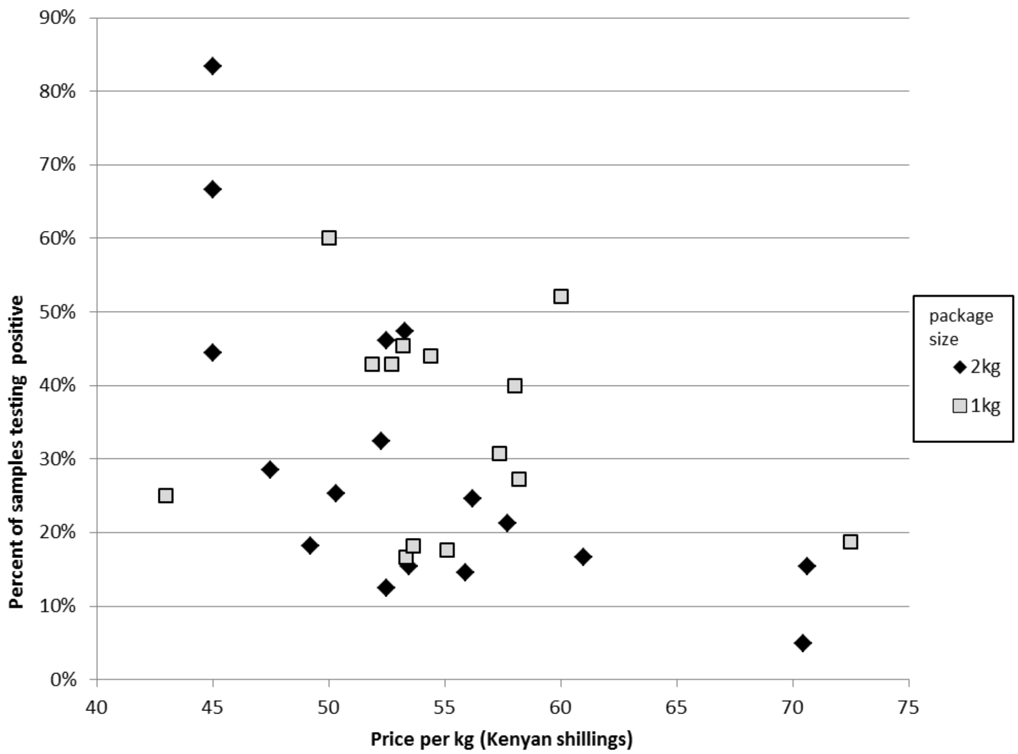
Table 3.1 Test results by average price and brand

Brand	Percentage of samples testing positive (>10 ppb)	Price per kilogram (Ksh)	Standard deviation of price	Number of packages sampled
A	5%	70.45	(4.23)	121
B	15%	55.69	(3.35)	65
C	17%	61.00	(0.00)	6
D	17%	53.54	(4.36)	24
E	17%	71.66	(3.03)	29
F	22%	52.30	(3.84)	23
G	24%	49.33	(2.65)	38
H	24%	57.91	(5.31)	80
I	26%	56.51	(4.38)	198
J	27%	45.86	(2.27)	11
K	28%	50.65	(1.86)	94
L	29%	52.52	(5.25)	49
M	40%	58.00	(4.14)	15
N	44%	52.62	(3.24)	61
O	44%	45.00	(0.00)	9
P	45%	53.92	(3.55)	44
Q	50%	57.50	(5.67)	36
S	83%	45.00	(0.00)	6
Total*	26%	56.99	(7.82)	919

Source: Data collected by the authors

Note: Ksh = Kenyan shillings; ppb = parts per billion. *Total includes brands with <5 observations not shown in table.

Figure 3.1 Percentage of samples testing above the limit of 10 parts per billion by price, for brands with six or more samples shown



Source: Data collected by the authors.

In addition to price, another variable of interest is package size. We hypothesize that this may be correlated with brand quality because different mills select into offering different package sizes (1 kg, 2 kgs, or both). Anecdotally, 1 kg packages seem to be marketed toward poorer consumers who do not have cash for the larger size. We do find evidence for this in our data. Table 3.2 shows the brands offered for sale in only 1 kg packages or both 1 and 2 kg packages.[4] No statistically significant difference is observed in price and test results for those offering only 1 kg versus those offering both 1 and 2 kg packages, but the differences between offering only 1 kg or both 1 and 2 kg packages versus offering only 2 kg packages are statistically significant. In other words, flour that is sold only in 2 kg packages tends to be higher in price and is less likely to be contaminated. Another possibility is that the higher contamination rate results not from differences in initial quality, but from 1 kg packages sitting on the shelves longer, which could lead to increasing levels of aflatoxins over time. In this case, we would observe within-brand differences in test results for those brands offering both package sizes. We test for this possibility in the next section.

[4] Because we observe only what was sold in the shops participating in the study, we cannot be certain that a particular miller does not produce other package sizes for other markets.

Table 3.2 Price and test results by package size

Package size	Number of brands	Total number of observations	Price (Ksh)/kg	Proportion of test results above limit
1 kg only	3	20	58.15	0.30
			(3.84)	(0.47)
Both 1 and 2 kg	7	752	55.02	0.28
			(5.91)	(0.45)
2 kg only	13	147	66.95	0.12
			(9.11)	(0.33)

Source: Data collected by the authors

Notes: kg = kilogram; Ksh = Kenyan shillings. Standard deviation is in parentheses.

4. EMPIRICAL RESULTS

The previous section provided some evidence that higher-priced flours have lower contamination rates, and this section explores this relationship further with additional analysis. Although our dataset includes more than 900 observations, we have only 23 distinct brands; and for some brands we have only a handful of observations. Prices per kilogram do vary within brands because of different locations, package size, and purchase dates; but a strong brand effect on price is obvious (as can be seen in Table 3.1). We present two estimation approaches: The first aggregates the data at the brand level and uses the percentage of samples testing positive by brand as the dependent variable, and the second uses the full set of test results, clustering the standard errors by brand.

Table 4.1 presents results for a regression of the percentage of positive test results by brand on the average price for that brand. Because of the trade-off in this dataset between having a large enough sample of tests for a particular brand to be considered reliable and having enough brand observations to run a regression, we estimate separate models for brands with at least 5 and 10 test observations per brand in models I and II, respectively. Model III adds the proportion of samples that were from 2 kg packages. All three models show that price is negatively related to the percentage of samples that test positive, and this is significant at the 5 percent level in the specifications using brands with at least 5 test observations. The coefficient on the package size variable is negative but not statistically significant.

Table 4.1 Regression of proportion testing above the limit on price by brand

Variable	Model I Brands with >5 observations		Model II Brands with >10 observations		Model III Brands with >5 observations with additional control	
Mean price	–1.33	**	–0.66	*	–1.46	***
	(0.023)		(0.083)		(0.012)	
Proportion of samples from 2 kg packages					–16.36	
					(0.17)	
Constant	104.12	***	64.48	***	122.23	***
	(0.004)		(0.006)		(0.00)	
Observations	18		15		18	
R-squared	0.30		0.14		0.37	

Source: Data collected by the authors.
Notes: kg = kilogram *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, p-values based on robust standard errors in parentheses.

The next set of estimations uses a linear probability model with the full (pooled) dataset of 919 observations with a binary dependent variable equal to 1 if the test result was positive for aflatoxin at the 10 ppb level. The relatively small number of clusters (23) in our dataset means that clustered standard errors may be biased downward. Therefore, the results presented in Table 4.2 use the wild cluster bootstrap-t procedure proposed by Cameron, Gelbach, and Miller (2008).[5] The large number of observations allows us to add additional control variables. Model I in Table 4.2 uses price as the only explanatory variable, and it has a strongly significant, negative effect on the probability of testing positive for aflatoxin contamination. Every 10 Ksh increase in price reduces the probability of testing positive by 10 percent. Taking the highest-priced brand (A) and the lowest-priced brands (O and S) from Table 3.1, the model predicts that flour of the highest-priced brand is 25 percent less likely to test positive.

[5] We use the cgmwildboot program written by J. Caskey for Stata available at https://sites.google.com/site/judsoncaskey/data. The results from standard clustered standard errors are generally consistent with those from the wild cluster bootstrap, with p-values that are slightly higher across the models.

Table 4.2 Linear probability model with bootstrapped clustered standard errors

Dependent variable = 1 if sample tests above regulatory limit	Model I, price only		Model II, with package size		Model III, controlling for highly refined brands		Model IV, with vendor dummies	
Price	–0.010		0.010		–0.007		–0.012	
	(0.040)	**	(0.046)	**	(0.08)	*	(0.040)	**
2 kg package			–0.107		–0.097		–0.062	
			(0.049)	**	(0.04)	**	(0.040)	**
Highly refined/high-priced brands (dummy)					–0.075			
					(0.60)			
Vendor dummies								
Vendor 2							–0.027	
							(0.760)	
Vendor 3							0.002	
							(1.040)	
Vendor 4							–0.024	
							(0.720)	
Vendor 5							–0.130	
							(0.480)	
Vendor 6							0.047	
							(0.600)	
Vendor 7							–0.025	
							(0.720)	
Vendor 8							–0.059	
							(0.640)	
Vendor 9							–0.148	
							(0.400)	
Vendor 10							–0.174	
							(0.280)	
Vendor 11							–0.053	
							(0.720)	
Constant	0.843		0.910		0.759		1.077	
	(0.000)		(0.726)		(0.00)	***	(0.000)	*
Observations	919		919		919		919	
R-squared	0.0339		0.0467		0.045		0.072	
Adjusted R-squared	0.0329		0.0446		0.045		0.060	

Source: Data collected by the authors

Notes: kg = kilogram. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; p-values are estimated following the wild bootstrap procedure described in Cameron, Gelbach and Miller (2008) and using the Stata program written by J. Caskey. The p-value is based on the empirical distribution of t-statistics.

Model II adds a dummy variable that equals 1 if the package size is 2 kgs (as opposed to 1 kg). Consistent with the discussion in the previous section, 2 kg packages are less likely to be contaminated. Two explanations are possible. First, since we are not controlling for brand, low-quality brands might be more likely to sell 1 kg packages marketed to poor consumers who can only buy small quantities at a time. Second, a difference could be possible between the two package sizes in how quickly they are sold or how frequently they are milled, as longer storage time is associated with greater risk of contamination. We address this issue below.

Model III adds a dummy variable to control for the two highly refined brands of flour with the highest prices—brands A and E in Table 3.1—to ensure that results are not driven by these outliers. The statistical significance falls slightly when we drop these observations, but the magnitude of the negative relationship between price and contamination remains similar to the previous models. Model IV in Table 4.2 adds vendor dummies. Because the testing took place over several months, beginning with vendor 1 and ending with vendor 11, these dummies control for both location and time period. Again, price is negatively related to the test result. The coefficient increases slightly in absolute terms from –0.010 to –0.012.

The final estimation tests one of the hypotheses regarding the relationship between package size and contamination. If the higher contamination rates in 1 kg packages are caused not by brands of heterogeneous quality offering only certain package sizes but by longer time left on the shelves than 2 kg packages, then we would expect the effect of package size to remain after controlling for brand. Table 4.3 presents results of a brand fixed-effects estimation to test for this effect. The coefficient on package size remains negative, but it is not significantly different from zero, suggesting that the effect of package size is largely driven by higher quality brands selecting into offering only 2 kg packages.

Table 4.3 Testing within-brand effect of package size: Brand fixed-effects estimation

Dependent variable = 1 if sample tests above regulatory limit	Model with price and package size	
Price	-0.005	
	(0.15)	
2 kg package	-0.049	
	(0.167)	
Constant	0.582	***
	(0.005)	
Observations	919	

Source: Data collected by the authors
Note: kg = kilogram *** $p < 0.01$; p-values reported in parentheses.

The evidence presented in this section and the previous section is consistent with our model of brand capital in that higher-priced brands do seem to provide safer maize flour to the market, even though this characteristic is unobservable to the consumer and the official regulation is not enforced. Some of this effect may be driven by correlation between contamination and other quality characteristics such as refining and moisture content. Although we are unable to control for these characteristics directly, the magnitude of the price–contamination relationship holds when we control for the most highly refined brands.

5. DISCUSSION

Improving food quality in the context of poor regulatory capacity is a challenge in many parts of the world. This is particularly true when the contaminant is unobservable to the consumer. We study this issue in the context of aflatoxin contamination in maize flour in Kenya and find that price is strongly correlated with a lower likelihood of contamination. The magnitude of the effect is quite large—our model predicts that the lowest-priced brands in our sample are 25 percent less likely to meet the regulatory standard for aflatoxin than the highest-priced brands. A few explanations for this relationship are possible, and we develop a model to explain heterogeneous investment in food safety. First, millers with higher-priced, established brands may have more to lose if an outbreak is linked to their product or if the results of aflatoxin tests performed on their product become public. Second, millers might expect that the government may begin enforcing regulations in the future and larger firms may be better able to invest in testing capacity in anticipation of this. Finally, aflatoxin contamination may be correlated with other quality characteristics, such as moisture content and refining, and lower contamination is an unintended benefit.

While there may be some spillover from investment in certain observable quality characteristics into lower aflatoxin levels, the authors' discussions with millers and visits to several mills reveal that certain millers are taking steps specifically to reduce aflatoxin levels in their flour. However, in the absence of regulatory enforcement, our results suggest that a segment of the market will continue to sell on price and fail to invest in safety. The primary strategy employed by maize mills to reduce aflatoxin exposure is to test maize for the contaminant prior to purchase—meaning the rejected maize can re-enter the market—which implies that purely voluntary enforcement has important distributional implications because poorer consumers who cannot afford higher-priced flours will be at risk of greater exposure to aflatoxin.

Although our study focuses on the formal-sector market for milled and packaged flour, these distributional concerns extend to the larger informal market, where consumers purchase whole maize grains in bulk. No systematic comparison has been done of contamination rates between the informal- and formal-sector maize markets in Kenya; however, anecdotal evidence and the fact that some standards for moisture content and aflatoxin are (imperfectly) applied in the formal sector suggest that contamination rates are likely higher in the informal sector. An additional concern is the risk that if millers comply with aflatoxin standards in the formal sector, contaminated maize will be pushed to the informal sector and poorer consumers. Because of the number of points of purchase and sale and the difficulty in tracing bulk sales, regulatory enforcement will be difficult in the informal sector.

In some scenarios, improved food safety in one segment of the market could instead have a pulling-up effect on the rest of the market. First, improved quality in one segment of the market might lead to increased consumer awareness of aflatoxin and greater demand for quality. Second, millers and traders might begin to demand (and pay for) better quality from farmers. However, because our work provides evidence that heterogeneous investment in quality is already occurring, all segments of the market need to be monitored going forward to limit the potential for the poor being at greater risk of exposure to aflatoxin.

In terms of the broader implications of our results, this study demonstrates both the potential and the risk of relying on private-sector voluntary compliance with food safety regulation. Our study of unobservable quality and risks of chronic exposure is relevant to many contaminants, such as pesticides and heavy metals. Although some firms may have incentives to invest in safety, relying on purely voluntary compliance may put some consumers at greater risk if the market is segmented.

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