Information efficiency in a lemons market: Evidence from Bt cotton seed market in Pakistan

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Abstract

Efficient information exchanges between sellers and buyers are essential if prices are to act as a signal for resource allocation in an economy. In the case of seed and planting materials, information on quality traits are often difficult for consumers (farmers) to obtain prior to purchase, resulting in failures in the market for seed-based technologies. While regulations on seed certification, labeling and packaging seek to remedy this problem, such regulations are often difficult to enforce where markets are large and diverse, or where the government's regulatory infrastructure is limited. The market for genetically modified insect-resistant Bt (*bacillus thuringiensis*) cotton seed in Pakistan appears to be one of these markets. In this paper, we test for the presence of asymmetric information in the seed market by comparing the quality of seed purchased across a representative sample of cotton farmers in Pakistan's two main cotton-growing provinces. We also test for the extent to which seed prices reflect the efficacy of the insect-resistance traits—a quality trait that is generally unobservable by the farmer—as measured by ELISA (enzyme-linked immunosorbent assay) readings of the Bt toxin expression levels. Drawing on initial results from these tests, we then explore the various regulatory mechanisms and market instruments that can be used to help farmers to better infer Bt seed quality.

Key words: Bt cotton, asymmetric information, Pakistan

1. Introduction

Efficient information exchanges between sellers and buyers are essential for prices to act as a signal for resource allocation in an economy. Fama (1970) defines an efficient market as one where prices always "fully reflect" available information. It is expected that in such an efficient market, prices should reflect the quality of the products traded. Akerlof (1970) demonstrates that a market may even desist if asymmetric information exists persistently, that is, if sellers hold off information on product quality from buyers. Subsequent empirical studies find that asymmetric information exists in many markets, for example, the market for used vehicles (Bond 1982, 1984; Sultan 2008; Emons and Sheldon 2009); slaves (Greenwald and Glasspiegel 1983); workers (Gibbons and Katz1991); drugs (Bate et al. 2011); and maize (Hoffmann et al. 2013). A variety of institutional tools and arrangements such as brands, licenses, and certificates have been developed to remedy this problem of asymmetric information.

The market for genetically modified Bt (*bacillus thuringiensis*) cotton seed in Pakistan appears to be characterized by asymmetric information since farmers are not fully informed of the quality of the seed they are purchasing. Bt cotton, due to its effective resistance to a group of cotton bollworms, has been widely adopted in many countries since its inception in 1996. However, low quality Bt cotton seed has been found in many developing countries such as China, India, Brazil, and Pakistan (Pemsl et al. 2005; Ramaswami and Pray 2007; da Silveira and Borges 2007). Pakistan, in particular, has lagged behind in acquiring government approval for commercialization in comparison to China, where it was approved in 1997, India, where it was approved in 2002 and also Brazil in 2005. However, Bt cotton has been present in the market since early 2000s through smuggling and other illegal channels from neighboring countries (Hayee 2005; Ali and Abdulai 2010; Nazli et al. 2012), resulting in unapproved seed proliferation and an adoption rate of 75% of the planted area in

Pakistan (Ali and Abdulai 2009). It was not until 2010 that Bt cotton was officially approved for commercialization for the first time.

The effectiveness of Bt cotton depends on the expression of insecticidal Bt genes embedded in the cotton variety. In Pakistan, breeders develop Bt cotton varieties by backcrossing local genotypes with alien Bt varieties that have the Cry1Ac gene of non-patented event (Ali et al. 2012). Depending on the local genotypes, the Bt varieties used in backcrossing, laboratory conditions and other factors, Bt cotton varieties produced in Pakistan are of various qualities and some of them do not have the required level of Bt toxin expressions to kill bollworms (Shafiq-ur-Rehman 2009; Ali et al. 2010, 2012). However, as buyers (consumers) of these cotton varieties farmers have little information on the quality of these locally produced varieties prior to planting. In fact, results from a survey conducted in 2013, across a representative sample of cotton farmers in Pakistan's two main cotton-growing provinces, suggest that farmers are not even sure whether the varieties they purchase are Bt or not. For instance, for certain approved Bt varieties, more than 10 percent of the farmers in the sample think that they are not Bt varieties; whilst for some unapproved Bt varieties, this percentage is as high as 48 percent (Spielman et al. 2014).

In this paper, we measure the extent to which Bt cotton seed market in Pakistan is efficient in allocating cotton seed varieties of varying quality, that is, the extent to which prices of cotton seed reflect their quality; as well as how efficiently cotton farmers infer seed quality through other indicators, for example, packaging, certification, or based solely on information from their neighbors. Our study is unique in the use of a scientific scale constructed to measure of the quality of Bt cotton seed, the ELISA (enzyme-linked immunosorbent assay) test of the Bt toxin expression level of a cotton variety. This measure has been widely adopted by agronomists to measure the quality of the Bt gene embedded in cotton seed (Ali et al. 2010, 2012) but it has rarely been used by economists

(Pemsl et al. 2005; Hoffmann et al. 2013). Following the literature on empirical asymmetric information studies, we test for asymmetric information in the seed market by comparing the quality of seeds purchased by farmers who are better informed of the seed quality, for example, farmers who purchased seeds from dealers in the same village or farmers who are dealers themselves, to those farmers who are possibly less informed. With the application to a unique data set we identify information asymmetry in the Bt cotton seed market in Pakistan. We also test to what extent seed prices reflect the seed quality measured by ELISA (enzyme-linked immunosorbent assay) readings of the Bt toxin expression levels, and what signals or instruments farmers may adopt to infer Bt seed quality and how these factors affect seed prices. We find that the labeling on seed package is an effective way to infer Bt cotton seed quality in the context of Pakistan and it is the most important factor that affect seed prices. Interestingly, the signals sent by the public sector, for example, the approval status of the variety, does not have a significant impact in revealing seed qualities. We also find that poor cotton farmers tend to buy cheaper Bt cotton seeds with lower quality, which puts them at a disadvantage in adopting Bt cotton and, in fact, may reduce their income and welfare.

The rest of the paper is organized as follows: section two provides the background of cotton seed regulation in Pakistan; section three describes the sampling strategy of the survey and the data; section four presents the interpretation and results of our analysis and section five concludes.

2. Cotton seed regulations in Pakistan

The current cotton seed regulation system in Pakistan originates from the litigation conflict between Monsanto and the Pakistan government tracing back to the beginning of Bt cotton adoption in Pakistan in the mid 2000s. Since the patent on Cry1Ac gene (Bollgard® or MON531) was not granted in Pakistan, many local cotton breeding programs started making use of Monsanto's Cry1Ac gene and supplying unbranded Bt cotton varieties to the market. Although such unregulated Bt cotton varieties were being widely adopted, the Government of Pakistan was reluctant to legitimize these locally developed Bt cotton varieties because of the potential threat of litigation from Monsanto.

Between 2005 and 2010, the Government of Pakistan sought to regulate the widespread presence of Bt cotton by issuing the 2005 Biosafety Rules and the 2005 Biosafety Guidelines. The National Biosafety Committee (NBC), operating under the auspices of the Pakistan Environmental Protection Agency (EPA), was established as the responsible entity for conducting biosafety evaluations and issuing approvals. The NBC issued its first approvals for Bt cotton varieties in 2010, with the majority of them on a limited duration of three years. Meanwhile, the Punjab Seed Council (PSC) began issuing its own approvals—some limited in duration to one to two years, some unlimited—for cultivation of new Bt cotton varieties only in Punjab. The PSC issued and renewed approvals in 2010, 2011, and 2013, but it was not until 2014 that the NBC met again to approve a new set of Bt cotton varieties (Table 1).

A possible reason for the delay in biosafety regulation may be inherent in the design and implementation of Pakistan’s biosafety rules and guidelines. To date, biosafety approvals have been granted for specific variety/event combinations, wherein almost all events have been the MON531 Bt transgene. Yet most other industrialized and developing countries, on the other hand, limit their biosafety evaluations and approvals to crop/event combinations. Were this same approach to be taken in Pakistan, there would be no need to allocate public resources to seek approval for each of the varieties/event combinations released to date. Instead, those resources could be allocated to improving market surveillance designed to provide farmers with more effective signals on the technology’s safety and efficacy.

Biosafety regulation, itself, may have limited contribution in revealing information on quality of the cotton varieties, however, without the biosafety approval, a Bt cotton variety would not be able to get registered and certified by the Federal Seed Certification and Registration Department (FSC&RD). In Pakistan, the 1976 Seed Act sets rules and procedures for varietal registration, seed certification, and labeling which are overseen by the FSC&RD. The FSC&RD regulates the registration of each seed variety, the quality standards that must be met, and the type of information that must accompany its sale. For a Bt cotton variety, it can provide a certificate that serves as a signal for quality, such as seed purity, rate of germplasm, conditional on the approval from the NBC for commercialization. Therefore, indirectly the biosafety approval serves as the first step for any Bt cotton variety in Pakistan to get quality certification.

Without an effective regulation system that differentiates the quality of seeds, the cotton seed market in Pakistan has seen proliferation of varieties with variable, inconsistent, and sometimes ineffective insect-resistance traits. For example, Ali et al. (2010) conducted a survey in 10 districts in Sindh and 11 in Punjab during the cotton growing season of 2007-2008 and found that 10 percent of the samples taken in Punjab and 19 percent in Sindh tested non-positive for the Cry1Ac gene.[1] For those samples that were positive for the Cry1Ac gene, only 42 percent in Sindh and 36 percent in Punjab showed high levels of toxic protein concentration. The remainder exhibited either medium or low levels of toxin expression. Ali et al. (2010) concluded that such low level of toxin expression in these cotton varieties may be attributable to seed mixing (adulteration) or poor breeding methods that fail to recover the gene of interest in the recurrent parent. These reportedly low levels of Cry gene expression have the potential to reduce resistance to targeted pests, and therefore reduce cotton yields and incur economic losses for cotton-growing households. In 2011, Ali et al. (2012)

[1] Ali et al. (2010) also tested for the Cry2Ab and Cry1F genes—both of which are reportedly less prevalent genes in the Bt cotton cultivated in Pakistan—and found all of their samples to be non-positive.

conducted a similar study in which they purchased Bt cotton seed in the market, grew the seed, and tested the plants in a similar manner. Results from their tests showed that 30 percent (14 out 46) of the varieties tested non-positive for any Cry gene. The presence of poor-quality trait expression, in turn, can contribute not only to poor realization of gains from damage abatement by farmers, but also the development of Bt resistance in *lepidopteran* pests via natural selection.

Table 1. Approved Bt cotton varieties in Pakistan, 2012

Variety name	Developing institute or company	Type, source, and year of approval
IR-NIBGE 3701	National Institute of Biotechnology and Genetic Engineering (NIBGE), Faisalabad	Permanent PSC approval in 2010; NBC approval in 2010
Ali Akbar 703	M/s Ali Akbar Seeds, Multan	Permanent PSC approval in 2010; NBC approval in 2010
MG-6	M/s Nawab Gurmani Foundation, Kot Addu and M/s. Agri. Farm Services, Multan	Permanent PSC approval in 2010; NBC approval in 2010
Sitara-008	M/s Nawab Gurmani Foundation, Kot Addu and M/s. Agri. Farm Services, Multan	Permanent PSC approval in 2010; NBC approval in 2010
GM-2085[a]	M/s Guard Agricultural Research Services, Lahore	Provisional PSC approval in 2010; NBC approval in 2010
IR-NIBGE-1524	NIBGE, Faisalabad	Provisional PSC approval in 2010; NBC approval in 2010
FH-113	Cotton Research Institute, AARI, Faisalabad	Provisional PSC approval in 2010; NBC approval in 2010
Ali Akbar-802	M/s Ali Akbar Seeds, Multan	Provisional PSC approval in 2010; NBC approval in 2010
Neelam-121	M/s Neelam Seeds, Multan	Provisional PSC approval in 2010; NBC approval in 2010
Tarzen-1	M/s Four Brothers Lahore (Provisional: 2012; Final: 2014)	Provisional PSC approval in 2012; NBC approval renewed in 2014
MNH-886	M/s. Ali Akbar Seeds, Multan (Provisional: 2012; Final: 2014)	Provisional PSC approval in 2012; NBC approval renewed in 2014
NS-141	M/s Neelam Seeds, Multan (Provisional: 2012; Final: 2014)	Provisional PSC approval in 2012; NBC approval renewed in 2014
FH-114	Cotton Research Institute, AARI, Faisalabad (Provisional: 2012; Final: 2014)	Provisional PSC approval in 2012; NBC approval renewed in 2014
IR-NIBGE-3	NIBGE, Faisalabad (Provisional: 2012; Final: 2014)	Provisional PSC approval in 2012; NBC approval renewed in 2014
IR-NIBGE-901	NIBGE, Faisalabad	Approval deferred
CIM-598	Cotton Research Institute, Multan (Provisional: 2012; Final: 2014)	Provisional PSC approval in 2012; NBC approval renewed in 2014
Sitara-009	Sitara Seed Company, Multan	Provisional PSC approval in 2012; NBC approval renewed in 2014
A-One	M/s Weal-AG Seed, Multan	Provisional PSC approval in 2012; NBC approval in 2010
VH-259	Cotton Research Institute, Vehari	Provisional PSC approval in 2013; NBC approval in 2014
BH-178	Cotton Research Station, Bahawalpur	Provisional PSC approval in 2013; NBC approval in 2014
CIM-599	Central Cotton Research Institute, Multan	Provisional PSC approval in 2013; NBC approval in 2014
CIM-602	Central Cotton Research Institute, Multan	Provisional PSC approval in 2013; NBC approval in 2014
FH-118	Central Cotton Research Institute, Faisalabad	Provisional PSC approval in 2013; NBC approval in 2014
FH-142	Central Cotton Research Institute, Faisalabad	Provisional PSC approval in 2013; NBC approval in 2014
IR-NIAB-824	Nuclear Institute for Agricultural Biology (NIAB), Faisalabad	Provisional PSC approval in 2013; NBC approval in 2014
A-One IUB-222	College of Agri & Environmental Sciences, Islamia University, Bahawalpur	Provisional PSC approval in 2013; NBC approval in 2014
Sayaban-201	M/s Auriga Seed, Lahore	Provisional PSC approval in 2013; NBC approval in 2014
Sitara-11M	M/s Agri Farm Service, Multan	Provisional PSC approval in 2013; NBC approval in 2014
A-555	M/s Weal AG, Multan	Provisional PSC approval in 2013; NBC approval in 2014
KZ-181	M/s Kanzo Seeds, Multan	Provisional PSC approval in 2013; NBC approval in 2014
Tarzan-2	M/s Four Brothers Seed, Multan	Provisional PSC approval in 2013; NBC approval in 2014
CA-12	Centre of Excellence in Molecular Biology (CEMB), Lahore	Provisional PSC approval in 2013; NBC approval in 2014
CEMB 33	Centre of Excellence in Molecular Biology (CEMB), Lahore	Provisional PSC approval in 2013

Source: Punjab Seed Council 2012; James 2013a; James 2013b; GAIN 2013, PABIC 2014, The News 2013, Business Recorder 2013 [a] Contains Cry1Ac and Cry1Ab GFM event known as the "fusion gene" from China.

The existence of poor-quality cotton varieties could have far-reaching consequences to the cotton industry and the general welfare of cotton farmers in Pakistan. First, it slows down the technological change in cotton. Although Bt cotton has been present in Pakistan since early 2000s, it is still relying on first-generation Bollgard® (MON531) Cry1Ac event and is missing out on second-generation Bt events such as Bollgard® II and other technologies such as resistance to glyphosate, a herbicide. This may contribute to the slow growth rates for both cotton yields and output in absolute terms as well as relative to past periods and competitor countries. Second, the absence of clear biosafety regulations and a pathway to commercialization may be a strong disincentive to investment in cotton seed research, particularly in the private sector. Already, it is clear that the global leaders in Bt technology—Monsanto, in particular, and other leading crop science firms, more generally,—are not investing in Pakistan's cotton seed market and not bringing their latest technologies to Pakistan's cotton farmers. Domestically, there are also concerns that neither public research centers nor private seed companies are willing to organize themselves collectively to access new Bt genes, expand the varietal backgrounds in cotton in which Bt has been introgressed, or promote policy changes that would remedy the uncertainty in the Bt cotton seed market. A third issue relates to the environmental risks posed by the continuous introduction of sub-par Bt cotton varieties that can give *lepidopteran* pests an opportunity to adapt and evolve resistance to the Bt toxin. Already, Monsanto has confirmed that the pink bollworm has evolved resistance to Bollgard® in India, demonstrating the speed with which nature evolves and competes with technology (Monsanto 2009). A fourth issue pertains to individual and household welfare. If farmers who are unable to purchase effective Bt technologies are instead forced to rely on products of unproven efficacy or products that may be poorly labeled or poorly understood, then an important component of their livelihoods is put at risk. And cotton farmers—like most farmers in Pakistan—are subject to both poverty and vulnerability that makes such risks potentially catastrophic. This, in turn, puts the livelihoods of individuals and households engaged in non-farm rural and urban activities that rely on cotton at risk as well. If both market and regulatory failures impede farmers' access to new cotton production technologies, then this potentially important pathway for welfare improvement becomes limited in scope.

3. Data

3.1. Data source: surveys

The data for this study comprise of two sources: (i) a household survey, and (ii) a biophysical survey from the same sample of cotton farmers that are selected to be representative of all cotton-growing agro-ecological zones in both Punjab and Sindh, the main cotton producing area that constitutes approximately 99 percent of cotton cultivated area and cotton lint production in Pakistan. We select 728 households through two-stage stratified random sampling. The sample is first stratified over six cotton-growing agro-ecological zones, then in the first stage 52 villages are chosen with probabilities proportionate to population sizes (PPS), and in the second stage 14 cotton households are chosen randomly with equal probabilities. Figure 1 shows the selected villages and the six agro-ecological zones on a map of Pakistan.

<< Figure 1 here >>

The first round of the household survey was conducted in April 2013, and collected information on household characteristics including age, education, household size, etc. The second round of the household survey was conducted in October 2013 and included information on input use for cotton, such as seed, fertilizer use. Among the 728 cotton growing households identified in the first round, forty six households did not sow cotton in Kharif 2013, seventy households cultivated cotton but their crop was destroyed completely, four households migrated, one household refused to partake in the survey, and in three households, no eligible household member was found. Thus, the total sample size in round two dropped to 720 households and complete information on cotton cultivation in 2013 was collected for 604 households only.

The second part of the data comes from the biophysical survey which collects the samples of leaves and bolls of the cotton plants being cultivated by sample farmers in their *main plots* and then analyzes these samples in the laboratory to measure the Bt toxin expression levels. This survey has been conducted in collaboration with the University of Agriculture, Faisalabad (UAF), and the National Institute of Genomics and Biotechnology (NIGAB), Islamabad. Two rounds of the biophysical survey were implemented at 70 days after sowing (DAS) and at 120 days after sowing (DAS) respectively. The first round at 70 DAS was conducted during June-August 2013. The teams identified the main plot of the farmer with the help of monitors from Innovative Development Strategies (IDS) Private Ltd., the agency that was responsible for implementing the household survey. In the first round of 70 DAS, the teams randomly selected five plants in the main plot of the selected farmer. The selected plants were tagged so that the same plants could be easily identified for sample collection later at 120 DAS. Teams collected two leaf samples from the leaves of similar size, color and age, and two bolls from the same identified plants. The procedure was repeated for two different randomly selected plants in each selected plot. The collected samples in Punjab were transported to the laboratories under appropriate storage conditions at -20 degrees temperature. Samples in Sindh were tested on the spot right after they were collected in the field[2]. The Bt toxin presence and level is examined by two different types of tests: the Immunostrip and the ELISA test respectively. The second round at 120 DAS was held between August and October 2013 and the leaf and boll samples collected were tested according to the same procedure as in the first round by both UAF and NIGAB. Detailed information on the bio-physical survey can be found in the Appendix.

Since the biophysical survey and the household survey were conducted by different teams and at different time periods, at the end of the surveys there were 562 sample farmers for whom complete biophysical data were available while 166 farmers dropped out either in the second round household survey or in the biophysical survey. Table 2 lists the summary statistics for both those farmers that stayed and those that dropped out. The table shows that the two group of farmers are not significantly different in terms of household characteristics. For example, they have similar education levels, household size, land owned, total landholding size, expenditure on food consumptions and they fall into the same wealth quintiles. The main significant difference is the cotton yield they produced in 2012: the farmers who dropped out have significantly lower yield in 2012, which may have discouraged them from growing cotton in 2013. These results also suggest that the attrition bias is minimal in our final sample.

<< Table 2 here >>

[2] Partially because of the difference in the testing procedure, the ELISA values from Punjab are significantly lower than those from Sindh. We tried to adjust the values in Punjab so that the distribution in these two provinces may be similar (Appendix 3). In our empirical analysis we still use the original values.

3.2. Farmers' adoption and their misperception of Bt cotton varieties

Although Bt cotton has been adopted in Pakistan since 2000s, the exact adoption rate is hard to find in the literature. Among the 720 households in our data, 615 households reported that they had adopted Bt cotton before 2013 or planted Bt cotton in 2013 and the rest of the 105 households reported that they had never adopted Bt cotton to date (2013). Figure 2 presents the adoption trend based on sample farmers' self-reported numbers. It suggests that Bt cotton adoption first started around 2003 and accelerated after 2010, which coincides with the year when the government of Pakistan first officially approved the commercialization of Bt cotton. In 2013 about 85 percent of sample farmers reported to be Bt cotton adopters.

<< Figure 2 here >>

However, farmers may be wrong about their adoption status. Based on the Immunostrip test results, we find that 11 percent of the sample farmers, who believe they are cultivating Bt cotton in 2013, are actually not, that is, the strip tests suggest that their cotton varieties are in fact non-Bt; interestingly, 6 percent of sample farmers who believe they are cultivating non-Bt cotton are in fact cultivating Bt varieties; and about 18 percent of farmers do not know whether they are cultivating Bt cotton varieties or not (Table 3). This suggests that there is considerable misperception among farmers about the nature of cotton seeds they purchase from the market. Such confusion could misguide them regarding input use and pest management, reducing profits and cotton production.

<< Table 3 here >>

4. Analysis of the price-quality relationship

In this section, we investigate the extent to which seed prices reflect seed quality in the Pakistan Bt cotton seed market and how farmers use different signals to infer seed quality. The quality index we used is the Bt expression level that is measured by the ELISA tests of the leaf samples at 70 DAS.[3] The price information is collected in the household survey for each variety that is purchased by each household. We first check the quality difference between purchased seeds versus seeds that are saved or bartered, then we check the price-quality relationship for the purchased seeds only.

4.1. Purchased seeds vs. saved or bartered seeds

Approximately 25 percent of the sample households planted seeds that they saved from last years' harvest or received in barter or as a gift therefore they we do not have price information for them. We first check for the quality differences between these seeds that are saved or received in barter or as a gift vs. purchased seeds. Figure 3 presents the quality difference between these two groups of seeds. It suggests that the ELISA test results either from the first sample leaf or from the second sample leaf, for the purchased seeds, or even the average values of the two samples are significantly higher than those seeds that are saved or received in barter or as gift.[4] On average, the ELISA results from the saved or bartered seeds are around the level of 0.8 microgram per gram, the threshold level of the Bt expression that is lethal to bollworms. It implies that about half of those saved or bartered seeds are ineffective to kill bollworms by their own Bt toxin and have to rely on chemical insecticides in order to protect cotton plants from bollworm attacks. In comparison, purchased seeds on average have Bt expression levels

[3] The 120 DAS ELISA test results are in general lower than the 70 DAS data but other than that they provide very similar quality information.

[4] A t-test suggests that the difference is statistically significant at the 1% level.

measuring around 1.3 microgram per gram, which is above the lethal concentration and should be able to effectively protect cotton plants from bollworms.

<< Figure 3 here >>

4.2. Price-quality relationship of the purchased seed

Next, we examine the price-quality relationship of the seeds purchased from the market. Figure 4 shows a plot of seed prices and their Bt expression levels in Punjab and Sindh provinces, respectively. The fitted line suggests that there is a positive relationship between the seed price and seed quality, and this relationship is more significant in Sindh. To further quantify the price-quality relationship, we run a simple regression of seed price to Bt expression levels. The results presented in Table 5 Model (1) suggest that there is a positive and significant correlation between seed prices and the Bt expression level: with all other factors equal, 1 ug/g increase of the Bt toxin expression level is associated with an increase of about20 rupees in seed price.

Although this estimated number may not completely reflect the value of the Bt toxin expression level, the significant and positive correlation between seed price and seed quality suggests that the Bt cotton seed market in Pakistan *somehow* works despite little government regulation. A natural question to ask is: how do farmers infer the quality of Bt cotton seed without the access of a scientific measure? In the next two subsections we will try to address this question with the current available data.

<< Figure 4 here >>

4.3. Possible tools for cotton farmers to infer the quality of Bt seed

Since cotton farmers in Pakistan do not have access to a scientific quality measure like the ELISA test, they may use other cues to infer seed quality. Common tools for consumers include the type of distribution channels, such as brand or purchasing sources, package of the product, and various other information sources that are available to avoid counterfeit products (Qian 2008, 2010). In the context of Bt cotton seed market in Pakistan the possible instruments for cotton farmers include: purchasing sources, the location of the seed supplier, seed package, other information sources such as progressive farmers, friends and neighbors, etc. The demographic variables may also affect the ability of farmers to obtain and process such information. So we include both the information tools and farmers' demographic variables to examine the mechanism that farmers could use to access the seed quality information.

The estimation results are presented in Table 4. The first model estimates the effects of the market instruments without individual characteristics and the second model includes individual characteristics. It is interesting to note that most of the results remain the same. To control for the effect of weather and climate on the Bt expression level, we include a provincial dummy and the fixed effect of agro-ecological zones in both models.

<< Table 4 here >>

Notice that we also include a dummy variable that indicates whether or not a farmer purchase seeds from a supplier who resides in the same village. The underlying hypothesis is that if the seed supplier and the farmer are in the same village, the chance that the supplier withholding the true quality information may be limited and therefore farmers may buy better quality seeds. The positive and significant sign of the variable suggests that farmers indeed get better quality seeds if they purchase the seeds from a supplier in the same village, which further implies information asymmetry in the market.

Our survey suggests that cotton farmers purchase Bt cotton seeds mostly from seed dealers. A dummy variable that indicates seed dealers as the purchasing source is included in the estimation. The result suggests that its estimated coefficient is negative although not statistically significant, which implies that seeds purchased from input dealers do not have better quality than seeds purchased from other sources like landlords or friends.

Seed package, if it is labeled, and in most cases sealed, usually indicates better quality seeds. The estimation results suggest that a seed package with labeling on average indicates more than 0.2 ug/g (17%) higher Bt expression level than those seed without labeling.

We also include a dummy variable that indicates the approval status of the variety in the year 2013. The results suggest that approval status has little impact in revealing the seed quality. Similarly, we find that information from extension agents are not useful revealing seed quality neither, comparing that most other information sources such as progressive farmers, landlords, input dealers, or friends and neighbors, all positively correlate with the ELISA test scores. This suggests that the public sector fails to provide useful information to guide farmers in selecting better quality Bt cotton seeds.

Among all individual characteristics, only the poverty status is significantly correlated with the ELISA test score. It suggests that poorer farmers tend to get low quality of seeds, which might be because: (i) poor farmers may be more constrained in terms of information access, or; (ii) poor farmers tend to buy cheaper Bt cotton seeds because of constraints on input investment.

4.4. Quality signals for seed price

The subsection above examines the market instruments that are effective indicators of the seed quality. However, farmers in reality may not fully utilize these instruments when they purchase cotton seeds. In this subsection, we explore what factors influence farmers' willingness-to-pay for Bt cotton seeds. Since farmers do not observe seed quality, their willingness-to-pay for better quality seeds could be measured by the seed prices they paid. Similar to subsection 4.3, here we examine both the information tools and farmers' demographic variables to quantify the extent to which farmers value these quality signals.

<< Table 5 here >>

Table 5 presents the estimation results. It suggests that in the farmer's eyes, the distribution channels, that is, the purchasing sources (input dealers) and the location of the supplier (within the same village), are not important signals of seed quality. The only important signal among the market instruments is seed package. If the package of Bt cotton seed is properly labeled, farmers are willing to pay about 57 rupees per kg more than seeds that are not labeled. It suggests that farmers perceive proper packaging and labeling as important signals for better seed quality.

The signals from the public sector are of little value to farmers. The coefficient of the approval status of Bt cotton varieties is actually negative and significant, which suggests that approved Bt cotton varieties on average have lower prices than non-approved Bt varieties. This may be explained by the anecdotal evidence that many high quality Bt varieties actually come from the black market, or are circulated within small groups. Access to information sources such as extension agents, input dealers, landlord etc. does not affect farmers' willingness-to-pay for the Bt seeds they purchase.

Most of the individual characteristics do not correlate with farmers' willingness-to-pay except for poverty status. Poorer households tend to buy cheaper seeds, which in most cases are seeds with lower Bt expression levels as suggested by the estimation results in the last subsection. This implies that poor households are at a disadvantage in adopting better quality Bt cotton seeds, which may reduce their cotton yield during harvest and further lower their income levels.

5. Conclusion

In this paper we examine the price-quality relationship in an agricultural input market with minimal government regulation. In the context of Bt cotton seed market in Pakistan, we find evidence that information asymmetry exists in the market: in comparison to Bt cotton seeds purchased from other sources, seeds that are purchased from someone in the same village, on average, have higher quality. Farmers in the same village usually know each other well and it is less likely that seed dealers would withhold quality information from their local consumers.

The existence of information asymmetry does not fail the market, courtesy of a range of market instruments that are used to infer seed quality. Based on our analysis, we find that seed packaging and labelling are effective signals of seed quality that is unknown to most cotton farmers prior to planting. Labeling on the seed package is associated with an increase of about 0.2 ug/g (17%) in the seed quality index and an increase of 57 rupees in seed prices (20%). Signals provided by government, such as the approval status of Bt cotton varieties, do not have strong effect in indicating seed quality. We also find that poor cotton farmers tend to buy cheaper Bt cotton seeds with lower quality, which puts them at a disadvantage in adopting Bt cotton and may reduce their income and welfare.

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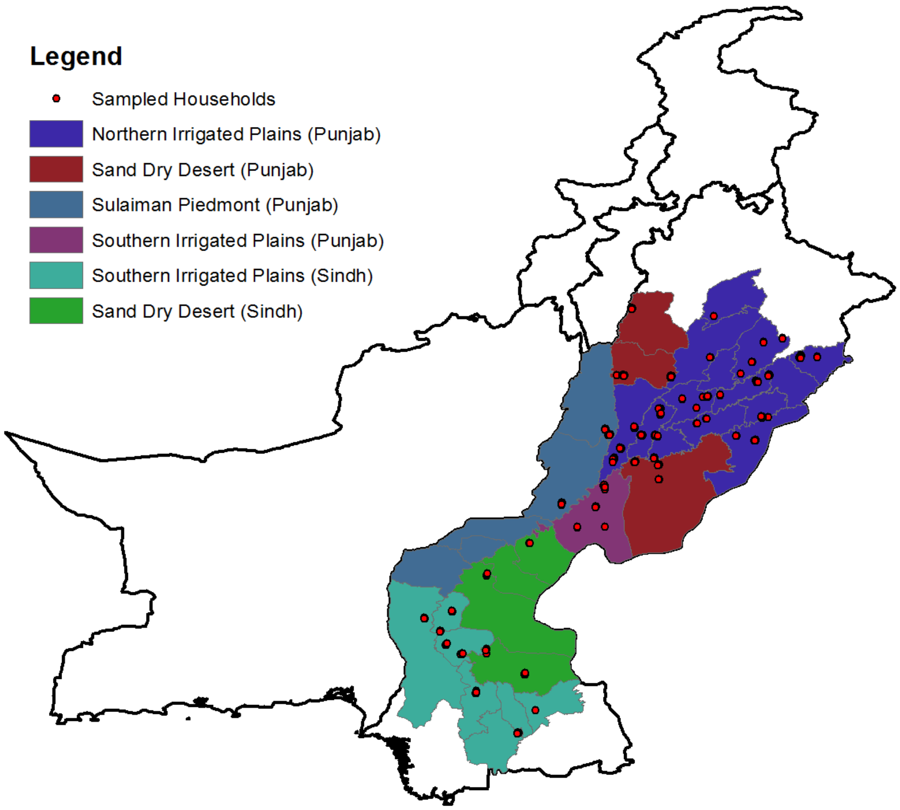
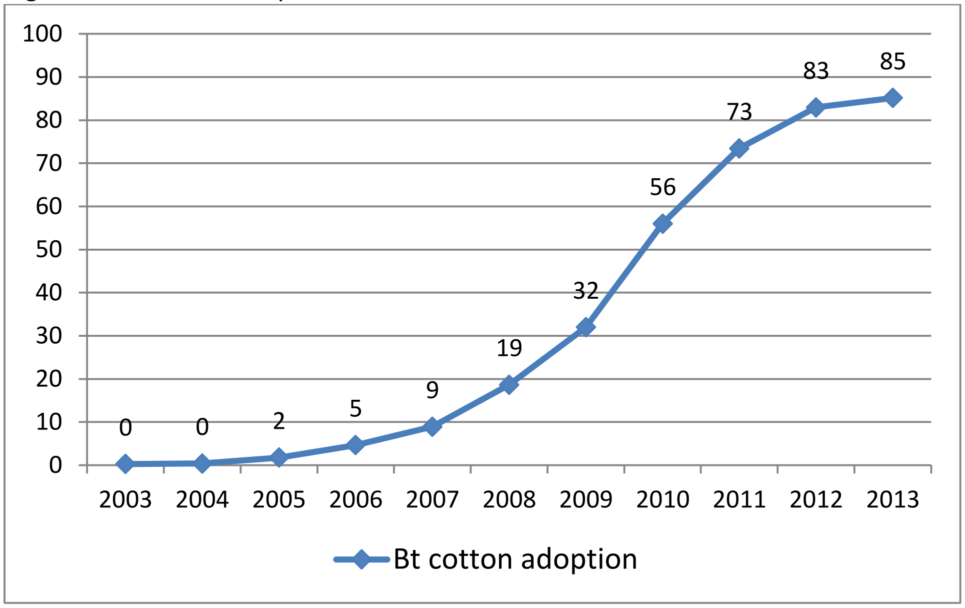
Appendix 1: Figures

Figure 1: survey sites



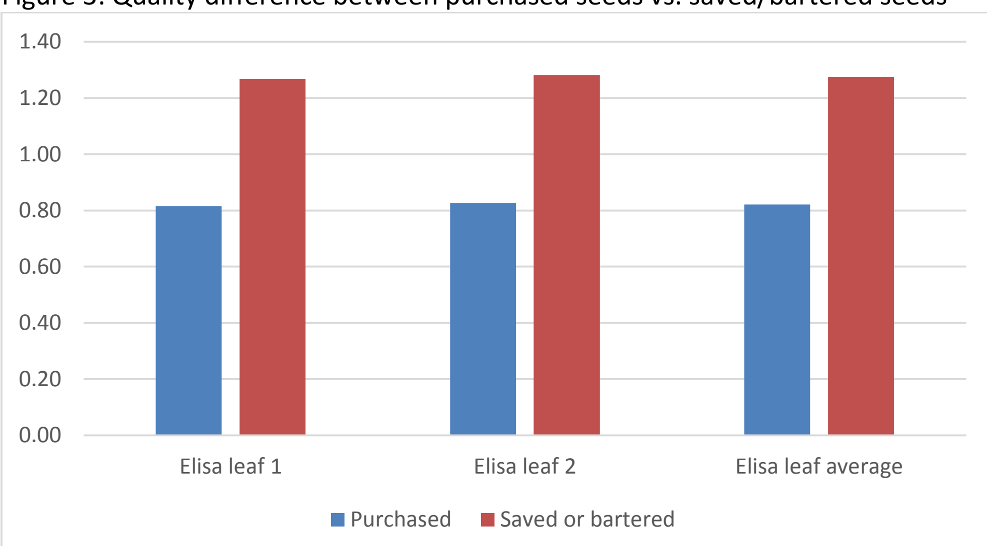
Source: PSSP cotton survey (2013).

Figure 2: Bt cotton adoption in Pakistan



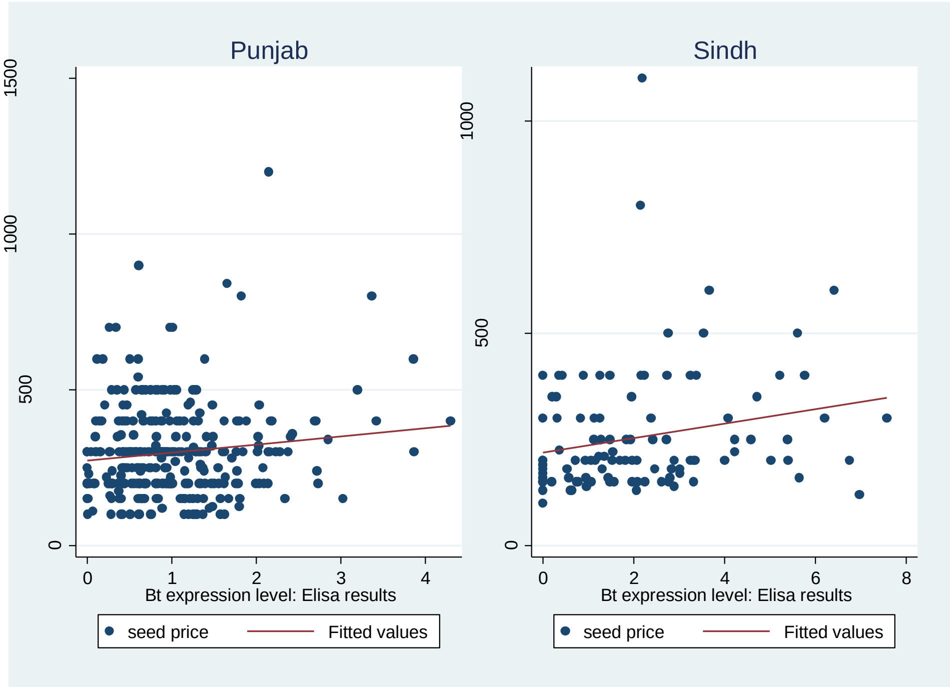
Source: PSSP cotton survey (2013).

Figure 3: Quality difference between purchased seeds vs. saved/bartered seeds



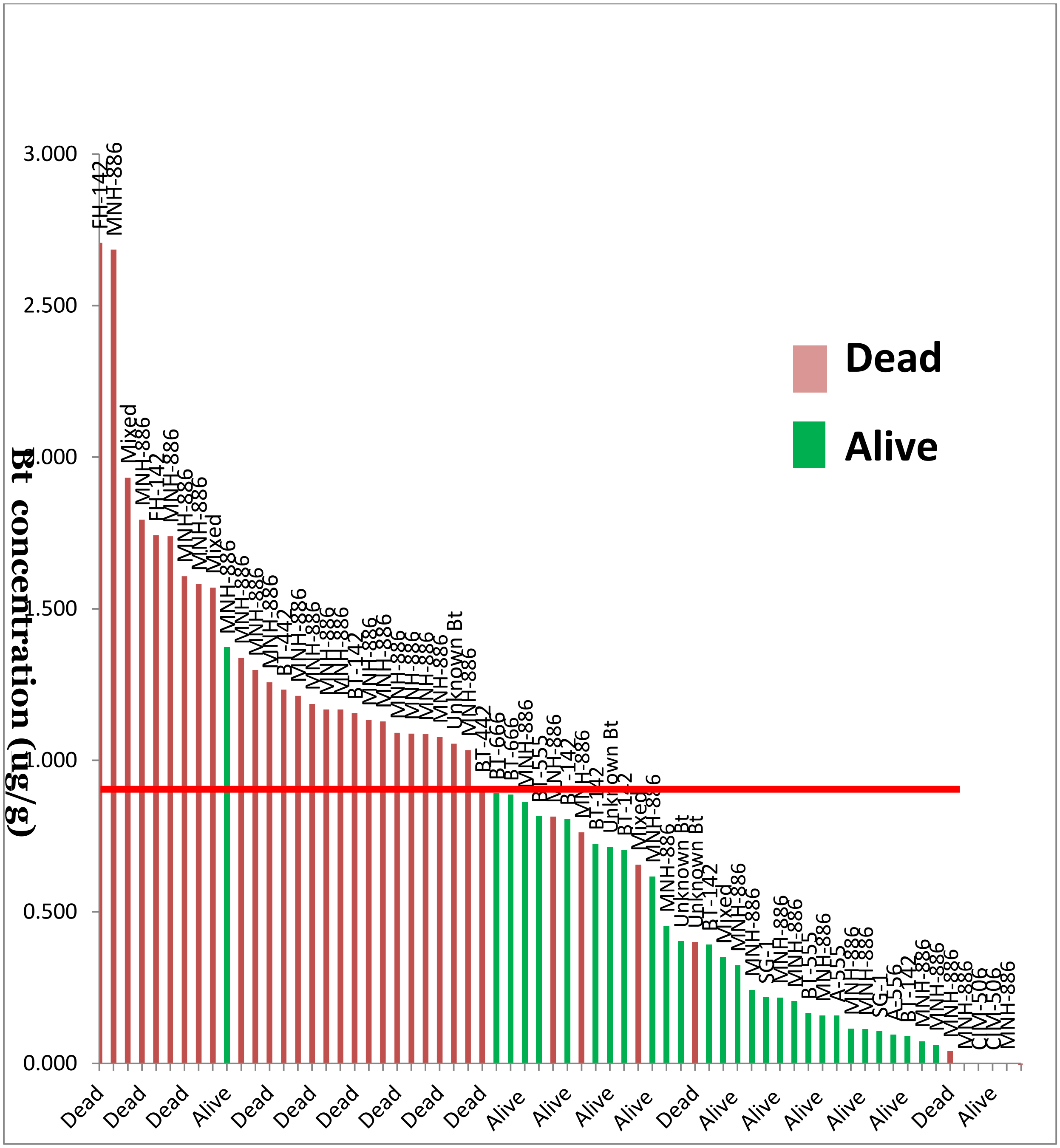
Source: PSSP cotton survey (2013).

Figure 4: Price-quality relationship



Source: PSSP cotton survey (2013).

Figure 5: Insect bioassay



Appendix 2: Tables

Table 1 is in the text.

Table 2: Mean comparison for sample attrition

	Retained (562)		Dropped (166)		
	Mean	S.E.	Mean	S.E.	
Education (years)	4.71	0.19	4.35	0.36	
Household size (No. of people)	8.96	0.19	9.17	0.39	
Land owned (acre)	6.06	0.40	6.72	0.86	
Landholding size (acre)	9.24	0.74	8.10	0.84	
Wealth (quintile)	3.00	0.06	2.99	0.11	
Expenditure per day (Rs.)	303.71	231.09	397.20	308.80	
Cotton yield last year (kg/acre)	915.36	16.92	725.25	33.08	***

Note: *** denotes that the mean difference is significantly at 1% level.

Table 3: Farmers' perception of their cotton seeds

ImmunoSTRIP Test result	Farmers believe seed is Bt	Farmers believe seed is not Bt	Farmers don't know
ImmunoSTRIP test positive (Bt)	342 (61%)	31 (6%)	79 (14%)
ImmunoSTRIP test negative (non-Bt)	60 (11%)	27 (5%)	23 (4%)
Total	402 (72%)	58 (10%)	102 (18%)

Table 4: Factors that may help infer the quality of Bt seeds

Dependent variable: Elisa results, leaf sample average	(1) Coef.	S.E.	(2) Coef.	S.E.
Purchased within the same village	0.285**	0.131	0.281**	0.132
Labelled	0.216*	0.126	0.234*	0.127
Purchased from input dealers	-0.179	0.165	-0.172	0.165
Official approved	0.158	0.115	0.174	0.115
Punjab	-1.227***	0.323	-1.265***	0.346
Information source (base: no info)				
Input dealer	0.929**	0.441	1.024**	0.448
Progressive farmers	0.745	0.459	0.851*	0.466
Landlord	0.954**	0.449	0.962**	0.450
Extension agents	0.574	0.536	0.699	0.547
Friends and neighbors	0.723	0.455	0.858*	0.462
Individual Characteristics				
Age			-0.001	0.005
Years of education			-0.001	0.014
Poor			-0.224*	0.122
Wealth index			-0.030	0.032
Tenancy status			-0.154	0.130
Constant	1.184***	0.497	1.296***	0.541
AEZs	yes		yes	
Observations	425		425	
R-squared	0.196		0.206	

Note: ***, **, * denote p<0.01, p<0.05, and p<0.1 for significance of difference.

Table 5: Quality signals for seed price

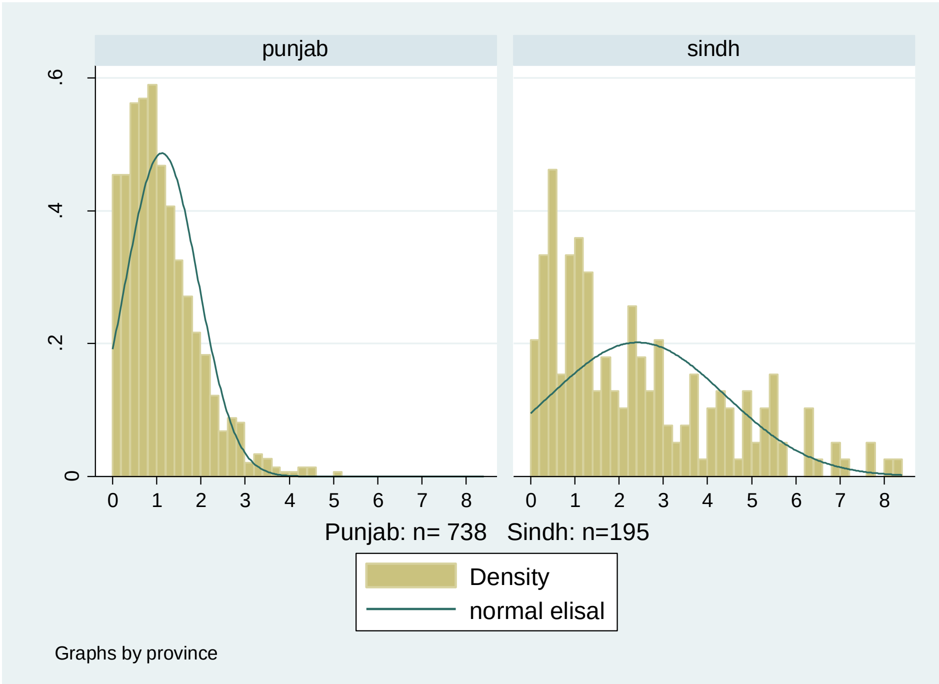
Dependent variable: seed price	Model (1) Coef.	S.E.	Model (2) Coef.	S.E.	Model (3) Coef.	S.E.
Elisa test scores	19.642***	6.265				
Purchased within the same village			10.227	15.777	12.053	15.772
Labelled			56.812***	15.170	57.085***	15.230
Purchased from input dealers			-2.313	19.850	-0.996	19.783
Official approved			-54.691***	13.821	-52.907***	13.818
Punjab	64.711***	17.402	-80.465**	38.950	-93.447**	41.449
Information source						
Input dealer			11.683	53.182	28.033	53.668
Progressive farmers			21.997	55.300	41.058	55.760
Landlord			79.501	54.099	83.639	53.834
Extension agents			60.051	64.610	78.534	65.415
Friends and neighbors			36.217	54.833	62.353	55.312
Individual Characteristics						
Age					-0.860	0.601
Years of education					0.340	1.689
Poor					-37.058**	14.615
Wealth index					-2.057	3.806
Tenancy status					-20.890	15.527
Constant	213.884***	18.977	247.415***	59.899	299.218***	64.733
AEZs	no		yes		yes	
Observations	425		425		425	
R-squared	0.039		0.199		0.221	

Note: ***, **, * denote p<0.01, p<0.05, and p<0.1 for significance of difference.

Appendix 3: Adjust ELISA values

During the biophysical survey in the Bt cotton study, because the two teams, UAF in Punjab and NIGAB in Sindh, used different procedures in conducting the ELISA test, the ELISA test results from these two provinces are significantly different (As shown in Figure A3.1):

Figure A3.1: ELISA results of the leaf samples from Punjab and Sindh (70DAS)



The NIGAB team tested on fresh leaf samples from Sindh, while UAF tested on samples from Punjab that were stored under low temperature. Consequently, samples from Sindh have higher Bt expression levels on average and also display wider variations, while samples from Punjab concentrate on the lower range of the ELISA test readings.

How to adjust?

Suppose the ELISA test results in both provinces follow the same log-normal distribution. Because NIGAB used fresh samples we assume there are no measurement error in their test. We first convert all log-normal distributions into normal distribution by taking the natural logarithm. Let x_P denote the transformed distribution in Punjab with $x_P \sim N(\mu_P, \sigma_P^2)$, x_S denote the transformed distribution in Sindh and $x_S \sim N(\mu_S, \sigma_S^2)$. The measurement error is also assumed to be log-normal distributed as the storage only decreases the Bt expression levels. It should be independent of the Bt expression levels as all leaf samples were subjected to the same storage conditions. Let e denote the transformed measurement error with a normal distribution. Then

$$x_P + e = x_S$$

where e should follow a normal distribution with $e \sim N(\mu_S - \mu_P, \sigma_S^2 + \sigma_P^2)$.

Right now the transformed normal distribution for Punjab and Sindh samples are:

	Mean	Variance	Obs.
Punjab	-0.27	1.28	738
Sindh	0.45	1.15	195

So the transformed measurement error should follow a normal distribution with mean 0.72 and variance 2.43, i.e., $e \sim N(0.72, 2.43)$.

Different scenarios of Bt protein degradation

To test the effect of storage on Bt expression levels, the NIGAB team has done a series of experiments to demonstrate the Bt protein degradation under different scenarios (Table A3.1 and A3.2, sample size are all 10).

Table A3.1: Bt protein degradation in 5, 10, 15, 20, 25 days under storage temperature -20℃ (μg/g)

				-20℃		
	Original	5 days	10 days	15 days	20 days	25 days
Mean of the sample	2.35	2.24	1.70	0.76	0.37	0.21
Variance of the sample	2.19	2.12	1.11	0.23	0.03	0.08

Note: Calculation based on the experiments done by NIGAB

Table A3.2: Bt protein degradation in 5, 10, 15, 20, 25 days under storage temperature -80℃ (μg/g)

				-80℃		
	Original	5 days	10 days	15 days	20 days	25 days
Mean of the sample	2.35	2.23	1.71	0.75	0.39	0.30
Variance of the sample	2.19	2.28	0.95	0.15	0.05	0.14

Note: Calculation based on the experiments done by NIGAB

According to the report by UAF, the actual procedure they followed are more close to the scenarios that the samples were tested after being stored for about 10-15 days under temperature -20℃. It was confirmed by the following table that the distribution of the measurement errors are most similar to the theoretical value in the 10-15 days scenario.

Table A3.3: Bt protein degradation in 5, 10, 15, 20, 25 days under storage temperature -20℃ *(Transformed Normal distribution)*

				-20℃		
	Original	5 days	10 days	15 days	20 days	25 days
Mean of the distribution	0.70	0.65	0.39	-0.44	-1.07	-1.16
Variance of the distribution	0.57	0.57	0.55	0.57	0.39	1.09
Mean of measurement error (e)		0.05	0.31	1.14	1.77	1.86
Variance of measurement error (e)		1.14	1.11	1.11	0.96	1.49

Note: Calculation based on the experiments done by NIGAB

Adjustment

A proposed adjustment is to choose a scenario or a mixed scenario from the above to adjust the ELISA values for the Punjab sample. Based on the mean and variance of measurement errors under the above scenarios, we use the average values of the 10 days and 15 days under storage temperature -20℃, i.e., we assume that the transformed measurement error for the Punjab samples follows a normal distribution with mean 0.72 and variance 1.11. After the adjustment we take the exponential of the adjusted values to obtain the updated ELISA results for the Punjab sample. The ELISA results for the Sindh sample remain the same throughout the process.

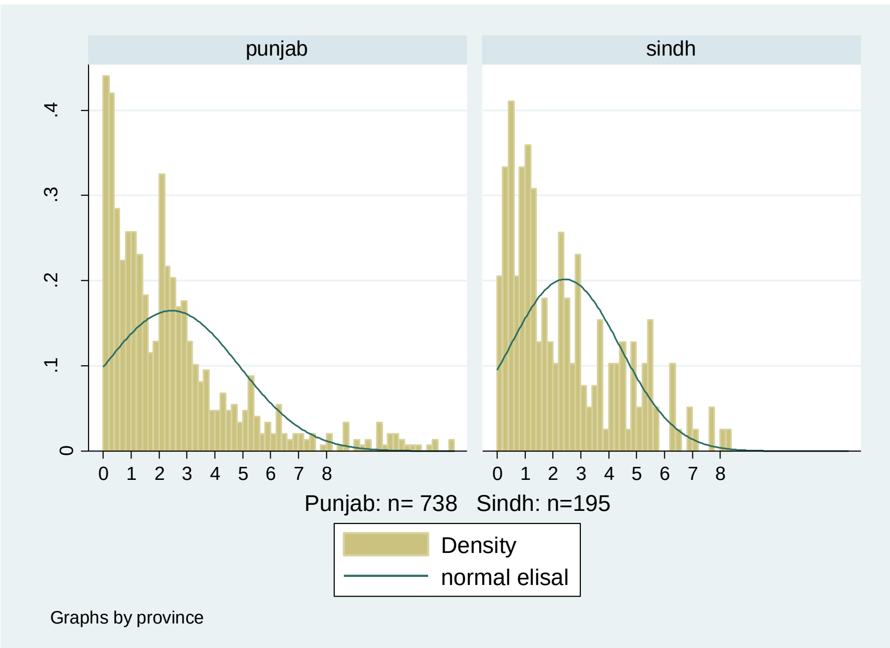
An important note is that: to avoid the extreme values of the measurement error, we restrict their maximum value to be 1.77, which is one standard deviation above the mean and is 5.87 of the original Bt expression level.[5] We also restrict the adjustment to those Bt expression levels that are below 2 µg/g, under the assumption that the degradation of high values is less a problem for the purpose of later analysis.[6]

Figure A3.2 shows the distribution of ELISA results for Punjab and Sindh after the adjustment. Now the two distributions are more similar:

	Mean	Variance	Obs.
Punjab	2.45	5.86	738
Sindh	2.43	3.91	195

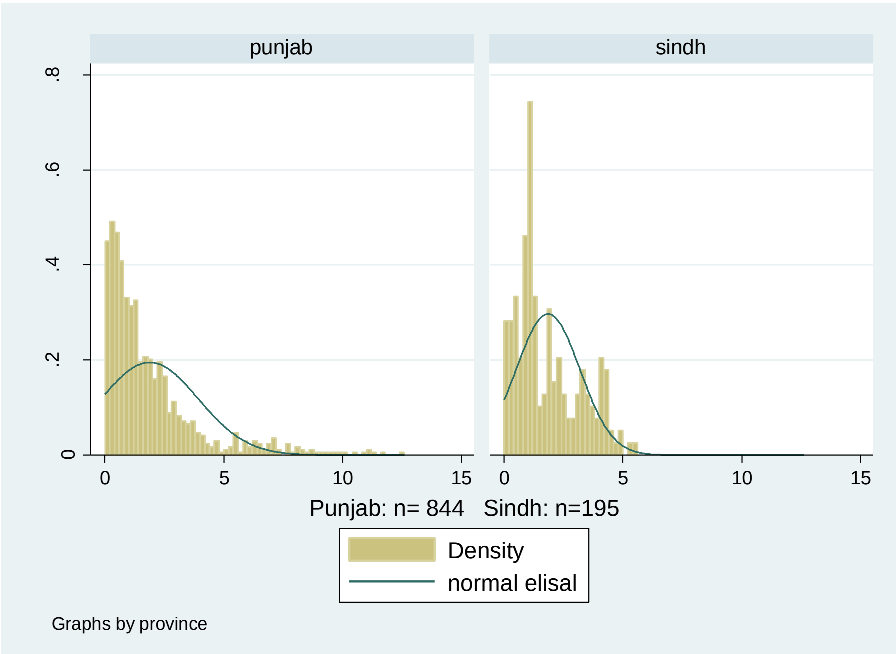
In fact, the t-test suggests that there is no statistically difference between the mean of these two distributions after the adjustment.

Figure A3.2: ELISA results of the leaf samples from Punjab and Sindh after the adjustment (70DAS)



Similarly the adjusted value for the 120 DAS data is as following:

[5] It means that the maximum Bt toxin degradation is 5.87 µg/g.
[6] This may be problematic as degradation could happen to these observations as well. It will not be a big problem if we categorize all values that are above 2 µg/g as effective levels.


punjab
sindh
0
.2
.4
.6
.8
0
5
10
15
0
5
10
15
Punjab: n= 844   Sindh: n=195
Density
normal elisal
Graphs by province