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Technological Opportunity, Regulatory Uncertainty, and Bt Cotton in Pakistan

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Genetically modified, insect-resistant Bt cotton has been adopted extensively across Pakistan's cotton-growing regions during the past decade, and prior studies have linked Bt cotton adoption to both reductions in on-farm production costs and increases in cotton yields. However, studies also suggest that there is much confusion in the market for Bt cotton seed, stemming largely from weak regulation and the dissemination of seed of unknown quality to farmers. The persistence of uncertainty in Pakistan's market for Bt cotton seed may have consequences for cotton production, rural livelihoods, and Pakistan's wider economy. This article aims to shed new light on Bt cotton in Pakistan. First, the article explores the technological, economic, and institutional aspects to Bt cotton, the history of its introduction in Pakistan, and the controversy that has accompanied it during the past decade. Second, the article characterizes cotton-producing households across several dimensions using household survey data collected in 2012. Third, the article examines areas for further policy-relevant research that could improve the capacity of cotton-producing households in Pakistan to realize greater benefits from Bt cotton cultivation.

Key words: Bt cotton, seed systems, biosafety, intellectual property rights, Pakistan.

Introduction

Genetically modified, insect-resistant *Bacillus thuringiensis* (Bt) cotton has been adopted extensively across Pakistan's cotton-growing regions during the past decade. Evidence suggests that benefits have been realized in Pakistan in terms of reductions in crop damage and losses, quantity and cost of pesticide application, and harmful health effects of pesticide use, as well as increases in yields (Ali & Abdulai, 2010; Bakhsh, 2013; Kouser & Qaim, 2013a; Nazli, Orden, Sarker, & Meilke, 2010). However, the release and marketing of Bt cotton varieties has largely been unregulated in Pakistan. Subsequently, questions have emerged around the possible impact of widespread adoption of unapproved Bt cotton and the diffusion of varieties with variable, inconsistent, and sometimes ineffective insect-resistance trait (Ali et al., 2012; Ali, Shahid, Shahid, Ali, & Yusuf, 2010).

There are relatively few safeguards to prevent the spread of poor-quality cotton seed (and cotton technologies embodied in seed) because of the inherent nature of seed markets. In most seed transactions in these markets, farmers cannot evaluate the quality of a seed or the technology embodied in that seed upon visual inspection. Nor can farmers evaluate seed or technology quality if regulatory systems do not enforce rules requiring seed sellers to provide technical information on quality alongside their products, and/or if the judicial system does not provide sufficient recourse for farmers defrauded by seed sellers. This means that there is scope for firms—seed companies, seed wholesalers and retailers, or farmers who produce and sell seed to others—to use information asymmetries in the market for (Bt or non-Bt) cotton seed as a means of securing rents. This can be further exacerbated when firms collude to ensure that a weak regulatory regime remains in place, thus extending access to rents for longer periods of time. Concerns about poor-quality seed-based technologies, information asymmetries between farmers and firms, weak regulatory regimes, and possible collusion among firms are at the heart of the policy discourse around Bt cotton in Pakistan (Rana, 2010, 2014; Rana, Khawar, Gilani, & Rana, 2013).

The absence of sufficient evidence to substantiate these concerns and motivate policy action can have a range of negative consequences. First, it is possible that the quality of Bt cotton—more specifically, the level of Bt gene expression or the quality of seed—can affect cotton production and cotton-producing households. The number of farmers potentially affected is non-trivial: approximately 2.2 million farms cultivate cotton in Pakistan, accounting for 26% of all farms in the country (Government of Pakistan [GOP], 2012).

Second, technologies that are designed to improve cotton yields, reduce production costs, or otherwise improve the returns to cotton farming can directly affect growth in the supply of cotton to Pakistan's textiles industry, a major component of the country's overall manufacturing industry. Again, the numbers are not trivial. Pakistan is the world's fourth-largest producer and third-largest consumer of cotton, and cotton production accounts for 7.8% of value added in agriculture, 1.6% of GDP, and about 67% of foreign exchange earnings (Pakistan Economic Survey [PES], 2012).

Third, Bt trait expression levels can have implications for the natural development of resistance in the targeted pests through natural selection. The emergence of pest resistant to the Bt gene could mean that farmers would have to revert to their previous insecticide-spraying practices or, if not, then run the risk of yield losses due to pest infestation. This puts a sizable amount of land under cotton cultivation at risk. In 2012-13, cotton was cultivated on 2.88 million hectares (7.11 million acres) of land, and during the summer *kharif* (monsoon) season, cotton accounts for nearly 70% of all cultivated area, primarily in the provinces of Punjab and Sindh, which produce almost 80% of the country's cotton supply (PES, 2013).

In short, the net benefits of Bt cotton may be potentially significant to Pakistan's cotton farmers and its economy as a whole: Pakistan cannot afford to miss out on this technological opportunity. Yet already, it has. Pakistan is one of the few countries that still relies on first-generation Bt technologies, while other industrialized and developing countries have moved on to new and more effective transgenic events and new combinations of events to address biotic stresses in cotton including both insect resistance and herbicide tolerance. This lost opportunity is likely related to a number of factors, one of which may be the state of Pakistan's regulatory system that oversees the development and delivery of improved seed and seed-based technologies.

Ironically, improved varieties, seeds, and genetically modified crops such as Bt cotton are subject to extensive regulation in most countries. Variety testing and registration are required to demonstrate that new varieties can stably exhibit desirable traits such as higher yields or resistance to pests, diseases, or other stresses. Seed certification systems are designed to ensure that seed sold to farmers meets acceptable standards for purity, germination, and moisture. Truth-in-labeling regulations similarly provide farmers with assurances that seed meets some required standard and that legal recourse is available should the seed fail to meet such standards. Biosafety regulations provide government, industry, and society with an indication that new transgenic events and/or organisms do not pose a significant threat to human or environmental health.

Yet in Pakistan, many of these regulatory safeguards have failed, possibly leaving cotton farmers in an unenviable position of uninformed consumer in the market for Bt cotton seed. Meanwhile, the seed industry has flourished, with over a dozen private seed companies and public research institutes, alongside countless farmers themselves, marketing Bt cotton varieties—some of which are effective and backed by brand confidence, others of which are more questionable. This article aims to shed new light on Bt cotton in Pakistan and the consequences of weak regulation, uncertainty, and asymmetric information. Its analytical focus revolves around the gains to technological change in Pakistan's smallholder farming systems where cotton is cultivated. As such, it does not explicitly tackle related controversies in the textile manufacturing sector, nor with the vagaries of international trade in cotton, textiles, and garments. Rather, it concerns itself strictly with market and institutional factors relating to technological opportunities at the farm level.

The article continues with a review of the technological and economic benefits associated with Bt cotton, evidence of these benefits being realized in Pakistan, and the institutional complexities of Bt cotton's introduction in Pakistan. Then we examine evidence on Bt cotton cultivation by drawing from a household survey conducted in 2012 to provide a descriptive analysis of cotton-producing households in Pakistan—who they are, where they reside, how they produce cotton, and how well-off they are relative to other rural households. Finally, the article identifies areas for further policy-relevant research that could help cotton-producing households in Pakistan to realize greater benefits from Bt cotton cultivation.

Background

We begin this section with a brief review of the economic evidence associated with the impact of Bt cotton cultivation in several developing countries. We then describe the introduction of Bt cotton in Pakistan and review the evidence on its impact to date and the associated regulatory issues.

Technical and Economic Aspects of Bt Cotton

GM cotton was first commercialized in the United States in 1996 and is now cultivated in 15 countries, with Bt and herbicide-tolerant (HT) maize and HT soybean being cultivated in another 12 countries (James, 2013a). The first commercialized Bt cotton varieties and hybrids contained the Cry1Ac gene from the transgenic event MON 531, developed by Monsanto—a multinational company that is the global leader in genetically modified seed and traits—and were marketed under the trademark Bollgard®. Bollgard® is shown to be effective in controlling certain types of *lepidopteran* pests such as American bollworm (*Helicoverpa armigera*), pink bollworm (*Pecthinofora gossypiella*), spiny bollworm (*Earias spp.*), and tobacco budworm (*Heliothis virescens*), but less effective against cotton leafworm (*Spodopteras litura*) and fall armyworm (*Spodoptera frugiperda*). In 2002, Monsanto released a more effective Bt technology under the name Bollgard II® that contained both the Cry1Ac and Cry2Ab genes and has been proven to be highly effective against pink and American bollworm as well as cotton leafworm and fall armyworm (Showalter, Heuberger, Tabashnik, & Carriere, 2009).

The introgression of Cry genes into cotton does not guarantee resistance to *lepidopteran* pests. Gene expression is determined by a number of distinct factors, including the efficacy of the Cry gene, the genetic background in which the gene is introgressed,[1] the techniques used to introgress the gene, the practices used in breeding and seed multiplication, and the environmental conditions under which the cotton is cultivated. Technical constraints such as poor-quality backcrossing, gene segregation in F1 generations, heterozygosity, variation in nucleotide sequences, the type of promoters used, the insertion site in the host DNA, and growing conditions (soil type, rainfall, and temperature) can all affect gene expression and, ultimately, the efficacy of Bt cotton's insect-resistance trait (Guo, Sun, Guo & Zhang, 2001; Showalter et al., 2009; Xia, Xu, & Guo, 2005). In addition, adulteration, admixture, moisture, and contaminants can reduce the quality of Bt cotton seed purchased by a given farmer, thus leading to poor efficacy of the technology at the farm or plot level. These are the main factors that underlie concerns about variable, inconsistent, and sometimes ineffective insect-resistance traits found in Bt cotton.

In spite of these concerns, the story of Bt cotton in developing countries has largely been one of success. The economic performance of Bt cotton has been documented extensively across a range of countries during the past decade, and much of the evidence suggests that farmers—including small-scale, resource-poor farmers—have realized benefits in terms of reductions in insecticide use, increases in yields, or both. See Smale et al. (2009) and Qaim (2009) for reviews of this literature.

But while the popular narrative tends to focus on yield gains associated with Bt cotton, it is probably more appropriate to concentrate on its economic benefits in terms of damage abatement. In other words, the Bt technology reduces losses associated with the pest it targets, but may have ambiguous effects on yields depending on the type of insecticide-use regime and pest-management practices used in the absence of the Bt technology. For example, in most industrialized countries where cotton is cultivated, farmers have traditionally used insecticides to control for the same *lepidopteran* pests targeted by the Bt technology, meaning that Bt cotton's advantage derives from the fact that it is merely a lower-cost substitute for insecticide use, with the added benefit of generating fewer negative health or environmental externalities associated with insecticides. This explains why differences in yields between Bt and non-Bt cotton are generally not observed in these countries. On the other hand, farmers in many developing countries may cultivate cotton under low (or less than optimal) insecticide-use regimes. In such cases, Bt cotton may provide such farmers with a more effective insect-management system than provided by their conventional practices, thus reducing losses to pests, increasing yields and, depending on the relative costs of seed and other inputs associated with higher yields (for example, weeding, harvesting) to insecticides, reducing production costs.

Only until recently have there been efforts to analyze these implications across regions and countries to assess the precision and consistency of the documented benefits of Bt cotton over conventional crops. For example, a meta-analysis of GM crops by Finger et al. (2011) evaluates the performance of Bt cotton across several economic indicators—yield, gross margin, seed, labor, and pesticide cost. Overall results suggest that Bt cotton, in comparison to conventional cotton, increases yields (46%), gross margin (86%), labor costs (7%), and seed cost (98%), but also lowers pesticides costs (48%).

A similar meta-analysis using different data and methods by Areal, Riesgo, and Rodríguez-Cerezo (2013) arrives at a similar conclusion. Specifically, they find that while Bt cotton is associated with higher costs of production than their conventional counterparts, Bt

1. *In this context, introgression refers to the introduction of genetic material from one organism into the gene of another organism.*

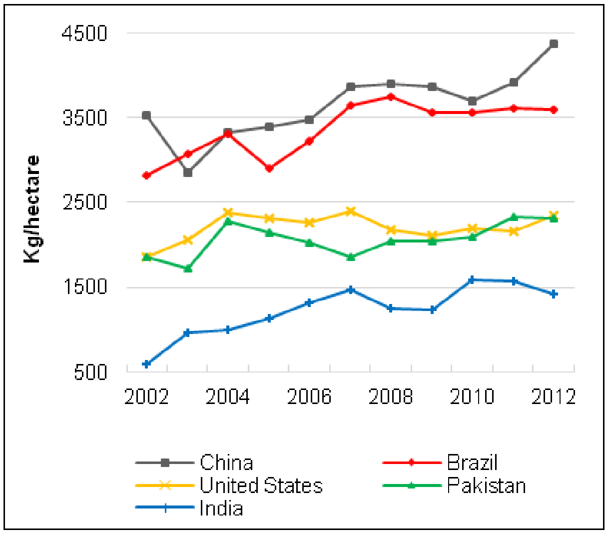

Figure 1. Cotton yields in Pakistan and other world-leading cotton-producing countries, 2002-2012.
Source: FAO (2014)

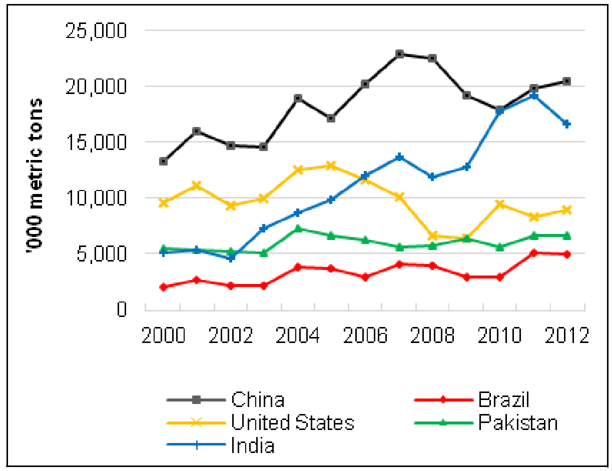

Figure 2. Cotton production in Pakistan and other world-leading cotton-producing countries, 2002-2012.
Source: FAO (2014)
Note: Data on cotton production shown here are based on FAOSTAT data for "seed cotton," which is also referred to as unginned cotton.

cotton outperforms conventional cotton because of higher yields. However, they caution that their results do not distinguish between yield gains that are attributable to Bt technology itself or to better farmer management of Bt cotton fields, or (more likely) a combination of both. This point is addressed, for example, by Gruère and Sun (2012), who examine data from 1975 to 2009 and attribute a significant part of India's cotton yield growth prior to 2005 to both increased fertilizer use and genetic improvements embodied in cotton hybrids that occurred prior to the Bt technology.

Pakistan's Experience with Bt Cotton

In this section, we examine Pakistan's experience with Bt cotton. The analysis presented here is based on comprehensive review of the literature and key informant interviews conducted in 2012-14 with over 40 representatives of the seed and agribusiness sector, government policymakers, regulators, civil servants, and members of the research community working on issues related to national agricultural policy matters, biotechnology, crop improvement, and other biophysical sciences.

As described earlier, cotton is an essential component of Pakistan's agricultural sector and overall economy. Yet cotton yields in Pakistan remained at around 2,200 kg/ha between 2002 and 2012 while yields in China, the world's leading cotton-producing country, averaged 3,700 kg/ha during the same time period. And although cotton yields in Pakistan continue to exceed those of neighboring India and remain comparable to those in the United States and to the world average, annual yield growth in India, Brazil, and China has been 7.1%, 2.2%, and 2.4%, respectively, during the last decade against 0.8% in Pakistan (Figure 1). The total production of cotton in Pakistan has remained at around 6,000,000 metric tons with a 1.3% annual rate of increase, while in China it has increased from 14,748,000 tonnes to 20,520,000 tonnes and India from 5,210,000 tonnes to 16,600,000 tonnes, with average annual rates of increase at 3% and 12%, respectively (Figure 2; Food and Agriculture Organization of the United Nations [FAO], 2014).

Nonetheless, several studies have shown that Bt cotton in Pakistan has had a positive and significant impact on net margins and yields, while also reducing pesticide applications and increasing household welfare.[2] In a cross-sectional study of 325 farmers in the Punjab province in 2007, Ali and Abdulai (2010) reported positive and significant impacts of Bt cotton adoption on yields, household income, and poverty reduction and a negative

2. *Several other studies examine related topics, including impacts of Bt cotton adoption on yields, pest management, and cropping patterns (Abdullah, 2010; Mehmood et al., 2012; Sabir, Tahir, & Khan, 2011); adoption determinants (Arshad, Suhail, Asghar, Tayyib & Hafeez, 2007); and cultivation and resource-use efficiency (Abid et al., 2011), although few address issues of sample selection bias in a manner found in the studies described in detail here.*

impact on the use of pesticides. Their estimates indicated that cotton yields are 50 kg/acre higher for Bt cotton farmers and that average household incomes of adopters are between Rs. 16,500 and Rs. 17,500 higher than non-adopters. In a study of 206 farmers in both Punjab and Sindh provinces during 2009, Nazli and Haider (2012) found positive impacts of Bt cotton adoption on farmer wellbeing through reduction in pesticide expenditures and higher yields, gross margins, and per-capita incomes. However, they found that the extent of these gains depended significantly on agro-climatic conditions and farm size. Overall, Bt cotton adoption was associated with lower expenditures on pesticide in the order of Rs. 1,082/acre, higher yields of 186 kg/acre, higher gross margins of Rs. 5,733/acre, and higher per-capita incomes of Rs. 1,666/month. In a resource-use efficiency analysis based on a sample of 150 Bt cotton farmers in Punjab province during 2008-09, Abid, Ashfaq, Quddus, Tahir, and Fatima (2011) found that management and use of inputs including fertilizer, irrigation, and labor had a significant impact on Bt cotton productivity. The study found that cotton growth and yield was positively affected by the application of fertilizer for small Bt cotton farmers. Mehmood, Farooqi, Bakhsh, Anjum, and Ahmad (2012), in their study of 120 farmers in Punjab in 2010, found that farmers who cultivate Bt cotton varieties have higher yields than farmers cultivating conventional cotton varieties, indicating a positive impact of Bt cotton on productivity.

In their study of 352 farmers in Punjab in 2010-11, Kouser and Qaim (2013b) observed that Bt cotton generated US$218.63 per acre in additional economic benefits for adopters than non-adopters because of the increase in yield and savings in pesticide expenditure. Their study further shows that positive health and environment benefits, US$35.86 and US$35.00 per acre, respectively, can be added to these benefits. Aggregating across all Bt cotton-cultivated area, they conclude that the total annual benefits of Bt cotton in Pakistan approximate to US$1.72 billion. In another study of 573 farmers from two cotton-growing seasons in Punjab in 2008-09, Bakhsh (2013) found that, on average, the net revenue for farmers cultivating Bt cotton was US$626 per hectare as opposed to a return of US$492 for farmers not cultivating Bt cotton. He also found that the increase in Bt cultivation resulted in farmers using 22% less pesticides.

Two studies extend this work to consider the negative environmental and health consequences of pesticide use for which Bt cotton aims to partly substitute. Kouser and Qaim (2013b) show that while cotton farmers in Pakistan under-use pesticides when considered only in terms of individual farm-level profit-maximization, the wider social and economic costs of pesticide use strongly indicate negative economic returns to increased pesticide use in cotton cultivation. They further argue that substituting Bt cotton for pesticides not only generates yield gains in excess of 20%, but also reduces negative consequences to environmental and human health. Similarly, Abedullah and Qaim (2014) estimate that the use of Bt cotton increases environmental efficiency by 37%. According to their estimation, to achieve similar results, farmers planting conventional cotton would need to incur a cost of US$54 per acre, equivalent to 7% of their total revenue.

Despite these reported benefits, there are several factors that may be hampering greater present or future realization of Bt cotton's benefits in Pakistan. First is the possibility that the release and marketing of Bt cotton varieties have been largely unregulated. As a consequence, Pakistan has seen the widespread adoption of unapproved Bt cotton and the dissemination of varieties with variable, inconsistent, and sometime ineffective insect-resistance traits. Poor gene expression, in turn, can contribute not only to poor realization of the gains from damage abatement by farmers, but also the development of Bt resistance in *lepidopteran* pests via natural selection.

For example, Ali et al. (2010) conducted a survey in 10 districts in Sindh and 11 in Punjab during the cotton-growing season of 2007-08 and found that 10% of the samples taken in Punjab and 19% in Sindh tested non-positive for the Cry1Ac gene.[3] For those samples that were positive for the Cry1Ac gene, only 42% in Sindh and 36% in Punjab showed high levels of toxic protein expression. The remainder exhibited either medium or low levels of toxin expression. Ali et al. (2010) concluded that such low levels of 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) conducted a similar study in which they purchased Bt cot-

3. *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.*

ton seed in the market, grew the seed, and tested the plants for Cry gene expression. Results from their tests showed that 30% (14 out 46) of the varieties tested non-positive for any Cry gene. Both of these studies demonstrate the significant presence of either adulterated Bt cotton seed, ineffective Bt technology expression, or both in Pakistan's cotton seed market.

So how did Pakistan end up in this situation, and why is it a potentially more acute state than what India initially experienced with the unapproved release of Bt cotton in 2000? The first signs of conflict emerged in in the mid-2000s when actors in Pakistan's seed industry—progressive farmers who ran their own breeding and seed distribution operations—decided to make use of Monsanto's Cry1Ac gene in the MON531 event. Keep in mind that Monsanto neither held a patent on this event in Pakistan nor had it submitted the MON531 event for National Biosafety Committee (NBC) approval. Thus, Pakistan's seed industry is not legally infringing any property rights when using Monsanto's technology. Despite this, Monsanto raised issue with the proliferation of its MON531 event in Pakistani cotton varieties, while concerns emerged that Pakistani cotton containing Monsanto's transgenic event might be barred from export to countries where patents *were* held. Indeed, Monsanto did threaten legal action in Pakistan seeking to recoup royalties on the prolific use of its MON531, a claim it withdrew in 2008 after it was recognized that Monsanto had filed no patent for is technology in Pakistan and thus could not claim royalties. Because of this outcome, Monsanto still has no official presence in Pakistan's cotton seed market, making it more difficult for Pakistan to access second-generation technologies. See Rana (2014), Roberts, Nazli, Wach, and Zafar (2012), and Rana (2010) for an account of this early controversy.

The next set of issues occurred between 2005 and 2010 when the Government of Pakistan sought to "regularize" the presence of Bt cotton that had emerged in the seed market by stealth. This move may have been driven by a number of factors including strong expressions of interest and widespread adoption of the technology by farmers, concerns about market power being held by a few domestic seed providers, and interest in supporting Bt cotton public research. In 2005, the government paved the way for environmental release and commercialization of Bt cotton by issuing the Biosafety Rules and Biosafety Guidelines. These regulations established a system to evaluate the health and environmental safety of genetically modified organisms prior to release for commercial use. The NBC, operating under the auspices of the Pakistan Environmental Protection Agency (EPA), was established as the responsible entity for conducting these evaluations and issuing approvals. The NBC issued its first approvals for Bt cotton varieties in 2010 (based largely by accepting well-established international biosafety data rather than data from tests conducted in Pakistan), but did so for 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). It is unclear whether PSC approvals were meant to circumvent or preempt NBC approvals, whether they were conducted in harmony with the NBC review process, or whether these national and provincial approval processes focused on different regulatory aspects.

This regulatory uncertainty and confusion was precipitated by several events. First was the devolution of agricultural matters to the provinces under the 18th Amendment to the Constitution of Pakistan in 2010, which may have provided provincial governments with the perception that approvals for genetically modified organisms could be taken up on a provincial basis regardless of federal mandates that preceded the 18th Amendment—and especially in light of federal-level inaction at the NBC. Second, no clear ministerial line of responsibility was established to oversee the NBC—a situation likely exacerbated by the reorganization of ministry and division responsibilities that followed the promulgation of the 18th Amendment—such that the NBC was unable to meet between 2011 and 2014 to evaluate and make decisions on Bt cotton variety approvals. Third, the NBC's limited capacity to conduct biosafety evaluations may have delayed the federal government's ability to act on new Bt varieties submitted for approval and provisionally approved at the provincial level. As a result, Pakistan's biosafety regulatory regime has been of limited relevance in promoting the safe and effective use of Bt cotton.

Another issue 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, almost all of which have been based on the MON531 event. 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

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

Source: PSC (2012), James (2013a; 2013b), Vasquez and Ur Rehman (2013), Pakistan Biotechnology Information Center (2014), The News (2013), Amin (2014)

[a] *Contains Cry1Ac and Cry1Ab GFM event known as the "fusion gene" from China*

taken in Pakistan, there would be no need to allocate public resources to seeking 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.

Yet another problem is the limited contribution made by Pakistan's seed market regulations. In theory, seed laws and rules provide a means of regulating how seed is sold, what quality standards must be met, and what type of information must accompany its sale. In Pakistan, the 1976 Seed Act sets rules and procedures for varietal registration, seed certification, and labeling, which are overseen by the Federal Seed Certification and Registration Department (FSC&RD). However, as in the case of the NBC, the 18th Amendment introduced some uncertainty over provincial versus federal authority for seed regulation. More importantly, the structure of Pakistan's seed system is poorly positioned to oversee the private sector's growing participation in the market, having been developed in earlier decades around a state-controlled seed-provisioning strategy. As a result, there is very little in the seed regulations that provides for strict enforcement or market surveillance of cultivar performance, seed quality, or efficacy of transgenic traits in an increasingly competitive, private-sector-led market (Rana, 2014).

In sum, Pakistan's situation is a case of both market failure and a failure in the regulations designed to correct the market failure. The consequence is that farmers may be on the short end of transactions in the cotton seed market. Whereas seed sellers—retailers, wholesalers, companies, breeders, or enterprising farmers who produce seed themselves—may have information about seed adulteration or poor gene expression, farmers do not have similar access to this information because they cannot evaluate seed or technology quality upon visual inspection prior to sowing. In the absence of regulations to address these information asymmetries, seed suppliers can behave opportunistically and extract rents from farmers. This problem can be particularly acute where farmers have limited education, are unable to seek independent verification of seed quality, or are unable to seek legal recourse in the case of fraud. All in all, 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. We explore these ground-level dimensions of cotton production in greater detail below.

A Household-level Characterization of Cotton in Pakistan

This section draws on both government statistics and recently collected household data (described below) to characterize (1) the welfare status of cotton farmers in absolute terms and relative to other farmers; (2) the production practices of cotton farmers in terms of their cropping combinations by agro-ecological zone and in terms of major sources of cotton damage and loss; (3) the technological choices of cotton farmers, particularly with respect to use of specific cotton varieties and the Bt technology; and (4) seed purchasing and sourcing practices of cotton farmers. Note that the figures presented in this section are meant to characterize cotton farmers in Pakistan across several dimensions and are not intended to assign any causal relationship between Bt cotton adoption and their welfare status. See Spielman, Nazli, Ma, Zambrano, and Zaidi (2014) for additional details.

Data and Data Sources

Data used in the following analysis are drawn from the first round of the Pakistan Rural Household Panel Survey (RHPS) conducted in 2012. The RHPS was undertaken by the International Food Policy Research Institute (IFPRI) and Innovative Development Strategies (Pvt.) Ltd. (IDS) under the auspices of the Pakistan Strategy Support Program (PSSP). The objective of this survey was to collect information on poverty dynamics and micro-level constraints on income generation and economic growth for a typical rural household in Pakistan. The analysis presented here utilizes a sub-set of 942 households interviewed in November 2012. Of these, a total of 292 agricultural households cultivated cotton in *kharif* 2011: 250 in Punjab and 42 in Sindh. See Spielman et al. (2014) for additional details.

Note that because the RHPS sampling frame was not constructed around heterogeneity in Pakistan's cotton-production systems, the descriptive statistics and analysis presented here are not necessarily representative of all cotton-cultivating households. However, they do provide an opportunity to compare cotton-farming households with non-cotton-farming households in a limited context, and should be interpreted as such.

Cotton Production and Producers: A Characterization

So how might we characterize cotton-producing households in Pakistan relative to other households in the rural population? A simple way of characterizing the relative welfare status of cotton-producing households in Pakistan is to calculate where they fall within the national income distribution. Against income quintile distribution estimates for rural Pakistan based on RHPS data (Malik, Nazli & Whitney, 2014a, 2014b), the average cotton-producing household falls within the highest

Table 2. National annual household income by income quintiles for rural households (Rs '000).

Quintile	Description	Mean	Std. dev.	Min	Max
1	Lowest 20%	33.4	3.72	-198.8	74.7
2	Second lowest 20%	103.4	1.83	74.8	140.8
3	Middle 20%	180.0	2.49	141.6	229.5
4	Second highest 20%	300.5	4.62	229.6	402.5
5	Highest 20%	784.0	57.60	405.7	4941.2
	Cotton-producing household income	424.9	52.20	-106.2	4762.9

Source: Authors, based on RHPS data; Malik et al. (2014a, 2014b)

Table 3. Poverty estimates for non-agricultural, agricultural, cotton-farming, Bt, and non-Bt cotton-producing households in Pakistan, 2011.

Household category	Poverty rate (%)	Sample size (n)
All households (national poverty rate)	*26*	--
Panel 1	**Poverty rate based on full RHPS sample**	
All RHPS households	48	2,090
All agricultural households	38	942
All non-agricultural households	56	1,148
All non-cotton-producing agricultural households	39	650
All cotton-producing agricultural households	36	292
All Bt cotton-producing agricultural households	39	171
All non-Bt cotton-producing agricultural households	33	121
Panel 2	**Poverty rate drawn from bottom three quintiles**	
All RHPS households	30	2,090
All agricultural households	23	942
All non-agricultural households	37	1,148
All non-cotton-producing agricultural households	22	650
All cotton-producing agricultural households	24	292
All Bt cotton-producing agricultural households [a]	26	171
All non-Bt cotton-producing agricultural households [b]	22	121

Source: Authors, based on RHPS data and Malik et al. (2014a, 2014b)

[a] *Denotes all households who cultivated at least one officially approved cotton variety*

[b] *Denotes all households who did not cultivate any officially approved cotton variety*

quintile with an average annual income of Rs. 424,900 in 2011 (Table 2).

A more nuanced assessment of wealth and poverty among cotton-producing households requires estimation of specific poverty rates (see Malik et al., 2014a, 2014b). Using an adult-equivalent daily calorie intake measure of poverty, we estimate the poverty rate with RHPS data for cotton-producing households and comparison households.[4] Table 3 shows the poverty estimates for different groups of farmers in the RHPS sample. Poverty lines in Panel 1 are calculated by using the full RHPS sample, while poverty lines in Panel 2 are calculated by using the bottom three quintiles. Although the poverty rates estimated by using the bottom three quintiles are systematically lower than the poverty rates estimated by using the full sample, they follow a similar pattern. First, agricultural households in general are less poor than non-agricultural households in the rural area.

4. *Note here that the poverty line and resultant poverty rates are based on Malik et al. (2014a; 2014b), who use RHPS data and not the corresponding lines and rates set forth by the Government of Pakistan. See Malik et al. (2014b) for a comparison of the accuracy of these two sources of poverty data.*

Table 4. Poverty estimates for Bt and non-Bt cotton-producing household by agro-ecological zones, 2011.

Agro-ecological zone/ farming system	Bt cotton-producing agricultural households [a]	Poverty rate	Non-Bt cotton-producing agricultural households [b]	Poverty rate
Rice/wheat Punjab	7	0.29	4	0.25
Mixed Punjab	27	0.11	11	0.18
Cotton/wheat Punjab	111	0.29	50	0.26
Low intensity Punjab	11	0.18	29	0.24
Barani Punjab	0	--	0	--
Cotton/wheat Sindh	14	0.36	26	0.15
Rice/other Sindh	1	--	1	--
Other KPK	0	--	0	--
Total	171	0.26	121	0.22

Source: Authors, based on RHPS data and Malik et al. (2014a)
[a] Denotes all households who cultivated at least one officially approved cotton variety
[b] Denotes all households who did not cultivate any officially approved cotton variety

Table 5. Land tenure arrangements among rural households in Pakistan, 2011.

	Non-cotton-producing households (n=650)		Cotton-producing households (n=292)	
Land tenure arrangement	**Share (mean %)**	**Mean (std. dev.)**	**Share (mean %)**	**Mean (std. dev.)**
Self-owned	61.3	2.80 (5.91)	63.8	4.04 (5.28)
Rent in	8.3	1.47 (3.12)	16.0	1.60 (3.82)
Rent out	2.9	0.02 (0.35)	5.2	0.02 (0.30)
Sharecrop in	30.1	0.45 (2.23)	20.2	1.74 (5.31)
Sharecrop out	1.4	0.16 (1.39)	0.5	0.33 (1.58)
Mortgage but self-managed	0.3	0.01 (0.12)	0.02	0.00 (0.06)

Source: Authors, based on RHPS data

Second, cotton-producing agricultural households are not significantly different (in statistical terms) from non-cotton-producing agricultural households in terms of poverty status. Third, the difference between Bt cotton-producing households and non-Bt cotton-producing households is statistically insignificant. The estimates based on the bottom three quintiles are more relevant to the measurement of poverty as they capture the relationship between food expenditure and minimum caloric intakes per capita, and because they are more consistent to national estimates. Based on the estimates by using the bottom three quintiles, the poverty rate among cotton-producing households was 24% in 2011.

Poverty estimates can be further disaggregated between Bt and non-Bt cotton-producing households. Of the 292 cotton-producing households identified in the RHPS, 171 (59%) were cultivating officially approved Bt cotton varieties during *kharif* 2011, and the remaining 121 cotton-producing households (41%) were cultivating other cotton varieties, mostly non-Bt. We estimated the poverty rate among these Bt cotton-producing households at 0.26 and non-Bt cotton farmers at 0.22 (Table 4). This gives us an indication of the disparity in the wealth/income distribution that correlates to Bt cotton adoption in Pakistan, although direct causal inferences should not be readily made without a more complete model that explains this relationship and, preferably, a larger number of household observations in the non-traditional cotton-growing areas. In any case, disaggregation by agro-ecological zones and farming system reveals no conclusive pattern in the poverty rates.

An analysis of landholding sizes and lend tenure arrangements in cotton production reveal additional insights into the welfare status of cotton-producing households in Pakistan. Agricultural Census data shows that cotton-producing farmers cultivate cotton on farms of less than 5 acres (GOP, 2012). The RHPS identifies six different tenure arrangements for cotton-producing households: self-owned, rented in, rented out, share-

Table 6. Land tenure arrangements among Bt and non-Bt cotton-producing households, 2011.

	Officially approved Bt cotton-producing agricultural households [a] (n=173)		Non-Bt cotton-producing agricultural households [b] (n=121)		
Land tenure arrangement	**Share (mean %)**	**Mean (std. dev.)**	**Share (mean %)**	**Mean (std. dev.)**	**p-value**
Self-owned	68.6	4.55 (6.08)	57.6	3.32 (3.80)	0.04**
Rent in	17.6	0.87 (2.37)	13.5	2.63 (5.06)	0.24
Rent out	4.4	0.00 (0.00)	6.3	0.05 (0.46)	0.57
Sharecrop in	13.8	2.07 (6.15)	29.0	1.27 (3.78)	0.00***
Sharecrop out	0.0	0.33 (1.48)	1.1	0.33 (1.71)	0.19
Mortgage but self-managed	0.03	0.01 (0.08)	0.0	0.00 (0.00)	0.40

*Source: Authors, based on RHPS data. Asterisks denote significance: *** p < 0.01, ** p < 0.05, * p < 0.10*

[a] Denotes all households who cultivated at least one officially approved cotton variety

[b] Denotes all households who did not cultivate any officially approved cotton variety

Table 7. Acreage share of cotton cultivation by agro-ecological zones in Pakistan, 2011.

Agro-ecological zone	Estimated share of area allocated to cotton cultivation (%)	Estimated share of area allocated to Bt cotton cultivation (%)
Rice/wheat Punjab	7.5	51.5
Mixed Punjab	7.6	74.6
Cotton/wheat Punjab	35.7	75.0
Low intensity Punjab	10.4	22.6
Barani Punjab	--	--
Cotton/wheat Sindh	30.5	32.0
Rice/other Sindh	0.6	55.6
Other KPK	--	--

Source: Authors, based on RHPS data

cropped in, sharecropped out, and mortgaged but self-managed (Table 5). In general, cotton-producing households tend to own and rent more land than non-cotton-producing households and sharecrop less. Mean landholding sizes tend to be larger under self-owned, rented-in, and sharecropped-in tenureship arrangements. This may simply reflect the fact that landholdings are generally larger in the cotton-wheat zones (which make up the majority of our sample) than in other zones.

Furthermore, Bt cotton-producing households are more prevalent among self-owned and rented-in land tenure arrangements than non-Bt cotton-producing households, with the former household type cultivating more land on average under self-owned and sharecropped-in arrangements than the latter household type (Table 6). This gives us another clue as to disparities in the distribution of Bt cotton adoption in Pakistan.

Cotton farmers in the RHPS survey, for the most part, specialized in cotton cultivation during the 2011 *kharif* season. Only 5% of cotton-producing households in the RHPS sample cultivated cotton on less than 25% of their total cultivable land area, while 47% allocated more than 80% of their cultivable land to cotton. Across agro-ecological zones, the share of area under cotton cultivation in a given agro-ecological zone was—as might be expected—highest in the cotton/wheat Punjab and cotton/wheat Sindh zones. However, the share of Bt cotton in these zones varied: 75% in cotton/wheat Punjab and only 32% in cotton/wheat Sindh (Table 7). This gives us an early clue as to disparities in the spatial distribution of Bt cotton adoption in Pakistan.

Another insight into spatial dimensions of Bt cotton adoption is provided by a measure of the distance to output and input markets. On average, cotton-producing households were located less than 5 km from local markets while all other agricultural households were located slightly more than 7 km away (Table 8). Distances did not vary significantly between Bt and non-Bt cotton-producing households.

Another dimension of Bt cotton adoption relates to the means by which farmers access seed and seed-based technologies such as Bt. Figure 3 shows cotton seed sources by income quintiles, and landholding categories that were calculated from the RHPS data. From this figure we can see that the dominant sources for cotton seed are input dealers, private seed companies (i.e., company retail outlets), and own saved seeds. The figure also suggests that better-off cotton-producing households tend to purchase seed directly from private seed companies and are less likely to purchase from input dealers. This observation is generally consistent across other welfare classifications such as wealth and landholdings. We also

Table 8. Distances to the seed market by agricultural household types in Pakistan, 2011.

Household type	No. of obs.	Mean distance (km)	Std. dev	p-value
All households	742	6.57	11.04	0.00*** [a]
Cotton-producing households	269	4.71	0.42	0.00*** [b]
Non-cotton-producing household	473	7.15	27.39	
Bt cotton-producing households	163	4.38	6.57	0.54 [c]
Non-Bt cotton-producing households	106	4.93	7.52	

*Source: Authors, based on RHPS data. Asterisks denote significance: *** p < 0.01, ** p < 0.05, * p < 0.10 for:*

[a] *all households vs. cotton-producing households*

[b] *cotton-producing households vs. non-cotton-producing households*

[c] *Bt cotton-producing households vs. non-Bt cotton-producing households*

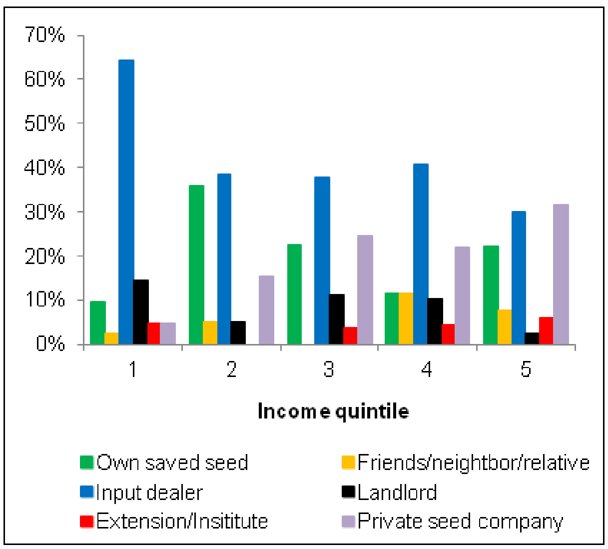

Figure 3. Cotton seed sources by income quintiles in Pakistan, 2011.

Source: Authors, based on RHPS data

find that cotton farmers in Sindh's agroecological zones acquire seeds mainly from input dealers and landlords, which contrasts sharply with a much more diverse seed sourcing practice found in Punjab's agroecological zones (Figure 4).

The top variety under cultivation in the RHPS sample was MNH-886, accounting for 36% of all cotton-producing households and 37% of all area under cotton cultivation in the sample (Table 9). Taken together, the top 10 varieties occupy 78% of the cotton area, and 70%

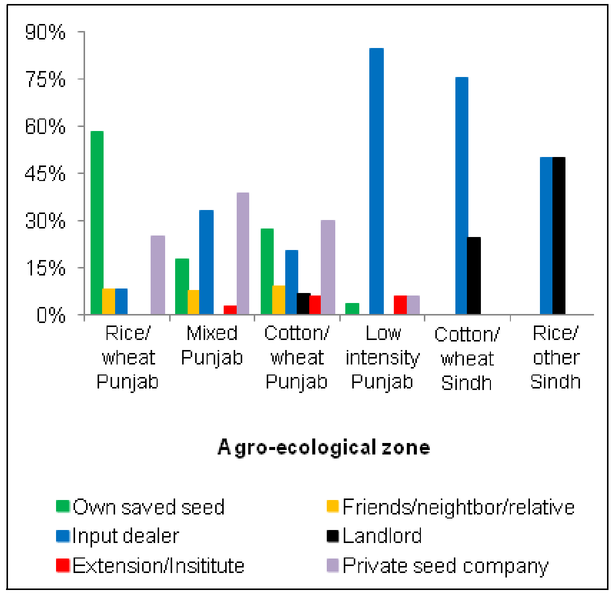

Figure 4. Cotton seed sources by agro-ecological zones in Pakistan, 2011.

Source: Authors, based on RHPS data

of cotton farmers grew them in 2011. It is interesting to note that among the top 10 cotton varieties, 50% were non-Bt varieties, accounting for 18% of cotton-producing households and 19% of area under cotton cultivation in the sample. Varietal choice and prices paid for specific varieties vary across several dimensions, including wealth, expenditure, landholding size, and agroecological zone.

In terms of yields for *kharif* 2011 reported by cotton-producing households in the RHPS survey, several observations are worth noting. First, there is ambiguous evidence suggesting that Bt cotton yields are higher across agroecological zones (Figure 5). Second, across varieties, the highest yields are reported for NIAB-111 (1133 kg/acre) and FH-685 (883 kg/acre), both of which are non-Bt varieties, and MNH-886 (868 kg/acre), which is a Bt variety (Table 9). These figures give us another set of clues as to the ambiguous nature of the evidence surrounding Bt cotton in Pakistan, and opens the door for further analysis of the technology's contribution to increasing cotton yields or improving other aspects of cotton production.

To sum up, these descriptive figures provide some insight into the complexity of cotton cultivation in Pakistan. There is significant social, economic, and spatial heterogeneity among cotton-producing households and between Bt and non-Bt cotton-producing households. There is also a significant amount of variation in how such households interact with the market to purchase

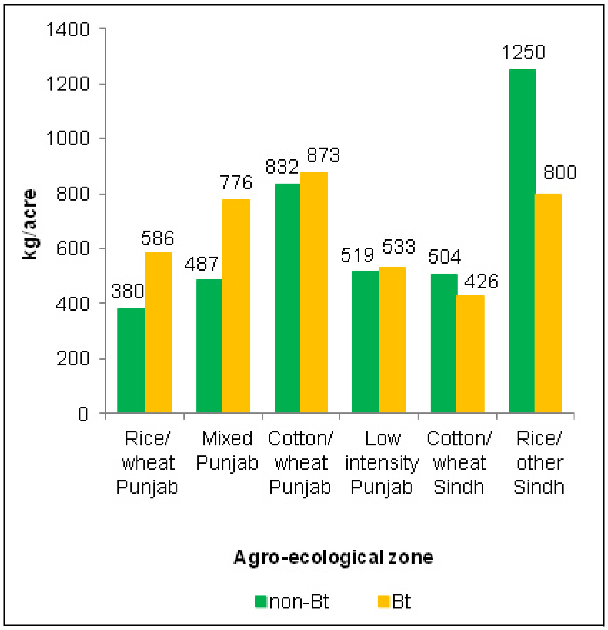

Figure 5. Cotton yields (kg/acre) by agro-ecological zones, 2011.

Source: Authors, based on RHPS data

seed and the Bt cotton technology. While these descriptives are not meant to infer a causal relationship between, say, household welfare status and Bt cotton cultivation, they do encourage further consideration of these relationships. For instance, the last set of figures raise the issue of whether Bt cotton is yield-improving, as some authors have argued, or merely a cost-reducing substitute for pesticides. Earlier figures suggest a correlation between Bt cotton cultivation and higher on-farm income, but further analysis is required to fully understand what other confounding farm- and household-level attributes might explain these yield differences. These figures also open the door to further exploration of heterogeneity in these relationships over dimensions such as farming systems, province, landholding size, or land tenure arrangement. The figures further encourage us to consider how farmers' seed purchasing decisions correlate with access to quality seed and, in turn, the performance of their cotton crop. Given the uncertainties introduced into the cotton seed market that emerged with the introduction of Bt cotton and the resulting policy and regulatory responses, these are all issues for further research. In this sense, the aim of our article is to raise more questions rather than answer them definitively.

Table 9. Reported yields for the top 10 most popular cotton varieties in Pakistan, 2011.

Variety name	Proportion of: Farmer cultivating the variety (%)	Proportion of: Area under cotton cultivation with the variety (%)	Yield (kg/acre): Mean	Yield (kg/acre): Std. dev.
MNH-886	36	37	868	390.2
IR-3701	3	9	627	167.9
Ali Akbar-802	6	6	568	354.3
CIM-496	5	5	808	297.7
B-821	6	4	507	153.3
Ali Akbar-703	5	4	801	426.3
NIAB-111	3	4	1,133	430.6
FH-901	3	4	203	147.2
FH-114	2	3	647	266.5
FH-685	1	2	883	390.2

Source: Authors, based on RHPS data

Conclusion

This article explores the technological, economic, and institutional aspects to Bt cotton, the history of its introduction in Pakistan, and the controversy that has accompanied its adoption during the past decade. By using the data from a unique household survey conducted in 2012, the article characterizes cotton-producing households across several dimensions. We argue that much more analysis is needed to fully understand the link between farmers' technology adoption choices, production practices, and farm-level performance, on the one hand, and the poorly regulated market for transgenic technologies, improved cotton varieties, and seeds, on the other hand. Questions for future exploration include the following.

First, how efficient is the cotton seed market in providing cotton farmers with high-quality seed-based technologies in Pakistan? A key question in the Bt cotton seed market is whether, in the absence of complete information on the quality of Bt cotton seed, the price of seed reflects its quality and efficacy. A related question is whether efficiency in the Bt cotton seed market varies across spatial dimensions, provinces, farm sizes, and land-tenureship categories, thus affecting welfare outcomes of cotton-producing households on different geographic, social, and economic levels.

Second, can we improve the assessment of Bt cotton's direct impacts on yields, net margins at the farm level, as well as its indirect impacts on such issues as gender, labor, and health, with better data? To date, very few analyses are based on samples that are representative of all major cotton-producing areas of Pakistan, despite the valuable insights that representative data could offer individuals and organizations who guide national policymaking on cotton, biotechnology, biosafety, and related issues.

Third, are policies and investments required to reduce the potentially negative impacts of asymmetries of information in Pakistan's market for Bt cotton seed? Would a more responsive NBC and a simpler event-based approval process strengthen the confidence or signal that regulations are meant to give breeders, seed companies, and farmers? Would greater clarity of roles and responsibilities at the federal and provincial levels reduce uncertainty and expedite approval processes? Would stronger enforcement of seed-market regulations and intellectual property rights encourage foreign direct investment? Would collective action by industry associations and farmer organizations compel the government to pursue policy reforms more urgently? Would government investment efforts yield better results by simplifying the regulatory system and directing scarce resources to solve other pressing constraints to cotton production, such as cotton leaf curl virus?

In sum, this article raises more questions than it answers. But what it does suggest is that regulatory uncertainty in Pakistan associated with Bt cotton may be having significantly negative consequences on productivity, welfare, and the environment. Further research is required to ascertain the potential gains and losses from policy action aimed at addressing this uncertainty.

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