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Technological Opportunity, Regulatory Uncertainty, and the Economics of 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 paper aims to shed new light on Bt cotton in Pakistan. First, the paper 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. Second, the paper characterizes cotton-producing households across several dimensions using household survey data collected in 2012. Third, the paper 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.

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1. INTRODUCTION

Genetically modified, insect-resistant Bt cotton has been adopted extensively across Pakistan's cotton-growing regions during the past decade. The seed-based technology renders the cotton plant toxic to certain types of pests, potentially reducing crop damage and losses, reducing the quantity and cost of pesticide application, limiting the harmful health effects of pesticide use, and increasing yields (Ali and Abdulai 2010; Nazli et al. 2010; Bakhsh 2013; Kouser and Qaim 2013a). However, the release and marketing of Bt cotton varieties have 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. 2010, 2012).

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 et al. 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 are non-trivial: approximately 2.2 million farm cultivate cotton in Pakistan, accounting for 26 percent of all farms in the country (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 percent of value added in agriculture, 1.6 percent of GDP, and about 67 percent of foreign exchange earnings (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 percent of all cultivated area, primarily in the provinces of Punjab and Sindh, which produce almost 80 percent 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 paper 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 paper continues in Section 2 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. Section 3 examines evidence on Bt cotton cultivation by drawing on 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. Section 4 identifies areas for further policy-relevant research that could help cotton-producing households in Pakistan to realize greater benefits from Bt cotton cultivation.

2. BACKGROUND

We begin this section with a brief description of the technical dimensions of Bt cotton: what is entailed in this technology, how it operates, and its history. This is followed by a review of the economic evidence associated with the impact of Bt cotton cultivation in several developing countries, with particular reference to China and India. We then describe the introduction of Bt cotton in Pakistan and review the evidence on its impact to date. The section closes with a discussion of possible implications of technological, market, and regulatory issues pertaining to Bt cotton in Pakistan.

2.1. Technical aspects of Bt cotton

We begin this section with a brief review of the technical and economic dimensions of Bt cotton. In its simplest explanation, the Bt technology is based on the introgression of genes from *Bacillus thuringiensis* (Bt), a soil-borne bacterium that produces crystalized proteins that are toxic to *lepidopteran* (chewing) pests such as bollworms.[1] Several Cry genes from the Bt bacterium are used to confer this trait, including Cry1Ac, Cry1Ab, Cry2Ab, and Cry1F.

GM cotton was first commercialized in the U.S. in 1996 and is now cultivated in 15 countries, with Bt and herbicide-tolerant (HT) maize, soybean and canola being cultivated in another 12 countries (James 2013a). Among developing countries, Mexico was the first to commercialize Bt cotton in 1996, followed by China in 1997, Argentina and South Africa in 1998, Colombia and India in 2002,Brazil in 2006, Burkina Faso in 2008, Costa Rica in 2009, Myanmar and Pakistan in 2010, and Sudan and Paraguay in 2012. 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 control-

[1] In fact, the Bt bacterium has been used extensively as an insecticide prior to its introduction into crops such as cotton and maize. The insecticidal qualities of Bt were first discovered in the early 20th century and Bt has been produced on industrial basis as an insecticide since 1959 (Sarker and Mahbub 2012; Beegle and Yamamoto 1992).

ling 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 *(*Spodoptera*s 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 et al. 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,[2] 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 (Showalter et al. 2009; Xia et al. 2005; Guo et al. 2001). 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.

2.2. The economic impact of Bt cotton

Yet 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, labour, and pesticide cost. Overall results suggest that Bt cotton, in comparison to conventional cotton, increases yields (46 percent), gross margin (86 percent), labor costs (7 percent) and seed cost (98 percent,) but also lowers pesticides costs (48 percent) (Table 1).

[2] In this context, introgression refers to the introduction of genetic material from one organism into the gene of another organism.

Table 1. A review of economic performance indicators for Bt and conventional cotton

Country	Technology	Economic performance indicator									
		Yield (kg/ha)		Gross margin (US$/ha)		Seed costs (US$/ha)		Pesticide cost (US$/ha)		Management and labor (US$/ha)	
India	Non-Bt	1315.3 *(n= 96)*		294.1 *(n= 55)*		24.1 *(n= 27)*		113.9 *(n= 47)*		221.7 *(n= 38)*	
	Bt	1982.7 *(n= 76)*	***	389.5 *(n= 42)*	*	80.4 *(n= 27)*	***	79.7 *(n= 37)*	***	305.9 *(n= 26)*	***
South Africa	Non-Bt	879. *(n= 7)*		50.2 *(n= 5)*		20.1 *(n= 5)*		30.33 *(n= 7)*		43.3 *(n= 3)*	
	Bt	1133.0 *(n= 7)*		107.5 *(n= 5)*	*	39.5 *(n= 5)*	***	14.7 *(n= 7)*	***	43.2 *(n= 3)*	
China	Non-Bt	2277.2 *(n= 15)*		295.1 *(n= 24)*		49.1 *(n= 6)*		164.0 *(n= 7)*		1164.0 *(n= 12)*	
	Bt	2342.9 *(n= 27)*		−58.7 *(n= 17)*	***	62.9 *(n= 7)*		46.5 *(n= 9)*	***	939.9 *(n= 19)*	***
Australia	Non-Bt	1764.3 *(n= 13)*		n.a.		n.a. *na*		326.70 *(n= 13)*		n.a.	
	Bt	1788.6 *(n= 13)*		n.a.		113.0 *(n= 6)*		254.8 *(n= 13)*	**	n.a.	
United States	Non-Bt	1055.9 *(n= 20)*		1047.2 *(n= 17)*		36.19 *(n= 16)*		138.4 *(n= 17)*		n.a.	
	Bt	1064.6 *(n= 16)*		938.5 *(n= 13)*		116.5 *(n= 13)*	***	116.2 *(n= 13)*		n.a.	

Source: Finger et al. 2012.

Note: Asterisks denote significant at the * 10 percent, ** 5 percent, and *** 1 percent levels, respectively. The number of study sites *(n)* is denoted in parentheses.

A similar meta-analysis using different data and methods by Areal et al. (2013) arrives at a similar conclusion (Table 2). Specifically, they find that while Bt cotton is associated with higher costs of production than their conventional counterparts, Bt 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.

Table 2. Estimated differences between Bt cotton and conventional cotton

Item	Unit	Mean	S.D.	N
Yield	Ton/Ha	0.30	0.039	77
Production cost	Euros/Ha	13	20	73
Gross margin	Euros/Ha	84	14.2	60

Source: Areal et al. (2013).

Among developing countries where Bt cotton has been commercialized, India and China provide further evidence on precise costs and benefits associated with the technology (Annex 1).[3] In India, for example, Bt cotton has been viewed by many as a success story in the commercialization of transgenic technologies for developing-country smallholders, although it is not without detractors.[4] In 2002, India's Genetic Engineering Approvals Committee (GEAC) approved the commercial release of the first three Bt cotton hybrids in India based on applications that were submitted by a joint venture between Mahyco, an Indian seed company, and Monsanto.[5] Soon after approval for commercialization was granted, Bt cotton caught on quickly among Indian farmers, and by 2009, Bt cotton had expanded to 8.3 million hectares, covering 87 percent of the total area planted to cotton in India (James 2009). The number of Bt hybrids in the market also grew exponentially, from just the original three hybrids in 2002 to 283 by the end of 2008 (GEAC 2012). Until 2009, each Bt cotton hybrid or variety underwent the GEAC regulatory approval process prior to commercialization, despite the fact that the majority of them contained the Cry1Ac gene from same transgenic cotton line MON 531 developed by Monsanto. This fact probably prompted the GEAC to change its application review process in March 2009 from approval being granted on a hybrid/variety basis to approval on an event basis, in line with regulatory practices found in most other countries where GM crops are commercially cultivated (see MoEF 2014; IGMORIS 2005). The new application review process was a likely contributor to a rapid increase in commercial releases. Between 2009 and 2012, the GEAC approved the release of an additional 844 Bt cotton hybrids, or an average of 281 approvals per year compared to an average of 34 hybrids per year between 2002 and 2008 (GEAC

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[3] The commercialization of Bt cotton in South Africa also provides insights, but with some strong caveats. Smale et al. (2009) show that of the 15 on-farm studies of Bt cotton adoption in South Africa, almost half were based on a same sample of 100 small-scale farmers in Makhathini Flats, northern KwaZulu Natal. These farmers were initially purposively selected by the local ginnery to participate in a program to plant Bt cotton, implying that subsequent studies could be subject to sample selection bias—a problem that the studies' authors have recognized (Thirtle et al. 2003; Ismael et al. 2002.) In an effort address the systematic and observable differences between small- and large-scale farmers and between large-scale farmers located in irrigated or dry lands, Gouse et al. (2005) generate specific results for each group indicating that while Bt cotton appears to be beneficial for all farmers, large-scale farmers located in irrigated lands appear to have gained the most from adoption. Despite evidence from Gouse et al. (2005) of seemingly widespread adoption—especially among small-scale farmers in the Makathini Flats whose adoption rate exceeded 90 percent—rapid disadoption occurred once the supply of seed and credit was withdrawn as ginneries who supply these inputs began to compete (Shankar and Thirtle 2005).

[4] Ironically, Bt cotton's introduction in 2000 with controversy when Navbharat, an Indian seed company, marketed an unapproved Bt cotton to farmers in Gujarat. When tests conducted in 2001 confirmed that the cotton was transgenic and had not received approval by the Genetic Engineering Approvals Committee (GEAC), Navbharat was the subject of criminal proceedings while the government ordered the destruction of the standing Bt cotton crop and other measures. See Herring (2007), Roy et al. (2007), and Scoones (2008) for detailed accounts of the incident.

[5] Mahyco Monsanto Biotech (India) Limited (MMB) is a 50–50 joint venture between Mahyco, a leading Indian seed company, and Monsanto Holdings Private Limited (MHPL), itself a 100 percent wholly owned subsidiary of Monsanto Company, a multinational seed company based in the U.S. MMB markets Bollgard® and Bollgard II® Bt cotton technologies to other seed companies in India.

2012). With the increase in the number of commercially released hybrids there was also an expansion in the Bt cotton area in India, from 7.6 million in 2008 to 11 million hectares in 2013, or 95 percent of total area planted to cotton in the country.

Kathage and Qaim (2012) summarize the net benefits of Bt cotton cultivation for smallholders in India's major cotton production systems using data collected from cotton seasons in 2002, 2004, and 2006. Their findings indicate that Bt cotton farmers use fewer insecticides and lower quantities of insecticides, and have profited substantially from the technology. Despite the fact that Bt cotton seed is substantially more expensive (and in spite of higher expenditures on fertilizer and labor for Bt cotton, at least up to 2006), the reduction in insecticide application and the increase in yields resulted in gross profits for Bt farmers that were approximately 70 percent higher than those obtained by non-Bt farmers (Table 3). Kathage and Qaim (2012) extrapolate from these results to find that Bt cotton has resulted in approximately US$ 1.13 billion in annual gains for smallholders in India.

Findings for specific states or regions of India are documented by several authors. Pemsl et al. (2004) compare the economic benefits of insecticide use versus Bt cotton cultivation of in controlling for bollworms in Karnakata, and show that Bt cotton cultivation is more profitable than insecticide use for conventional (non-Bt) cotton only when bollworms are present and are the main pest attacking the crop, and only when the Bt cotton is effective. Morse et al (2005a) compare the agronomic and economic (gross margin) performance of Bt cotton and non-Bt cotton plots in Maharashtra, and conclude that Bt cotton plots outperform non-Bt cotton plots, despite the fact that the cost of Bt cotton seed is substantially higher than conventional cotton seed. Similar results are documented by other authors (Bennett et al. 2005, 2006; Morse et al 2005b, 2007). Looking beyond the issue of yields and profitability, Kouser and Qaim (2011) also find evidence from India that reductions in pesticide applications on the order of 50 percent (and 70 percent for the most toxic chemicals) have reduced the incidence of acute pesticide poisoning among cotton growers, with sizeable implications for healthcare savings.

Table 3. Percentage difference of Bt over conventional cotton, India

Item	2002		2004		2006	
Number of insecticide sprays	-38.2	***	-36.1	***	-13.2	*
Insecticide used	-50.5	***	-50.0	***	-21.1	*
Yield	34.2	***	34.8	***	42.7	***
Seed cost	221.4	***	208.5	***	67.2	***
Insecticides cost	-40.8	***	-34.8	***	3.1	
Fertilizer cost	13.5	***	13.1	**	33.1	
Labor cost	29.6	***	17.8		13.1	
Other cost	16.2		0.0		68.4	**
Total cost	16.8	***	12.6	***	23.5	***
Revenue	32.6	***	37.3	***	39.8	***
Profit	68.9	***	128.2	***	70.4	***

Source: Kathange and Qaim 2012.
Note: Asterisks denote significant at the * 10 percent, ** 5 percent, and *** 1 percent levels, respectively.

Despite these findings, there remain questions about whether yield gains observed in India are actually attributable to Bt cotton. Crost et al. (2007) address concerns about self-selection bias in many of the early results presented for India, and demonstrate that these results tend to overestimate the yield benefits of Bt plots in relation to conventional plots. Nonetheless, using a fixed-effect model to control for selection bias, the authors' results confirm that adoption of Bt cotton increases yields. Of equal importance is the question of whether the technology is, in effect, merely a lower-cost substitute for insecticides which, under a high insecticide-use regime, should have no effect on yields. Using panel data from 1975 to 2009 for nine cotton-producing states in India, Gruère and Sun (2010) conclude that only 19 percent of the increase in the India's cotton yields during the period is attributable to the Bt technology. Other factors that explain the yield increases are the increase use of cotton hybrids and fertilizer. The likely story is that a combination of factors—the dissemination of cotton hybrids, the introduction of the Bt technology, and area expansion with lower insecticide-use regimes—have played a part in increasing cotton yields and output, and reducing production costs. From a broader perspective, these gains are also attributable to a policy environment that encouraged private sector investment in cotton research, seed production and marketing. When considered together, cotton yield increases in India may be the result of a broad transformation of the cotton seed industry driven in part by Bt cotton but also by other factors. See, for example, Ramaswami et al. (2009) and Murugkar et al. (2007, 2006) on changes in the structure of India's cotton seed industry. Importantly, these factors have moved India from its position as the world's third largest cotton importer in 2002–2003 to the second largest exporter in 2012–2013.

As in the case of India, the introduction of Bt cotton in China has also been viewed by many as a success for smallholders. Huang et al. (2002a, 2002b, 2002c, 2005a, 2005b) and Pray et al. (2001, 2002) have documented the yield gains, cost reductions, and reduction in pesticide applications of Bt cotton relative to conventional varieties (Table 4). Studies such as (Pray et al. 2001) have also estimated positive health and environmental benefits of the technology.

Table 4. Percentage difference of Bt over conventional cotton, China

Item	1999	2000	2001
Output revenue (% difference)	7.7	55.8	10.7
Seed cost (% difference)	-1.6	181.0	333.3
Pesticides cost (% difference)	-82.5	-55.9	-58.1
Fertilizer cost ((% difference)	0.0	3.1	-23.2
Organic fertilizer cost(% difference)	-17.6	127.8	-17.0
Other costs (% difference)	36.4	22.9	26.2
Labor cost (% difference)	-18.5	-0.1	-34.2
Total costs (% difference)	-20.5	1.3	-27.5
Net revenue (US$/ha difference)	357	550	502

Source: Pray et al. 2002

Unique to China is a series of studies that explore the causes and consequences of variations in Bt toxin expression levels, insecticide application rates, and agronomic practices among farmers. Pemsl et al. (2005, 2008) argue that the continued high-level use of insecticides by Bt farmers in Shandong Province is partly explained by the fact that most farmers plant low-price Bt seed that express low concentrations of the Bt toxin and thus low efficacy levels against targeted pests. Importantly, these studies suggest that indiscriminate application of insecticides coupled with the use of seed with low Bt toxin expression levels has reduced the efficacy of these strategies against targeted pests or, quite possibly, encouraged the natural selection of pests with resistance to these control strategies. Using the same data collected by Pemsl et al. (2005), Kuosmanen et al. (2006) show that the impact of Bt toxin is negligible when there is high insect pressure, although when the pest pressure is lower than normal the authors estimate that a 1 nanogram (ng) increase in the Bt toxin translates on average to a 1.3 percent increase in yield per hectare. Xu et al. (2008) document the high variation and fluctuation of Bt expression across different varieties/hybrids, regions, and seasons, and find that regional variability is better explained by differences in agronomic practices among farmers than by differences in temperature which, under experimental conditions, have been associated with reduced Bt expression levels. It is, however, worth noting that despite the variations in Bt expression documented by Xu et al. (2008), the majority of varieties tested by the authors were above China's set efficacy threshold of Bt toxin expression of 450 ng/g, suggesting that most varieties/hybrids were potentially effective against bollworms.

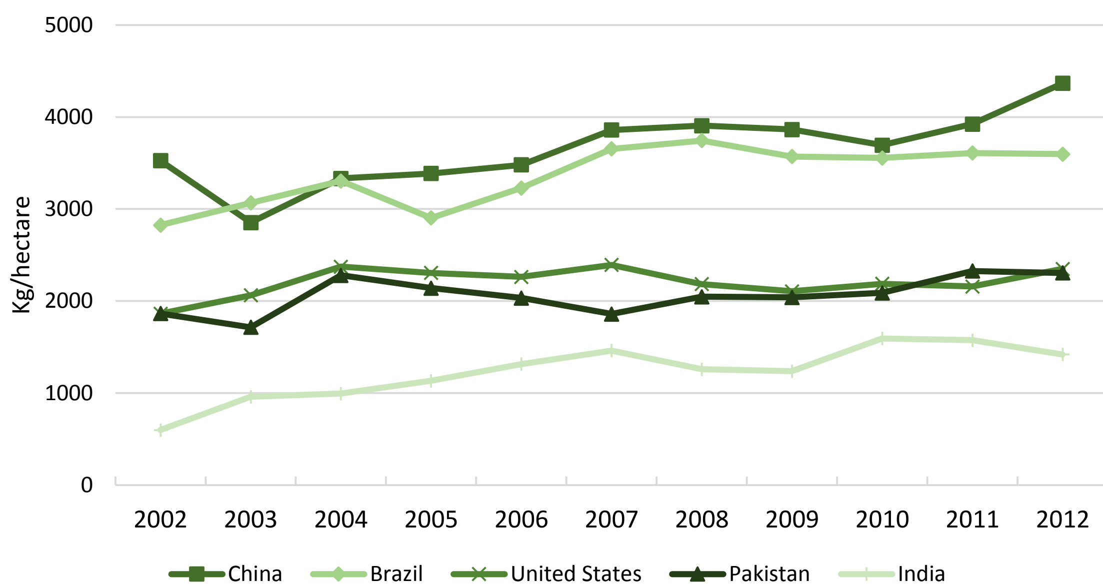
In summary, there is much evidence to suggest that Bt cotton has been beneficial to developing-country farmers in terms of increasing yields and reducing insecticide costs. However, evidence may also suggest that many of the gains attributed to the Bt technology might also be associated with improvements in the genetic backgrounds in which the Cry genes were introgressed. Further, evidence also suggests that the technology's efficacy can vary in relation to insecticide use, *lepidopteran* infestation levels, weather conditions, agronomic practices, and host germplasm. These limitations strike at the heart of concerns about the introduction and widespread adoption of Bt cotton in Pakistan.

2.3. 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, and civil servants; and members of the research community working on issues related to national agricultural policy matters, biotechnology, crop improvement, and other biophysical sciences.

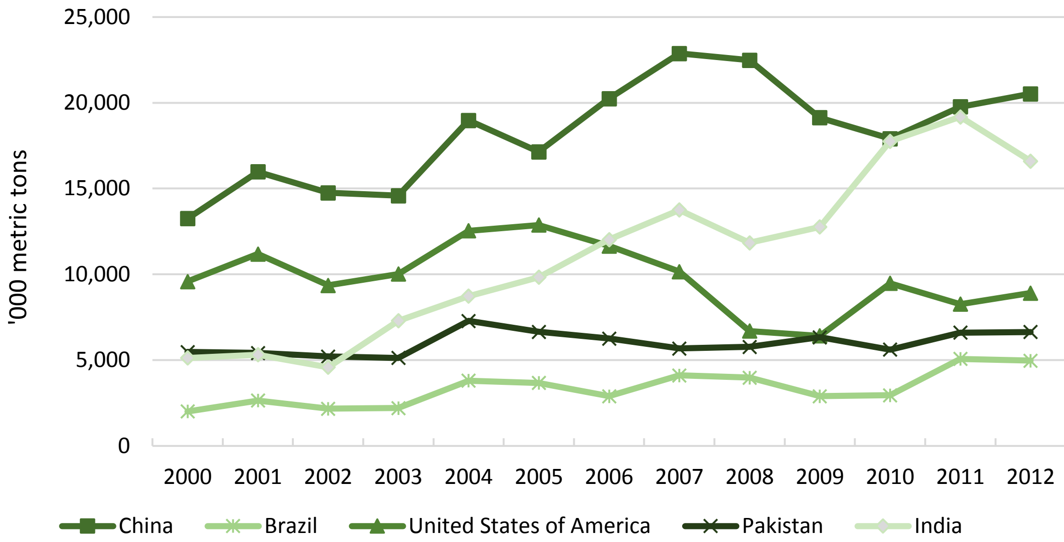
As described earlier, cotton is an essential component of Pakistan's agricultural sector and overall economy. Yet cotton yields in Pakistan have remained at around 2,200 kg/ha between 2002 and 2012 while yields in China, the world's leading cotton-producing country, averaged 3,700 kg/ha during the same time period. And although cotton yields in Pakistan continue to exceed those of neighbouring India and remain comparable to those in the United States and to the world average, yield growth in India, Brazil and China has been 7.1, 2.2, and 2.4 percent, respectively during the last decade, against 0.8 percent in Pakistan (Figure 1). The total production of cotton in Pakistan has remained at around 6,000,000 metric tons with a 1.3 percent 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 percent and 12 percent, respectively (Figure 2) (FAOSTAT 2014).

Figure 1. Cotton yields in Pakistan and other world leading cotton producing countries, 2002-2012



Source: FAOSTAT 2014.

Figure 2. Cotton production in Pakistan and other world leading cotton producing countries, 2002-2012



Source: FAOSTAT 2014.
Note: Data on cotton production shown here are based on FAOSTAT data for "seed cotton" which is also referred to as unginned cotton.

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.[6] 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 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 et al. (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 on 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 et al. (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 et al. (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 (2013a) observed that Bt cotton generated US$204 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 when the positive health and environment benefits are included, US$79 per acre, 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$1.8 billion. In another study of 573 farmers from two-cotton growing seasons in Punjab in 2008-09, Baksh (2013) found that, on average, the net revenue for farmers cultivat-

[6] Several other studies examine related topics including: impacts of Bt cotton adoption on yields, pest management, and cropping patterns (Mehmood et al. 2012; Abdullah 2010; Sabir et al. 2011); adoption determinants (Arshad et al. 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.

ing 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 percent less pesticides.

Two studies extend this work to consider the negative environmental and health consequences of pesticide use that Bt cotton aims to partly substitute for. Kouser and Qaim (2013b) show that while cotton farmers in Pakistan underuse 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 percent, 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 percent. According to their estimation, in the absence of Bt cotton, conventional cotton cultivation costs farmers US$54 per acre (7 percent of total revenue) when the costs of negative health and environmental consequences are included.

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 2007-2008 and found that 10 percent of the samples taken in Punjab and 19 percent in Sindh tested non-positive for the Cry1Ac gene.[7] 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 expression. The remainder exhibited either medium or low levels of toxin expression. Ali et al. (2010) concluded that such low level 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 cotton seed in the market, grew the seed, and tested the plants for Cry gene expression. Results from their tests showed that 30 percent (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 that was marketed globally under the brand Bollgard.® 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 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 more difficult for Pakistan to access second-generation technologies. See Rana (2014), Roberts et al. (2012), and Rana (2010) for an account of this early controversy.

[7] 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.

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 Bt cotton environmental release and commercialization 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 National Biosafety Committee (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 5). It is unclear whether PSC approvals were meant to circumvent or preempt NBC approvals, or 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 convene to 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 misstep 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 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 misstep—or more of a long-standing 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).

Table 5. 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
GN-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; James2013b; GAIN 2013; PABIC 2014; The News 2013; Business Recorder 2013.

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

2.4. Discussion: The challenges posed by a regulated technology in an imperfect market

Pakistan's experience with Bt cotton to date may suggest that rather than improving market efficiency or addressing potential market failures, the country's regulatory system has introduced a level of uncertainty in the country's Bt cotton seed market. The consequence may be placing farmers on the short end of transactions conducted in these markets. 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 are unlikely to have similar access to this information. Farmers 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.

Asymmetries of information between farmers and firms may explain why Bt cotton remains a major source of contention in Pakistan's agricultural policy discourse. At least three major issues emerge from this discourse. The first issue revolves around the impact of a slow rate of technological change in cotton. This does not mean that the dissemination or adoption of Bt cotton has been slow in Pakistan: by most accounts, Bt cotton varieties have rapidly made their way to farmers in Pakistan and been readily adopted. Rather, it suggests that technological change has been primarily characterized by the introduction of a single Cry1Ac event from the MON531 line. This means that Pakistan is missing out on more recent Bt technologies such as the improved insect resistance embodied in Bollgard II®, herbicide resistance in Monsanto's Roundup Ready Flex®, and "stacked" combinations of Bollgard II® with Roundup Ready® Flex.

A second issue relates to investment in research on cotton improvement and biotechnology. The absence of clear biosafety regulations and a pathway to commercialization may be a strong disincentive to investment in research, particularly in the private sector. Already, it is clear that the global leaders in Bt technology—Monsanto, in particular, but also other leading cropscience firms—are not investing in Pakistan's cotton seed market and not bringing their latest technologies to Pakistan's cotton farmers. Several reasons may be behind this reticence, including concerns that (1) the government cannot prevent the unlicensed use of patented transgenic events, (2) the government cannot enforce a patent holder's claims for royalty payments when other companies use the event without a license, (3) neither government nor the industry can maintain industry-wide stewardship practices and standards that ensure against the misuse or abuse of a patented events, and (4) the seed market in Pakistan may simply not offer the profit margins and returns on investment expected by these firms.[8] These circumstances tend to favor smaller domestic seed companies in the Bt cotton market, many of whom can operate under conditions of little regulatory oversight, potentially contributing to the proliferation of low-quality Bt cotton varieties in the market. 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, improve or expand the somewhat narrow set of varietal backgrounds in which Bt has been introgressed,[9] or promote policy changes that would remedy the uncertainty and confusion in the Bt cotton seed market.

A third issue relates to the environmental risks posed by the continuous introduction of sub-par Cry gene expression in Bt cotton can give *lepidopteran* pests greater opportunity to adapt and evolve resistance to the Bt toxin. Already, Monsanto has confirmed that pink bollworm has evolved resistance to Bollgard® in India, demonstrating the speed with which nature evolves and competes with technology (Monsanto 2009).

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[8] Somewhat ironically, it is precisely these regulatory barriers—and the cost required to navigate complex regulatory systems—that Monsanto and other leading multinational cropscience firms use to secure their market power and inhibit the entry of smaller, often domestic competitors. See Pray et al. (2006a, 2006b) for a description of the situation in India.

[9] Of particular concern, for example, is the fact that the currently available Bt cotton varieties in Pakistan are primarily longer-duration varieties that encourage farmers to plant early as a means of avoiding the onset of cotton leaf curl virus (CLCV). This production practice, however, impedes on the growth and harvest of the preceding *rabi* wheat crop which, though a less important source of income for farmers, is central to the discourse on food security at both a national and household levels.

A fourth issue pertains to individual and household welfare. Farmers who unknowingly purchase ineffective or uncertain Bt technologies may make incorrect decisions on crop protection and insecticide use resulting in increased production costs, pest damage, or yield losses. And cotton farmers—like most farmers in Pakistan—are subject to both poverty and vulnerability that makes such risks potentially significant. This, in turn, puts the livelihoods of individuals and households engaged in non-farm rural and urban activities that rely on cotton at risk. 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.

3. 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 agroecological 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, are not intended to assign any causal relationship between Bt cotton adoption and their welfare status.

3.1. 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 first RHPS round was conducted in March 2012 in Punjab, Sindh and Khyber-Pakhtunkhwa (KPK).[10] The sample universe included all rural households in these three provinces, resulting in the selection of 2,124 households from 76 revenue villages (*mouzas*) in 19 districts in the three provinces. The number of districts chosen in each province was based on the province's share of total rural households in the three provinces, and a total of 12 districts were selected from Punjab, 5 from Sindh and 2 from KPK. See Nazli and Haider (2012) for further details.

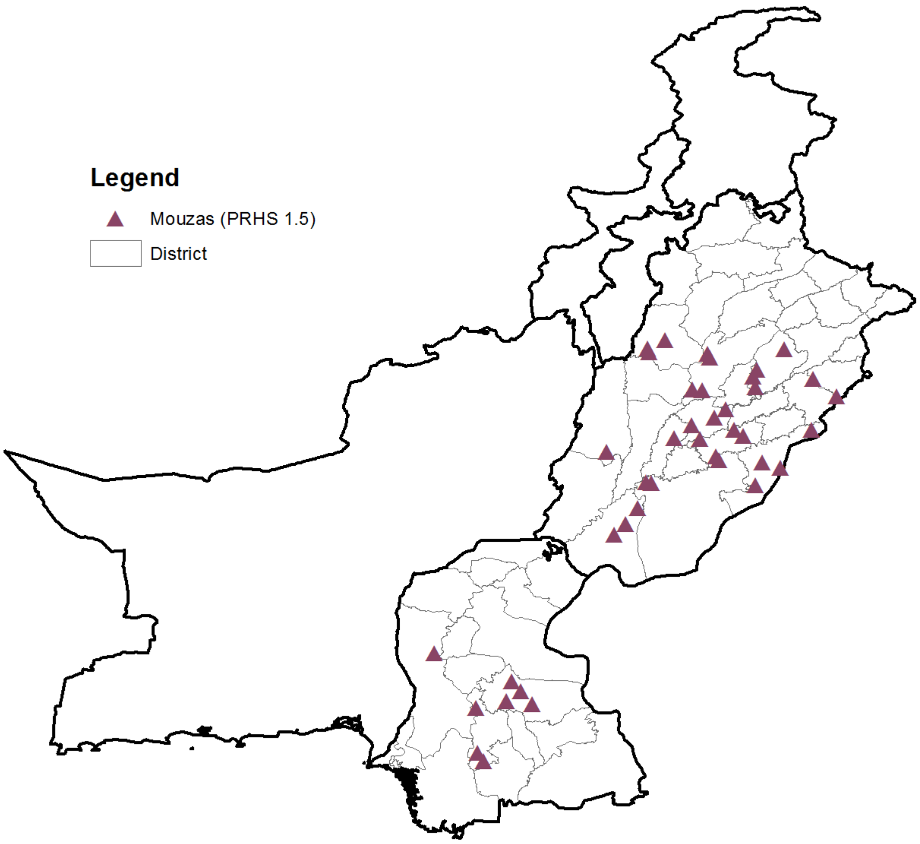
Initial analysis of the RHPS Round 1 revealed that 981 households in the total sample (47 percent) were agricultural households, defined as those households that cultivated land in the past one year. From among these agricultural households, 295 households (30 percent) had cultivated cotton in the past year. RHPS Round 1.5, launched in November 2012, surveyed these agricultural households to collect detailed information on agricultural production for each crop and for each individual plot under cultivation for the *kharif* 2011 and *rabi* 2011/12 seasons. The survey covered 980 farm households in 76 mauzas of 19 districts. Of these households, 543 are located in 12 districts of Punjab, 317 in 5 districts of Sindh, and 120 in 2 districts of KPK. Information on 38 households could not be collected due to unavailability, refusal, or in some cases the household members were agricultural wage workers and did not qualify as agricultural/cultivating households, reducing the total number of households to 942. Of these, a total of 292 agricultural households cultivated cotton in *kharif* 2011: 250 in Punjab and 42 in Sindh (Figure 3).

The analysis presented in subsequent section is based on data from RHPS rounds 1 and 1.5. Because the RHPS sampling frame was not constructed around heterogeneity in Pakistan's cotton production systems, these descriptives are not

[10] Due to security concerns, only the following districts in KPK were included in the sampling design: Charsadda, Nowshera, Peshawar, Abbotabad, Haripur, Malakand, Mansehra, Chitral, Swat, Mardan and Battagram.

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.

Figure 3. *Mouzas* where cotton is cultivated in the RHPS Survey Round 1.5, November 2012



Source: Authors, based on RHPS 1.5 data.

3.2. 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 et al. 2014a; 2014b), the average cotton-producing household falls within the highest quintile with an average annual income of Rs. 424,900 in 2011 (Table 6).

Table 6. National annual household income by quintile for rural households (Rs '000)

Quintile	Description	Mean	Std. dev.	Min	Max
1	Lowest 20 percent	33.4	3.72	-198.8	74.7
2	Second Lowest 20 percent	103.4	1.83	74.8	140.8
3	Middle 20 percent	180.0	2.49	141.6	229.5
4	Second highest 20 percent	300.5	4.62	229.6	402.5
5	Highest 20 percent	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 Rounds 1 and 1.5 data; Malik et al. (2014a; 2014b).

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.[11] Table 7 shows the poverty estimates for different groups of farmers in the RHPS sample. Poverty lines in Panel A are calculated by using the full RHPS sample, while poverty lines in Panel B 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. 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 calorie 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 percent in 2011.

[11] 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. (20014b) for a comparison of the accuracy of these two sources of poverty data.

Table 7. Poverty estimates for non-agricultural, agricultural, and cotton-farming households

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 Rounds 1 and 1.5 data and Malik et al. (2014a; 2014b).

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

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

A comparison between cotton- and non-cotton-producing households disaggregated by agroecological zones and farming systems provides further detail. These estimates (Table 8) suggest that poverty rates are generally high among cotton-producing households, with the exception of households in the Sindh Cotton/wheat system. However, these estimates are based on a relatively small number of observations in each household category, suggesting caution in interpreting these results.

Table 8. Poverty estimates for cotton-producing households by agro-ecological zones

Agro-ecological zone/ farming system	Non-cotton-producing agricultural households (*n*)	Poverty rate (%)	Cotton-producing agricultural households (*n*)	Poverty rate (%)
Rice/wheat Punjab	28	11	11	27
Mixed Punjab	87	12	38	13
Cotton/wheat Punjab	60	25	161	28
Low intensity Punjab	80	14	40	23
Barani Punjab	16	25	0	--
Cotton/wheat Sindh	43	37	40	23
Rice/other Sindh	220	29	2	00
Other KPK	116	16	0	--
Total	650	22	292	32

Source: Authors, based on RHPS Rounds 1 and 1.5 data; Malik et al. (2014a; 2014b).

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 percent) were cultivating officially approved Bt cotton varieties during *kharif* 2011, and the remaining 121 cotton-producing households (41 percent) 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 9). 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 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.

Table 9. Poverty estimates for Bt and non-Bt cotton-producing household by agro-ecological zones

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 Rounds 1 and 1.5 data and Malik et al. (2013).
[a] Denotes all households who responded affirmatively in the survey to questions on whether they believed they were cultivating a Bt cotton variety, and were able to identify the name of the variety from a pre-coded list containing officially approved Bt cotton varieties.
[b] Denotes all households who responded negatively in the survey to questions on whether they believed they were cultivating a Bt cotton variety.

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 a majority of cotton-producing farmers cultivate cotton on farms are of less than 5 acres (Annex 2). The RHPS identifies six different tenure arrangements for cotton-producing households: self-owned, rented in, rented out, sharecropped in, sharecropped out, and mortgaged but self-managed. 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 (Table 10). 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.

Table 10. Land tenure arrangements among rural households

Land tenure arrangements among…	non-cotton-producing households (*n*=650)		cotton-producing households (*n*=292)	
	Share (mean percent)	Mean (std. dev.)	Share (mean percent)	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 Rounds 1 and 1.5 data.

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. This gives us another clue as to disparities in the distribution of Bt cotton adoption in Pakistan (Table 11).

Table 11. Land tenure arrangements among Bt and non-Bt cotton-producing households

Land tenure arrangement	Officially approved Bt cotton-producing agricultural households[a] (*n*=173)		non-Bt cotton-producing agricultural households[b] (*n*=121)		p-value
	Share (mean percent)	Mean (std. dev.)	Share (mean percent)	Mean (std. dev.)	
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 Rounds 1 and 1.5 data. Asterisks denote significance as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
[a] Denotes all households who responded affirmatively in the survey to questions on whether they believed they were cultivating a Bt cotton variety, and were able to identify the name of the variety from a pre-coded list containing officially approved Bt cotton varieties.
[b] Denotes all households who responded negatively in the survey to questions on whether they believed they were cultivating a Bt cotton variety.

Several social indicators, including education of household head, household dependency ratios tend to be better for all cotton-producing households when compared to all agricultural households, and for Bt cotton-producing households when compared to non-Bt cotton producing households. Related economic indicators such as access to credit do not suggest significant credit constraints among cotton-producing households. See Annex 3.

Cotton farmers in the RHPS survey, for the most part, specialized in cotton cultivation during the 2011 *kharif* season. Only 5 percent of cotton-producing households in the RHPS sample cultivated cotton on less than 25 percent of their total cultivable land area, while 47 percent allocated more than 80 percent of their cultivable land to cotton. Across agroecological zones, the share of area under cotton cultivation in a given agroecological 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 percent in cotton/wheat Punjab, and only 32 percent in cotton/wheat Sindh (Table 12). This gives us an early clue as to disparities in the spatial distribution of Bt cotton adoption in Pakistan.

Table 13. Share of cotton cultivation by agro-ecological zone

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 Rounds 1 and 1.5 data.

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 to local markets while all other agricultural households were located slightly more than 7 km (Table 14). Distances did not vary significantly between Bt and non-Bt cotton-producing households.

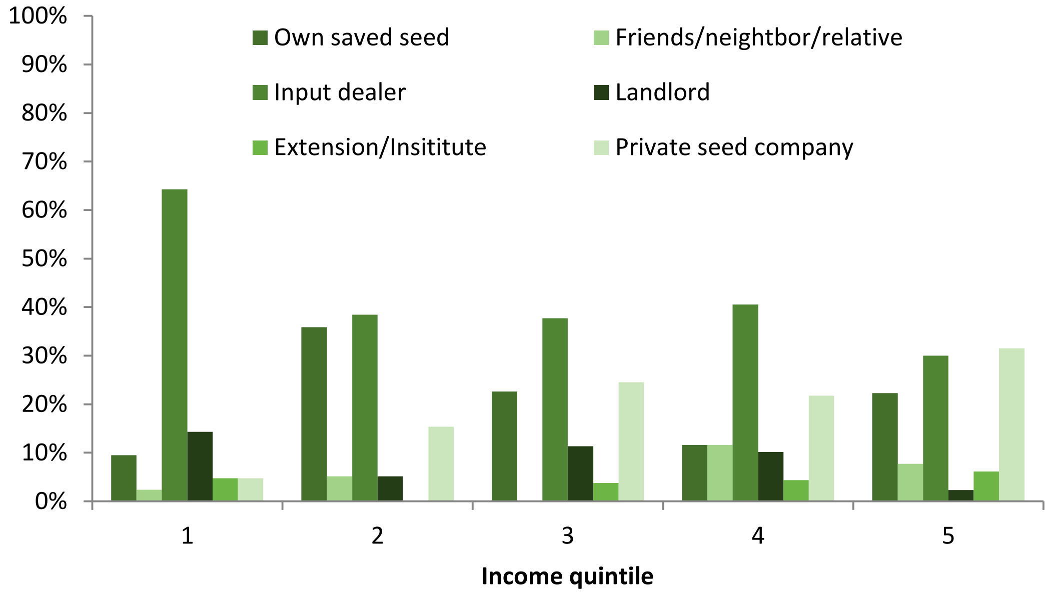
Table 14. Distances to market, by agricultural household type

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 Rounds 1 and 1.5 data. Asterisks denote significance as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$ for [a] all households vs. cotton-producing households; [b] cotton-producing households vs. non-cotton-producing households; and [c] Bt cotton-producing households vs. non-Bt cotton-producing households.

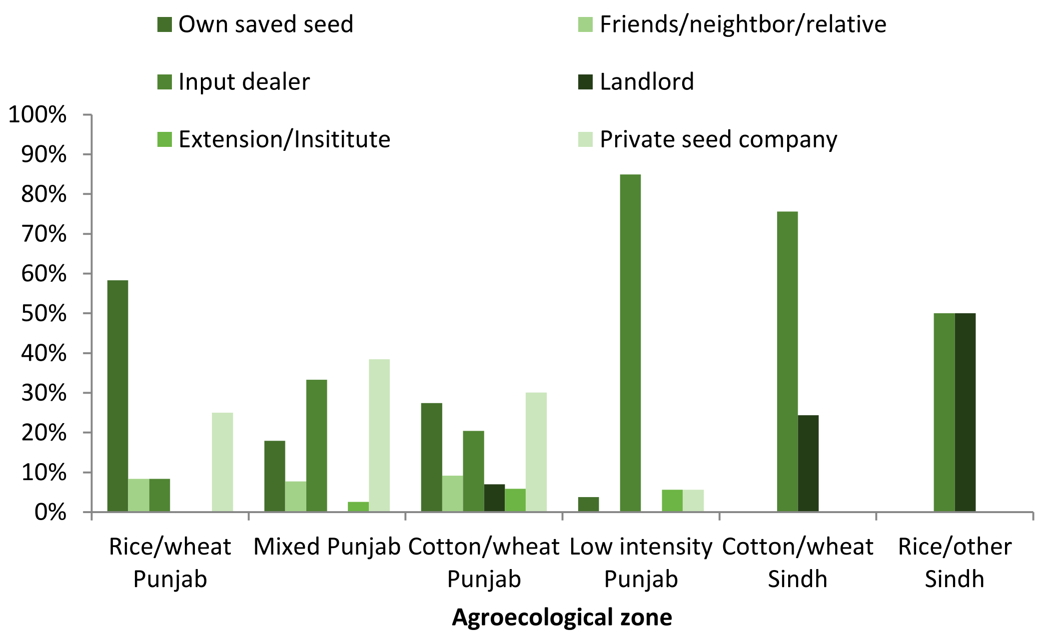
Another dimension of Bt cotton adoption relates to the means by which farmers access seed and seed-based technologies such as Bt. Figure 4 shows cotton seed sources by income quintiles that were calculated from the RHPS data. From this figure we can see that the dominant sources for cotton seed are input 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 (Annex 4). We also 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 practices found in Punjab's agroecological zones (Figure 5).

Figure 4. Cotton seed sources by income quintiles



Source: Authors, based on RHPS Rounds 1 and 1.5 data.

Figure 5. Cotton seed sources by agro-ecological zone

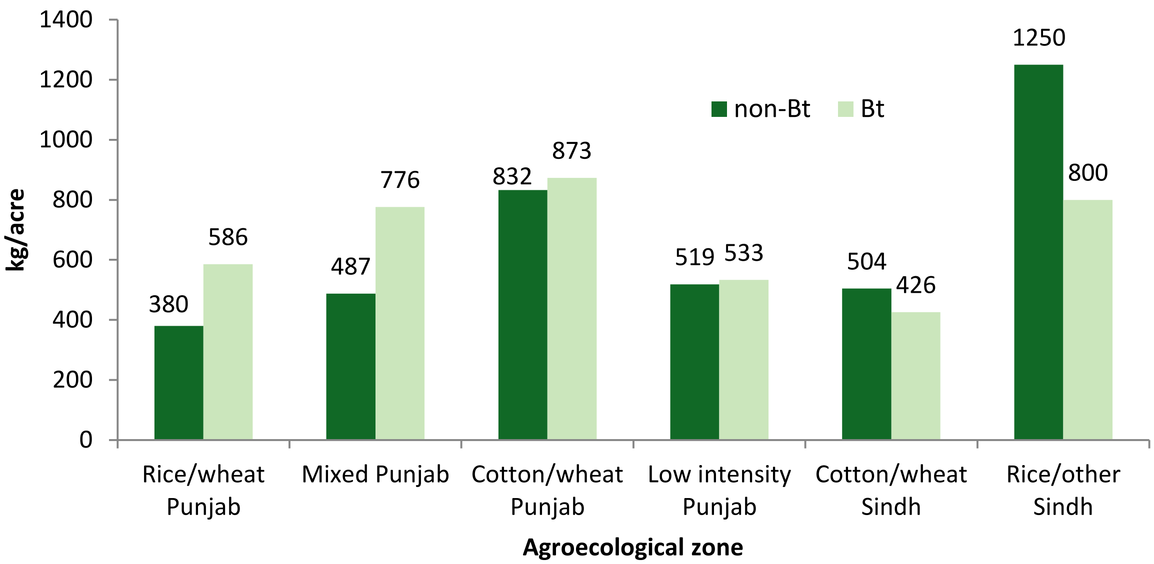


Source: Authors, based on RHPS Rounds 1 and 1.5 data.

The top variety under cultivation in the RHPS sample was MNH-886, accounting for 36 percent of all cotton-producing households and 37 percent of all area under cotton cultivation in the sample (Table 15). Taken together, the top ten varieties occupy 78 percent of the cotton area and 70 percent cotton farmers grew them in 2011. It is interesting to note that among top ten cotton varieties, 50 percent were non-Bt varieties, accounting for 18 percent of cotton-producing households and 19 percent 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 (Annex 5).

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 6). 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 15). 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.

Figure 6. Cotton yields (kg/acre) by agroecological zones, 2011



Source: Authors, based on RHPS Rounds 1 and 1.5 data.

Table 15. Reported yields for the top ten most popular cotton varieties, 2011

Variety name	Proportion of…		Yield (kg/acre)	
	farmer cultivating the variety (%)	area under cotton cultivation with the variety (%)	Mean	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 Rounds 1 and 1.5 data.

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 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. They 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 paper is to raise more questions rather than answer them definitively.

4. CONCLUSION

This paper argues 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 government to pursue policy reforms more urgently? Would government investment efforts yield better results by simplifying the regulatory system and directing scare resources to solve other pressing constraints to cotton production such as cotton leaf curl virus (CLCV)?

In sum, this paper 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.

REFERENCES

Abdullah A. 2010. "An Analysis of Bt Cotton Cultivation in Punjab, Pakistan Using the Agriculture Decision Support System (ADSS)." *AgBioForum* 13(3): 274-287.

Abedullah, S. K. and M. Qaim. 2014. "Bt cotton, Pesticide Use and Environmental Efficiency in Pakistan." *Journal of Agricultural Economics*. doi: 10.1111/1477-9552.12072

Abid, M., M. Ashfaq, M. A. Quddus, M. A. Tahir and N. Fatima. 2011. "A Resource Use Efficiency Analysis of Small Bt Cotton Farmers in Punjab, Pakistan." *Pakistan Journal of Agricultural Science* 48(1): 75-81.

Ali S., S. H. Shah, G. M. Ali, A. Iqbal, M. Asad, Y. Zafar. 2012. "Bt Cry Toxin Expression Profile in Selected Pakistani Cotton Genotypes." *Current Science* 102(12) (25): 1632-1636

Ali, S., H. Shahid, M. Shahid, G.M. Ali, and Z. Yusuf. 2010. "Status of Bt Cotton Cultivation in Major Growing Areas of Pakistan." *Pakistan Journal of Botany* 42(3): 1583-1594.

Ali, A., and A. Abdulai. 2010. "The Adoption of Genetically Modified Cotton and Poverty Reduction in Pakistan." *Journal of Agricultural Economics* 61(1): 175-192.

Areal, F.J., L. Riesgo, and E. Rodríguez-Cerezo. 2013. "Economic and Agronomic Impact of Commercialized GM crops: a meta-analysis. Agricultural Science." *Journal of Agricultural Science* 151(1): 7-33

Arshad, M., A. Suhail, M. Asghar, M. Tayyib and F. Hafeez. 2007. "Factors Influencing the Adoption of Bt Cotton in the Punjab, Pakistan." *Journal of Agricultural and Social Sciences* 3(4): 121-124.

Bakhsh, K. 2013. *Economic and Environmental Impacts of Bt cotton: Evidence from Pakistan*. Working Paper 79-13. Kathmandu: South Asian Network for Development and Environmental Economics.

Barwale, R. B., V. R. Gadwal, U. Zehr, and B. Zehr. 2004. "Prospects for Bt cotton Technology in India." *AgBioForum* 7 (1&2): 23–26.

Beegle, C.C. and T. Yamamoto. 1992. "Invitation Paper (C. P. Alexander Fund): History of Bacillus Thuringiensis Berliner Research and Development." *Canadian Entomologist* 124: 587–616.

Bennett, R., U. Kambhampati, S. Morse, and Y. Ismael. 2006. "Farm-level Economic Performance of Genetically Modified Cotton in Maharashtra," *India Review of Agricultural Economics* 28(1): 59–71.

Bennett, R., Y. Ismael, and S. Morse. 2005. "Explaining Contradictory Evidence Regarding Impacts of Genetically Modified Crops in Developing Countries: Varietal Performance of Transgenic Cotton in India." *Journal of Agricultural Science* 143(1): 35–41.

Bennett, R., Y. Ismael, U. Kambhampati, and S. Morse. 2004. "Economic Impact of Genetically Modified Cotton in India." *AgBioForum* 7(3): 96–100.

Business Recorder. 2014. "Commercialisation of 15 GMO Bt Cotton Varieties Approved." March 13.

Crost, B., B. Shankar, R. Bennett, and S. Morse. 2007. "Bias from Farmer Self-selection in Genetically Modified Crop Productivity Estimates: Evidence from India Data." *Journal of Agricultural Economics* 58(1): 24–36.

Dev, S. M. and N. C. Rao. 2007. *Socio-economic Impact of Bt cotton.* Centre for Economic and Social Studies (CESS) Monograph No. 3. Hyderabad, India: CESS.

FAOStat (Food and Agriculture Organization of the United Nations Statistical Database). 2014. "Production Data." Accessed March 2014. http://faostat3.fao.org/home/index.html#DOWNLOAD.

Finger, R., N. El Benni, T. Kaphengst, C. Evans, S. Herbert, B. Lehmann, S. Morse, and Nataliya Stupak. 2011. "A Meta-analysis on Farm-level Costs and Benefits of GM Crops." *Sustainability* 3:743–62.

GAIN (Global Agricultural Information Network). 2013. "Pakistan Agricultural Biotechnology Annual Report 2013." Accessed April 2014. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Agricultural%20Biotechnology%20Annual_Islamabad_Pakistan_7-18-2013.pdf.

Gandhi, V. and N. Namboodiri. 2006. *The Adoption and Economics of Bt Cotton in India: Preliminary Results from a Study*, Working Paper No. 20006-09-04. Institute of Management: Ahmedabad.

GEAC (Genetic Engineering Approval Committee). 2012. "Yearwise List of Commercially Released Varieties of Bt Cotton Hybrids by GEAC (Year 2002-upto May 2012)." Accessed July 2013. http://dbtbiosafety.nic.in/Standing_Committee/YearWise_List2002_May2012.pdf.

GOP (Government of Pakistan). 2012. *Census of Agriculture 2010.* Lahore: Agriculture Census Organization. Accessed April 2014. http://www.pbs.gov.pk/content/agricultural-census-2010-pakistan-report

Gouse, M., J. Kirsten, B. Shankar, and C. Thirtle. 2005. "Bt Cotton in KwaZulu Natal: Technological Triumph but Institutional Failure." *AgBiotechNet* 7(134): 1-7.

Gruère, G.P., and Y. Sun. 2012. *Measuring the Contribution of Bt Cotton Adoption to India's Cotton Yields Leap*. Environment and Production Technology Division IFPRI Discussion Paper no. 1170. Washington, DC: International Food Policy Research Institute.

Gruère, G. P., P. Mehta-Bhatt, and D. Sengupta. 2008. *Bt Cotton and Farmer Suicides in India: Reviewing the Evidence.* IFPRI Discussion Paper 808. Washington D.C.: International Food Policy Research Institute.

Guo, W.Z., J. Sun, Y. F. Guo and T.Z. Zhang. 2001. "Investigation of Different Dosage of Inserted *Bt* Genes and their Insect-resistance in Transgenic *Bt* Cotton." *Acta Genetica Sinica* 28: 668-676.

Herring, R.J. 2007. "Stealth Seeds: Bioproperty, Biosafety, Biopolitics." *Journal of Development Studies* 43(1): 130–157.

Huang, J., R. Hu, S. Rozelle, and C.E. Pray. 2005a. "Insect-resistant GM Rice in Farmers' Fields: Assessing Productivity and Health Effects in China." *Science* 308(5722): 688-690.

Huang, J., R. Hu, C.E. Pray, and S. Rozelle. 2005b. "Development, Policy and Impacts of Genetically Modified Crops in China: A Comprehensive Review of China's Agricultural Biotechnology Sector." Paper presented at Workshop on Agricultural Biotechnology for Development: Institutional Challenges and Socio-economic Issues in Bellagio, Italy, 30 May - 1 June.

Huang, J., R. Hu, C.E. Pray, F. Qiao, and S. Rozelle. 2003. "Biotechnology as an Alternative to Chemical Pesticides: A Case Study of Bt Cotton in China." *Agricultural Economics* 29(1): 55-67.

Huang, J., R. Hu, C. Fan, C.E. Pray, and S. Rozelle. 2002a. "Bt Cotton Benefits, Costs, and Impacts in China." *AgBioForum* 5(4): 153-166.

Huang, J., R. Hu, S. Rozelle, F. Qiao, and C. Pray. 2002b. "Transgenic Varieties and Productivity of Smallholder Cotton Farmers in China." *Australian Journal of Agricultural and Resource Economics* 46(3): 367-387.

Huang, J., R. Hu, Q. Wang, J. Keeley, and J. Falck-Zepeda. 2002c. "Agricultural Biotechnology Development, Policy and Impact in China." *Economic and Political Weekly* 37(27): 2756-2761.

IGMORIS (Indian GMO Research Information System). 2005. "Biosafety Data of Approved Genes/Events of GM Cotton." Accessed July 2014. http://igmoris.nic.in/major_developments1.asp.

Ismael, Y., R. Bennett, and S. Morse. 2002. “Benefits from Bt Cotton Use by Smallholder Farmers in South Africa.” *AgBioForum* 5(1): 1-5.

James, C. 2013a. *Global Status of Commercialized Biotech/GM Crops: 2013*. Ithaca, NY: International Service for the Acquisition of Agri-biotech Applications.

James, C. 2013b. *Biotech Facts and Trends 2013.* ISAAA Brief no. 46. Ithaca, NY: International Service for the Acquisition of Agri-biotech Applications.

James, C. 2009. *Global Status of Commercialized Biotech/GM Crops: 2009.* ISAAA Brief no. 41. Ithaca, NY: International Service for the Acquisition of Agri-biotech Applications.

Kathage, J., and M. Qaim. 2012. “Economic Impacts and Impact Dynamics of Bt *(Bacillus thuringiensis)* Cotton in India.” *Proceedings of the National Academies of Science* 109(29): 11652–11656.

Kuosmanen, T., D. Pemsl, and J. Wesseler .2006 “Specification and Estimation of Production Functions Involving Damage Control Inputs: A two-Stage, Semiparametric Approach.” *American Journal of Agricultural Economics* 88(2): 499-511.

Kouser S., and M. Qaim. 2013a. “Valuing the Economic, Health and Environmental Benefits of Bt Cotton Adoption in Pakistan.” *Agriculture Economics* 44(3): 323-335.

Kouser S., and M. Qaim. 2013b. “Bt Cotton, Damage Control and Optimal Levels of Pesticide Use in Pakistan.” *Environment and Development Economics* 19: 1-20.

Kouser S., and M. Qaim. 2011. “Impact of Bt cotton on Pesticide Poisoning in Smallholder Agriculture: A Panel Data Analysis.” *Ecological Economics* 70(2011): 2105-2113.

Malik, S., H. Nazli and E. Whitney. 2014a. “Trends in Poverty Numbers from the HIES Data: 2001-2010.” Presentation given at the IFPRI Pakistan Strategy Support Program (PSSP) Annual Conference, Islamabad, January 21-22.

Malik, S., H. Nazli and E. Whitney. 2014b (forthcoming). *The Official Estimates of Poverty in Pakistan – What is Wrong and Why? Illustrations using the Government of Pakistan’s Household Integrated Economic Survey 2010-11.* Pakistan Strategy Support Program (PSSP) Working Paper. Washington DC: International Food Policy Research Institute.

Mehmood, Y., Z. Farooqi, K. Bakhsh, M. B. Anjum and M. Ahmad. 2012. “Impact of Bt Cotton Varieties on Productivity.” *Journal of Agricultural and Social Sciences* 8(3): 109-111.

MoEF (Ministry of the Environment and Forest, Government of India.) 2014. “Genetic Engineering Approval Committee (GEAC). Streamlining of the Regulatory Procedure for transgenic crops.” Accessed July 2014. http://www.moef.nic.in/division/genetic-engineering-approval-committee-geac?theme=moef_normal.

Monsanto. 2009. “Pink Bollworm Resistance to GM Cotton in India.” Accessed April 2014. http://www.monsanto.com/newsviews/pages/india-pink-bollworm.aspx.

Morse, S., R. M. Bennett, and Y. Ismael. 2007. “Inequality and GM Crops: A Case-study of Bt Cotton in India.” *AgBioForum* 10(1): 44–50

Morse, S., R. M. Bennett, and Y. Ismael. 2005a. “Comparing the Performance of Official and Unofficial Genetically Modified Cotton in India.” *AgBioForum* 8(1): 1–6.

Morse, S., R. M. Bennett, and Y. Ismael. 2005b.”Genetically Modified Insect Resistance in Cotton: Some Farm Level Economic Impacts in India.” *Crop Protection* 24(5): 433–440.

Murugkar, M., B. Ramaswami, and M. Shelar. 2007. “Competition and Monopoly in the Indian Cotton Seed Market.” *Economic and Political Weekly* 62(37): 3781-3789.

Murugkar, M., B. Ramaswami, and M. Shelar. 2006. *Liberalization, Biotechnology, and the Private Sector: The Case of India's Cotton Seed Market.* Discussion Paper no. 06-05. New Delhi: Indian Statistical Institute.

Naik, G., M. Qaim, A. Subramanian, and D. Zilberman. 2005. "Bt Cotton Controversy: Some Paradoxes Explained." *Economic and Political Weekly* 40(15): 1514-1517.

Narayanamoorthy, A., S. S. Kalamkar. 2006. "Is Bt Cotton Cultivation Economically Viable for Indian Farmers? An Empirical Analysis." *Economic and Political Weekly* 41(26): 2716-2724.

Nazli H., D. Orden, R. Sarker, and K. Meilke. 2012. "Bt Cotton Adoption and Wellbeing of Farmers in Pakistan." Selected paper presented at the 28th Triennial Conference of the International Association of Agricultural Economists (IAAE), Foz do Iguaçu, Brazil, August 18–24.

Nazli, H. and S. H. Haider. *Pakistan Rural Household Panel Survey 2012 (Round 1): Methodology and Community Characteristics.* PSSP Working Paper no. 7. Washington DC: International Food Policy Research Institute.

Orphal, J. 2005. *Comparative Analysis of the Economics of Bt and Non-Bt Cotton Production.* Special Issue Publication Series, No. 8. A Publication of the Pesticide Policy Project, Hannover, Germany: Universität.

PABIC (Pakistan Biotechnology Information Center). 2014. "NBC Grant GM Cotton Varieties for Commercialization." Accessed April 2014. http://www.pabic.com.pk/news_detail.php?nid=24.

Pemsl, D., A.P. Gutierrez, and H. Waibel, 2008. "The Economics of Biotechnology under Ecosystem Disruption." *Ecological Economics* 66: 177-183.

Pemsl, D. 2006: *Economics of Agricultural biotechnology in Crop Protection in Developing Countries - The Case of Bt Cotton in Shandong Province, China*. Special Issue Publication Series, No. 11. A Publication of the Pesticide Policy Project, Hannover, Germany: Universität.

Pemsl, D., H. Waibel, and A.P. Gutierrez. 2005. "Why Do Some Bt-Cotton Farmers In China Continue To Use High Levels of Pesticides?" *International Journal of Agricultural Sustainability* 3(1): 44-56.

Pemsl, D., H. Waibel, and J. Orphal. 2004. "A Methodology to Assess the Profitability of Bt-cotton: Case Study Results from the State of Karnataka, India." *Crop Protection* 23(12): 1249-1257.

PES (Pakistan Economic Survey). 2012-13. "Chapter 2: Agriculture." Accessed August 2013. http://www.finance.gov.pk/survey/chapters_13/02-Agriculture.pdf.

PES (Pakistan Economic Survey). 2011-12. "Chapter 2: Agriculture." Accessed April 2014. http://finance.gov.pk/survey/chapter_12/02-Agriculture.pdf.

Pray, C.E., J. Huang, R. Hu, Q. Wang, B. Ramaswami, and P. Bengali. 2006a. "Benefits and Costs of Biosafety Regulation in India and China." In *Regulating Agricultural Biotechnology: Economics and Policy,* edited by E. Just, M. Julian, D. Zilberman, 481-508. New York: Springer.

Pray, C.E., Ramaswami, B., J. Huang, R. Hu, P. Bengali and H. Zhang. 2006b. "Costs and Enforcement of Biosafety Regulations in India and China." *International Technology and Globalisation* 2(1/2): 137-157.

Pray, C.E., J. Huang, R. Hu, and S. Rozelle. 2002. "Five Years of Bt Cotton in China—The Benefits Continue." *Plant Journal* 31(4): 423-430

Pray, C.E., D. Ma, J. Huang, and F. Qiao. 2001. "Impact of Bt Cotton in China." *World Development* 29(5): 813-825.

Punjab Seed Council. 2012. Minutes of the 42nd meeting of the Punjab Seed Council, February 2012. Lahore: PSC.

Qaim, M. 2009. "The Economics of Genetically Modified Crops." *Annual Review of Resource Economics* 1: 665–694.

Qaim, M., A. Subramanian, G. Naik, and D. Zilberman. 2006. “Adoption of Bt cotton and impact variability: insights from India.” *Review of Agricultural Economics* 28(1): 48-58.

Qaim, M. and D. Zilberman. 2003. “Yield Effects of Genetically Modified Crops in Developing Countries.” *Science* 299: 900–902.

Qaim, M. 2003. “Bt cotton in India: Field Trial Results and Economic Projections.” *World Development* 31(12): 2115-2127.

Qayum, A., and K. Sakkhari. 2006. *Bt cotton in Andhra Pradesh –A Three-year Assessment. The First Sustained Independent Scientific Study of Bt cotton in India*. Andhra Pradesh, India: Deccan Development Society.

Ramaswami, B., M. Murugkar, and M. Shelar. 2009. “Product Proliferation in India’s Cotton Seed Market: Are There Too Many Varieties?” *Journal of Agricultural and Food Industrial Organization* 7: 1-16.

Rana, M.A. 2014. *The Seed Industry in Pakistan: Regulation, Politics and Entrepreneurship.* Pakistan Strategy Support Program (PSSP) Working Paper no. 19. Washington, DC: International Food Policy Research Institute.

Rana, M.A., H. Khawar, A. T. Gilani and H. S. Rana. 2013. *Exploring Dynamics of Cotton Seed Provision in Sindh.* IGC Working Paper. London/Lahore: International Growth Center.

Rana, M. A. 2010.”Formalising the Informal: The Commercialisation of GM Cotton in Pakistan.” PhD thesis, Melbourne School of Land and Environment, University of Melbourne, Australia.

Roberts, A., H. Nazli, M. Wach, and Y. Zafar. 2012. “An Analysis of the Development and Regulation of Agricultural Biotechnology in Pakistan.” Washington, DC: International Life Sciences Institute.

Roy, D., R.J. Herring, and C.C. Geisler. 2007. “Naturalising Transgenics: Official Seeds, Loose Seeds and Risk in the Decision Matrix of Gujarati Cotton Farmers.” *Journal of Development Studies* 43(1): 158–176.

Sabir, H.M., S.H. Tahir and M.B. Khan. 2011. “Bt cotton and its Impact on Cropping Pattern in Punjab.” *Pakistan Journal of Social Sciences* 31(1): 127-134.

Sadashivappa, P. and M. Qaim. 2009. “Bt cotton in India: Development of Benefits and the Role of Government Seed Price Interventions.” *AgBioForum* 12(2): 172-183.

Sahai, S., and S. Rehman. 2004. “Bt-Cotton 2003-2004, Fields Swamped with Illegal Variants.” *Economic and Political Weekly* 39(26), 2673-2674.

Sahai, S., and S. Rehman. 2003. “Performance of Bt cotton: Data from First Commercial Crop.” *Economic and Political Weekly* 38 (30): 3139–3141.

Sarker, N., and K.R. Mahbub. 2012. “Bacillus thuringiensis: An Environment Friendly Microbial Control Agent.” *Microbiology Journal* 2(2): 36-51.

Scoones, I. 2008. “Mobilizing Against GM Crops in India, South Africa and Brazil.” *Journal of Agrarian Change* 8: 315–344.

Shankar, B., and C. Thirtle. 2005. “Pesticide Productivity and Transgenic Cotton Technology: The South African Smallholder Case.” *Journal of Agricultural Economics* 56(1): 97-116.

Showalter A.M., S. Heuberger, B. E. Tabashnik and Y. Carriere. 2009. “Development, Agronomic Performance and Sustainability of Transgenic Cotton for Insect Control.” In *Biotechnology and Agricultural Development: Transgenic Cotton, Rural Institutions and Resource-poor Farmers,* R. Tripp, ed. New York: Routledge.

Smale, M., P. Zambrano, G. Gruère, J. Falck-Zepeda, I. Matuschke, D. Horna, L. Nagarajan, I. Yerramareddy, and H. Jones 2009. *Measuring the Economic Impacts of Transgenic Crops in Developing Agriculture during the First Decade Ap-*

proaches, Findings, and Future Directions. IFPRI Food Policy Review No. 10. Washington DC: International Food Policy Research Institute.

Subramanian, A. and M. Qaim. 2009. “Village-Wide Effects of Agricultural Biotechnology: The Case of Bt Cotton in India.” World Development 37 (1):256-267.

The News. 2013*.* “PSC approves 39 new varieties of crops.” December 12.

Thirtle, C., L. Beyers, Y. Ismael, and J. Piesse. 2003. “Can GM Technologies Help the Poor? The Impact of Bt Cotton in Makhathini Flats, KwaZulu-Natal.” *World Development* 31(4): 717-732.

Wang, S., D. R. Just, and P. Pinstrup-Andersen. 2006. “Damage from Secondary Pests and the Need for Refuge in China.” *Natural Resource Management and Policy* 30 (Section III.2): 625-37.

Wang, S., D. R. Just, P. Pinstrup-Andersen. 2008a. “Bt-cotton and Secondary Pests.” *International Journal of Biotechnology* 10 (2/3):113 – 121.

Wang, Z., H. Lin, J. Huang, R. Hu, S. Rozelle, and C. Pray. 2009. “Bt Cotton in China: Are Secondary Insect Infestations Offsetting the Benefits in Farmer Fields?” *Agricultural Sciences in China* 8(1): 83-90.

Xia, L., Q. Xu and S. Guo. 2005. “*Bt* Insecticidal Gene and its Temporal Expression in Transgenic Cotton Plants.” *Acta Agronomica Sinica* 31: 197-202.

Xu, J., Z. You, W. Wang, and Y. Yang. 2004. “Economic Analysis of Bt Cotton Planting in Jiangsu.” *Journal of Yangzhou University, Agricultural and Life Sciences* 25 (3): 65-69.

Yang, P. Y., M. Iles, S. Yan, and F. Jolliffe. 2005. “Farmers’ Knowledge, Perceptions and Practices in Transgenic Bt Cotton in Small Producer Systems in Northern China.” *Crop Protection* 24 (3): 229–239.

ANNEXES

Annex 1. Summary of the economic literature on Bt cotton in China, India and Pakistan

Table A1.1. A comparative review of economic studies on Bt cotton in China, India and Pakistan

Author (Year)	Survey year(s)	Geographical Focus	Research Question	Sample size	Methods
China					
1. Pray, C., D. Ma, J. Huang, and F. Qiao (2001)	1999	Five counties of Hebei and Shadong provinces	Economic, environmental and health impact of Bt cotton	283 farmers	Farm survey analysis, economic surplus
2. Huang, J., R. Hu, S. Rozelle, F. Qiao, and C. Pray (2002a)	1999	Hebei and Shadong	Impact of Bt adoption on productive efficiency of smallholders and the use of pesticides	282 farmers	Farm survey analysis, pesticide use model, IV estimation, damage control production function
3. Huang, J., R. Hu, C. Fan, C. Pray, and S. Rozelle (2002b)	1999, 2000, 2001	Hebai, Shadong provinces (1999), China; included two counties in Henan province (2000); added Anhui and Jiangsu (2001)	Effect of Bt cotton adoption on yields, incomes, health, and the environment	283; 407; 366 farmers	Descriptive analysis, two-stage least squares estimation of pesticide use and cotton yield based on Cobb-Douglas and damage abatement control production functions.
4. Huang, J., R. Hu, C. Pray, F. Qiao, and S. Rozelle (2003)	1999	Hebei and Shadong provinces, China	Impact of Bt cotton on pesticide usage	282 farmers	Descriptive analysis, budget analysis, multivariate analysis using OLS
5. Yang, P. Y., M. Iles, S. Yan, and F. Jolliffe (2005)	2002	Northern China	Assessing farmers' knowledge, perceptions and practices on Bt cotton	92 farmers	Farm survey analysis
6. Kuosmanen, T., D. Pemsl, and J. Wesseler (2006)	2002	Shadong province, China	Assessment of productivity of damage control input (pesti-cides)	150 farmers	Damage control and production function plot monitoring; two-stage semiparametric technique, leaf tissue analysis

Author (Year)	Survey year(s)	Geographical Focus	Research Question	Sample size	Methods
7. Pemsl, D., H. Waibell, and A. P. Gutierrez (2005)	2002	Shadong province, Northern China	Assessment of Bt variety and pesticide-based control strategies for the cotton bollworm	150 farmers	Farm survey analysis; Bio-economic model; Damage control production function, plot monitoring, leaf tissue analysis
8. Pemsl, D (2006)	2002	Shadong, China	Assess the contribution of the insect resistance trait in Bt-varieties to the productivity and profitability of small scale cotton cultivation	150 farmers	Household survey; Damage control function, efficiency analysis, partial budgeting, bio-economic model,
9. Wang, S., D. R. Just, and P. Pinstrup-Andersen (2006)	1999, 2000, 2001 and 2004	Hebei, Shangdong, Henan, Anhui and Hubei provinces in China	Damage from secondary pests and the need for refuge	283, 407, 366 and 481 farmers	Household survey analysis (panel); First degree Stochastic Dominance (SD) tests
10. Wang, S.,D. R. Just, and P. Pinstrup-Andersen (2008a)	2004	Hebei, Shangdong, Henan, Anhui and Hubei provinces in China	Damage from secondary pests and the need for refuge	481	Farm survey analysis; Stochastic Dominance (SD) testing
11. Wang, Z. L Hai, H. Ji-kun, H. Rui-fa, S. Rozelle and C. Pray (2009)	1999-2006	China	Impact of emergence of secondary insect pests in Bt cotton fields	522 farmers, 2762 plots	Farm level analysis; Insecticide use model, IV and 2SLS estimates

Author (Year)	Survey year(s)	Geographical Focus	Research Question	Sample size	Methods
India					
1. Sahai, S., and S. Rehman (2003)	2002-2003	Maharashtara and Andhra Pradesh	Performance of Bt cotton in two of the six states to be granted to commercially cultivate Bt cotton	100 farmers	Farm survey analysis
2. Qaim, M. (2003)	2001	Maharashtra and Madhya Pradesh in central India, Tamil Nadu in South India	Productivity effects of Bt cotton at present and in the future	157 farmers	Field trial data analysis; Household survey analysis; Damage control specification function
3. Qaim, M., and D. Zilberman (2003)	2001	Maharashtra and Madhya Pradesh in central India, Tamil Nadu in South India	Contribution of pest-resistant genetically modified crops to yields and agricultural growth	157 farmers	Trial data analysis, yield-density function, logistic damage control function
4. Sahai, S., and S. Rehman (2004)	2002-2003	Maharashtra and Andhra Pradesh	Performance of Bt vs. non Bt cotton	100 farmers	Farm survey analysis, key informant
5. Pemsl, D., H. Waibel, and J. Orphal (2004)	2002	Karnatka, India	Assessment of the profitability of Bt cotton	100 farmers	Stochastic partial budget
6. Bennett, R., Y. Ismael, U. Kambhampati, and S. Morse (2004a)	2002-2003	Maharashtara, India	Economic impact of GM cotton	7751 (2709); 1580 (787) plots (farmers)	Farm survey analysis
7. Barwale, R.B., V.R. Gadwal, Usha Zehr, and Brent Zehr (2004)	2001	Maharashtra and Madhya Pradesh in central India, Tamil Nadu in South India	Assessment of Bt cotton technology in India	157 farmers	Analysis of earlier field trial data
8. Bennett, R., Y. Ismael and S. Morse (2005)	2003/04	Gujarat, India	A comparison of the perfor-mance of official and unofficial hybrid varieties of Bt cotton and conventional (non-Bt) hybrids	622 farmers	Farmer survey analysis; General Linear Model
9. Morse, S., R. Bennett, and Y. Ismael (2005a)	2003	Gujarat, India	Comparing the performance of official and unofficial GM cotton	622 farmers	Farm survey analysis

Author (Year)	Survey year(s)	Geographical Focus	Research Question	Sample size	Methods
10. Morse, S., R. Bennett, and Y. Ismael (2005b)	2002-2003	Maharashtara, India	Impact of insect-resistant Bt cotton on costs and returns over the first two seasons of commercial release	7793; 1577 plots	Farm survey analysis
11. Naik, G., M. Qaim, A. Subramanian, and D. Zilberman (2005)	2003	Maharashtra, Karnatka, Andhra Pradesh and Tamil Nadu, in Central and Southern India	Economic benefits of Bt cotton given heterogeneity among farmers	341 farmers	Farm survey analysis, production function
12. Orphal, J. (2005)	2002-2003	Karnataka	Comparison of the economic performance of Bt cotton and non-Bt cotton in farmers' fields	100 farmers	Farm survey analysis
13. Bennett, R., U. Kambhampati, S. Morse, and Y. Ismael (2006a)	2002-2003	Maharashtara (2002); Maharashtara, Gujarat, Madhya Pradesh, Karnataka (2003)	Farm-level economic performance of Bt cotton	7751 (2709); 1580 (787) plots (farmers)	Farm survey analysis, C-D production function
14. Narayanamoorthy, A., and S. S. Kalamkar (2006)	2003			150, (50 non-bt) farmers	Farm survey analysis
15. Qaim, M., A. Subramanian, G. Naik, and D. Zilberman (2006)	2003	Maharashtra, Karnatka, Andhra Pradesh and Tamil Nadu, in Central and Southern India	Variability of the impact of Bt cotton on agronomic and economic outcomes	341 farmers	Farm and household survey analysis, production function
16. Gandhi, V. P. and N.V. Namboodiri (2006)	2004	Gujarat, Maharashtara, Andhra Pradesh, Tamil Nadu, in India	Economics of Bt cotton adoption in India	694 farmers	Farm survey analysis
17. Qayum, A and K. Sakkhari (2006)	2002-03, 2003-04, 2004-05	Warangal, Andhra Pradesh, India (2002/03); Warangal, Adilabad, Kurnool (2003/04); Warangal, Adilabad, Nalgonda (2004/05)	A three year assessment of Bt cotton and its socioeconomic impact	225 farms in 2002, 164 farms in 2003, and 220 farms in 2004	Farm survey analysis
18. Crost , B, B. Shankar, R. Bennett and S. Morse (2007)	2002 and 2003	Jalgaon district, Maharashtara, India	Assessment of self-selection bias in Bt cotton productivity estimates	338 farmers , 718 plots	Farm survey analysis, fixed effects, panel data, selectivity bias, Cobb-Douglas production function

Author (Year)	Survey year(s)	Geographical Focus	Research Question	Sample size	Methods
19. Morse, S., R. Bennett and Y Ismael (2005a)	2002 and 2003	Jalgaon, Maharashtara state, India	Impact of introduction of Bt cotton on Inequality	63 non-adopters and 94 adopters	Comparison between adopters and non-adopters via one-way analysis of variance.
20. Morse, S., R. Bennett and Y Ismael (2005b)	2002 and 2003	Jalgaon, Maharashtara state, India	Assess the 'farmer effect' in economic advantages claimed from Bt cotton varieties	63 non-adopters and 94 adopters	Comparison between adopters and non-adopters on Bt and non-Bt plots using one-way ANOVA; inequality of gross margin using Gini coefficient
21. Dev, S. M., and N. C. Rao. (2007)	2004-05	Warangal, Nalgonda, Guntur amd Kurnool in Andhra Pradesh, India	Socio-economic impact of Bt cotton	437 Bt and 186 non-Bt farmers	Descriptive analysis, comparison of Bt and non-Bt cotton using simple statistics
22. Gruère, P., P. Mehta-Bhatt, and D. Sengupta (2008)	1997-2006	Maharashtara, Andhra Pradesh, Karnatka, Madhya Pradesh, Gujarat, Other States, India	Assessing the role of Bt cotton in farmer suicides in certain regions in India	Secondary data (India Stat and National Crime Records Bureau)	Meta-analysis of available literature; conceptual framework to examine the farmer suicides and Bt cotton in Central India
23. Subramanian, A., M. Qaim (2009)	2004	Maharashtara, Karna-taka, Andhra Pradesh amd Tamil Nadu (2005) Village census in Kanzara, Maharashtara (2004)	Village-wide effects of Bt cotton	305 village households for the census	Developed a village SAM on the basis of complete census of one village (all households and institu-tions are covered). Two simulations: (i) 10% increase in Bt area (ii) 10% increase in conventional variety of cotton
24. Sadashivappa, Prakash and Matin Qaim (2009)	Panel data 2002-03, 2004-05, 2006-07	Maharashtara, Karna-taka, Andhra Pradesh, and Tamil Nadu	Assessing the benefit and role of government interventions in seed pricing	341, 318 and 289 farmers	Descriptive analysis and willingness to pay

Author (Year)	Survey year(s)	Geographical Focus	Research Question	Sample size	Methods
Pakistan					
1. Abid *et al*. (2011)	2008-09	Rahimyar Khan, Multan, Mianwali, in Punjab	Input use efficiency and returns-to-scale among small Bt cotton farmers	150	Farm survey analysis; Cobb-Douglas production function to measure resource use efficiency
2. Ali and Abdulai (2010)	2007	Bahwalpur, Bahawalnagar, Vehari, Khanewal, Multan, Lodhran and Rahimyar Khan, Punjab	Direct effects of adoption of Bt cotton on yields, pesticide demand, household income and poverty	325	Farm survey analysis; Propensity Score Matching; Treatment effect model
3. Bakhsh (2009)	2008-09	Punjab	Productivity/income effects of Bt cotton; input-output analysis	288	Farmer interview-based survey; Panel FE gross margin function
4. Kouser and Qaim (2013b)	2010-11	Vehari, Bahawlnagar, Bahawalpur, Rahimyar Khan	Economic, health & environmental benefits	352	Farm survey analysis; Partial budget and choice experiment cond. Conditional logit model; choice experiment on pesticides
5. Nazli *et al*. (2010)	2009	Bahawalpur,Punjab; Mirpur Khas, Sindh	Socio-econ characteristics, production and income effects	208	Questionnaire-based survey; Propensity score matching; Partial budget Statistical differences
6. Ali *et al*. (2010)	2007-08	Punjab and Sindh	Scientific testing to estimate the extent of Bt cotton spread in the country	126 locations	ImmunoStrip analysis for the detection of Bt-Cry protein; ELISA testing for npt-II; Limited farm survey in Nawabshah, Sanghar, Mirpur Khas in Sindh; Multan, Khaewal and Vehari in Punjab
7. Sabir *et al*. (2011)	2008-09	Vehari, Multan, Bahwalpur (Cotton Zone), Punjab; Jhang,	The impact of Bt on the existing cropping pattern through wheat and sugarcane	300	Farm Survey Analysis

Author (Year)	Survey year(s)	Geographical Focus	Research Question	Sample size	Methods
		TTS, Faislabad (Central Zone), Punjab			
8. Ahsan Abdullah (2010)	2005-06	Punjab	Impacts vis-à-vis pest and pesticide groups; pest classes (sucking and chewing); predators and pest sprays	3000+	Agriculture Decision Support System
9. Arshad *et al*. (2007)	2006	Punjab	Factors influencing farmers' adoption of Bt cotton (costs, information assymetries)	65	Farm-level survey analysis
10. Mehmood et al. (2012)	2010	Punjab	Impact of Bt cotton varieties on productivity	120	Cobb Douglas production function
11. Bakhsh (2013)	2013	Punjab	Economic and environmental impacts of Bt cotton: Evidence from Pakistan	288 farmers each year, total 573 farmers com-bined and 801 plots	Production function-panel analysis-random effect model

Annex 2: Official figures on farm size and cotton farming in Pakistan

Figures from GOP (2012) indicate that out of a total of 8.26 million farms in the country, 26 percent are cotton farms occupying 17 percent of the country's total cultivated area. The average size of a cotton farm is about 4.3 acres, with 32.5 percent of all cotton farms measuring less than 2.5 acres. These farms occupy 9 percent of total cotton area. Only 5.2 percent farms are above 25 acres, accounting for 24.3 percent of total cotton area under cultivation (Table A2.I).

Table A2.1. Farms and cultivated area under cotton by farm size, 2010

Farm size (acres)	Percentage distribution of all farms by size	Percentage distribution of all farms area by size	Percentage distribution of cotton farms by size	Percentage distribution of cotton area by size
Under 1.0 acre	15.2	1.0	6.0	0.6
1.0 to under 2.5 acres	28.3	6.9	26.5	8.4
2.5 to under 5.0 acres	21.2	11.4	23.3	13.9
5.0 to under 7.5 acres	13.7	12.3	15.9	14.4
7.5 to under 12.5 acres	11.1	16.5	14.1	19.2
12.5 to under 25.0 acres	6.8	17.7	9.0	19.2
25.0 to under 50.0 acres	2.6	12.7	3.7	13.3
50.0 to under 100.0 acres	0.8	7.8	1.1	6.2
100.0 to under 150.0 acres	0.2	2.6	0.2	1.9
150.0 acres and above	0.2	11.1	0.2	2.9
Total farms (%)	100.0	100.0	100.0	100.0
Total farms (number)	8,264,480	52,910,408	2,168,855	9,226,387

Source: GOP 2012.

Annex 3: Social and economic indicators

Table A3.1. Household size, dependency ratio and household head age across different groups:

Indicator	Non-cotton farmers	Cotton farmers	(p value)	Bt cotton farmers	Other cotton farmers	(p-value)
Household size	6.72 (3.25)	7.47 (3.74)	0.00***	7.59 (4.33)	7.30 (2.68)	0.51
Dependency ratio	0.43 (0.23)	0.41 (0.22)	0.14	0.39 (0.22)	0.43 (0.22)	0.08*
Age of hh head	45.31 (13.34)	49.10 (12.89)	0.00***	49.80 (12.11)	48.10 (13.92)	0.27

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

Table A.3.2. Education of household head

Indicator	Non-cotton farmers	Cotton farmers	(p-value)	Bt cotton farmers	Other cotton farmers	(p-value)
Read	0.43 (0.49)	0.48 (0.50)	0.11	0.51 (0.50)	0.44 (0.50)	0.20
Attend school	0.49 (0.50)	0.57 (0.50)	0.03**	0.60 (0.49)	0.52 (0.50)	0.20
Math	0.89 (0.66)	0.82 (0.60)	0.11	0.87 (0.58)	0.75 (0.62)	0.09*

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

Table A.3.3. Education of household head's spouse

Indicator	Non-cotton farmers	Cotton farmers	(p-value)	Bt cotton farmers	Other cotton farmers	(p-value)
Read	0.11 (0.31)	0.16 (0.37)	0.02	0.19 (0.39)	0.12 (0.33)	0.12
Attend school	0.12 (0.33)	0.22 (0.41)	0.00	0.23 (0.42)	0.19 (0.39)	0.39
Math	0.45 (0.73)	0.55 (0.76)	0.07	0.53 (0.73)	0.57 (0.80)	0.70

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

Table A.3.4. Access to formal/informal credit among farmers

Indicator	Description	Non-cotton farmers	Cotton farmers	(p-value)	Bt cotton farmers	Other cotton farmers	(p-value)
Did your household obtain or try to obtain a loan last year (during *Kharif* 2011 or *Rabi* 2011-12)?	Percent (number) responding "yes"	29 (191)	24 (71)	0.11	23 (39)	26 (32)	0.48

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

Table A.3.5. Reasons why farmers did/did not obtain a loan in the previous year

Why did your household not try to obtain a loan last year (during *Kharif* 2011 or *Rabi* 2011-2012)	Freq.	Percent
No need	511	75.15
Inadequate collateral	65	9.56
Had outstanding loan	7	1.03
Bad credit history	1	0.15
Interest rates too high	38	5.59
Lenders not located nearby	2	0.29
Procedures too cumbersome	15	2.21
Need to pay bribes	41	6.03
Total	680	100

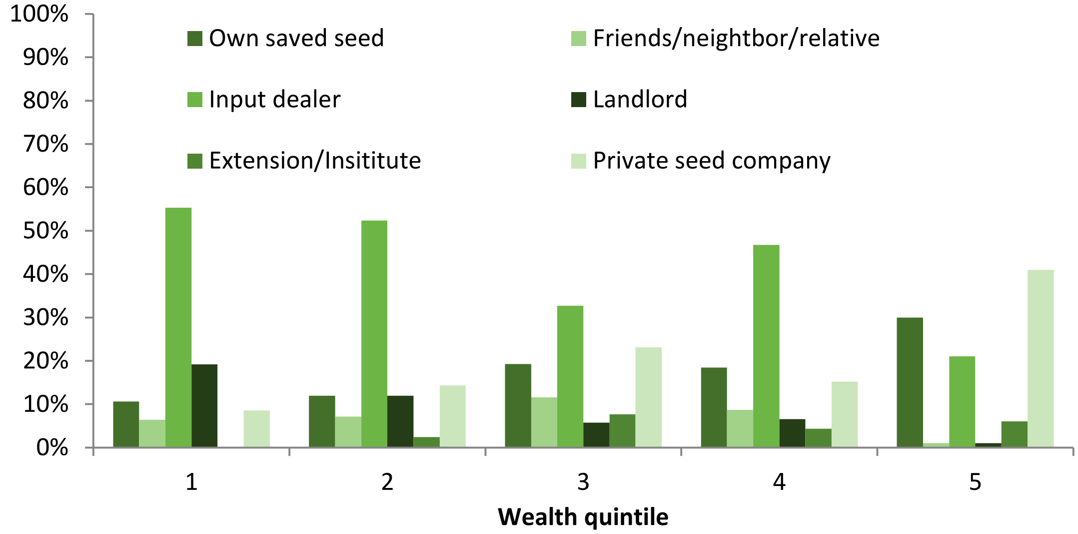
Table A.3.6. Access to extension services by farmers

Indicator	Description	Non-cotton farmers	Cotton farmers	(p-value)	Bt cotton farmers	other cotton farmers	(p-value)
Had you or any member of your household met with an extension agent in 2011?	Percent (number) responding "yes"	21 (136)	30 (89)	0.00***	36 (61)	23 (28)	0.02

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

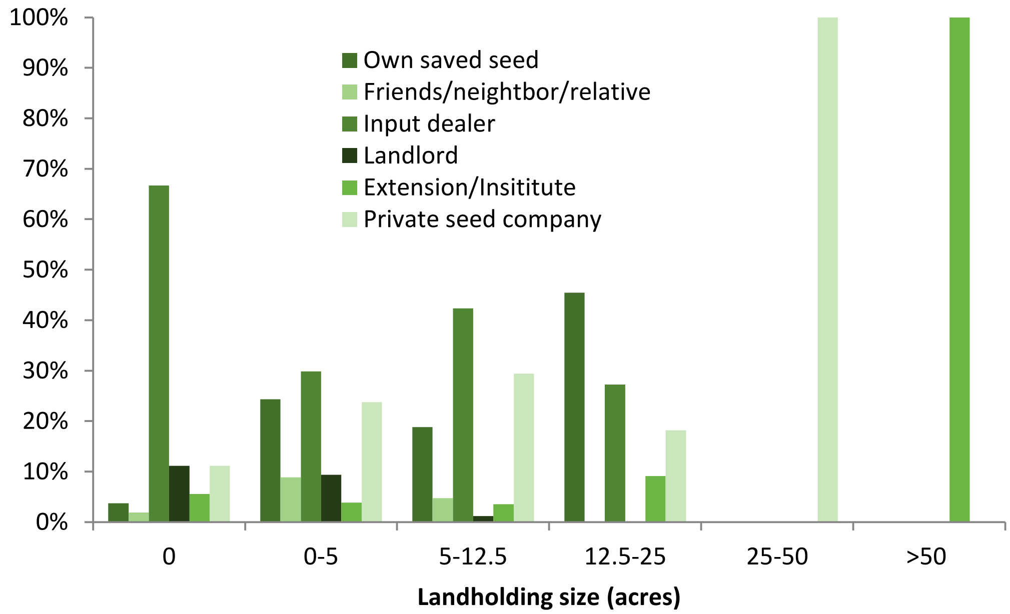
Annex 4. Cotton seed sources

Figure A.4.1. Cotton seed sources by wealth quintile



Source: Authors, based on RHPS Rounds 1 and 1.5 data.

Figure A.4.2. Cotton seed sources by landholding



Source: Authors, based on RHPS Rounds 1 and 1.5 data.

Annex 5: Cotton production practices

Figure A.5.1. Cotton seeding density (kg per acre) by wealth quintile

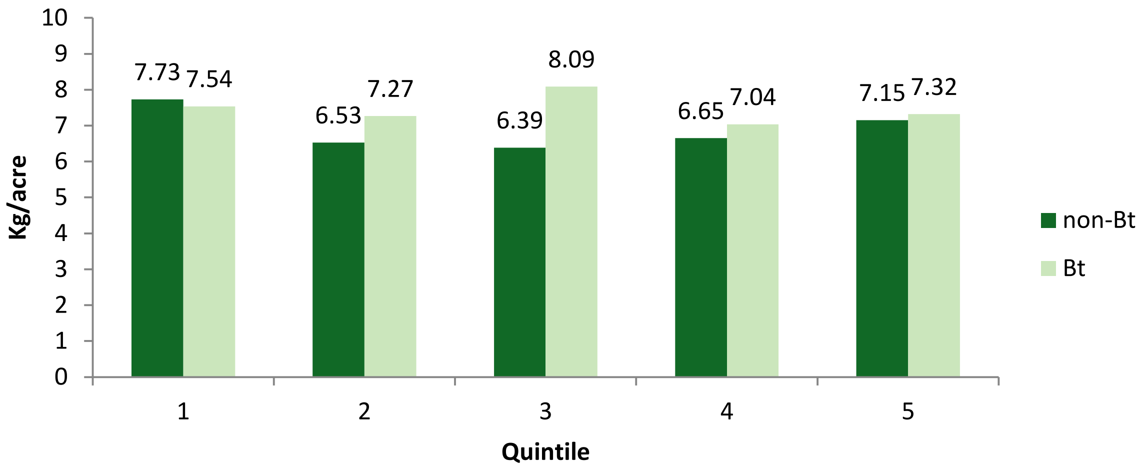


Figure A.5.2. Cotton seeding density (kg per acre) by income quintile

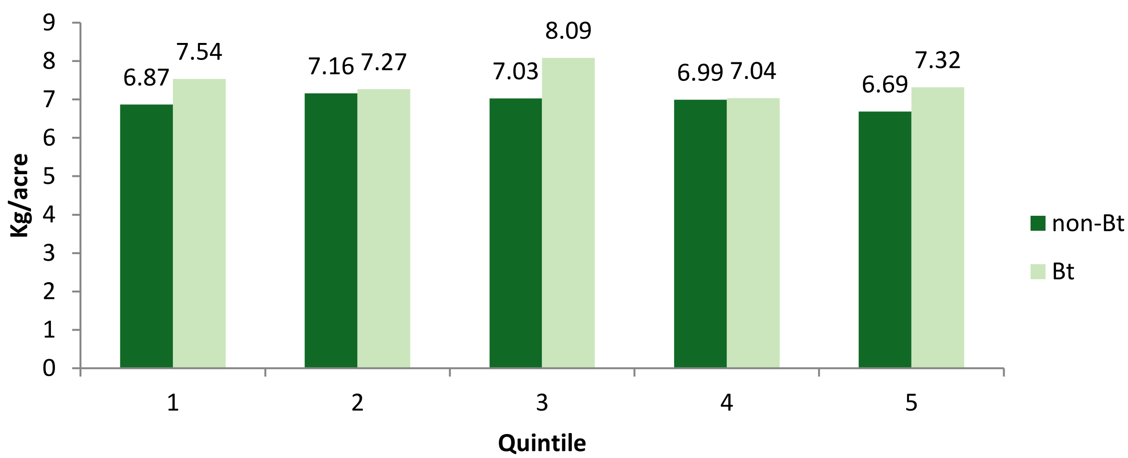


Figure A.5.3. Cotton seeding density (kg per acre) by landholding

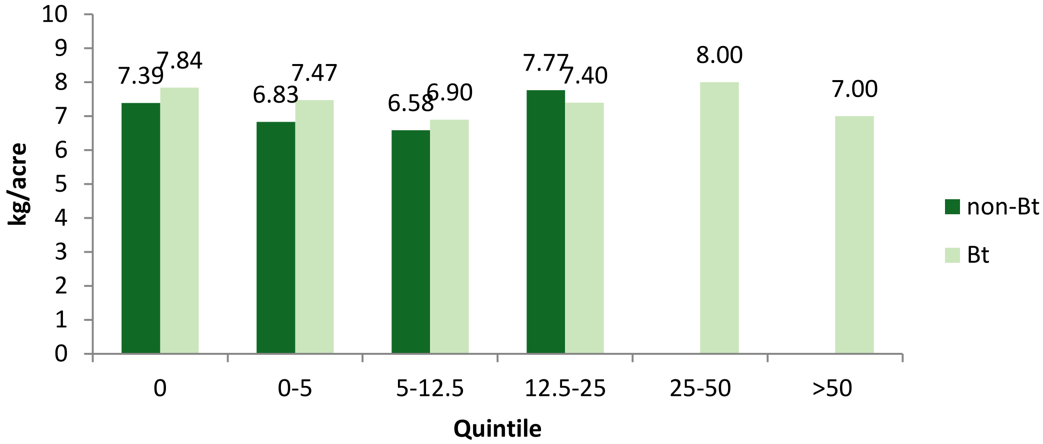


Figure A.5.4. Cotton seeding density (kg per acre) by agro-ecological zone

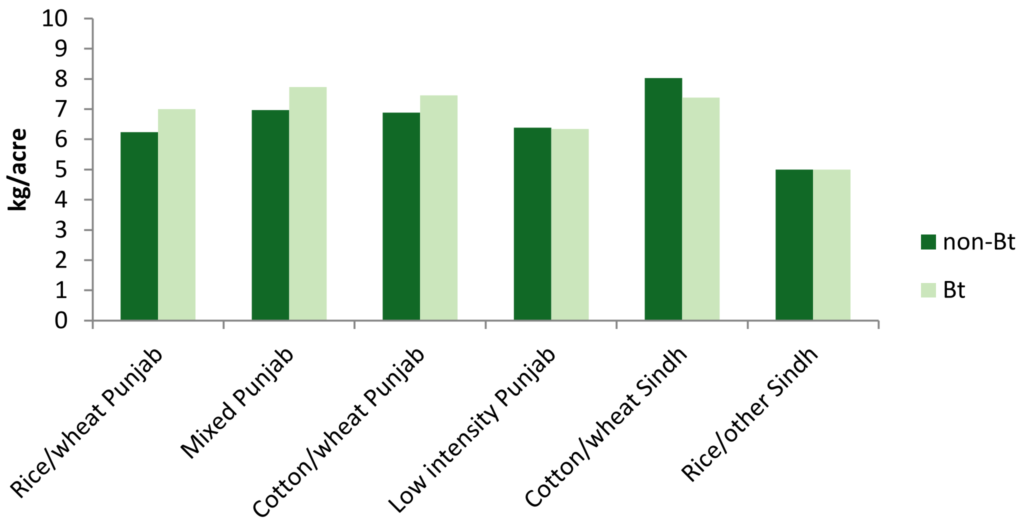


Figure A.5.5. Fertilizer usage (kg per acre) by wealth quintile

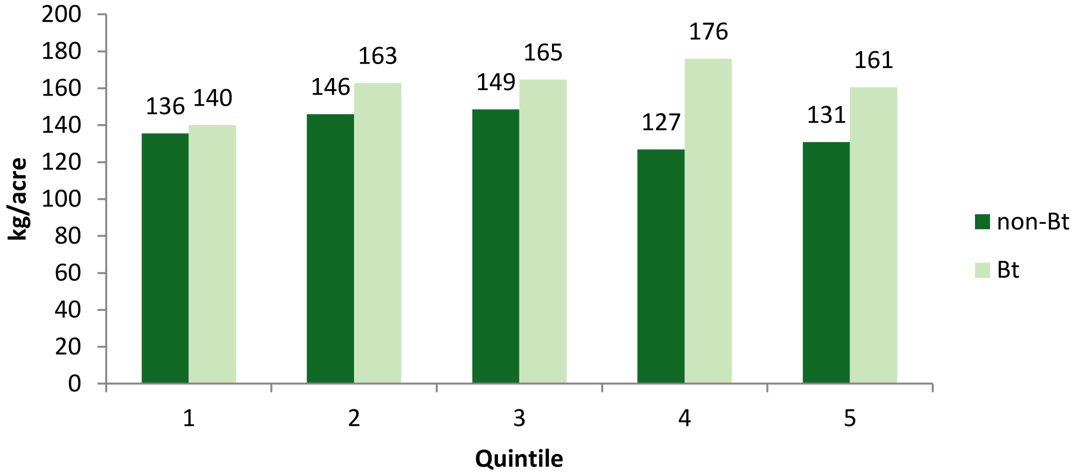


Figure A.5.6. Fertilizer usage (kg per acre) by income quintile

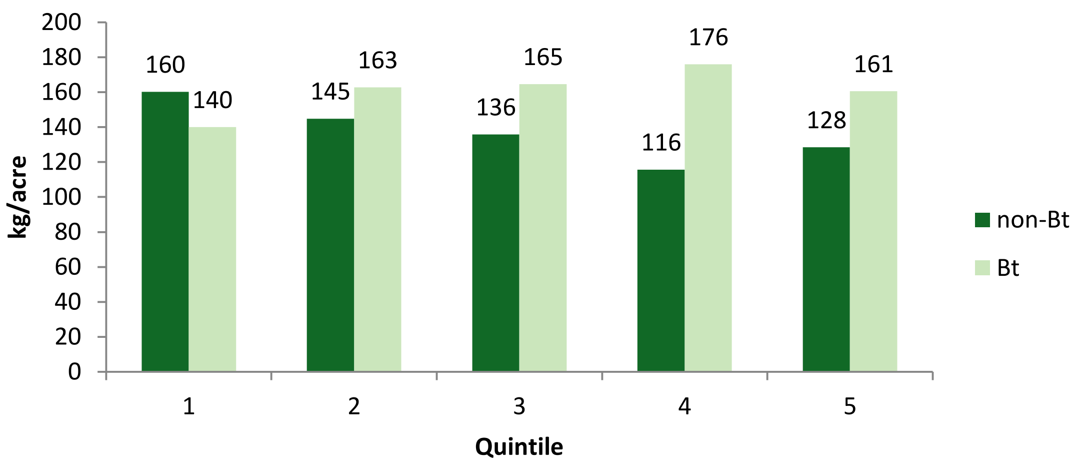


Figure A.5.7. Fertilizer usage (kg per acre) by landholding

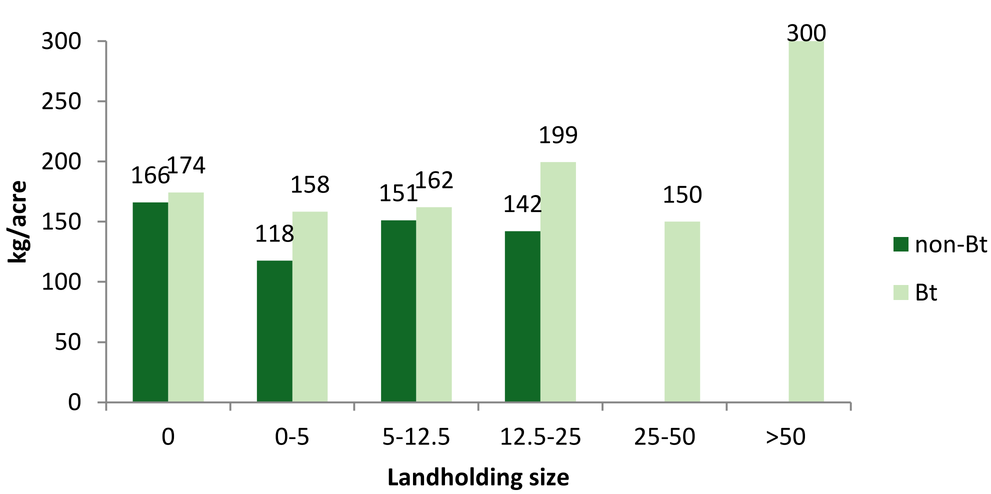


Figure A.5.8. Fertilizer usage (kg per acre) by agro-ecological zone

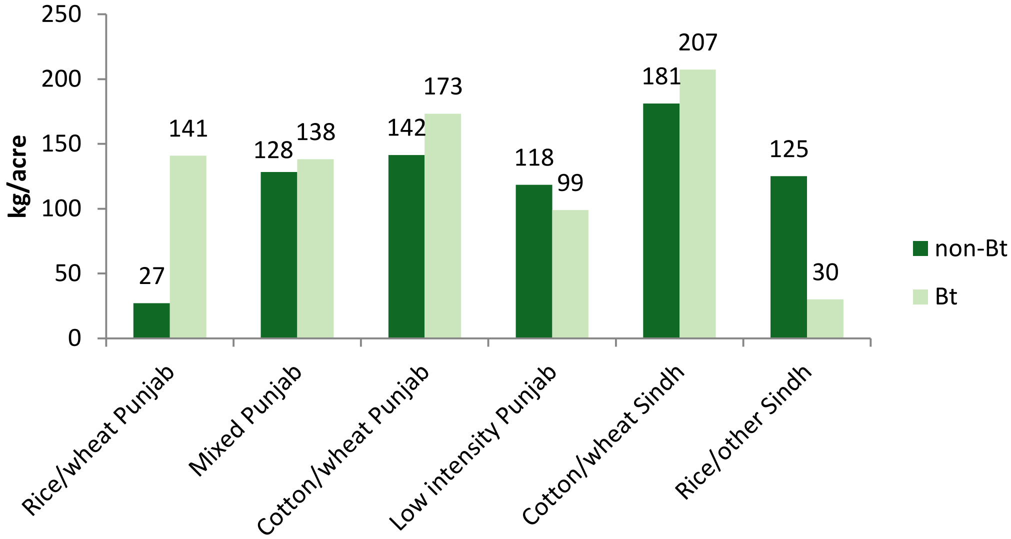
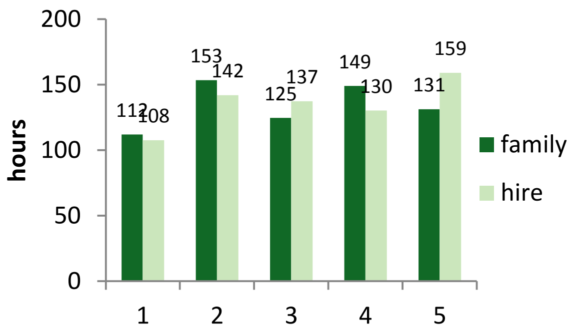


Figure A.5.9. Labor input (total hours) by wealth quintile



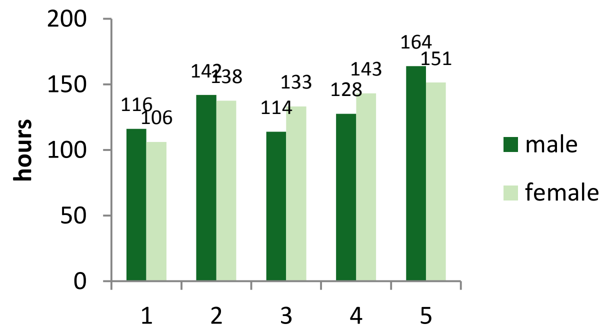


Figure A.5.10. Labor input (total hours) by income quintile

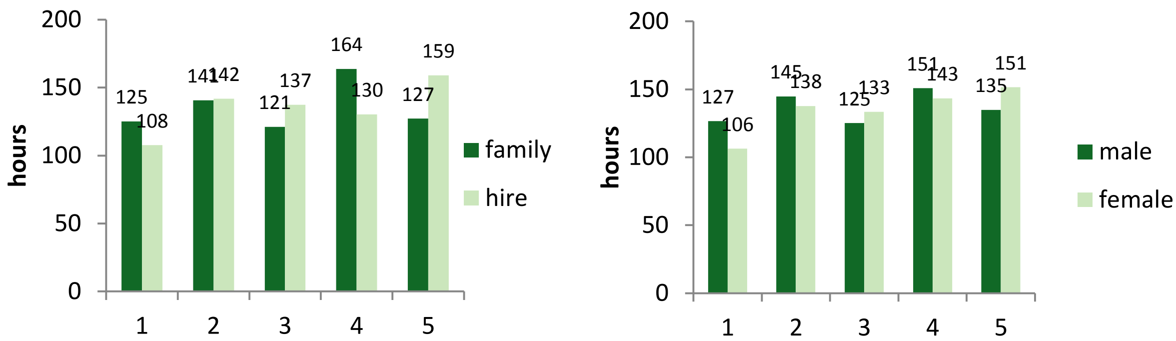


Figure A.5.11. Labor input (total hours) by landholding

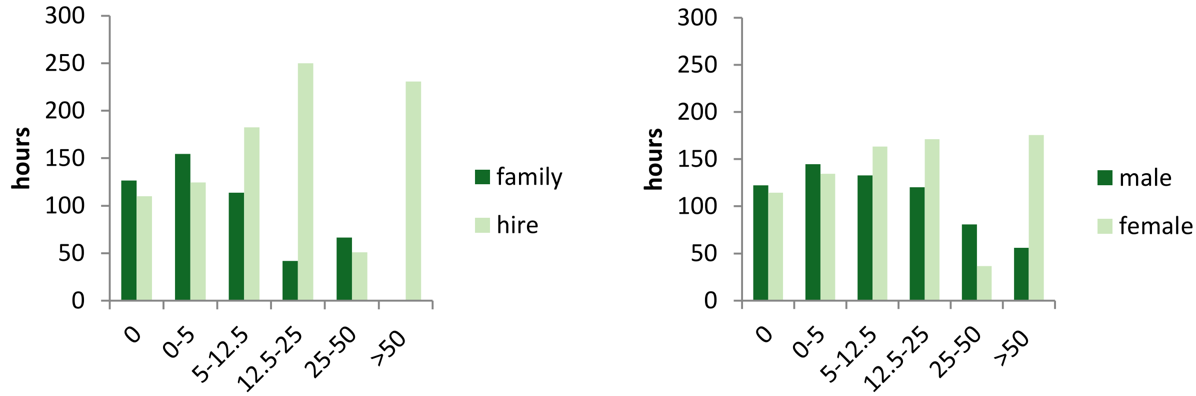


Figure A.5.12. Labor input (total hours) by agro-ecological zone

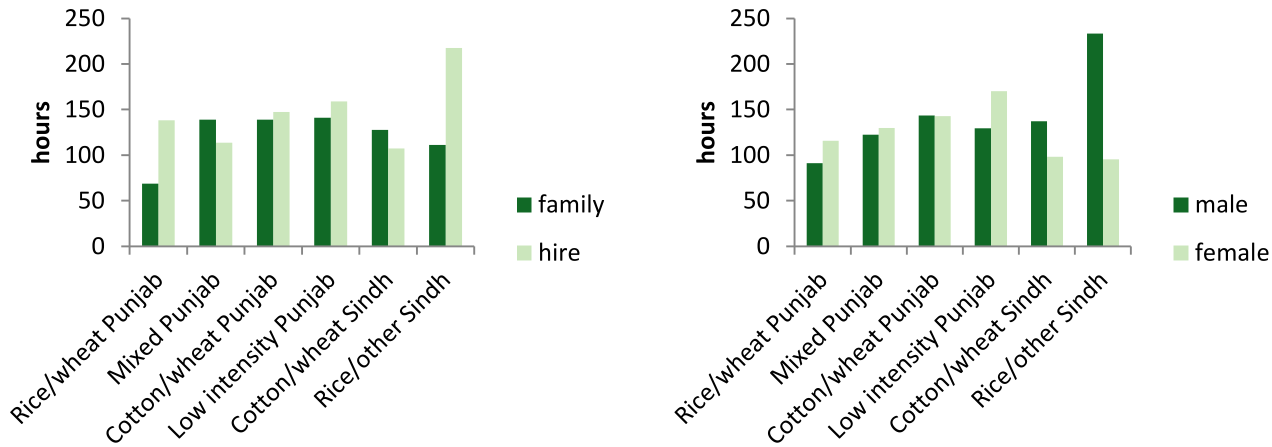


Figure A.5.13. Cotton yield (kg/acre) by wealth quintiles

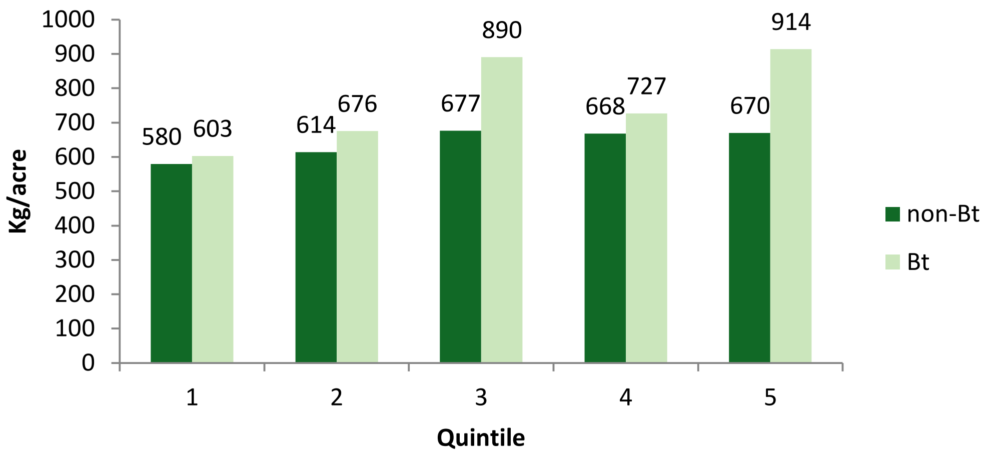


Figure A.5.14. Cotton yield (kg/acre) by income quintiles

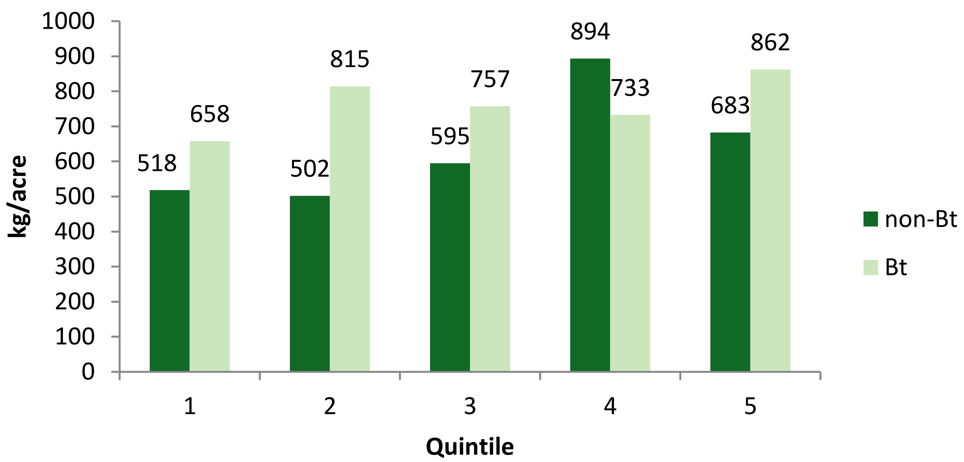


Figure A.5.15. Cotton yield (kg/acre) by landholding

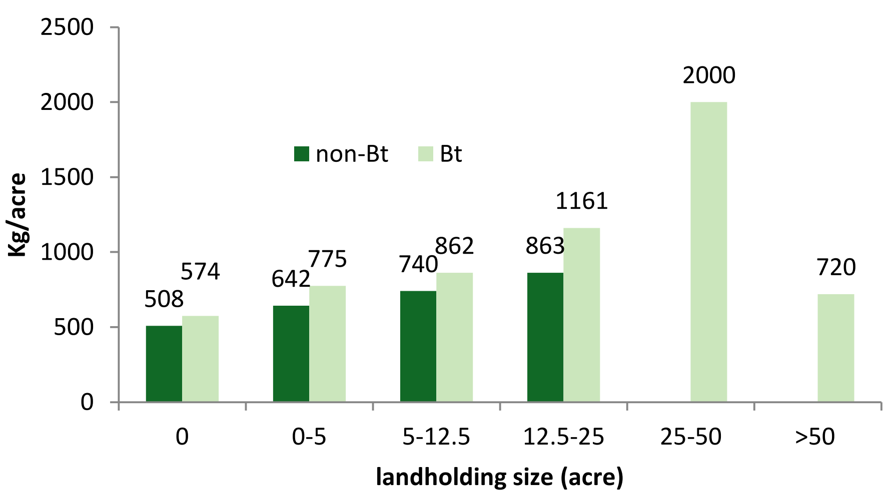


Table A.5.1. Top five varieties by wealth quintiles

Wealth quintile	Variety 1	Variety 2	Variety 3	Variety 4	Variety 5
1	Desi Ravi	CIM-496	FH-629	FH-629	NEELAM-121
2	FH-629	B-622	FH-113	Sitara-008	NEELAM-121
3	FH-113	BH-95	CIM-483	IR-3701	Ali Akbar-802
4	B-622	CIM-473	FH-114	FVH-49	CIM-109
5	Desi Ravi	NEELAM-121	B-896	FH-634	MNH-554

Table A.5.2. Top five varieties by income quintiles

Income quintile	Variety 1	Variety 2	Variety 3	Variety 4	Variety 5
1	MNH-536	Desi Ravi	Fh-113	S-14	Ali Akbar-703
2	B-622	Neelam-121	B-803	Fh-114	Fh-901
3	FH-629	Ali Akbar-703	Neelam-121	Cim-506	B32/97
4	FH-113	Desi Ravi	Ir-3701	B-896	Fh-629
5	FH-634	B-622	B-622	Mnh-536	Mnh-554

Table A.5.3. Top five varieties by landholding size

Land owned (acres)	Variety 1	Variety 2	Variety 3	Variety 4	Variety 5
0	FH-113	Sitara-008	NEELAM-121	Ali Akbar-703	FH-114
0-5	FH-113	FH-634	B32/97	FH-901	MNH-554
5-12.5	B-496	840/97	CIM-109	Desi Ravi	MNH-536
12.5-25	Ali Akbar-703	BH-95	NEELAM-121	VS-135	S-12
25-50	MNH-886				
>50	MNH-886				

Table A.5.4. Top five varieties by agro-ecological zones

Agroecological zone	Variety 1	Variety 2	Variety 3	Variety 4	Variety 5
Rice/wheat Punjab	Ali Akbar-703	Ali Akbar-703	MNH-886	MNH-886	MNH-886
Mixed Punjab	B-896	MNH-554	CIM-473	CIM-768	FH-629
Cotton/wheat Punjab	FH-634	FH-113	FH-113	Desi Ravi	840/97
Low intensity Punjab	B32/97	NEELAM-121	B-496	B-622	A-one
Cotton/wheat Sindh	B-496	NEELAM-121	Ali Akbar-905	FH-682	MNH-886
Rice/other Sindh	AEC/73/3/89	Ali Akbar-802			

Table A.5.5. Average seed prices paid by wealth quintile

Wealth quintile	Mean price paid for non-Bt cotton seed	Mean price paid for Bt cotton seed	(p-value)
1	163 (93)	161 (85)	0.94
2	177 (194)	190 (104)	0.81
3	241 (168)	314 (317)	0.40
4	242 (188)	377 (744)	0.34
5	227 (135)	256 (230)	0.56

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

Table A.5.6. Average seed prices paid by income quintile

Income quintiles	Mean price paid for non-Bt cotton seed	Mean price paid for Bt cotton seed	(p-value)
1	230 (191)	183 (86)	0.41
2	260 (150)	322 (415)	0.66
3	189 (96)	215 (133)	0.49
4	198 (240)	351 (741)	0.40
5	212 (126)	264 (228)	0.20

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

Table A.5.7. Average seed prices paid by landholding

Land holding (acres)	Mean price paid for non-Bt cotton seed	Mean price paid for Bt cotton seed	(p-value)
0	197 (98)	209 (136)	0.74
0-5	240 (206)	308 (571)	0.42
5-12.5	187 (118)	268 (176)	0.03**
12.5-25	183 (29)	233 (161)	0.62
25-50	--	60 (--)	--
>50	--	300 (--)	--

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

Table A.5.8. Average seed prices paid by agro-ecological zone

Land holding (acres)	Mean price paid for non-Bt cotton seed	Mean price paid for Bt cotton seed	(p-value)
Rice/wheat Punjab	600 (--)	763 (642)	--
Mixed Punjab	290 (139)	312 (285)	0.87
Cotton/wheat Punjab	145 (164)	272 (513)	0.14
Low intensity Punjab	278 (117)	242 (95)	0.33
Cotton/wheat Sindh	190 (169)	178 (82)	0.81
Rice/other Sindh	200 (--)	200 (--)	--

Note: Standard deviations in parentheses. Asterisks *, **, and **** denote statistical significance at the 10, 5, and 1 percent levels, respectively for t-test of pairwise differences in means.

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