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Price Controls and Biotechnology Innovation: Are State Government Policies Reducing Research and Innovation by the Ag Biotech Industry in India?

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In 2006, the governments of major cotton-producing states in India ordered all seed companies to lower their prices of Bt cotton seed to Rs. 750 per packet of seed, down from Rs. 1,600 per packet. Although biotech firms challenged these price controls at the Supreme-Court level, the controls are still in effect. It is obvious that farmers will benefit from these price reductions in the short run. An important question for farmers and policy makers, however, is whether these price controls are having a chilling effect on biotech research and innovation in India, which could harm farmers in the long run. Cotton research and innovation by private firms grew rapidly with the spread of hybrid seed and Bt cotton. The profits of cotton biotech and seed firms also grew rapidly, especially after the approval of Bt cotton in 2002. The high profits of biotech and seed firms from 2002 to 2005 were a major incentive for many firms to increase their investments in R&D. The implementation of price controls in 2006 was followed by an immediate, large decline in the profits of seed and biotech firms. So far, this decline did not lead to an obvious decline in either research or innovation, but economic theory, the experience of China, and interviews with private firms in India suggest that continued price controls could negatively impact research and innovation in India in the future.

Key words: Bt cotton, price control, research and innovation, agbiotechnology, India.

Introduction

Some state governments in India drastically reduced Bt cotton seed prices and royalties for innovators by imposing price controls on genetically modified (GM) cotton seed starting in 2006. In the short run, this benefits farmers by reducing the price of their seed. It may also benefit some seed companies that are not conducting research to develop new biotech traits because their sales of hybrid cotton seed could increase due to low prices, while their royalty payments to the providers of the GM trait may decline. There is a potential problem, however. In the long run, biotech companies may reduce their investments in research to develop or import new plant technology for India because of lower-than-expected or uncertain revenues from innovation. If this happens, farmers stand to be the losers because they will not get access to improved hybrids and genes developed by private firms.

This article reviews the recent history of research and innovation in the seed/biotech industry in India to see if there is evidence that price controls are reducing research and development (R&D) and innovation by this industry. First, the article presents a brief review of the literature on the role of price controls and other factors that influence the amount of research in biology-based industries. This is followed by a brief history of the growth of biotech and conventional cotton research, which was influenced by the success of hybrid and Bt cotton and other factors since the mid-1990s in India. The following section describes the imposition of seed price controls. Then, the article examines the available evidence of the impact of price controls on seed sales and profits of Indian farmers, seed companies, and biotech companies. The next section looks at the impacts of the price policies on research and innovation by biotech and seed firms. The final section brings together the lessons from India and suggests that in the medium and long term, the price controls could reduce farmers' ability to get access to some important new technology.

Economics of Research and Innovation in India

Pray and Fuglie (2001), in their paper on the growth of R&D by private seed firms in India, used an induced innovation framework in which the major factors determining the levels of R&D were expected demand for new technology, the ability of firms to appropriate the benefits from R&D, the technological opportunities—a combination of the expected costs of research and inno-

vation and their assessment of the probability of successful innovation—and government policies. The most important factor in the growth of private seed industry R&D between 1987 and 1995 was seed industry liberalization—reforms in industrial policy, which allowed large Indian companies and multinational corporations to enter the seed industry. A second factor was the ability of firms to capture some of the value of their innovations by selling new cultivars that were hybrids. Farmers cannot multiply the seeds of hybrids themselves, and hybrids are not easy for other seed companies to copy. This allows companies to sell these seeds at higher prices than the seeds of conventional varieties and to increase profits despite having covered the extra costs of research and innovation. The commercial seeds of all of the major crops for which seed firms were developing new cultivars in India were hybrids—maize, sorghum, pearl millets, and cotton, and in recent years, hybrid rice and hybrid mustard had greatly increased investments in those crops. The third major factor in the growth of Indian industry R&D was liberalization of the rules on who could participate in the seed industry. Before 1986, the seed industry was reserved for small Indian firms. After new regulations and laws came into effect in 1986 and 1988, large Indian firms and foreign firms were allowed into the seed industry. Ramaswami, Pray, and Kelley (2001) found that about one third of the R&D in 1995 could be accounted for by research by large Indian firms and foreign-owned firms. The authors also noted that growing demand for hybrid seed was another factor leading to more research and that some firms were increasing R&D due to new technological opportunities from biotechnology and from research by the Indian and State governments, as well as international centers such as International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Maize and Wheat Improvement Center (CIMMYT), and International Rice Research Institute (IRRI).

Based on economic theory and the empirical results from case studies of agribusiness R&D in India, Pakistan, Indonesia, Malaysia, Thailand, Philippines, and China, Pray and Fuglie (2001) argue that increases in appropriability through technical means such as hybrids, legal means such as intellectual property rights, or through other industrial policies that grant temporary monopolies increase companies' investments in R&D, while reduced appropriability reduces R&D *ceteris paribus*.

The incentives for firms to do research—even with hybrids or intellectual property rights (IPRs)—are reduced if governments keep the prices that the firms can charge for their innovations at low levels. While the economic theory clearly shows that the incentive to perform research would decline, there are few empirical studies on the impact of price controls. In the pharmaceutical sector, one study by Vernon (2005) estimated that price regulation in the United States would decrease the industry R&D intensity (R&D expenditures divided by sales) substantially. Another study by Giaccotto, Santerre, and Vernon (2005) found that drug price control would result in fewer introductions of new drugs. In a study of the 28 largest pharmaceutical markets from 1980 to 2000 using an Organisation for Economic Co-operation and Development (OECD) dataset, Kyle (2003) found that price regulation leads to delays in new-product launches.

In the field of agriculture, studies of price control and its impact on private firms' R&D investments and future benefits are limited. Lence, Hayes, McCunn, Smith, and Niebur (2005) provide a theoretical framework for analyzing the effect of price controls on agricultural biotechnology. If the government fixes the seed price and trait value at a low arbitrary level (as happened to Bt cotton in India), farmers' benefits might further increase in the short run, but company revenues shrink and so does the incentive to invest in the development of new technologies. Sadashivappa and Qaim (2009) conducted a study on farmers' willingness to pay (WTP) for Bt cotton seed in India and argued that farmers in that country were willing to pay high prices for high-quality seed with the Bt trait. In their opinion, continued price controls on Bt cotton seed would impact firms' incentive to invest more towards future R&D in India. In the case of Bt cotton in Argentina, however, where Bt cotton seed was priced at the same levels as in the United States, Qaim and de Janvry (2003) used the same research methods and found that seed had been priced too high and that both farmers and the seed companies would have had higher profits from lower prices. They did not speculate on how lower prices would have affected research.

Economic theory and this brief review of the literature suggests that the profitability of the early years of Bt cotton sales would increase R&D until the price controls were imposed, after which R&D on cotton should decline.

Growth of R&D and Innovation in Cotton from the 1990s to 2010

Agricultural research using the tools of the new biotechnology has been conducted extensively by the public

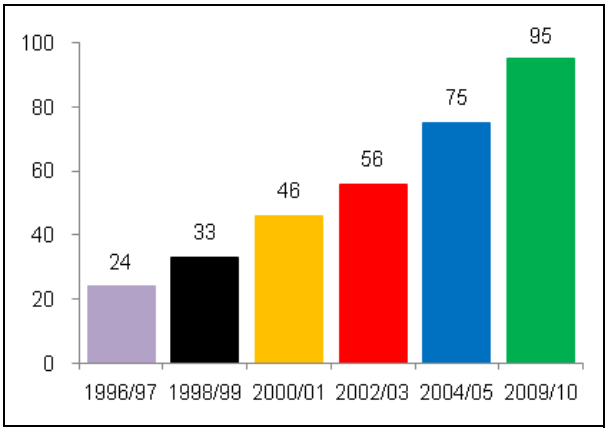

Figure 1. Proprietary cotton hybrids market share (%).
Source: Francis-Kanoi Agri-Inputs Marketing Research (2010)
Note: Bt cotton was introduced in the 2002 season.

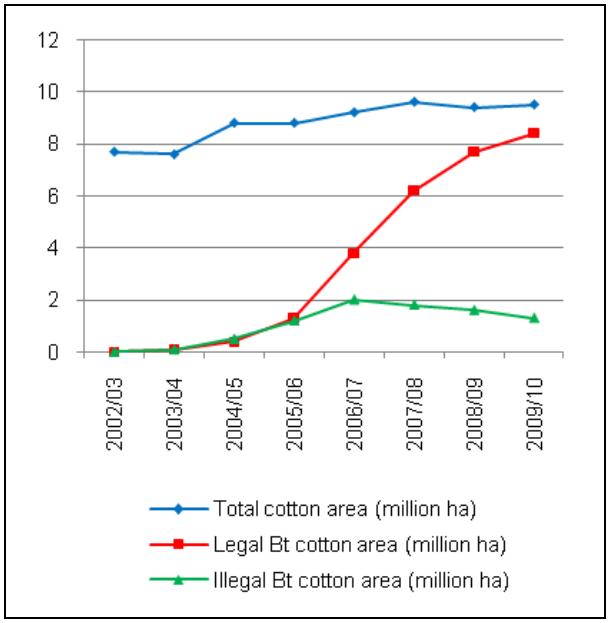

Figure 2. Trends under Bt cotton adoption in India, 2002/03 to 2009/10.
Source: 2002 to 2006=Singh (2007); 2007 to 2010=Seed industry sources (Personal communication)

sector in India since the 1980s. Public-sector biotechnology research and higher-education programs on biotechnology provided the foundation for private seed and biotech research at the beginning of the 21st Century. However, no successful biotech innovations were available to Indian farmers until the success of Bt cotton in 2000.

Because there was no clear path to markets and profitability, the first investments in agricultural biotech research in India by the private sector were primarily by nonprofit foundations such as the SPIC (Southern Petrochemical Industries Corporation) Foundation and Barwale Foundation in the early 1990s—often with financial support for their research from the Department of Biotechnology (DBT). In addition, Monsanto established a biotech lab in Bangalore in 1998 as part of its global research network, and ProAgro (now owned by Bayer) made some investments in mustard and vegetable biotech research. Two agricultural biotech start-up companies—Avesthagen and Metahelix—were founded in 1998 and 2001, respectively, but there was not much enthusiasm by most Indian seed companies for investing in biotech.

The potential profitability of private research investments became more clear as cotton hybrids seed sales took off and Bt cotton became a commercial success starting in 2002. Figure 1 shows that proprietary hybrids were only 24% of cotton seed sales in 1996/97 but had increased to 56% of the market by 2002/03 when the first Bt cotton seeds were introduced. All the Bt cotton seed that is sold in India is hybrid cotton seed. As a result, when Bt cotton became popular, the share of proprietary hybrids increased further to take over 95% of the market 2009/10 (Figure 1).

The approval of Bt cotton in 2002 further increased the profits both to the providers of hybrids and the owners of the Bt gene. The first Bt hybrids combined the Bt gene from Monsanto with hybrid cotton cultivars from Mahyco. The joint venture Mahyco Monsanto Biotech (MMB) also licensed Bt technology to anyone willing to meet their financial and other contractual requirements. The Bt hybrids were in great demand with farmers because of increased yields and reduced pesticide use (Sadashivappa & Qaim, 2009).

These Bt cotton hybrids spread quickly even though Mahyco's initial Bt hybrid cultivars were based on older hybrids that were not competitive in most markets without Bt. Other cotton hybrids with the same Bt gene had been introduced in Gujarat around 2000 without the approval of the Indian Government. Adoption of both the legal and illegal Bt cottons increased rapidly over the next few years (see Figure 2). MMB eventually licensed the Bt to all of the major cotton seed companies. For the seed companies it was either license the Bt, develop a competing Bt, or completely lose their cotton seed market. The Bt hybrids with Bt licensed from MMB from Rasi, Nuziveedu, and Ankur seed companies reached the market in 2005. By 2008, more than 30 firms licensed Bt technology from MMB and nearly 82% of the cotton planted was under Bt cultivars from

Table 1. Private-sector R&D investment in cotton-crop improvement in India over years (Real Rupee terms; million Rs.).

Year	Total R&D investment by seed firms in crop improvement	R&D investment in cotton-crop improvement	Number of firms with cotton R&D	Sources
1987	417	40	9	Pray, Ribiero, Mueller, and Rao (1991)
1995	1,549	270	27	Pray & Kelley (1998); Pray & Ramaswami (2001)
2003	2,000	500-750	30-32	*Biospectrum* (2009); James (2008)
2009/10	6,000	2,500-3,000	>50 [a] (37 Bt cotton)	Authors' survey & National Seed Association of India (NSAI)/Industry estimates (2009/10)

[a] *More than 50 companies are engaged in cotton-crop improvement and breeding aspects, out of which 37 companies have directly engaged in Bt transformation.*

these firms. In 2009/10, the area under Bt cotton cultivation had reached nearly 90% of the cotton area.

Prices of Bt cotton seed were established by market forces initially. The contracts that MMB had with licensees did not specify the seed price, but did specify a technology fee of Rs. 1,250 per 450 gram packet of seed (enough seed to plant an acre of land in India). The seed companies added on their costs of seed production and distribution plus some costs of their research to develop competitive hybrids and profit margins to satisfy their shareholders. Mahyco set their retail Bt cotton seed price at Rs. 1,600. When other licensees came into the market, they set their prices at the same level of Mahyco or higher. These prices compare to the price of conventional hybrids, which varied from Rs. 300 to 500 per packet (Pray, Bengali, & Ramaswami, 2005). The illegal Bt cotton hybrid seeds were sold at the rate of Rs. 1,148 per acre (450 gram packet) in Gujarat villages during the 2004 season (Lalitha, Pray, & Ramaswami, 2008).

MMB was able to charge a substantial technology fee because they had a superior product that reduced farmers' total cost per acre and increased net revenue. India's regulatory system gave MMB a temporary monopoly on the Bt gene. From 2002 until 2006, MMB owned the only Bt gene that could be legally sold in India. By 2005, MMB's licensees were selling about 3 million packets at Rs. 1,200 per packet for Rs. 3.6 billion (US $72 million) in royalties (Pray et al., 2005). This was a nice return on the US $2 million investment that they paid to get Bollgard I (BGI) approved through the regulatory process in India. Pray et al. (2005) calculated that MMB made a 45% internal rate of return on that investment. These returns did not go unnoticed by the seed industry. We believe that MMB's profits were a major incentive for many firms to increase their investments in R&D, especially biotech research on cotton. The increased interest in cotton R&D by the seed firms is evident from the number of seed firms engaged in cotton crop improvement and the money they invested in R&D (see Table 1). Between 1987 and 1995, R&D investment in cotton went from almost nothing to Rs. 27 million. Then it doubled between 1995 and 2003 (hybrid development phase), followed by a 5-times increased investment between 2003 and today. In 2009, 2 companies invested more than 40-50% of their total R&D in cotton-crop improvement.[1] It appears that Bt cotton has pulled up total private seed industry investments in to other crops also—see Column 2 in Table 1.

As a result of these R&D investments, new Bt genes and new Bt hybrids were developed (see Table 2). The number of hybrids increased exponentially since 2006. New Bt genes started to appear in 2006. In May 2006, MMB produced hybrids with stacked Bt genes, Bollgard II (BGII). In the same year, two domestic seed companies, JK AgriGenetics Ltd and Nath Seeds Ltd., had new Bt genes approved for commercialization. JK AgriGenetics developed "Event 1," featuring the Cry1Ac gene sourced from the Indian Institute of Technology (IIT), Kharagpur. "Vishwanath"—a hybrid by Nath Seeds—contained a fusion Cry1Ac/Cry1Ab Bt gene from Biocentury Transgene Technology Company, which was developed at the Chinese Academy of Agricultural Sciences.

Imposition of Price Controls

In 2005, the government of Andhra Pradesh (AP) filed a petition with the Monopolies and Restrictive Trade Practices Commission (MRTPC) seeking to have MMB and its licensees declared monopolists and to reduce Bt cotton seed prices. Early in 2006, the Commission agreed and stated that the state government should set the price of Bt cotton. MMB appealed against this price-

1. *Personal communication with seed industry sources by the authors and Rutgers University/National Seed Association of India (RU-NSAI) Seed Industry Survey, 2009/10.*

Table 2. Bt cotton approved events and private firms' participation in India, 2002-2010.

Particulars	2002	2003	2004	2005	2006	2007	2008	2009[a]	2010[b]
# of Bt hybrids approved	3	3	4	20	62	131	274	248	104
Events approved [c]	1	1	1	1	4	4	5	6	6
# of companies with Bt cultivars	1	1	1	3	15	24	31	33	37

Source: Compiled from the Indian GMO Research Information Service (IGMORIS) website (n.d.), James (2008), Adityendra (2007), and Genetic Engineering Approval Committee (GEAC, 2009).

[a] Approved cultivars by GEAC exclusively for 2009

[b] Approved cultivars exclusively until May 2010

[c] Approved events are Monsanto's BGI and BGII; JK (Indian Institute of Technology Kharagpur collaboration); Nath event (Chinese Bt event); Metahelix; Dharwad-University of Agricultural Sciences (Central Institute for Cotton Research collaboration). Events in the pipeline include the traits by Monsanto, Dow AgroSciences, JK, and Bayer Crop Sciences.

control order set by the MRTPC to the Supreme Court, but the issue is still pending five years later. Meanwhile during 2006, the planting time for cotton was approaching, so the seed companies negotiated with the AP government to set the price of hybrid cotton seed containing the BGI event at Rs. 750 ($18)/packet inclusive of technology fee. The AP government sent a letter about the 'new (controlled) prices' to other state governments, which prompted them to adopt the same price policy as that of the AP government. Now these price caps have spread to important cotton-growing states throughout the country, including Maharashtra and Gujarat, and have influenced prices in the rest of India. The domestic firms, such as Nath Seeds and JK AgriGenetics, with their own Bt events were also required to sell hybrid seeds at the mandated price of Rs. 750 ($18) per 450-gram packet. MMB's licensees sold BGII seeds at Rs. 1,390 per 450-gram packet in 2006 when it was first sold commercially.

In 2008, the AP government decided to go one step further and reduced prices on BGI to Rs. 650/packet and BGII to Rs. 750/packet. In the spring of 2010 they announced that they would keep seed prices at this level. These prices were matched by state governments in Maharashtra and Gujarat. In the northern states, prices were not officially controlled by the state governments, but they were clearly influenced by the price further south and ended up at nearly the same level—from 750 to 925/packet (Table 3). The last two columns of Table 3 show what happened to the trait fee and the actual royalty that came back to MMB. The total trait fee for BGI went from Rs. 1,200 in 2002/03 to Rs. 150/packet. Of this, about two-thirds goes to MMB while one-third is divided between the seed companies and others in the seed supply chain. The last two columns of this table show the actual royalties that went to MMB. These were shared equally by Monsanto and Mahyco.

Impact of Price Controls on Seed Sales and Profits of Farmers, Seed Companies, and Technology Providers

The adoption of Bt cotton cultivars increased rapidly after price controls were implemented. In 2006, the adoption of Bt cotton increased to 63% of the cotton area, up from 28% in 2005. In 2007, Bt cotton spread to 69% of the total area, covering more than 90% of the area under hybrid cotton (Singh, 2007). Biotech companies and seed companies benefited from introducing this technology through increased profits, but in aggregate the biggest winners were the farmers who adopted Bt cotton.

Part of the increased sales and adoption of Bt seed was due to the increase in the availability of locally adapted hybrids, i.e., technology development that had worked their way through the regulatory process since 2005 and high prices for the output (Arora & Bansal, 2010). MMB believes that the quantity of their seed sales in 2006 season would have increased between 100% and 133% above 2005 even if the seed price had stayed at Rs. 1,600, but because of the combined effect of technology and price reductions, the quantity of seed sold in 2006 was actually 180% higher (personal communication with former MMB official, 2008). Another part of these increased sales of legal Bt cotton seed was because farmers are now able to buy authorized seeds for reduced prices rather than the illegal seed. The spread of the illegal seed slowed down and then declined after 2006 (see Figure 2). In recent years, state governments also regulated the cotton seed trade by penalizing illegal seed suppliers through heavy fines and punishments (in terms of jail terms and suspension of license), thus assuring more seeds of tested and approved hybrids reach farmers.[2] For example, in Gujarat, which has the maximum acreage under illegal Bt cotton (nearly 60%), the area planted to illegal seeds declined to 34% of the total area planted in Bt cotton in

Table 3. Bt cotton seed prices in Indian states (with and without price controls), share of trait fee, and technology provider's fee per packet of seeds sold.

	Seed sales price in states/450 gms (Indian Rupees)				Total trait fee/450 gms (Rs.) in states with price controls		Technology provider fee/450 gms (Rs.) in states with price controls	
	States with no price controls [a]		States with price controls [b]					
Year	BGI	BGII	BGI	BGII	BGI	BGII	BGI	BGII
2002/03	1,600		1,600		1,200		696	
2003/04	1,600		1,600		1,200		696	
2004/05	1,675		1,675		1,250		726	
2005/06	1,700		1,700		1,250		726	
2006/07	**750**	**1,390**	**650**	**750**	**260**	**435**	**150**	**225**
2007/08	750	925	650	750	150	260	96	160
2008/09	750	925	650	750	150	260	96	160
2009/10	750	925	650	750	150	260	96	160

Notes: BGI=Monsanto's single-protein technology; BGII=Monsanto's double-protein technology
Source: Personal communication with officials from Monsanto (July-August, 2010); NSAI (personal communication, May 2010).
[a] Price controls were officially imposed by states of Andhra Pradesh, Maharashtra, and Gujarat from the 2006 season onwards. These three states in total occupy nearly 80% of the total Bt cotton acreage. In Madhya Pradesh, though, price controls were imposed during the 2006 season; it was withdrawn upon defeat against the case by MMB in the High Court.
[b] Price controls were not adopted in states of Haryana, Punjab, Rajasthan, Karnataka, or Tamil Nadu.

2006/07, and was forecast to further decline to 27% in 2007/08. While illegal seeds are still common, price restrictions appear to be having the positive effect of making the legal product more price competitive with illegal Bt cotton (Lalitha et al., 2008).

Virtually all of the studies published in refereed journals—plus many other government and industry reports—find that farmers obtained large increases in profits due to adoption of Bt cotton and that profits have increased over time. For example, Sadashivappa and Qaim (2009) found that farmers' profits went from US $121 per ha in 2002/03 to US $165 in 2006/07. From their two rounds of survey in 2002 and 2003, Bennett, Kambhampati, Morse, and Ismail (2006) also concluded that the Bt growers received a higher gross margin (US $1,157/ha) than non-Bt growers (US $665/ha), after taking into account the seed cost and varying cotton prices. Gandhi and Namboodri (2006) in their extensive survey across four major cotton-growing states in India found that the profits per hectare of Bt cotton cultivation ranged from US $347 to $729, while non-Bt cotton profits ranged from US $123 to $414 per hectare. A study by the Association of Chambers of Commerce and Industry of India and Indian Market Research Bureau International (ASSOCHAM & IMRB, 2007) conducted across 23 districts in 6 states reported an increase in the net revenue of US $432 per ha with Bt adoption—earning an average 64% higher income per acre than conventional growers. The Brookes and Barfoot (2008) summary of the published Indian studies found that yields of Bt cotton were 54% higher than non Bt and that the increase in farm income at the national level due to Bt cotton adoption in 2006 at US $839.9 million.

Table 4 presents our best estimates of the total net revenue (profits) realized by the major stakeholders in the Bt seed value chain (including farmers but excluding consumers) since its introduction in 2002.[3] The farm-level revenues were calculated based on seed industry estimates on the quantity of seeds sold and also acreage covered from 2002 to 2010. We used estimates of Qaim (2009) on net revenues realized per hectare of Bt cotton by farming households. It is evident from Table 4 that the farmers' shares of the net revenue have increased substantially by the adoption of Bt seed price controls since 2006. Nearly 85-90% of the total profits earned by the Bt cotton industry as a whole (includes technology provider and seed firm's profits) went to farm profits.

Table 4 also shows the dramatic impact of the price controls on the shares of the providers of Bt genes and

2. *Personal communication with Nath Seeds for 2008/09 and Rasi seeds for 2010.*

3. *These estimates in Tables 4 and 5 should be taken as rough estimates of the shares and the actual profits of the different groups because some of the information about the actual prices and costs of the seed firms is proprietary information that came from industry and cannot be checked against other sources.*

Table 4. Estimated shares of total revenue to farmers, technology providers (MMB), and seed firms.

Year	Bt seed packets sold (million)	Bt cotton area (million ha)	Net revenue Bt cotton (million Rs.) Farmers [a] + firms + MMB	Share of stakeholders in net revenue (%) Farmers	Firms	MMB
2002/03	0.07	0.05	474.1	71.2	18.2	10.6
2003/04	0.23	0.10	1,110.9	60.8	24.8	14.4
2004/05	1.30	0.50	5,975.0	56.5	27.7	15.8
2005/06	3.13	1.30	15,113.3	58.1	26.9	15.0
2006/07*	4.00	3.80	26,762.0	95.8	1.9	2.3
2007/08	16.00	6.30	45,550.9	93.4	3.1	3.6
2008/09	27.00	7.60	56,761.6	90.4	4.2	5.4
2009/10	30.00	8.40	63,434.4	89.4	4.4	6.3

Source: Calculated from authors' assumptions based on industry estimates of total seed packets sold over years.
[a] The net revenues for farm households were calculated based on field-based studies conducted by Qaim and Zilberman (2003), Qaim, Subramanian, Naik, and Zilberman (2006), and Qaim (2009). The net revenue assumptions for the years 2002/03 to 2006/07 were based on Qaim et al. (2006) and Qaim (2009) farm-level survey results; for 2009/10, assumptions were based on Francis-Kanoi Agri-Inputs Marketing Research Cotton Crop Track (2010).
** Price controls were imposed in the 2006/07 season.*

the seed companies that licensed the gene. The profit shares were as high as 28% and 16% for seed firms and MMB, respectively, prior to the 2006/07 cropping season. They declined dramatically after the imposition of price controls. The revenue earned by the seed firms was especially affected. This decline was due to two reasons: a significant reduction in seed prices (nearly 50-60% caused by price controls), and an increase in the cost of seed production (a roughly 35-40% increase).[4] More than 80% of the Bt seed packets (also acreage) sold by seed firms are in three major cotton growing states—Andhra Pradesh, Gujarat, and Maharashtra—where the price controls are in effect.

The main technology provider is MMB, although Nath Seeds and JK AgriGenetics also had some sales of their Bt. Since Monsanto does most of the research and product development in the United States, the R&D costs are assumed to be sunk costs; hence, the marginal cost of producing one extra unit of technology in India is zero. The cost of regulatory approval does occur in India, but it is independent of sales of the specific product. Thus, we can say that there is zero marginal cost and a perfectly elastic supply of Bt cotton technology. As mentioned earlier, Monsanto distributes Bt cotton

Table 5. Estimated revenue realized by technology providers (MMB) and seed firms from Bt cotton seed sales in India, 2002-2010.

Year	Net revenue (million Rs.) Technology providers (MMB) [b]	Seed firms [a] (Excl. trait fee)	Share of Bt cotton packets sold in price-control states (%)[c]
2002/03	50.2	86.4	86
2003/04	160.1	275.8	76
2004/05	943.8	1,656.2	79
2005/06	2,272.4	4,065.9	80
2006/07*	612.0	500.0	83
2007/08	1,617.9	1,408.0	77
2008/09	3,058.6	2,403.0	76
2009/10	3,974.4	2,760.0	73

Source: Authors' calculations based on the information provided by industry sources.
[a] Technology providers' revenue is calculated from their share in total trait value. Of the total revenue, Monsanto shares 50% of revenue with their domestic partner, Mahyco.
[b] Net revenue of seed firms = Bt seed sales price – Technology provider trait fee (MMB fee) – Cost of seed production (which includes revenue shared with actors in distribution channels) × the number of packets (450gms) sold. The cost of seed production incurred by seed firms assumed indifferent for BGI and BGII.
[c] Indicates the share of the Bt cotton seeds sold (as well as acreage) in Andhra Pradesh, Maharashtra, and Gujarat. These are the three states where price controls for cotton have been imposed officially by the state governments.

4. The decline in seed company profits in 2006/07 is probably exaggerated because we do not have the cost of seed production for every year—we just know that it went up by 35-40% due to increased costs of production (labor, fertilizer, etc.) over the period from 2003/04 to 2007/08. We arbitrarily applied the increase in prices of cost of seed production from the 2006/07 crop year.

Table 6. R&D expenses incurred by technology providers and sub-licensees of Bt gene.

R&D expenses [#] (million Rs.)	2003	2004	2005	2006	2007	2008	2009
4 firms with own Bt events [a]	289.5	437.7	540.3	669.9	724.8	912.7	1,164.5
5 major sub-licensees of Bt events [b]	26.8	34.9	33.5	59.5	82.6	87.1	159.6

[#] R&D expenses were calculated based on Author's surveys (2009/10); Estimates based on authors' interviews with NSAI, New Delhi in 2009 and 2010; Department of Scientific Industrial Research (DSIR, Annual reports, 2003 to 2009)

[a] R&D expenses of firms with own events here refer to Mahyco, Monsanto, JK AgriGenetics, and Nath Seeds.

[b] Sub-licensees expenses refers to Rasi, Nuziveedu, Ajeet, Ankur, and Krishidhan seed firms only.

through its joint venture with Mahyco, called Mahyco Monsanto Biotech (or MMB). The income to MMB can thus be calculated simply by multiplying the royalties by the quantity of seed sold, i.e., *Profits* = (*# of packets sold* × *trait fee for technology provider*). Seed firms that license Bt pay a one-time lump-sum payment for technology fees of Rs. 50 million to MMB to acquire Bt gene technology (BGI, BGII, and RR Flex cottons; Pray et al., 2005). Currently 37 firms have sub-licensed Monsanto's Bt gene technology in India. Of the total MMB profits, Monsanto shares nearly half of its revenue with Mahyco as per their agreement.

Table 5 shows what happened to the total royalties of MMB (not including the lump sum payments) and the profits of the seed companies who licensed this technology. MMB took a major cut in royalties in the first year of price controls—from Rs. 2,275 million to Rs. 612 million. Royalties did not reach the 2005/06 levels again until last year. The profits of the licensees were reduced even more than Monsanto because they not only had lower revenue, but they were also hit with a 35-40% increase in costs of producing and marketing seed. It is interesting to note that before price controls, the seed companies captured more profits from sales of Bt seed than MMB, while after price controls MMB received more profits from Bt than the seed companies.

Impact of Price Controls on Research and Technology Supply

There is no substantial evidence yet of a slowdown in the provision of new technologies due to the price controls, but it is really too early to conclude anything. Table 2 indicates that two more GM cotton events were approved after 2006, and three more are in the pipeline to be approved. However, given the structure of the regulatory system, all of these traits were developed and entered into the regulatory system well before 2006. The development of new GM cultivars continued to accelerate until 2009(see Table 2), but again it is not obvious whether the increase and recent decline is due to the rise and decline of incomes of the seed companies and MMB or simply momentum from programs started before 2006.

The impact of the declines in royalties does not show up in the available R&D data (Table 6). Both biotechnology companies and licensees of biotech traits were affected by the revenue declines, but the total research expenditures of both groups continue to rise. Total research of biotech companies working on developing genes for cotton and major field crops—Monsanto, Mahyco, Nath, JK AgriGenetics—continued to grow rapidly (first row one). R&D by the licensees (second row in table) also grew rapidly throughout this period. It seems likely that firms continued to spend more towards cotton R&D in hopes that the price controls will soon be lifted. A few firms that we interviewed did acknowledge a shift in resources away from cotton and a rapid increase in expenditures on other crops after seed price controls took effect.

The journal *Biospectrum* publishes sales of Bt cotton by the major seed companies engaged in biotech crop sales in India (Table 7).[5] Of these, companies like Rasi, Nuziveedu, Ankur, and Krishidhan do not have major research programs to develop genes of cotton; rather, they focus their research on developing improved hybrids. The sales of this group of companies has definitely benefited from price controls, but declining net revenues of seed firms (or sub-licensees) from our calculations shown in the previous two tables (Tables 5 and 6) suggests that the increased gross revenue (as shown in Table 7) and the reduced royalties have not helped the profits of seed firms.

So far, the only signs that price controls may be slowing the supply of technology come from interviews with the companies and presentations to the government from the organizations that represent them. Two industry groups—the National Seed Association of India (NSAI) and the Association of Biotechnology Led

5. The survey by Biospectrum did not include a few firms whose market shares of Bt cotton cultivar sales have improved substantially since 2006/07; these companies include Tulasi, Monsanto, Vibha, and Ajeet Seeds.

Table 7. Total sales revenue of Bt cotton from leading agri-biotech domestic firms in India (million Rs.).

Companies	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Rasi	869	3,095	3,333	2,933	3,756	3,588
Nuziveedu		625	2,264	2,919	4,496	4,769
Mahyco	1,660	1,178	1,107	1,359	2,111	3,120
Ankur			695	557	803	1,095
Krishidhan			180	477	632	1,332
Nath			119	620	485	850
JK AgriGenetics			187	460	260	350
Metahelix			60	66	97	N/A

Source: Compiled from Biospectrum *(2009).*

Enterprises (ABLE)—have argued that prices should be increased because the cost of producing seeds has gone up and squeezing out royalties would likely discourage new investment in R&D.[6] The US-India Business Council (2009) identified non-market-based pricing as one of the most significant disincentives to the commercialization of new biotech seeds by global seed firms in India. According to the founder of Rasi Seeds, continued state government interference in pricing is harming the ability of indigenous companies to develop and commercialize biotech seeds (Suresh & Rao, 2009). During our interviews with multinational biotech firms in August 2010, it was clear they are wary of bringing in new GM traits such as drought tolerance or doing any research on traits for India-specific problems until the price-control situation is clarified.

Some of the small biotech companies have been particularly vocal in their opposition to price controls. In July 2009, Metahelix received approval to sell its new Bt gene. Metahelix is a small biotech and seed company that was founded in Bangalore in 2001 by scientists who had worked at Monsanto.[7] It was funded by "angel investors" from the information-technology industry. Their business plan was to develop appropriate biotech products for the Indian market. They started their Bt cotton program in 2003, lost at least one year of field trials due to objections to GM field trials raised at the Supreme Court by non-governmental organizations (NGOs), and then finally in 2009 received permission from the government to sell this Bt product. They had hoped to start selling the product in 2010, but in May 2010 the President of Metahelix reported that the price cap prevented them from introducing hybrids with new Bt in 2010:

> "I've spent over (Rs.) 25-30 crore [US$5-6 million] in the last seven years on research and regulatory approvals around our Bt genes, but with this price cap, I can't negotiate appropriate licensing fees with seed companies and I can't competitively price my seeds. So, we are bleeding," said K.K. Narayanan, managing director of Metahelix Life Sciences Pvt. Ltd, a Bangalore-based crop biotech firm (Koshy, 2010).

It must be particularly frustrating for Indian companies like Metahelix because government regulations gave MMB a monopoly for 5 years with royalties up to $24/packet and then when local companies break the monopoly by developing their own new biotech products, the government reduces prices to a level that makes profits on these investments almost impossible. Murugkar, Ramaswami, and Shelar's (2007) study of the seed industry concluded that price caps were particularly problematic for new domestic firms seeking to enter the market.

A final reason for concern that Indian farmers may be the losers because they do not get access to the best technology is the example of China. There, Bt cotton varieties were introduced by Monsanto and by the Chinese Academy of Agricultural Sciences in 1997. However, the lack of intellectual property rights either in the form of hybrids or effective patent protection meant that neither multinationals, Chinese seed companies, nor government research institutes could make substantial profits on the Bt trait (Hu et al., 2009). Monsanto and other multinationals decide there were not enough potential profits to support research or commercializing new imported genes for cotton, and the government institutes were also not successful in developing new GM traits. As a result and despite their head start on Indian farmers with the first Bt cotton, Chinese farmers have not gotten any new GM traits for cotton since

6. *NSAI-ABLE's memo to the Government of India in February 2010.*
7. *Rallis India Ltd. acquired Meta-Helix in December 2010.*

1997, and they do not have access to Bt cotton stacked with two Bt genes, which is the most popular Bt cotton in India.

Conclusions

The introduction of Bt cotton brought impressive increases in incomes to farmers and profits to biotechnology companies and seed companies. Approximately 60% of the benefits went to farmers before the imposition of price controls in 2006 (Table 4). With imposition of price controls in 2006, a much larger share (about 90%) of the benefits went to farmers, while the shares of biotech providers and seed companies declined. After price controls were implemented in 2006, biotech and seed companies continued to make profits, but profits were dramatically lower than they were in 2005. The technology providers did not reach their 2005 profit levels again until 2008, while the seed companies still have not returned to their previous profit levels.

Both economic theory and empirical research make it clear that price controls on the sale of new technology by private companies will reduce their investments in R&D and innovation. Empirical evidence to support this proposition comes primarily from the pharmaceutical industry. Foreign companies will send their technology first to countries where potential benefits are highest and then will bring them to places where the returns are lower and there is less uncertainty whether technology will be accepted. This is clearly what happened in China. Monsanto brought Bt technology to China in 1997 before India, but when they found that they could not make substantial profits there, they stopped doing research and bringing in new technology to China for almost a decade. As a result, Chinese farmers still do not have access to technology such as Bollgard II, which Indian farmers have had since 2006.

In India there is clear evidence that both Indian and foreign companies responded to evidence of high expected returns to R&D investment and made major investments in biotechnology research between 1995 and 2006. There is not yet any quantitative evidence that firms have reduced their research or their innovations due to the lower returns to companies that provided new biotech in India. Indian companies and Indian branches of multinationals say that as a result of the Bt cotton seed price controls, they are slowing down introduction of new technology, but it is too early to have any numbers to substantiate this claim.

Indian states now have a choice. They can choose to continue to please farmers and farmer groups who have a short-term perspective on technology and continue to squeeze the profits of biotech companies and seed companies by controlling prices in what was one of the most dynamic parts of the agricultural sector. This will reduce the profits of MMB; reduce profits and probably reduce research by small, innovative Indian companies such as Metahelix; and slow the provision of new genes to farmers. Or they can choose to encourage firms to innovate by supporting the innovation process with strong IPRs, biosafety regulations that are efficient and inexpensive, and strong public sector R&D. In addition, they can reduce the prices of new technology by making use of India's new competition policy to make sure that as many companies—both Indian and international—as possible can enter the biotech industry rather than slowing down small firms and new entrants through price controls.

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