ECONOMIC IMPACT OF PRICE CONTROLS AND REGULATIONS:

CASE OF GM COTTON IN INDIA

by

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ABSTRACT OF THE THESIS

ECONOMIC IMPACT OF PRICE CONTROLS AND REGULATIONS:

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Bt cotton has been extremely popular with Indian farmers ever since unapproved varieties were introduced in Gujarat in 2001 by Navbharat Seed Company Ltd. Cotton hybrids with approved bt traits were released by Monsanto through the joint venture MMB (Mahyco Monsanto Biotech) in 2002. MMB had the first mover advantage because they had the only approved bt genes for commercialization in India thereby making considerable profits. This attracted a large number of firms to license the technology from MMB. However, in 2006 the government of Andhra Pradesh (AP) filed a petition with the Monopolies and Restrictive Trade Practices Commission (MRTPC) seeking to reduce prices. The Commission agreed but MMB appealed to the Supreme Court. Meanwhile, the AP government negotiated with the seed companies to set the prices of hybrid bt cotton seed at $18/packet (of 450 grams) inclusive of technology fee which is much lower than the $29/packet that MMB had been selling it at. Soon other state governments adopted the same pricing policy.

This paper primarily attempts to perform a cost-benefit analysis using the economic surplus model to address the immediate and longer term impact of price controls on farmers. A number of seed companies, especially the multinationals are concerned that this governmental intervention could inhibit innovation, which would mean that farmers would lose out on economic surplus in the future. We attempt to measure these losses. Our analysis finds that the current benefits to the farmers outweigh the losses of benefits due to non availability of some of the most easily measurable new technologies.

ACKNOWLEDGEMENTS

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My parents Sumitra and Janardhan Rao have struggled very hard so that their children have nothing but the best. They have always stressed on the importance of education and placed utmost confidence in my abilities. Mom Dad, I hope to make you proud.

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1. INTRODUCTION

Cotton is a major cash crop in India. From 1990 to 2006 the average area under cotton increased from 18 million acres to 23 million acres, an increase of 21% , average production increased from 1.67 million tons to 3.58 million tons, an increase of 114% and average yields increased from 91 kg/acre to 159 kg/acre, an increase of 89% (Ministry of Agriculture 2007). India exported 1.75 million tons of cotton which comprised 7% of the global cotton exports in 2005 (USDA Production, Supply and Distribution Online Database). The nine major cotton growing states [see Appendix A for a map of India] can be classified under three zones, viz., Northern zone covering the states of Punjab, Haryana and Rajasthan; central zone comprising of Gujarat, Madhya Pradesh and Maharashtra and southern zone consisting of states Karnataka, Andhra Pradesh and Tamil Nadu.

Seeds are sown during May-June and the crop is harvested between September-December, covering the entire kharif[1] season. All four varieties of cotton -- *Gossypium arboretum* (Asian Cotton), *Gossypium herbaceum* (Asian Cotton), *Gossypium barbadense* (Egyptian Cotton), *Gossypium hirsutum* (American Upland Cotton) – grow in Indian climatic conditions. Approximately about 2/3[rds] of cotton in India is grown under rain-fed conditions, and the rest is irrigated (Sundaram, et al. 1999). Asian and Egyptian varieties of cotton, widely known as Desi Cotton (diploid[2]), are suitable for rain-fed areas. American Hybrids (tetraploids[3]) – long and extra long stapled, have better yield potential and fiber quality; and are suitable for irrigated areas primarily under commercial cultivation. Hybrid cotton varieties are more popular among farmers than openly pollinated varieties and they cover about 70% of the total cotton area contributing to

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[1] *Kharif* season is one of two major cropping seasons in India. It occurs during the Southwest monsoon or from July through October.

[2] A *diploid* a cell or an organism consisting of two sets of chromosomes: usually, one set from the mother and another set from the father.

[3] A *tetreploid* has four sets of chromosomes in each cell of the plant

95% of the total value of cotton sales in India (Murugkar, Ramaswami and Shelar 2006).

Introduction and Spread of bt[4] cotton in India

Even before the official approval of bt cotton for cultivation, unauthorized (illegal) varieties of genetically modified cotton seeds was available to farmers of Gujarat, sold by a private seed firm namely Navbharat Seeds. These varieties had not undergone the rigorous testing and trials as mandated by bio-safety regulations and were not approved by the Genetic Engineering Approval Committee (GEAC); hence the term “illegal seeds”.

In March 2002, with the approval of GEAC, Monsanto in collaboration with its Indian partner Maharashtra Hybrid Seed Company (Mahyco) released three bt cotton hybrids for cultivation[5]. The hybrids were marketed by a 50-50 joint venture called Mahyco Monsanto Biotech (MMB) and were made commercially available to farmers in the Central and Southern zone.

A good monsoon season in the year 2003 increased the popularity of insect-resistant cotton considerably among the farmers. This further encouraged MMB to sub-license the bt gene to regional seed companies selling popular hybrids, who also were market leaders in their respective locations. The regional companies in turn incorporated the bt gene in to their own hybrid varieties and released into the market after meeting necessary regulatory formalities. The price for a packet (of 450 grams) was fixed at $45, out of which $30 was charged as the “technology fee” to be payable to MMB.

By the year 2005, twenty BG-I varieties were approved for cultivation by GEAC and a few of them were specifically suited for agro-ecological conditions of the Northern zone.

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[4] *Bacillus thuringiensis* (bt) is a spore-forming bacterium, which produces crystal proteins that are toxic to many species of insects. Bt cotton plants have been modified with short sequences of bt genes to express the crystal proteins that the bacterium produces, so that the plants can produce their own insecticidal proteins.

[5] The top seed company in India located in Maharashtra

In May 2006, hybrids with stacked bt genes, Bollgard-II[6] were approved for commercial release in the Central and Northern zones. In the same year, two domestic seed companies JK AgriGenetics Ltd and Nath Seeds Ltd also released their own approved events[7] of Bt- cotton. JK AgriGenetics developed "Event 1" featuring the *cry1Ac* gene sourced from Indian Institute of Technology (IIT), Kharagpur, a premier Indian educational and research institution. "Vishwanath" by Nath Seeds contained a fusion *cry1Ac/cry1Ab* bt gene, from Biocentury Transgene Technology Company (BTCC). By this time bt traits had been incorporated into a vast majority of preferred hybrids, that most farmers, even marginal switched to bt cotton.

Antitrust Case and Seed Price Controls

By 2005 MMB directly - through selling hybrid seeds, or indirectly- through sub-licensing[8] to private seed companies dominated the market for cotton hybrids (Damodaran 2002). Three MMB sub-licensees -- Mahyco, Raasi Seeds and Nuziveedu Seeds – nearly accounted for 70% of all BG-I seeds sold (Personal Communication: Nath Seeds, April 2008). The domestic companies who licensed bt trait from MMB were required to pay a one-time license fee of $122,000 for availing the gene. Further, the companies also paid an additional percentage of sale prices (about 67% from 2002 through 2004) for every packet of seeds sold towards technology fee. The companies also agreed not to sub-license the bt technology procured from MMB to other seed companies. The additional cost incurred by the domestic firms towards licensing and technology fee for bt cotton hybrids were passed on to the consumers i.e., cotton growers thus

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[6] BG-II contains a stacked combination of *Cry1Ac* and *Cry2Ab* genes and is designed to offer additional season long protection against pests like *spodoptera* and h*eliothis*.

[7] An event refers to the unique DNA recombination event that took place in one plant cell, which was then used to generate entire transgenic plants. Every cell that successfully incorporates the gene of interest represents a unique event.

[8] Sub-licensees of MMB ranked (in parenthesis) according to aggregates seed sales in India for the year 2004/2005 with MAHYCO being the top seller: Nuziveedu Seeds (3), Raasi Seeds(4), Ankur(5), Brahma/Paras (6), Tulasi Seeds(7). Others include Ganga Kaveri Seeds, Ajeeth Seeds , Emergent Genetics , JK AgriGenetics, Nath Seeds, Vikki Agrotech , Pravardhan Seeds , Krishidhan , Prabhat and Vikram Seeds (compiled using (Muragkar et al,2006) and (Biospectrum India 2006)).

resulting in wider price differences i.e., distorted prices (in 2004 bt hybrids cost $19 more per acre compared to non-bt hybrids (Murugkar, Ramaswami and Shelar 2006). This resulted in widespread discontent among the cotton growers and small and medium sized seed firms, who used to dominate the market in non-bt cotton hybrids. As a relief measure, the state of Andhra Pradesh tried to impose certain regulations targeted to control bt cotton prices sold by the firms, so as to make the technology affordable and accessible to all the small and marginal farmers in the state.

In January 2006, the government of Andhra Pradesh (AP) filed a case with the Monopolies and Restrictive Trade Practices Commission[9] (MRTPC) against MMB and sub-licensees for "*indulging in monopolistic trade practices with unreasonably high prices and limited technical developments*". On May 11, 2006, MRTPC passed an interim order directing MMB to reduce the price of bt cotton seeds, and "*fix a reasonable amount*" within a month. Assailing this order, MMB appealed to the Supreme Court[10] (MMB, 2006). The argument was that the technology fee being charged was not for the sale of any goods but for the knowledge transfer to the sub licensees and "*licensing of technology does not fall under the classification of goods or services*", therefore the MRTPC had no jurisdiction to adjudicate on this issue [11].

In response to MRTPC act imposed by the state of AP, MMB reduced the price for BG-I to $29 from the original price of $39 for a packet of 450 grams of seed. The government of AP felt that

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[9] Monopolies and Restrictive Trade Practices Commission (MRTPC), a quasi-judicial body was established under Section 5 of the Monopolies and Restrictive Trade Practices Act, 1969. The main function of the MRTPC is to enquire into and take appropriate action in the case of unfair trade and/or restrictive trade practices. A new competition policies law was passed in 2005 to supercede the MRTP act and according to the new law MRTPC would be eliminated and be replaced by a competition panel. However, this law has not yet come into effect.

[10] (MMB) Mahyco Monsanto Biotech (India) Ltd. Press Release, May 11, 2006.

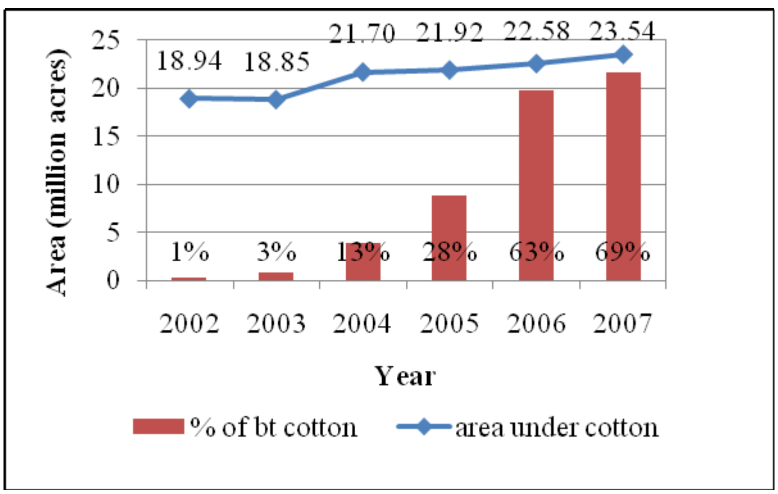
[11] *Govt of AP v MMB and sublicensees.* I.A. No 05/2005 RTPE 02/2006 (Monopolies and Restrictive Trade Practices Commission, New Delhi May 11, 2006).

this was still too high a price and in June 2006, and further released an Ordinance declaring that seed prices for bt cotton seeds in the state would be capped at $18/packet of 450 grams of seed (inclusive of technology fee). This pricing directive was soon adopted by other cotton growing states. Even the domestic firms with their own bt events such as Nath Seeds and JK AgriGenetics had no option but to sell hybrid seeds at the mandated price of $18/packet of 450 grams. MMB decided to sell BG-II seeds at $23/packet of 450 gram.

Post Price Controls

The scenario post price controls in India revealed a sudden increase in adoption and acreage under bt cotton cultivation in India. For instance, we could see that immediately after the government intervened price controls in 2006, the adoption of bt cotton soared up to 63 % from 28% in 2005 as shown in Figure 1. In 2007 also, bt cotton adoption was higher, occupying 69% of the total area under cotton, covering more than 90% of the area under hybrid cotton (Singh 2007).

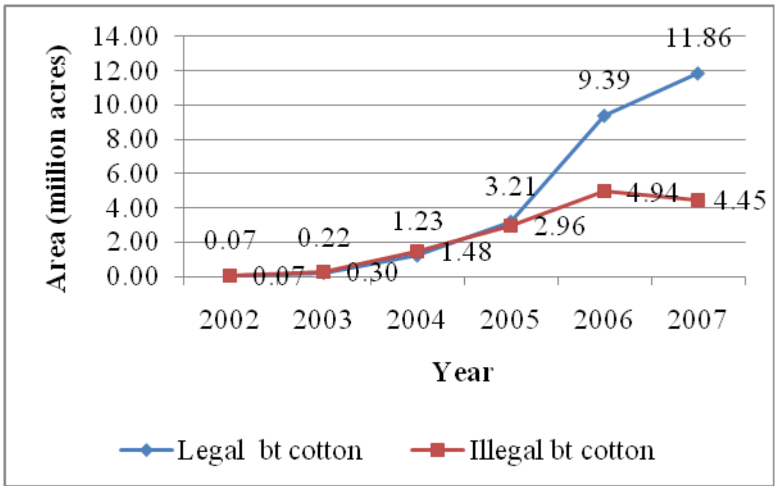
Figure 1: Adoption of bt cotton in India (million acres)



Source: Singh (2007)

In Figure 2, we note that after the implementation of price control legal varieties of cotton exceeded the illegal varieties. A large part of this increase could be because farmers are now able to buy authorized seeds for reduced prices. In recent years state governments also regulate 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 only tested and approved varieties reach farmers (Personal Communication: Nath Seeds, April 2008).

Figure 2: Spread of Legal versus Illegal Bt Cotton (million acres)



Source: Singh (2007)

Problem Statement

Technology fees are generally used to support current products and to fund research and further product development. Limiting the technology fee by imposing price controls may be a good way of transferring the bulk of the benefits from the seed companies to the farmers immediately or in the short-term.

Restricting the companies from collecting royalties has a negative impact on their profits. As explained later in Chapter 2, profits (both expected future profits and current profits) determine R&D investments and R&D investments in-turn fuel innovation. It is very likely that due to price controls firms may see no incentive to innovate or to introduce new technology. This in turn could deny consumer access to improved products, which may result in the reduction of consumer surplus in the long-term.

Research Objectives

The implementation of price controls has impacted both farmers and ag-biotech industry. The ag-biotech companies such as Monsanto and Mahyco do not like these price controls because they believe that their profits have been reduced and are now much below than what they might have otherwise been. They also argue that this will hurt farmers in the long-term because companies' incentives to produce new technology will be reduced because of lower profits and uncertainties about seed prices and technology fees policies (in India) in the future. The issues for policy makers and the objectives of this thesis are threefold:

- To study the impact of price controls on the welfare of farmers, and on profits in the seed business in the short-term.
- To evaluate the costs assuming that these price controls delay the introduction of new technology.
- To assess if the short-term gains for farmers outweigh the long-term losses because less technology will be available.

Methods Used

The aim is to perform a cost-benefit analysis of this policy, for the short-term and long-term scenarios. In the short-term one would expect the welfare of the farmer's to change positively as their costs of production are reduced due price controls. To measure such welfare gains we use data from past household studies and the historical spread of these varieties.

Interviews (personal, email) were conducted with personnel from Advanta-India, Monsanto, JK AgriGenetics, Nath Seeds and Bioseeds. Interactions with these representatives gave us an opportunity to understand how government-imposed regulations could affect the plans of the industry for the future.

These price distorting policies might reduce corporate investments in research and innovation thereby delaying the supply of new technology to farmers. We use the economic surplus model (Alston, Norton and Pardey 1995) to estimate the contribution to farmer benefits due to future GM technologies. We simulate the surplus models using as examples, herbicide tolerance and drought tolerance varieties. If price controls continue to be enforced well into the future these new technologies may not be available to the farmers for several years. The benefits denied due to non-availability of these technologies would therefore be a cost of the regulation.

Outline of the thesis

Studies related to the performance of bt cotton in India can be found in Chapter 2. This Chapter also delves into details on the background of the legal case against bt cotton seed producers followed by the economic theory price controls. Here we also introduce the conceptual framework for the study. Chapter 3 analyzes the economic impact of the price control regulation on cotton producers and seed providers in the short-term. Chapter 4 explains the possible long – term effects of the price controls and measures the impact on future welfare. Finally, Chapter 5 draws conclusions based on the analysis in the preceding chapters, points out the limitations of the study and avenues for the future work.

2. BACKGROUND, CONCEPTS AND METHODS

Performance of bt cotton in India – A Review of Past Studies

A spectrum of studies conducted on assessing the economic performance of bt cotton (Table 1) in India, revealed that the farmers benefited from the adoption of bt cotton technology, through increased yields and reduced pesticide costs. Although bt technology as such is not targeted towards increased yield, the substantial increase in yields is attributed to decreased pest damages. In spite of higher seed cost incurred towards bt cotton seeds, the cost savings due to reduced pesticide use offsets the farmers' increased cost on seed. There are also additional spill-over benefits such as improved quality of life due to increased income, better health due to less exposure to pesticides, peace of mind due to better yield assurance, etc (Dev and Rao 2007). Owing to constraints in measuring the indirect benefits, in this study we concentrate on analyzing the economic benefits through measurable outcomes such as increased profits due to increased yields and decreased pesticide usage.

Matin Qaim (Qaim 2003) in his pioneering work on analyzing the economics of bt cotton in India using field data from experimental trials prior to commercialization, reported that bt cotton cultivation required only 1/3rd of the total pesticides consumed by conventional cotton varieties. He concluded that under severe pest pressure, the yield gains were over 80% than conventional cotton varieties. However these results are to be interpreted with caution as they are based on experimental conditions rather depicting real world scenario. In a subsequent survey study by Qaim and few other researchers (Qaim et al, 2006), cotton farmers, both adopters and non-adopters of bt cotton from four states in India, namely Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu indicated that compared to other conventional and non-bt cotton varieties in their respective regions, MECH-162 did exceedingly well in every aspect of its agronomic performance.

A study funded by Mahyco (Barwale et al, 2004) documented the results of a survey of 1,069 farmers in six states during the 2002 season. According to their report, bt cotton increased yields by 42% and reduced pesticide usage by 57%. Another study with data on seed quantity, costs, number and cost of sprays, yields, cotton prices obtained from Bt and non-bt farms in Maharashtra in 2002 and 2003 emphasized the benefits of bt cotton (Bennett et al, 2004).

Bambawale along with his colleagues conducted a participatory field trial with MECH-162 variety of bt cotton in Maharashtra (Bambawale et al, 2004). Their results proved that IPM in cotton was most effective with Bt MECH-162 and emphasized that adoption of bt cotton resulted in increased returns despite the high initial cost for the seeds.

A Frontline Demonstration (FLD) study was undertaken by the Division of Agricultural Extension of the Indian Council of Agricultural Research (ICAR), in collaboration with various stakeholders under the Mini Mission – II of the Technology Mission of Cotton (TMC). This study used data collected from 1,200 demonstration and farmer plots across 11 States in 2005 growing season. Results confirmed that bt cotton yields were considerably higher than non-bt varieties by 31% and other openly pollinated varieties (OPV) by 66% (Indian Council of Agricultural Research 2005). Two researchers from Indian Institute of Management (IIM) analyzed data from the states of Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu and found that the high bt cotton yields were statistically significant under both irrigated and rain fed conditions (Gandhi and Namboodiri 2006). However the high seed cost they found were not compensated by reduction in pesticide cost. Center for Economic and Social Studies in Hyderabad (CESS) conducted a study in 4 districts of the State of Andhra Pradesh (Dev and Rao 2007). They found that the cost of production for an acre of bt cotton was 17 % higher than that of non-bt cotton. The yield of bt cotton was 32% higher than that of non-bt cotton. Table 1 summarizes the studies in a succinct fashion.

Table 1: Summary of Performance Studies

Study	Year	Summary
Qaim (2003)	2001	yield +80%,costs +18%, revenue 81%, net profit +426%
Bambawale(2004)	2002 Maharashtra	**Bt MECH compared to** **Non Bt MECH with IPM** costs +26% yield +29% returns +29 net profit +31% **CC with IPM** costs +23% yield +75% returns 39% net profit +54% **CC Non IPM** costs +21% yield +234% net returns 158% net profit increase 1619%
Barwale (2004)	2002	yield +42%; pesticide sprays -57%
Qaim (2006)	2002	Yield +34% # of sprays -36% cost of seed +221% cost of pesticide -41% total cost +17% profits +69%
Bennett (2004)	2002	# of boll worm sprays -63% cost of bollworm sprays -72% cost of seed +231.8% cotton yield +45.3% net profit +49.2%
	2003	# of boll worm sprays -77% cost of bollworm spray -83% cost of seed +217% cotton yield +63% net profit +74%
IIM (Gandhi and Namboodiri, 2006)	2004	Yield + 39% # of sprays -40% cost of seed +184% cost of pesticide -30% total cost +17% profits +103%
ICAR (2005)	2005	**Compared to Non-Bt:** Yield +31% **Compared to OPV**: Yield +66%.
CESS (Dev and Rao 2007)	2004	cost +17 % yield +32%

Source: Compiled by the Author

Antitrust Case – A Detailed Insight[12]

This section presents a more detailed discussion of the antitrust case, based on the official documents filed to the MRTP Commission[13]. On January 2nd, 2006 the Government of Andhra Pradesh filed a complaint with the MRTP Commission, in New Delhi against the following six respondents; MMB (India) Ltd, Monsanto (USA), Mahyco, Raasi Seeds, Pro-agro Seed Company, Nuziveedu Seeds accusing them of practicing price distortion in the hybrid cotton market.

Summary of the position of the Andhra Pradesh State Government

1. MMB is "*monopolizing*" the cotton seed market preventing the entry of both Indian seed companies and other multinational companies.
2. This high cost of bt cotton seeds ($39 to $45 per packet of 450 grams) is passed on to the farmers making this technology uneconomical and unaffordable.
3. The technology fee[14] charged is too high when compared to that charged in other countries like China and the US.

Summary of the position of the Respondents viz., MMB and sub-licensees

1. Transfer of technology is an "*intangible property*" and does not come within the definition of "goods and/or services" under the MRTP Act, hence does not fall under the purview of the MRTP Commission.
2. Farmers have the freedom of choice and those who choose to grow bt cotton are evidently doing so as they are making profits.

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[12] The description of the case and other details has directly been derived from government document on the MRTPC case obtained by the author in January, 2008.Other details of the case have been compiled using the Andhra Pradesh Gazette and MMB press statements.

[13] *Govt of AP v MMB and sublicensees.* I.A. No 05/2005 RTPE 02/2006 (Monopolies and Restrictive Trade Practices Commission, New Delhi May 11, 2006).

[14] technology fee for bt cotton hybrids

3. The technology fee has already been reduced to $22/packet of 450 grams of seed for the 2006 season.

Final Verdict of the MRTPC

The MRTPC decision was based on Section 12-A of the MRTP Act [See Appendix B]**.** MMB and its licensees were required to reduce the technology fee from $22 / packet 450 of grams, but the actual price was not explicitly specified. In June 2006, the government of Andhra Pradesh came out with an Ordinance mandating that bt cotton seeds cannot sell for more than $18 for a packet of 450 grams of seed[15]. Monsanto filed a petition in the Supreme Court challenging the above verdict, the case is still pending (as of September 2008).

Technology Fee and Willingness to Pay for bt Cotton hybrids

Farmers in different countries sow different amount of seeds per acre based on the agronomical and ecological conditions. In India, the recommended quantity is 450 grams per acre. In 2004 the technology fee charged per packet of 450 grams of seeds was $30 which was subsequently reduced to $22 in 2006. In China, farmers sow about 16 kg of cotton seeds per acre and pay $2/ kg as the technology fee (Source: Personal Communication: R.Hu, 2005), hence they pay $32/ ha which translates to $12/acre. In Argentina, the farmers pay a price of $42/acre for cotton seeds, out of which $32 constitutes the technology premium (Qaim and de Janvry 2003). In the US, degree price discrimination[16] is practiced by the seed companies but on an average the technology fee charged is $32/acre (International Cotton Advisory Committee). Table 2 compares the technology fee charged per acre in India, China, USA and Argentina. The technology fee in India is higher than that charged in China but lower Argentina and US.

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[15] The Andhra Pradesh Gazette Part IV-B Extraordinary. *Andhra Pradesh Acts, Ordinances and Regulations, etc*. Published by Authority. No. 23, Hyderabad, June 28, 2007.

[16] A seller charging competing buyers different prices for the same commodity depending on the demand elasticity

Table 2: Comparison of Technology Fee

Country	Year	Technology Fee ($/acre)
India[1]	2004	28
India[2]	2005	20
China[3]	2005	12
USA[4]	1998	32
Argentina[5]	2003	32

Source: Compiled by the Author
[1,2] Actual Market Price [3] Personal Communication: R.Hu, 2005 [4] ICAC [5] (Qaim & de Janvry 2003)

There have been some studies on the farmer's willingness to pay for bt cotton hybrids. We found evidence in 3 studies – 2 conducted in India and 1 in Argentina – that farmers feel that they were being overcharged. In Andhra Pradesh about 41% of the farmers cited that the high price was the top reason they were reluctant to adopt bt cotton (Dev and Rao 2007). Interestingly, in Gujarat it was found that the mean willingness to pay (WTP) for legal bt seeds was $19/packet of 450 grams of seed and for illegal bt seeds it was $74/packet of 450 grams of seed (Lalita, Pray and Ramaswami 2008). The willingness to pay (WTP) more for the illegal varieties could be due to the fact that Navbharat Seed, the most popular and wide spread illegal variety in Gujarat is best suited for the regions agro-ecological conditions.

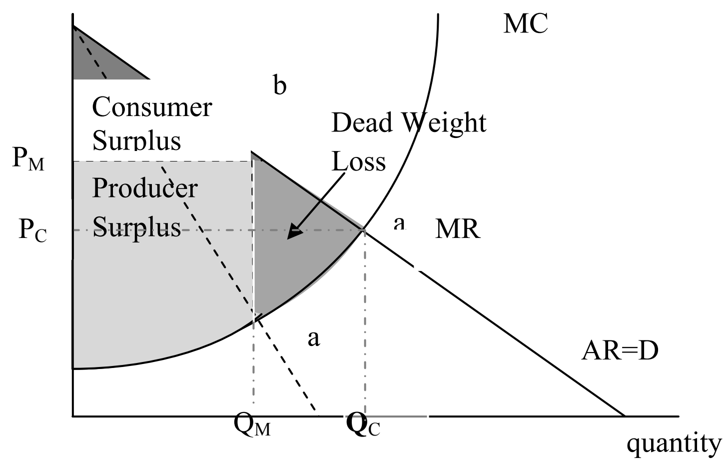
In Argentina the cost of bt cotton seeds required to sow one hectare of land is $103. It was shown that lowering the seed price would in fact increase the profits for Monsanto and D&PL until a price level of $58/ha (Qaim and de Janvry 2003). They concluded that lowering prices would result in larger profits for both the seed producers and the farmers.

India presents a unique case as this is the first time that a government body has intervened to impose pricing regulations on bt cotton hybrids. This action has evoked interesting debates on the merits and demerits of this regulation from policy makers, academics, farmers and farmer interest groups, public research organizations and private seed companies.

Monopoly and Price Controls-Economic Theory

Economic theory suggests that under monopoly, the monopolist increases total revenue and profits by pricing the goods above their marginal cost. The monopolist prices the goods at P_M and sells quantity Q_M , which is higher than the price P_C and lower than the quantity Q_C sold under perfect competition. Assuming that the monopolist has the same cost as a competitive firm, there results a deadweight loss (DWL) as shown by the triangular area in Figure 3.

Figure 3: Surplus distribution under Monopoly



One way to decrease this dead weight loss is for the government to impose price controls (as shown Figure 4), by setting selling price, P_{PC} equal to the marginal cost, MC. By lowering the price from P_M to P_{PC} not only increases the quantity available from Q_M to Q_{PC} , but also eliminates any DWL. There is gain in static efficiency [17] because DWL is minimized, but there may be a loss of dynamic efficiency[18] due to price controls. These controls reduce profits. Without profits,

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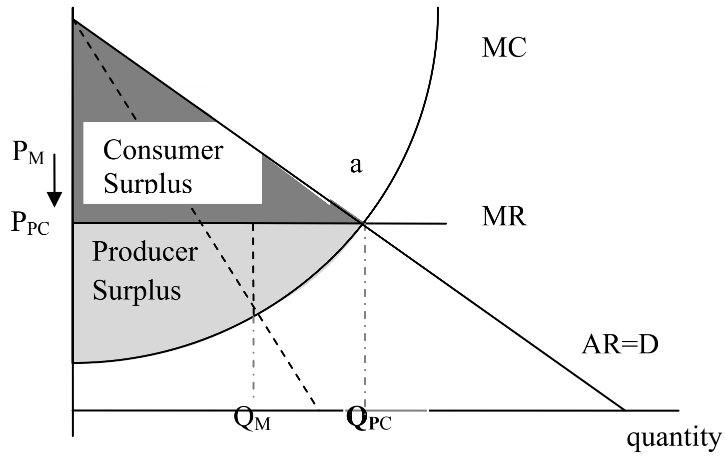
[17] "*Static efficiency refers to optimal allocation of resources at a point in time, like pricing the good at a lower price (near the marginal cost) to achieve the goal of efficient resource allocation in the short-run." (Sloan and Hsieh, 2007)*

[18] "*Dynamic efficiency, refers to efficient resource allocation over time, indicating pricing new goods higher to preserve incentives for research and development at the level at which the expected social returns on R&D investments equal the marginal cost of capital used to finance such investments. Dynamic efficiency thus refers to optimal resource allocation of investment effort in the long-run."(Sloan and Hsieh, 2007)*

or expectation of future profits companies are reluctant to take on expensive research. There is a loss for the society as farmers will be denied access to the latest technologies.

Figure 4: Imposing Price Control on a Monopoly



In the pharmaceutical sector, studies have been conducted, to better understand the impacts of imposing price controls on R&D investments and innovation by extension. Vernon estimates that a hypothetical price regulation would decrease the industry R&D intensity anywhere between 23.4% and 32.7% (Vernon 2005). Vernon along with two other researchers reports that pharmaceutical R&D intensity rises by 6% for every 10% increases in real drug price. Simulation based on regression models suggest that R&D spending would be 30% lower if the government intervenes and regulates prices. They further demonstrate that drug price control regime would have resulted in 330 to 365 fewer new drugs, reducing the new drug launches by 66% (Giaccotta, Santerre and Vernon 2005).

Impact of price controls on R&D and Innovation - Conceptual Framework

The framework explained by Vernon is based on the supply and demand framework for capital investment. The underlying principle is that firm's invest in capital until the expected marginal efficiency of investment (MEI) is equal to the marginal cost of capital (MCC) (Vernon 2005).

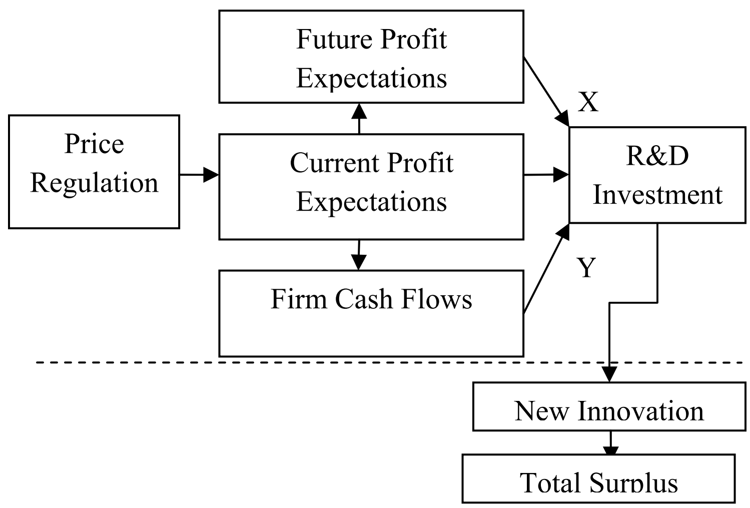
$MEI(R\&D,X) = MCC(R\&D,Y)$

$X \rightarrow$ Variables influencing the expected returns to R&D investment

$Y \rightarrow$ Variables influencing the opportunity cost of investment capital

$R\&D \rightarrow$ Firm's level of R&D investment

Figure 5: Possible impacts of price controls on R&D and Innovation



Source: Adapted from Vernon (2005).

Solving the above equation for R&D gives us the reduced-form solution of a firm's equilibrium level investment in R&D.

$R\&D^* = f(X,Y)$

Therefore, price regulation negatively affect R&D investment, mainly through two channels (a) Expected-Profit Effect, X and (b) Lagged Cash Flow Effect, Y. Therefore, price regulation negatively affect R&D investment, mainly through two channels (a) Expected-Profit Effect, X and (b) Lagged Cash Flow Effect, Y. We are concerned about these impacts because reducing R&D and innovation by the seed and biotech industry could reduce the benefits that farmers receive in the future. Thus the dynamic efficiency could be reduced because of price controls influencing the expected-profits.

3. IMPACT OF PRICE CONTROLS ON PROFITS OF FARMERS AND SEED COMPANIES

It is evident that the introduction of price controls in the year 2006, resulted in a sudden surge in the demand for bt cotton seeds in the cotton growing regions in India (Figure 1). Three reasons that could have caused the shift in demand curve outwards are:

- More farmers moving from conventional cotton to GM cotton due to "knowledge dissemination"
- More cotton farmers switching from illegal GM cotton to legal varieties due to reduced prices of the legal varieties
- The introduction of BG II and new events from JK AgriGenetics and Nath seeds, which have increased the portfolio of choices to farmers

In this context, in the following section, we have examined the effect of price controls on the welfare of both farmers and the firms (seed providers) during the years 2006 and 2007, using simple profit analysis. This was done by estimating the impact on spread of bt cotton area, seed sales and the seed prices under two regimes, namely, with and without price controls.

Data and Assumptions

Bt Cotton Area and Seed Sales [19]

<u>Data-With Price Controls</u>

USDA's Foreign Agricultural Services (FAS) publishes an annual report detailing the status of cotton production in India. The most recent version published in 2007 (Singh 2007) has information on the spread of bt cotton in India; segmented by both legal and illegal varieties

[19] Bt cotton seeds are sold in packets of 450 grams and it is recommended (and usually followed) that Indian farmers sow 1 acre of land with 1 packet of seed (for hybrids). Hence we assume that the number of packets sold is equal to the number of acres planted.

based on data supplied by the seed industry and government statistics. In addition, we also obtained detailed information on area under legal cotton varieties namely BG-1 and BG-II along with competitor's sales and illegal cotton seeds figures from Monsanto India Ltd.

Table 3: Actual Spread of bt Cotton from 2002 to 2007

Area: (million acres)	2002	2003	2004	2005	2006	2007
USDA Estimates[a]						
Legal Bt Cotton [BG-I],[BG-II]	0.069	0.222	1.235	3.211	9.386 [9.111],[0.275]	11.856 [10.196],[1.25]
† Area Data-Monsanto[b]						
Legal Bt Cotton	0.290	0.360	0.790	2.900	9.290	14.920
BG-I	0.040	0.120	0.644	2.471	8.439	12.833
BG-II	-	-	-	-	0.195	1.219
Competitors			0.145	0.430	0.651	0.864
Illegal Bt Cotton	0.100	0.380	1.520	2.320	3.756	2.931

Source: a-Singh, 2007, b-Monsanto Sales Data (Email Correspondence: MMB, in August 2008)
† excludes sales information for the states of Gujarat and Madhya Pradesh for the years 2002 through 2005

Using data from MMB, J.K AgriGenetics and Nath Seeds, we further estimated the market share of all the bt cotton suppliers. Table 4 shows the sales breakup for 2006 and 2007 of MMB, Nath Seeds and JK AgriGenetics.

Table 4: Actual Seed Sales with Price Controls

Sales: million packets Market Share: (%)	2005	2006	2007
MMB (BG-I)[a]	2.471 (100%)	8.439 (91%)	12.833 (72%)
MMB (BG-II)[a]	NA	0.195 (2%)	1.219 (7%)
Nath Seeds[b]	NA	0.250 (3%)	0.364 (4%)
JK AgriGenetics[c]	NA	0.401 (4%)	0.500 (5%)
Total legal Bt cotton	2.471 (100%)	9.285 (100%)	14.916 (100%)

Source: Constructed by Author using: a- Monsanto Sales Data, b- Damodaran (2006), c- Personal Communication: JK AgriGenetics, January 2008

Data Estimates- Without Price Controls

In the absence of price controls the area under bt cotton would have been considerably less because the price of the seed would have been twice as much. We were able to find two alternative estimates of what the area might have been. First, in discussions with MMB officials in 200, their best guess was that in the absence of price controls the 2006 of their Bt cotton would have been 6.1 to 7.0 million instead of the actual 8.5 million – that is 70 to 82% of the actual acreage. The prices controls were not imposed until halfway through the season. So, all of the farmers in northern India and many of the farmers in South India had already made their planting decision. In 2007 the price controls were in effect the entire season and so that impact would have been greater. Therefore we assume that 70% of actual acreage would have been grown in the absence of the price controls. These projections are found in Table 5.

An alternative scenario is the projections made by Dr Desai of Navbharat Seed in 2005 (Desai 2005). Using his extensive knowledge the cotton seed industry with the expectation that seed prices would remain at the high levels they were at before price controls, he projected area under legal bt at about 4.5 million acres in 2006 and 7 million in 2007 (Table 5). These are probably too low, but we also calculate the benefits using them.

Table 5: Estimated spread of bt cotton

Area: (million acres)	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsanto Sales Expectation WITHOUT price controls [a]						
BG-I					6.1-7.0	9.8
Desai(2005)[b]						
Legal Bt Cotton	0.070	0.230	1.300	**2.500**	**4.500**	**7.000**
Illegal Bt Cotton	0.150	0.600	2.000	**5.000**	**4.800**	**2.500**

a-Personal Communication: MMB January 2008, b-Actual data through 2004 and then projections 2005 to 2007, Desai (2005)

In our counterfactuals we assume that even without price controls the three companies would essentially command the same percentage of market share (91% MMB BG-1, 2% MMB BG-II, 3% JK AgriGenetics and 4% Nath Seeds in 2006, 72%, 7%, 4% and 5% respectively in 2007). According to our calculations the area covered would be as shown in Table 6.

Table 6: Estimated Seed Sales in the absence of Price Controls

Area: million acres	2005	2006	2007
MMB (BG-I)	2.500	4.090	5.033
MMB (BG-II)	0.000	0.095	0.478
Nath Seed	0.000	0.121	0.274
JK AgriGenetics	0.000	0.194	0.377
Total legal cotton	2.500	4.500	7.000

Source: Constructed by Author using Desai (2005) and market segmentation of MMB, JK AgriGenetics and Nath Seeds shown in Table 4.

Bt Cotton Seed Prices

Market prices-With Price Controls

Table 7 shows the trends in bt cotton seed prices since 2002. From 2002 to 2004 bt cotton seeds were sold at $45 out of which $30 dollars constituted the technology fee. In 2005 the prices were reduced to $39/packet. Since price controls went into effect, all bt cotton seeds were sold at $18/packet of 450 grams of seed.

Table 7: Seed Prices and Contract Prices for legal seeds

$/packet	2002	2003	2004	2005	2006	2007
Avg. Seed Price for BG-I	45	45	45	39	18	18
Technology Fee	30	30	30	22	9	9

Source: Compiled by the Author using market data.

Market prices – Without Price Controls

It is also known that in year 2005, at the onset of the antitrust case; MMB dropped the prices from $39 to $29/packet of 450 grams of seeds. Had the government of Andhra Pradesh not released an ordinance mandating prices MMB would have continued to sell the seed at the same price through 2006 and 2007. During our interviews, Nath Seeds and JK AgriGenetics reported that their proposed price (in the absence of price controls) was $22/packet (of 450 grams of seeds).

Calculations and Analysis

Calculation of Farmer Benefits

Table 8 summarizes the farm level studies conducted comparing the costs and benefits obtained from the cultivation of bt and non-bt cotton varieties in different regions in India. Almost all the studies concluded that the amount spent on bt cotton seeds was higher than the perceived benefits out of pesticide usage. However, it should be noted from these studies that farmers achieved higher yields, thus earned increased profits or revenue (yield x price of cotton) and returns (revenue – total cost) than non-bt growers.

Table 8: Summary of Past Bt Cotton Studies

Name of author(s)	Year	Sample Size	States	Pesticide Cost + Seed Cost ($/acre)	Total Cost ($/acre)	Yield (kg/acre)	Revenue ($/acre)	Returns ($/acre)
Qaim and Zilberman 2003	2001	157	Maharashtra, Madhya Pradesh, Tamil Nadu	16	28	283	136	108
Bambawale et al, 2004	2002	NA	Maharashtra	20	23	215	121	98
Bennett et al, 2004	2002	2709	Maharashtra	7	NA	275	134	126
Bennett et al, 2004	2003	787	Maharashtra	1	NA	352	215	214
Qaim et al, 2006	2002	341	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	5	30	208	82	**53**
Gandhi and Namboodiri 2006	2004	694	Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu	15	41	303	152	**111**
Dev and Rao 2007	2004	623	Andhra Pradesh	5	29	228	104	75

Source: Modified by the author from Ramaswami (2005)

Of the field studies summarized in Table 8, only two studies (Qaim and Zilberman 2006; Gandhi and Namboodiri 2006) covered all the major cotton growing zones, namely central and southern states in India. Therefore for this study, the profit levels reported by the above two field studies were used to calculate the monetary benefits of the farmers by the adoption of BG-I.

Accordingly, the profit estimates by Qaim et al (2006) was used to project the worst case scenario and the profit levels indicated in Gandhi and Namboodiri (2006) was used to calculate the best case situation that an Indian farmer can achieve in good cotton growing conditions. It is also assumed that the profits projected here could be between the best and worst case scenarios. The cumulative profits made by the farmers is given by the equation

$$\Pi^{C} = (\Pi_{MMB} \times A_{MMB}) + (\Pi_{Nath} \times A_{Nath}) + (\Pi_{JK} x A_{JK})$$

Π^{C}	Cumulative profits to farmers	(million $)
A_{MMB}	Area covered by seeds from MMB or sub-licensees	(million acres)
Π^{A}_{MMB}	Average profit to farmers using bt cotton seeds from MMB or sub-licensees	($/acre)
A_{Nath}	Area covered by seeds Nath Seeds	(million acres)
Π^{A}_{Nath}	Average profit to farmers using bt cotton seeds from Nath Seeds	($/acre)
A_{JK}	Area covered by JK AgriGenetics	(million acres)
Π^{A}_{JK}	Average profit to farmers using bt cotton seeds from Nath Seeds	($/acre)

With the above specification, short-term benefits for farmers are projected under 2 scenarios, with and without price controls, under perfect market conditions.

Farmer profits under Price Controls

The projections based on the farm studies considered in this study were conducted during 2002 and 2004 respectively, when the seed prices were as high as $45/packet (Table 7). With price controls imposed in 2006, the seed costs were subsequently reduced to $18/acre. Hence it could be estimated that with price controls in effect, the farmers would make an additional profit of $27/acre (=$45-$18). This would lead to a maximum profit of $138/acre (=$111+$27) and a minimum profit of $80/acre (=$53+$27) for the farmers per acre of bt cotton.

Farmer profits without Price Controls

Using the price assumptions that MMB would continue to sells seeds at $29/acre; the farmers would now have to spend $16 (=$45-$29) less per acre in 2006 and 2007 compared to what they had to spend in 2002 through 2004. The lower bound average profits for farmers using MMB $69/acre (=$53+$16) and the upper bound average profit for farmers using MMB would be $127/acre (=$111+$16). We assumed that Nath Seed and JK AgriGenetics would continue to sell their seeds at $22/acre in 2006 and 2007 thus it would lead to an additional profit of $23/acre (=$45-$22). Hence the lower bound profits for these farmers would $76/acre (=$53+$23) and upper bound profits would be $134/acre (=$111+$23).

Table 9: Profits to Farmers (due to adoption of BG I)

Years		**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
LOWER BOUND: Qaim et al(2006)							
WITH Price Controls $\Pi^A_{MMB} = \Pi^A_{Nath} = \Pi^A_{JK}$: 80 $/acre	**Area[a]: million acres**	0.069	0.222	1.235	3.211	9.111	10.606
	Profit: million $	6	18	99	257	**729**	**848**
Desai Estimates WITHOUT Price Controls Π^A_{MMB}: 69 $/acre $\Pi^A_{Nath} = \Pi^A_{JK}$: 76 $/acre	**Area[b]: million acres**	0.070	0.230	1.300	2.500	4.405	5.954
	Profits: million $	4	12	69	133	**306**	**397**
Change in Profits:	**million $**					**423**	**452**
UPPER BOUND: Gandhi and Namboodiri (2006)							
WITH Price Controls $\Pi^A_{MMB} = \Pi^A_{Nath} = \Pi^A_{JK}$: 138 $/acre	**Area[a]: million acres**	0.069	0.222	1.235	3.211	9.111	10.606
	Profit: million $	10	31	170	443	**1257**	**1464**
Desai Estimates WITHOUT Price Controls Π^A_{MMB}: 127 $/acre $\Pi^A_{Nath} = \Pi^A_{JK}$: 134 $/acre	**Area[b]: million acres**	0.070	0.230	1.300	2.500	4.405	5.954
	Profits: million $	8	26	144	278	**681**	**726**
Change in Profits:	**million $**					**576**	**737**

Source: Authors estimates
a-Singh 2007
b-Desai 2005 estimates for the projected areas

Analysis of Seed Industry Profits

Estimates of Profits to MMB

Since Monsanto does most of the research and product development in the US, the R&D costs are assumed to be sunk costs; hence the marginal cost of producing one extra unit of technology in India is constant. 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 perfectly elastic supply of bt cotton technology. As mentioned earlier, Monsanto distributes bt cotton 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.

Π = (quantity x royalties)

Monsanto's profit is nearly half of this. As mentioned earlier, we assume that without price control BG-I would sell at $29 (and approximately 70% i.e., $20 would be the technology fee).

Table 10: Estimate of MMB Profits from the sales of BG-I

Year		2005	2006	2007
WITH Price Controls	**Sales : million packets[a]**	3.100	8.439	12.833
	Profits: million $	54	76	115
WITHOUT Price Controls (Desai estimates)	**Sales: million packets[b]**		4.090	5.033
	Profits: million $		82	101
% difference from actual sales			106%	155%
% difference from actual profits[d]			-7%	15%
WITHOUT Price Controls (Monsanto estimates)	**Sales : million packets[c]**		6.550	9.8
	Profits: million $		131	196
% difference from actual sales			29%	31%
% difference from actual profits[d]			-42%	-41%

Source: Calculated by the Author utilizing Royalty Data in Table 7 with, a-Monsanto Sales data given in Table 4; b-Desai (2005), estimates for the projected areas in Table 5; c- Monsanto expectations in Table 5
d = $\Pi_{\text{(With Price Controls)}} - \Pi_{\text{(Without Price Controls)}}$

The above table shows 3 scenarios- 1 actual and 2 alternatives. We see that scenario I- which uses estimates given by Navbharat Seeds (Desai 2005), indicates that in 2007 MMB actually profited from the price controls. MMB believes that they are taking a huge cut in profits as a result of price controls as calculated in Scenario II.

Estimates of Profits of Nath Seeds and JK AgriGenetics

The profit estimates of new firm players such as Nath Seeds and JK AgriGenetics were calculated to estimate costs incurred due to regulation. Both companies paid an initial license fee which is considered as a sunk cost. They also paid royalty fee i.e., 4% of their total sales.

Π = (quantity x sale price) – (royalty x sale price) – (MC of seed production)

Hence the profit/packet

=> (1x18)-(0.04x18)-11=$6/packet, where $11 is the marginal cost[20].

Without the price control it is likely that the seeds would have sold at $22/packet, the profits would have been

=> (1x22)-(0.04x22)-11=10$/packet

According to JK AgriGenetics, they incurred loss in revenue though 500,000 packets were sold in the year 2007, due to 30 % reduction in seed prices due to the current price control. Due to this situation,JK AgriGenetics, has planned to engage in sub-licensing their technologies to other firms in the coming years to increase their sales revenue. (Personal Communication: JK AgriGenetics, January 2008).

Table 11 summarizes the estimates on the profits made by JK AgriGenetics and Nath Seeds with and without price controls. It is evident that both JK and Nath Seeds have made higher profits in the year 2006 than in 2007. A more detailed version of this table could be found in Appendix C.

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[20] *Govt of AP v MMB and sublicensees.* I.A. No 05/2005 RTPE 02/2006 (Monopolies and Restrictive Trade Practices Commission, New Delhi May 11, 2006).

Table 11: Profits of Domestic Seed companies

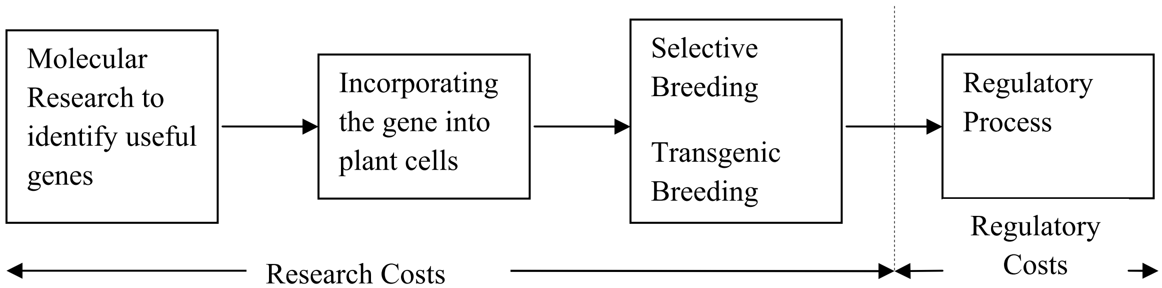
Year			2006	2007
NATH SEEDS	WITH Price Controls	Sales: million packets	0.250	0.364
		Profit: million $	1.500	2.184
	WITHOUT Price Controls	Sales: million packets	0.121	0.274
		Profit: million $	1.212	2.744
	% difference in sales		106%	33%
	% difference in profits		24%	-20%
JK AGRIGENETICS	WITH Price Controls	Sales: million packets	0.401	0.500
		Profit: million $	2.406	3.000
	WITHOUT Price Controls	Sales: million packets	0.194	0.377
		Profit: million $	1.943	3.770
	% difference in sales		106%	33%
	% difference in profits		24%	-20%

Source: Calculated by the Author

4. BENEFITS OF FUTURE TECHNOLOGIES

Ag-biotech companies invest a lot of time and money in order to do research and get novel traits into the market. Below (Figure 6), is a diagrammatic representation illustrating the process of getting a new gene or event into the market. There are two kinds of costs incurred – Research costs and regulatory costs.

Figure 6: Development and release of new gene/event



Source: Author

(I) R&D Expenditure: Agri-biotech research is very competitive and companies do all it takes to have an edge over their competitors. Overall, the average time required for the development of a transgenic crop is seven years and the average cost of development is $7 million (IFPRI and RIS 2007). Licensing genes from Monsanto requires a lump sum payment and followed by substantial royalties on every sale; licensing genes from the Indian public sector cost approximately $ 12,000, licensing an event in a plant could cost double. Added to this, are the regulatory costs and additional 4% royalties on sales (Email Correspondence: Nath Seeds, April 2008).

JK AgriGenetics, a relatively new player in the market invest about 13-15% of their sales revenue back into R&D and have tie-ups with both local institutes: Indian Institute of Technology in Kharagpur (IIT-K), Delhi University, Madurai Kamaraj University, and with several international organizations such as International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Rice Research Institute (IRRI), and The International Maize and Wheat

Improvement Center (CIMMYT). Bioseeds is in the process of strengthening their R&D capacities; funneling 8% to 10 % of their turnover in into research (Personal Communication: January 2008).

(II) Regulatory Costs: At present, India has a three-tier regulatory system for GM crops: Institutional Bio-Safety Committee (IBSA), a body within the research organization which carries out assessments of research proposals; a national Review Committee on Genetic Manipulation (RCGM) to assess field trials for environmental safety and allergic responses; and the Genetic Engineering Approval Committee (GEAC) — which is part of the environment ministry — which carries out environmental impact assessment, approves multi-location field trials and commercial cultivation.

When Monsanto first applied for the regulatory clearance of bt cotton in 2002, pre-approval costs (feeding studies, limited field trials, multi location field trails, large scale trails) and post-approval studies (socio-economic studies, resistance studies, office expenses etc) added to about $195,000 (Pray, Bengali and Ramaswami 2005)[Detailed description of the costs given in Appendix E]. "Event 1" (by JK AgriGenetics) took 2-3 years for R&D (IIT-K) and then trials were conducted from 2003 to 2006 – which constituted the bulk of their costs. (Personal Communication: JK AgriGenetics, January 2008).

Future Implications

Companies invest capital and labor; spend 5-7 years doing research followed by 2-3 in the regulatory procedure, and they intend to recoup the costs by pricing their product accordingly. The current situation is that all bt cotton seeds, irrespective of the source of gene or the company selling the hybrid, are regulated by price controls. In fact for the cotton growing season of 2008, States have taken control, regulating the price of BG-I and BG-II at $ 18 and $ 16 – respectively for 450 gram packet of seed (Email Correspondence: MMB, June 2008). During our interviews several (but not all) seed companies pointed out that price controls definitely makes it less attractive for them to invest in R&D and the introduction of new technology.

The government imposed price controls could have a negative impact on innovation in two ways. First, the companies especially multinationals may not invest in seeking approval for the release of new GM traits in India. For example, in China where there is virtually no protection of biotech intellectual property rights Monsanto has not even attempted to introduce BG-II or any other traits since they introduced BG-I in 1997. Second, as already mentioned, both India and multinational companies may defer investments in research in traits /varieties that would benefit the Indian market in particular. For example, Monsanto India pointed out that research and development of genes with resistance to sucking pests like thrips, leafhoppers and aphids may go unexplored, albeit there is a huge demand in India for such varieties and given that the farmers would benefit greatly from it (Personal Communication: Monsanto India Ltd, January 2008).

It would be challenging for seed companies and technology entities (public institutes or private research institutes) to formulate licensing agreements. As of now, is uncertain as to how long the States will choose to mandate and the industry is still awaiting the final verdict by the Supreme Court. Also, at this point, it is unclear how the new competition policy is going to affect this issue.

Currently genetically modified food and non-food crops are in various stages of the regulatory process. Table 12 contains an exclusive list of transgenic cotton from various multinational and domestic companies with explanation about the trait and details about the status. Once approved many of them are expected to bring benefits to the farmers as a number of these are stacked genes rendering additional protection against weed and drought. Herbicide Tolerant (HT) and Drought Tolerant (DT) varieties are particularly examples of cost saving technologies, which may greatly benefit farmers. In case a few or all of these varieties are delayed from entering the market as planned, welfare loss to farmers would result.

Table 12: Genetically Modified Bt Cotton Varieties/Traits in the Pipeline

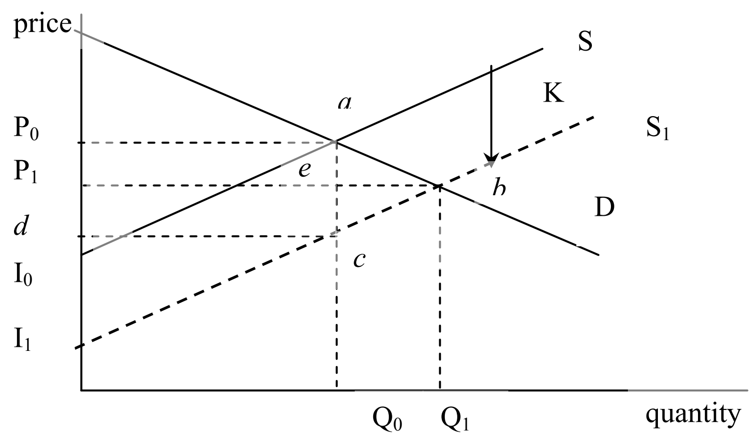
Name	Company	Status	Comments
VipCot[A] (Vip Cotton)	Delta Pine India Seed Pvt Ltd, Hyderabad	field trials Maybe 2009	Contains Vegetative insecticidal protein — discovered by Syngenta in 1994. This unique protein controls target lepidopteran pests by binding to specific receptors in the gut of the pest, disrupts its gut, causing the pest to quickly stops feeding and soon die.
WideStrike[B]	Dow Agro Science, Mumbai	Approval process	Contains *cry1Ac* & *cry1F* and renders protection against the tobacco budworm
Stacked Bt Genes[C]	Metahelix	Field trials in 2007	*cry1C* (Spodoptera control) and *cry1Ac* (Bollworm control)
Stacked Bt genes[D]	JK AgriGenetics	Possibly 2010	Stacked *cry1EC* gene & *cry1Ac* obtained from a publicly funded laboratory – the Council of Scientific and Industrial Research's (CSIR) National Botanical Research Institute, Lucknow. India.
BG-II RR flex[E] (HT)	Monsanto	Currently in MLRT	Stacked *cry1Ac*, *cry2Ab* (Event 15985) and *CP4epsps* (MON 88913). Allows applications of approved glyphosate herbicides up to seven days prior to harvest, providing a more flexible application window.
DT[F]	Monsanto	Estimated 2015	Undergoing experimental trials in Australia
Fertilizer efficiency[G]	Monsanto	N/A	Efficient use of fertilizer
DT[H]	Nath Seeds	unknown	Working on a Bt gene event from BTCC
HT[I]	Nath Seeds	N/A	Under consideration

Source: Compiled by the Author using:
(A) http://www.syngentacropprotection-us.com accessed on 03/19/2008 (B) GEAC ((Genetic Engineering Approval Committee 2008)2008) (C) http://www.meta-helix.com accessed on 04/02/2008 (D) (Hindu Business Line 2007) (E) Personal Communication: Monsanto India Ltd, January 2008 (F) & (G) (Jha 2007) & http://www.monsanto.com accessed on 3/20/2008 (H) & (I) Email Correspondence: Nath Seeds, April 2008.

Data and Framework for Measurement

To estimate the change in total surplus for cotton producers due to adoption of herbicide tolerant and drought tolerant varieties we use the model developed by Alston, Norton and Pardey (1995). This model was developed to help analyze the welfare effects of new agricultural technology in a partial equilibrium framework using the concept of economic surplus.

Figure 7: Surplus distribution in the basic model of research benefits



Source: (Alston, Norton and Pardey 1995)

For a closed economy, the initial demand curve is given by D and the supply curve prior to the availability of technology is S. The equilibrium price and quantity are denoted by P_0 and Q_0 respectively. Availability of new technology shifts the supply curve right from S to S_1; and the new equilibrium is at a lower price, P_1, and higher quantity, Q_1. The supply shift is assumed to be parallel.

Introduction of new technology results in an increase in total surplus. The entire area situated between S and S_1 and bordered on the upper right-hand side by the demand curve D denotes the societal gains (the aggregation of consumer and producer surplus). The gain in consumer surplus is given by P_0abP_1. Difference in the area bounded by P_1bI_1 and area bounded by P_0aI_0 gives change in the producer surplus.

Mathematically,

$$\Delta CS = P_0 Q_0 Z(1 + 0.5Z\eta)$$
$$\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5Z\eta)$$
$$\Delta TS = P_0 Q_0 K(1 + 0.5Z\eta)$$

K→ vertical shift of the supply curve as a proportion of initial price

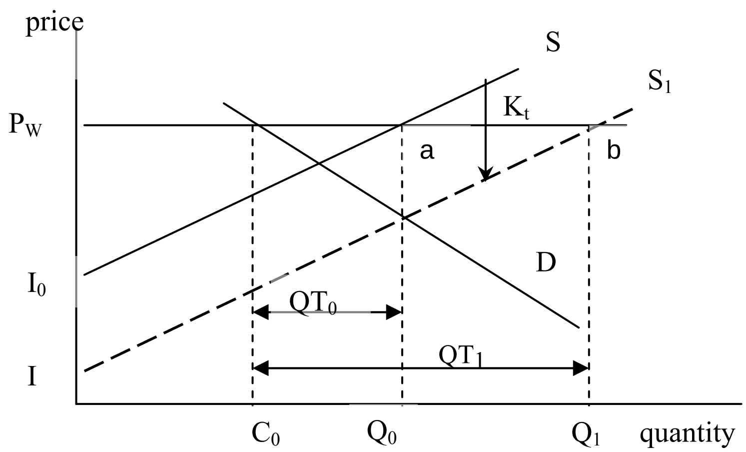
ε→ elasticity of supply

η→ elasticity of demand

Z→ Kε/(ε+η)

Twenty percent of India's raw cotton is exported (Singh 2007) and as mentioned earlier it forms only seven percent of the worlds' exports. We assume that India does not influence the international prices, hence for this study purpose we look at it as an ***open*** economy.

Figure 8: Social welfare benefit from technology improvement in an open economy



Source: (Alston, Norton and Pardey 1995)

Figure 8 illustrates the impact of research on an exporter. Before the availability of new technology, C_0 is the initial consumption and Q_0 initial production, QT_0 represents the exports, equal to the difference between consumption and production. The world price P_W denotes the opportunity cost of resources used in production and consumption. The availability of new technology (herbicide and drought tolerant varieties in our case) causes the supply curve to shift from outwards from S_0 to S_1. There is a corresponding increase in (cotton lint) production, Q_1 due to which exports increase to QT_1.

Since India's cotton exports constitute only 7% of the world cotton exports we assume that the world price remains unaffected due to increased supply. The economic surplus change is all producer surplus, in our case the cotton farmers.

$$\Delta PS = \Delta TS = P_W Q_0 K_t (1 + 0.5 K_t \varepsilon)$$

Given the information on potential yields changes, adoption rates, the absolute reduction in costs per unit of production K_t, can be projected as follows.

$$K_t = [\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1 + E(Y)}] pr(t)(1 - \delta)$$

$E(Y)$ is the expected proportionate yield change per unit of area due the new transgenic varieties, presuming research is successful and is fully adopted, $\frac{E(Y)}{\varepsilon}$ converts the proportionate yield change to a proportionate gross reduction in marginal cost per unit of output. In India cotton has a long term supply elasticity of 0.54 (Acharya and Agarwal 1994). $E(C)$ is the expected cost change, *p* is the probability of successfully leading to a new technology, assumed to be 100% in our study because both herbicide tolerant and drought resistant traits have already been tested for efficacy and have been incorporated into plants. r(t) is the predicted adoption rate. Adoption rates would follow a logistic pattern, slowly rising from zero coverage to a maximum coverage of 71.8% of the total cotton growing area in about seven years, as predicted by industry expert Dr. Desai (Desai 2005). δ is the declining-balance rate of depreciation in the new technology (we ignore this parameter for our calculations). For the purpose of hits study we only do a static analysis assuming the world price P_w constant at the 2005 price level.

Analysis of changes in Economic Surplus due new technologies

Simulating the benefits of weed resistant cotton

BG-II RR Flex is currently undergoing MLRT in 8 locations and scheduled for market release in 2011. Once available it is expected to save cost mainly by reducing or eliminating the need of manual labor.

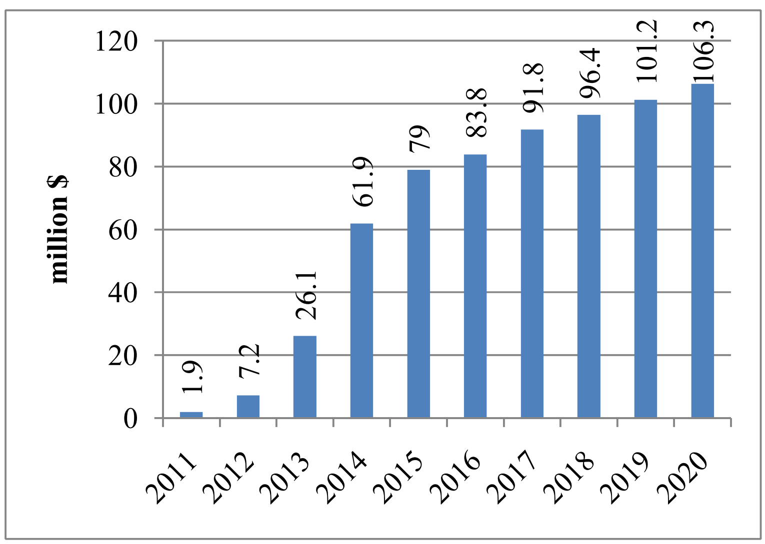
Table 13: Cost of Weeding in Gujarat ($/acre)

Mean	N	Std. Deviation	Sum	Minimum cost	Maximum cost
21.89	158.00	20.28	3457.97	1.16	128.05

Source: Gujarat Institute of Development Research

In a recent household survey conducted in the state of Gujarat it was estimated that farmers on average spend $21.89/acre for weed removal (Personal Communication: Gujarat Institute of Development Research, July 2008). It is estimated that the total cost of bt cotton cultivation in Gujarat is about $340/acre (Gandhi and Namboodiri 2006), out of which weeding constitutes 6%. So herbicide tolerant technology has potential to reduce the total cost of cultivation by 6%,i.e., E(C) is 6% in our economic surplus model and we use that to estimate the change in total surplus. [See Appendix F for details]

Figure 9: Change in total surplus due to adoption of BG-II RR flex (million $)



Source: Calculated by the Author using the economic surplus model

If farmers decide to adopt herbicide tolerant crops, they would enjoy up to $106 million dollars in additional surplus.

Simulating the benefits of drought resistant cotton

Sixty percent of the agricultural area is rain-fed and according to the agricultural statistics published by the Indian Ministry of Agriculture, for the year 2003-2004 (latest year available), 27.1% of the area under cotton production was irrigated.

Cotton seeds are planted after the first showers of the monsoon season and in case of an extended period of drought later on farmers have to replant; sometimes several times. Drought resistance varieties are designed to withstand drought even later in the season. Benefits would be saving of expense of replanting and higher yields. Seed companies see market opportunities for drought tolerant varieties.

Data: We use time-series data ranging from 1950 to 2006. The yield and irrigation data was acquired from the archives of the Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India and the rainfall information was gleaned from the archives of the Indian Institute of Tropical Meteorology. The years of drought were marked by IRRI researchers (Pandey, Bhandari and Hardy 2007) in their study on the effects of drought on rice production in India, and we use the same information to perform our statistical analysis.

Table 14: Variable Description and Summary (N = 57)

Variable*	Description	Mean	Range
Yield[a]	Yield of Cotton, Kg/acre	74.95	37.44-172.69
Rainfall[b]	Aggregate rainfall experienced in the months of June, July, August & September, cm	843.46	653.1 – 1020.5
Drought[c]	Dummy variable, drought years are denoted by 1	--	--
Irrigated Area[a]	area under irrigation, million acres	.831	0.212-1.438
Time	Year, a time variable to capture technological changes.	---	1950-2006

Source of the data: a-Ministry of Agriculture; b- Indian Institute of Tropical Meterology (http://www.tropmet.res.in); c- (Pandey Bhandari and Hardy, 2007)

Models: To estimating the impact of drought on cotton yields we use simple OLS regression models. Models 1 and 2 are identical to the models already used to study the impact of rainfall and drought on rice production in Northern India (Pandey, Bhandari and Hardy 2007).

1. *Yield = a + bTime + cRainfall + dRainfall2 + u*

In this model, the production function is a quadratic function of rainfall as well as too much rainfall is bad for the crop. Coefficients c and d measure the response to rainfall. Theoretically we expect c>0 and d<0.

2. *Yield = a + bTime + cDrought + u*

This model is a linear trend equation where drought is specified as a discrete dummy variable.

3. *Yield = a + bDrought + cIrrigatedArea + u*

We also have an alternate model where we have both the dummy for drought and a variable for the area under irrigation.

Results:

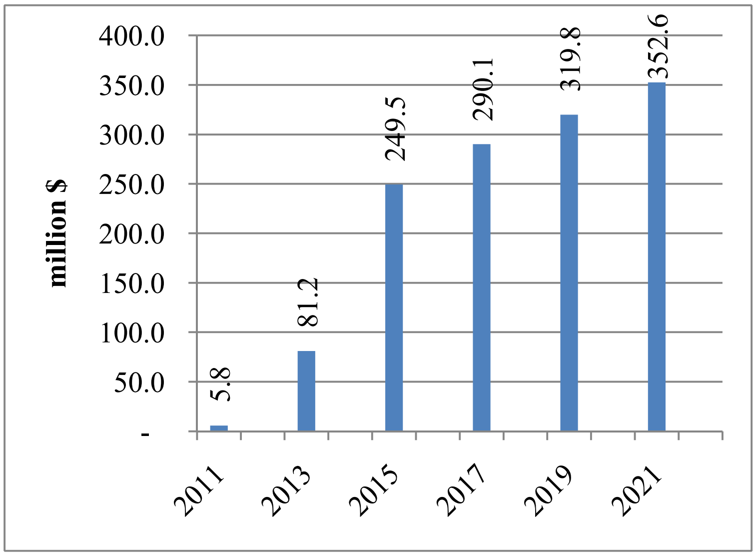
Table 15: Regression Results for yield models (N=57)

Parameter	Value	Parameter	Value	Parameter	Value
MODEL 1		**MODEL 2**		**MODEL 3**	
Intercept	-3608.89	**Intercept**	-3.33.931	**Intercept**	23.11
Time (t-value)	1.64 (14.67)	**Time**	1.62 (14.00)		
Rainfall (t-value)	0.99 (2.67)	**Drought**	-7.66 (-2.00)	**Drought**	-9.16 (-1.8)
Rainfall^2 (t-value)	-.0006 (-2.56)			**Irrigated Area** (t-value)	7.21 (9.35)
F-value	80.74	**F-value**	108.56	**F-value**	49.68
Adjusted R^2	.81	**Adjusted R^2**	.79	**Adjusted R^2**	.63

Source: Estimated by the Author

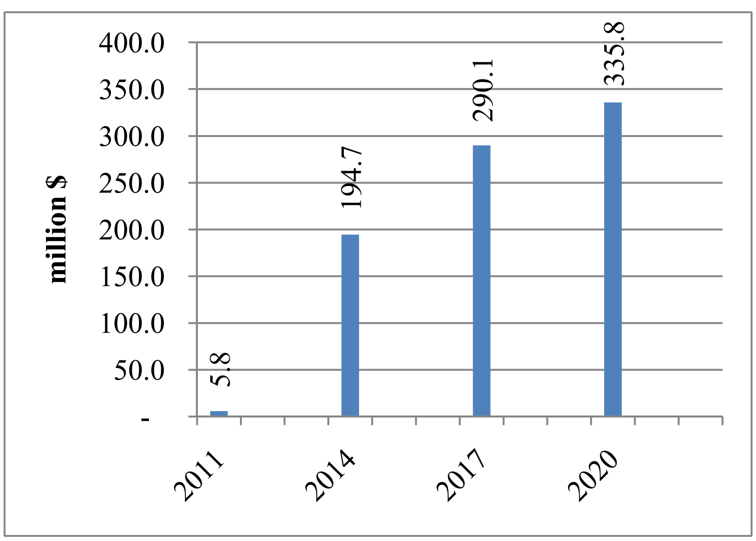
The results of the OLS models are presented in Table 15. Looking at the results of Model 2 we can assume that in case of drought the yield decrease is about 10% approximately. We use this as the yield change due to the introduction of new technology, i.e., E(Y) is equal to 10% in our economic surplus model. Estimates are calculated for occurrence of drought every 2 years and every 3 years as shown in Figure 10 and 11 [detailed spread sheet can be found in Appendix F]. We see that in drought years these varieties help provide financial security to the farmers and at maximum adoption levels the total savings could be up to $300 million.

Figure 10: Change in total surplus when there is drought every 2 years (million $)



Source: Calculated by the Author using the economic surplus model

Figure 11: Change in total surplus when there is drought every 3 years (million $)



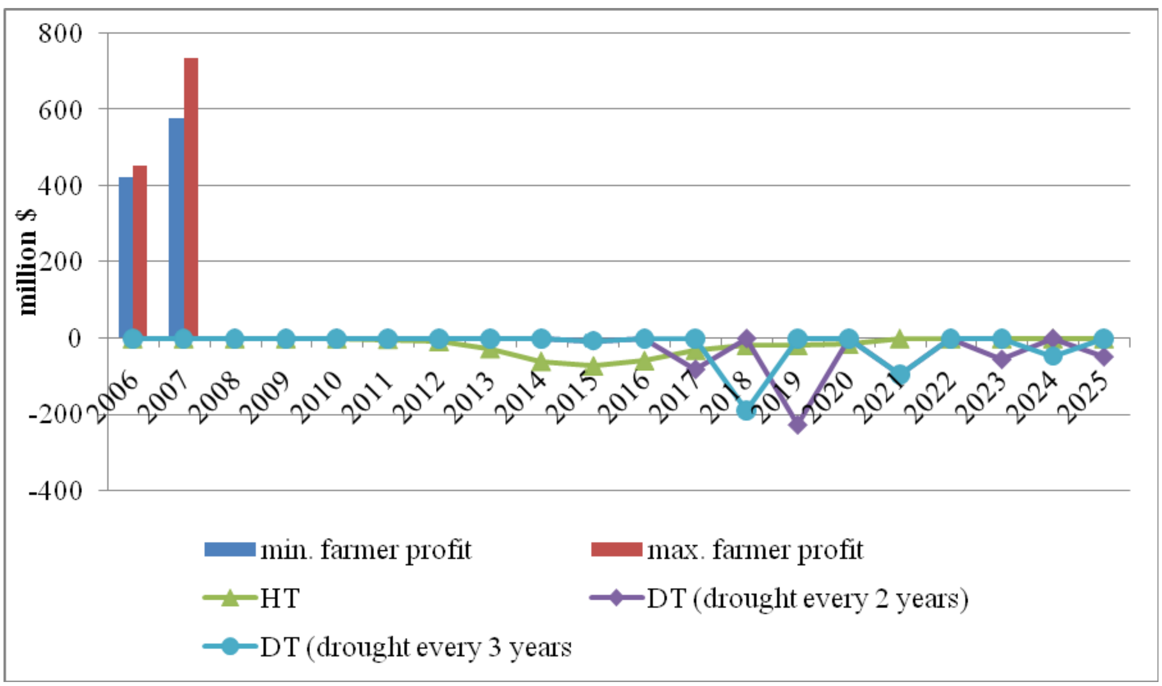
Source: Calculated by the Author using the economic surplus model

Impact on Economic Surplus in the Future

In case price controls continue to be implement well into the future, companies, mostly multinationals could put a hold on the release of new varieties into the Indian market while they make substantial profits in other countries. In such a scenario the farmers will have to forego the possible benefits that technologies bring for some years. During our interviews with seed companies we got an idea that this time lag could be at least 3 years and at most 5 years. To estimate the benefits lost due to the delay, we take the difference of the benefits lagged by 3 years and the current benefits [as shown in Figures [09, 10 and 11].

Figure 12 compares the current benefits to the benefits foregone due to a 3 year lag. We see that the price regulations provide farmers with much higher gains and they need not be concerned about significant welfare loses in the near future.

Figure 12: Comparison of current benefits to benefits foregone in the future



Source: Author using the analysis done in Chapter 3 and Chapter 4.

5. CONCLUSIONS

Implications

According to a study conducted in the initial years of Bt cotton adoption (Pray Bengali and Ramaswami 2005) the biggest hurdle in commercialization of GM modified crops in India was the inefficient regulatory processes and huge compliance costs. Since then lot of changes have been brought about to make the regulatory process efficient as well as cost effective. In mid 2007, a temporary moratorium was issued by the Supreme Court against field trials of GM crops in response to public interest litigation. Though this issue was resolved by the end of the year and the ban partially lifted, economic losses are likely due to delay in the release of bt eggplant, bt maize, and other crops.

Currently, one of the major challenges facing the Indian firms involved in bt cotton seed provision is the government imposed price controls. Here an attempt has been made to conduct a preliminary assessment of the economic repercussions of this price control primarily on farmer benefits and also on future technology benefits. Some of the findings of the study are as follows:

- Price controls were imposed to enhance the benefits to the farmers, and they definitely serve the purpose. We see that farmers enjoy substantially increased profits from 2006 onwards compared to previous years.
- Owing to the sudden increase in demand, after price controls, seed companies are definitely making increased sales. But our calculations show that they are making less than expected profits.
- At this point it is difficult to say the exact impacts on future R&D investments and innovation. In case there is delay on the release of new technology the farmers definitely stand to lose out on potential benefits from new and improved technologies in the future. The results from this study suggest that the short-term benefits from the

current policies seem to outweigh potential losses in the long-term.

It should however be noted that there could be additional losses that are largely unaccounted for in this study. MMB has decided to stop selling BG-II in Andhra Pradesh starting kharif season of 2008. This was in response to the new mandate stating that the price of BG-II would be capped at the level of BG-I. Recently, Monsanto indicated that they would be less likely to start research programs to develop varieties that are resistant to important sucking pests that are primarily a problem in India. There is a possibility that other multinationals could also slow down research and introduction of new technology in India.

Indian ag-biotech/seed companies claim that these price controls will not affect the amount or direction of their research or introduction of new GM crops; in fact they seem to welcome it as it reduces the profit of MMB. Because the GM traits they use can be purchased very inexpensively from the Indian public research institutes and from institutes in China, domestic companies claim to be making substantial profits even with low prices. There are a few small companies like Metahelix who are now trying to develop new genes. It is unclear as to how they would be affected.

Future Work

This is a study with a narrow focus in terms of impact on new technologies in the future, where we have tried to look at RR Flex and DT cotton without accounting for discounts or the changes in world price of cotton. We know nothing the potential benefits of other technologies such as VipCot or Widestrike, whether they would be delayed, and how they could alter the market dynamics once available for commercial cultivation.

Also, the benefits to farmers due to BG-II are largely omitted out of our study due to the unavailability of neither data on actual benefits nor academic studies detailing the benefits. The only evidence that BG-II is beneficial comes from a study commissioned by Monsanto, India and performed by International Market Research Bureau (IMRB). Also, our study does not attempt to calculate the benefits foregone due to possible delays in release of GM food crops

It would be interesting to attempt to understand the effect of the governmental pricing regulation on innovation. We do have some idea about the capital spent on research by ag-biotech seed companies [See Appendix D], but there is little to no India specific data available on new gene patents applied. An elaborate survey of seed companies may have to be undertaken in order to overcome the limitation. Another way to examine the effect of price controls would be to commission a study to gauge the dead weight losses before and after the pricing regulations.

Some of the factors influencing a private seed firm's investment in R&D are (1) size of the potential market for new products from research and the price elasticity of demand (2) ability of the firm to capture some of the benefits from the new technology (3) cost of developing the new technology (4) Contract legislation and enforcement (5) IPR regime, Anti-trusts policy and competition policy (Pray and Umali-Deininger, 1998). We have already seen that there is a huge market for cotton technology and that farmers are willing to adopt new beneficial technology. Most of the seed firms especially multinational are attracted by the inexpensive labor costs that India has to offer. Indian government needs to take initiative to strengthen the last 2 caveats to make it more conducive for firms to pursue R&D and do business.

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APPENDIX A: Map of India

Source: India Travel Trendz http://www.indiatraveltrendz.com/

APPENDIX B: Section 12-A of the MRTP Act

POWER OF THE COMMISSION TO GRANT TEMPORARY INJUNCTIONS

(1) Where, during an inquiry before the Commission, it is proved, whether by the complainant, Director General, any trader or class of traders or any other person, by affidavit or otherwise, that any undertaking or any person is carrying on, or is about to carry on, any monopolistic or any restrictive, or unfair, trade practice and such monopolistic or restrictive, or unfair, trade practice is likely to affect prejudicially the public interest or the interest of any trader, class of traders or traders generally or of any consumer generally, the Commission may, for the purposes of staying or preventing the undertaking or, as the case may be, such person from causing such prejudicial effect, by order, grant a temporary injunction restraining such undertaking or person from carrying on any monopolistic or restrictive, or unfair, trade practice until the conclusion of such inquiry or until further orders.

(2) The Provisions of rules 2A to 5 (both inclusive) of Order XXXIX of the First Schedule to the Code of Civil Procedure, 1908 (5 of 1908), shall, as far as may be, apply to a temporary injunction issued by the Commission under this section, as they apply to a temporary injunction issued by a civil court, and any reference in any such rule to a suit shall be construed as a reference to an inquiry before the Commission.

APPENDIX C: Profit Calculations for Seed Providers

			2006	2007
MMB:BG-I profits	WITH Price Controls	Sales: million packets	8.439	12.833
		Royalty:$	9	9
		Profit: million $	75.951	115.497
	WITHOUT Price Controls	Sales: million packets	4.090	5.033
		Royalty:$	20	20
		Profit: million $	81.800	100.668
	Increase in sales		106%	155%
	Decrease in Profits		-7%	15%
NATH SEES	WITH Price Controls	Sales: million packets	0.250	0.364
		Profit/Packet: $	6	6
		Profit: million $	1.500	2.184
	WITHOUT Price Controls	Sales: million packets	0.121	0.274
		Royalty:$	10	10
		Profit: million $	1.212	2.744
	Increase in sales		106%	33%
	Decrease in Profits		24%	-20%
JK AGRIGENETICS	WITH Price Controls	Sales: million packets	0.401	0.500
		Profit/Packet: $	6	6
		Profit: million $	2.406	3.000
	WITHOUT Price Controls	Sales: million packets	0.194	0.377
		Royalty:$	10	10
		Profit: million $	1.943	3.770
	Increase in sales		106%	33%
	Decrease in Profits		24%	-20%

Source: Calculated by the Author

APPENDIX D: R&D Expenditure of Private Seed/Pesticide Sector FY 2006

Name of the Company	**R&D Expenditure reported: 000 $**
Monsanto Holding Pvt. Ltd.*	7,561
BASF India	5,473
Mahyco	3,541
Syngenta India Ltd.	2,207
ProAgro Seed Company†	1,766
Nuziveedu Seeds Ltd.	1,427
Avestha Genuine Technologies Pvt. Ltd.	1,207
J.K. AgriGenetics Ltd.	1,202
Krishidan Seeds Ltd.	1,012
Ajit Seeds	844
Emergent Genetics Pvt. Ltd.*	788
Ankur Seeds Pvt Ltd	763
Seminis Vegetable Seeds India Ltd.*	717
Namdhari Seeds Ltd.	490
Advanta India Limited	466
Ganga Kaveri Seeds Pvt. Ltd.	466
Bayer Crop Sciences Ltd.†	463
Indo America Hybrid Seeds (India) Ltd.	412
Nunhems Seeds Ltd.†	359
Tulsi Seeds Pvt. Ltd.	293
Nirmal Seeds Pvt. Ltd	278
Rasi Seeds Ltd.	273

*** acquired by Monsanto** **† acquired by Bayer**

Source: DSIR website http://www.dsir.nic.in/(accessed on 03/24/2008) and converted at an exchange rate of 1 USD = 41 Indian Rupees

Note: In 2007 DuPont/Pioneer have invested over $20 million (http://www.pioneer.com)

APPENDIX E: Cost for Regulatory Approval for Monsanto (Bt Cotton)

Study	Number	Cost/Study	Total ($)
Pre-approval			
Goat feeding study-90 day	1	55,000	55,000
Cow feeding study	1	10,000	10,000
Water buffalo feeding study	1	10,000	10,000
Pollen flow	1	40,000	40,000
Soil Microflora	1	Small	
Absence of terminator	1	Small	
Poultry feeding studies	1	5,000	5,000
Fish feeding studies	1	5,000	5,000
Brown Norway rat allergenicity	1	150,000	150,000
Gene stability	1	Small	
Expression in oil and lint	1	Small	
Socio-economic study	1	15,000	15,000
Baseline resistance study	1	20,000	20,000
Greenhouse trials 1996		Small	
Limited field trials 96,97-98	6	5,000	30,000
Multi-location field trials 98/99	41	5,000	205,000
Multi-location field trials 99/00	10	5,000	50,000
Large-scale trials 2000/2001	40	2,500	100,000
Large-scale farm trials 2001/2002	400	500	200,000
Salaries and office expenses			
Years 1996-2001	6 years	150,000/year	900,000
Total Pre-approval			1,795,000
Post approval			
Socio-economic study	2	15,000	30,000
Resistance study	1	20,000	20,000
IPM package	2	10,000	20,000
Salaries and office expenses			125,000
Total post approval			195,000

Source: Modified from Pray (2005)

APPENDIX F: Excel Spreadsheet Simulations

Supply Elasticity (Column B): Supply elasticity is 0.54 in the long-term (Acharya and Agarwal, 1994).

Proportionate yield change (Column C): Expected proportionate yield change per hectare, E(Y), presuming research is successful and fully adopted.

Gross proportionate reduction in marginal cost per ton of output (Column D): Column C/Column B converts the proportionate yield change to a proportionate gross reduction in marginal cost per ton of output E(Y)/ε.

Proportionate change in input cost per hectare (Column E): Proportionate change in variable input costs per hectare, E(C), if any, to achieve the expected yield change.

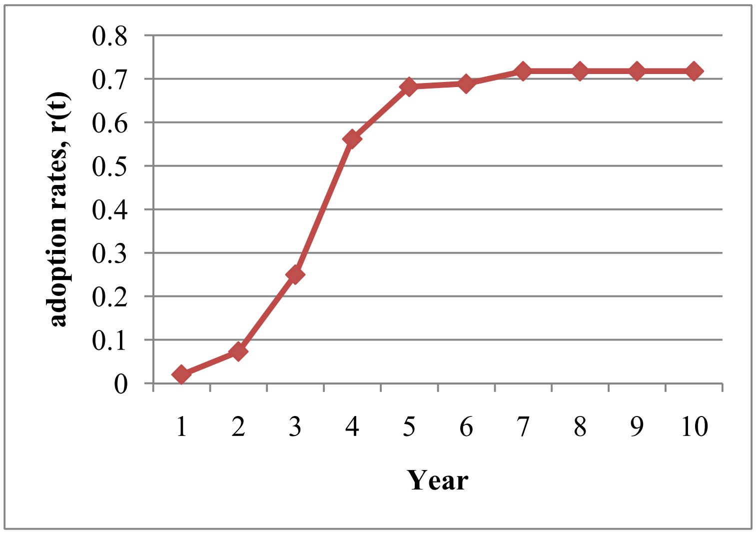
Proportionate input cost change per ton of output (Column F): Column E/(1+Column C) converts proportionate input cost change per hectare to a proportionate input cost change per ton of output.

Net proportionate change in cost per ton of output (Column G): (Column D- Column F) nets out the effect of variable input cost change per hectare to a proportionate input cost change per ton of output.

Probability of research success (Column H): Probability, *p*, that research will achieve the yield change in Column C or cost change in Column E.

Adoption rate (Column I): Reflects the rate of adoption, A_t, defined in relation to years, t, from introduction of new variety in the market.

Predicted adoption rates for herbicide tolerant and drought resistant varieties



Source: Desai (2005)

Depreciation factor (Column K): 1-rate of annual depreciation of the technology, (1-δ_t). δ_t assumed to be 0.

Proportional supply shift in year t-K_t (Column K): Column G x Column H x Column I x Column J, giving the cumulative proportionate shift downwards

World Price (Column L): World cotton prices for 2002-2008 are taken directly from FAO commodity price database (http://www.fao.org/es/esc/prices). For long-term benefits we take the world price to be constant at $1219.818/ton as a conservative estimate.

Exogenous growth rate (Column M): $g_Q = g_A + g_Y$. The exogenous output growth rate is equal to the sum of the growth rates of area g_A, or yield, g_Y, but not due to research.

Quantity (Column N): $Q'_t = Q_0(1 + g_Q)$, Q_0 is the initial base quantity and is adjusted by exogenous output growth.

From the time series data for pre-bt cotton years i.e., from 1950 to 2001 we find that the average increase in area per year is 1% and the average increase in yield per year is 4%, hence the exogenous growth rate is assume to be 5%.The average of yields for pre-bt cotton years from 1950 to 2001; 1227,000 tons.

Change in total surplus in year t - ΔTS_t (Column P): Column K x Column L x Column N x [1 + (0.5 x Column K x Column B)]. This column represents the change in total economic surplus equal to $K_t P_t' Q_t' (1 + 0.5 K_t \varepsilon)$ 000's of dollars per year.

Table A: Simulation of the economic surplus model for herbicide tolerant cotton

Year	E	Max. yield change	Gross cost change per ton	Input cost change per ha.	Input cost change per ton	Net cost change	prob. of success
A	B	C	D	E	F	G	H
2011	0.54	0	0	(0.06)	-0.060	0.060	1.00
2012	0.54	0	0	(0.06)	-0.060	0.060	1.00
2013	0.54	0	0	(0.06)	-0.060	0.060	1.00
2014	0.54	0	0	(0.06)	-0.060	0.060	1.00
2015	0.54	0	0	(0.06)	-0.060	0.060	1.00
2016	0.54	0	0	(0.06)	-0.060	0.060	1.00
2017	0.54	0	0	(0.06)	-0.060	0.060	1.00
2018	0.54	0	0	(0.06)	-0.060	0.060	1.00
2019	0.54	0	0	(0.06)	-0.060	0.060	1.00
2020	0.54	0	0	(0.06)	-0.060	0.060	1.00

Table A contd.

Year	Adopt. Rate	Adopt. Rate	Depr. Rate	K_t	Gross cost change per ton	Input cost change per ha.	Input cost change per ton	ΔTS_t
	I	I	J	K	L	M	N	O
2011	0.02	0.02	1	0.001	1219.818	0.05	1288.4	1886
2012	0.073	0.073	1	0.004	1219.818	0.05	1352.8	7236
2013	0.25	0.25	1	0.015	1219.818	0.05	1420.4	26095
2014	0.562	0.562	1	0.034	1219.818	0.05	1491.4	61904
2015	0.682	0.682	1	0.041	1219.818	0.05	1566.0	79030
2016	0.689	0.689	1	0.041	1219.818	0.05	1644.3	83843
2017	0.718	0.718	1	0.043	1219.818	0.05	1726.5	91783
2018	0.718	0.718	1	0.043	1219.818	0.05	1812.8	96372
2019	0.718	0.718	1	0.043	1219.818	0.05	1903.5	101191
2020	0.718	0.718	1	0.043	1219.818	0.05	1998.7	106250

Source: Author

Table B: Simulation of the economic surplus model for drought resistance when there is a drought every 2 years

Year	E	Max. yield change	Gross cost change per ton	Input cost change per ha.	Input cost change per ton	Net cost change	prob. of success
2015	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2016	0.54	0.0	0	0.00	0.000	0.000	1.00
2017	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2018	0.54	0.0	0	0.00	0.000	0.000	1.00
2019	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2020	0.54	0.0	0	0.00	0.000	0.000	1.00
2021	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2022	0.54	0.0	0	0.00	0.000	0.000	1.00
2023	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2024	0.54	0.0	0	0.00	0.000	0.000	1.00
2025	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2026	0.54	0.0	0	0.00	0.000	0.000	1.00

Table B contd.

Year	Adopt. Rate	Depr. Rate	K_t	Gross cost change per ton	Input cost change per ha.	Input cost change per ton	ΔTS_t
2015	0.02	1	0.004	1219.818	0.05	1288.4	5826
2016	0.073	1	0.014	1219.818	0.05	1352.8	0
2017	0.25	1	0.046	1219.818	0.05	1420.4	81217
2018	0.562	1	0.104	1219.818	0.05	1491.4	0
2019	0.682	1	0.126	1219.818	0.05	1566.0	249482
2020	0.689	1	0.128	1219.818	0.05	1644.3	0
2021	0.718	1	0.133	1219.818	0.05	1726.5	290077
2022	0.718	1	0.133	1219.818	0.05	1812.8	0
2023	0.718	1	0.133	1219.818	0.05	1903.5	319810
2024	0.718	1	0.133	1219.818	0.05	1998.7	0
2025	0.718	1	0.133	1219.818	0.05	2098.6	352590
2026	0.718	1	0.133	1219.818	0.05	2203.5	0

Source: Author

Table C: Simulation of the economic surplus model for drought resistance when there is a drought every 3 years

Year	E	Max. yield change	Gross cost change per ton	Input cost change per ha.	Input cost change per ton	Net cost change	prob. of success
2015	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2016	0.54	0.0	0	0.00	0.000	0.000	1.00
2017	0.54	0.0	0	0.00	0.000	0.185	1.00
2018	0.54	0.1	0.185185	0.00	0.000	0.000	1.00
2019	0.54	0.0	0	0.00	0.000	0.185	1.00
2020	0.54	0.0	0	0.00	0.000	0.000	1.00
2021	0.54	0.1	0.185185	0.00	0.000	0.185	1.00
2022	0.54	0.0	0	0.00	0.000	0.000	1.00
2023	0.54	0.0	0	0.00	0.000	0.185	1.00
2024	0.54	0.1	0.185185	0.00	0.000	0.000	1.00
2025	0.54	0.0	0	0.00	0.000	0.185	1.00
2026	0.54	0.0	0	0.00	0.000	0.000	1.00

Table C contd.

Year	Adopt. Rate	Depr. Rate	K_t	Gross cost change per ton	Input cost change per ha.	Input cost change per ton	ΔTS_t
2015	0.02	1	0.004	1219.818	0.05	1288.4	5826
2016	0.073	1	0.014	1219.818	0.05	1352.8	0
2017	0.25	1	0.046	1219.818	0.05	1420.4	0
2018	0.562	1	0.104	1219.818	0.05	1491.4	194659
2019	0.682	1	0.126	1219.818	0.05	1566.0	0
2020	0.689	1	0.128	1219.818	0.05	1644.3	0
2021	0.718	1	0.133	1219.818	0.05	1726.5	290077
2022	0.718	1	0.133	1219.818	0.05	1812.8	0
2023	0.718	1	0.133	1219.818	0.05	1903.5	0
2024	0.718	1	0.133	1219.818	0.05	1998.7	335800
2025	0.718	1	0.133	1219.818	0.05	2098.6	0
2026	0.718	1	0.133	1219.818	0.05	2203.5	0

Source: Author