Discussion Papers in Economics

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August 2012

Discussion Paper 12-02

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Abstract

The price for official Bt cotton seed in India in 2005 was Rs 1600. Concerns were raised that these prices are excessive because of the monopolistic market structure prevailing in the seed market and may in turn restrict the access to technology for resource poor farmers. The Indian government imposed a ceiling on the price of Bt cotton seeds in 2006. The drastic reduction in seed prices, on the other hand, could affect the profitability of the seed providing companies and might curb their incentive to innovate in future. This paper attempts to examine the impact of such price controls on the revenue and profitability of the seed providers in India. Using a panel data for 9 cotton growing states in India over 2002- 2008, we develop a dynamic logistic model to predict percentage area under Bt cotton. It is shown that the price controls have positively impacted the diffusion of technology in India and was also successful in increasing the revenue of the seed providers in the short run. We further examine impact of seed price control on profitability of the seed providers by postulating alternative cost conditions and find that the impact of price controls on profitability depends on the cost of providing Bt cotton seeds.

JEL Classification: Q 16, O 33

Keywords: Price controls, Bt cotton, diffusion, revenue, profitability.

1. Introduction

In 2002, Mahyco (Maharashtra Hybrid Seed Company) in collaboration with Monsanto introduced Bt cotton technology in India. Around 54,000 farmers in India grew officially approved Bt cotton hybrids on 50,000 hectares of land in 2002. Since then there has been a remarkable increase in the area cropped under Bt cotton in India —increasing to 8.4 million hectares by 2009.

Until 2005, Mahyco-Monsanto Biotech (MMB) dominated the market for cotton hybrids, either directly through selling hybrid seeds or indirectly through sub-licensing to private seed companies. India's regulatory system gave MMB a temporary monopoly on the Bt gene[1]. The domestic companies that licensed Bt trait from MMB were required to pay a one-time license fee as well as a royalty fee for availing the gene. This led to a large price differences between Bt and non-Bt hybrids. (In 2004 Bt hybrids cost $19 more per acre compared to non-Bt hybrids; Murugkar *et* al. 2007). The price for official Bt cotton seeds in India in 2006 was around Rs 1600 per packet of 450 gram, which was around four times the price of non-Bt hybrid. Out of the seed price of Rs 1600, Rs 1250 was charged by MMB as the trait value.

The large gap between the price of Bt cotton hybrid and non-Bt hybrid led to the fears that monopolistic market structure was prevailing in the cotton seed market that has resulted in excessive seed prices. Concerns were raised that high seed prices may restrict access of technology for resource poor farmers (Lalitha, 2004). The state of Andhra Pradesh imposed a ceiling of Rs 750 (inclusive of technology fee) on Bt cotton seed price in Andhra Pradesh to make the technology affordable and accessible to small and marginal farmers in the state. The other states of India also imposed the same ceiling.

[1] MMB derived a measure of protection for its gene through India's bio-safety laws. As biosafety approvals are obtained for the composite of the gene and the germ-plasm, hybrids that incorporate MMBs gene but do not go through the biosafety process are considered illegal. Thus, most of the firms have chosen to license the Bt technology from MMB as regulatory authorities are unlikely to approve a Bt hybrid that includes an unlicensed version of the MMB gene. However, in 2006, some non-MMB genes entered the market but their ability to compete in the technology market was handicapped by the first mover advantage of MMB.

The government imposed price control is one of the major challenges facing Indian firms involved in Bt cotton seed provision. The drastic reduction in seed prices led to the concerns that if seed prices and trait values are fixed at low arbitrary levels, farmers' benefits might increase in the short run but the incentive to invest in the development of new technologies might reduce due to shrinking of company revenues. Research and development (R&D) expenditures on new and patentable genetic traits and seeds are an important part of the production cost of seeds. Over the last few decades, private sector R&D expenditures in agriculture have increased sharply as applications of new biotechnologies have become associated with exclusive property rights for genetic traits. This has contributed to an increase in seed prices (Krull, Prescott, and Chum, 1998). The price markup acts as an incentive for them to develop new technologies and therefore, in the long run price controls could have negative implications for product development. Literature suggests that the profitability of the early years of Bt cotton sales would increase R&D until the price controls are imposed, after which R&D on cotton should decline (Pray and Nagarajan, 2010). Price controls may delay new product launches, due to which farmers may lose in the long run as they will not get access to improved seeds. This paper investigates the effect of seed price controls on the gross revenue and profitability of seed providers. We begin by discussing studies that have analyzed implications of different pricing strategies of Bt cotton seeds for farmers and seed providing companies.

Analyzing expected level of demand for Bt cotton seeds in Argentina under different pricing regimes, Qaim and de Janvry (2003) find that a high seed price is a barrier to adoption, especially for smallholder farmers. They argue that reducing Bt cotton seed prices would not only increase farmers profits', but would also be more profitable for the seed producing company. Reducing the seed prices could result in more than three times increase in the profit of the technology provider.

In contrast to the above paper, analyzing adoption of Bt cotton in India in the light of government seed price interventions, Sadashivappa and Qaim (2009) find a high willingness to pay (close to the official market price) for Bt cotton seeds. According to the study, the take off phase for Bt cotton had already begun before 2006 and thus the government seed price interventions had little impact on aggregate Bt cotton adoption. They apprehend that seed price controls might reduce the incentive of the company to innovate in the future.

Pray and Nagarajan (2010) reviewed the 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 and innovation by this industry. Collecting data on the total number of seed packets sold from industry sources, they have computed revenue realized by technology providers (MMB) and seed firms in India from 2002-2010 and postulated that the implementation of price controls in 2006 was followed by an immediate, large decline in the profits of seed and biotech firms. They argue that the seed price controls in case of Bt cotton in India would benefit farmers in the short run but 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. Farmers, thus, tend to lose in the long run as they would not get access to improved hybrids and genes developed by private firms. However, 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.

The above discussion raises an important question for policy makers: What has been the impact of these price controls on the revenue and profitability of the seed providers in India? Are these price controls curbing the incentive of the company to innovate in future, which could reduce farmers' ability to get access to new technology, or are these beneficial for the farmers as well as seed providers in terms of increased adoption and profitability from technology? If the prevailing market price for Bt cotton seeds is the profit maximizing price, a reduction in price cannot increase firms' profitability. If the price charged, however, is sub-optimal then price controls may result in an increase in profitability. This could be because of the firms' incomplete knowledge of the demand curve for Bt seeds. Qaim and Janvry (2003) find that the Bt cotton seed prices in Argentina were sub-optimal and this was due to the firm's lack of assessment of the demand curve. They show that a reduction in prices could lead to a large increase in demand which in turn could increase the profits of the company. Another possible reason for sub-optimal prices could be that the seed prices are set to maximize global profits rather than local profits.

Using a panel data for 9 major cotton growing states in India from 2002-08, this study attempts to quantify the impact of seed price interventions on gross revenue and profitability of seed providers by simulating and comparing gross revenue and profit curves under two alternative scenarios: no seed price intervention and seed price intervention. The Bt technology in India is developed by MMB, which has sub-licensed marketing rights to other companies. The benefits are distributed between MMB and the other seed companies according to the license agreements between them. It is difficult to divide the benefits amongst firms, therefore, the seed providers in our analysis include both seed companies as well as technology providers. The study also computes seed price elasticity of demand and finds it to be highly elastic.

The commercial release of plant varieties produced through genetic engineering requires approval from Genetic Engineering Approval Committee (GEAC). Initially GEAC followed a “case by case approval process”, which mandates extensive testing of each hybrid under trial. In 2006, the approval process was changed to an “event based approval system” from that of a case by case approval process. Accordingly, extensive bio-safety and agronomic testing is not necessary for an approved event. It was argued that this would speed up the introduction of new and diverse products for the Indian farmer, stimulate competition and offer a wider choice without compromising bio-safety and environmental safety (Ministry of Environment and Forests, Government of India, 2006).

Indeed after the initial approval of three hybrids, many more Bt cotton hybrids have been approved for commercial cultivation in India. The initial hybrids contained the single Bt gene *cry1Ac* owned by Monsanto which licensed the gene to MMB. Subsequently MMB has sub-licensed the gene to other firms in India. In 2005, 20 cotton hybrids using this gene construct were approved for cultivation by GEAC, some of which were specifically suited for agro-ecological conditions of the Northern Zone. In May 2006, another Bt hybrid developed by MMB called Bollgard II with stacked *cry 1 Ac* and *cry 2 Ab* genes was approved for commercial release in the central and northern zones. In the same year, JK Agri Genetics Ltd. and Nath Seeds Ltd also released their own approved events of Bt cotton. The number of approved hybrids increased from 62 in 2006 to 131 in 2007 and further to 274 in 2008 (James 2008). This rise in the approved varieties of Bt cotton hybrids resulted in an increase in the number of varieties available in the market, expanding the portfolio of choice for farmers, and helped them in finding the variety most suitable for their agro-climatic conditions. This effect of the number of Bt hybrids approved for commercial cultivation has been termed as varietal approval.

Studies that have attempted to estimate farmers' willingness to pay for Bt cotton technology in India have used contingent valuation methodology. Contingent Valuation (CV) techniques are often used to analyze individual preferences and elicit the WTP of consumers for goods that are non-marketable or not yet marketed. WTP depends on a number of interrelated factors, including socioeconomic and demographic characteristics, risk perceptions, awareness, and trust in the food safety and regulatory authorities. For the CV questions in a survey, often a double bounded dichotomous choice approach is employed. In the questionnaire respondents are asked whether they would be willing to purchase the specified good at a certain price bid. Price bids are randomly assigned to the questionnaires. Depending on the answer to the first bid, a second random bid is given, which is higher than the first bid for a "Yes" response, and lower for a no response. Based on the responses a log likelihood function is maximized and finally the mean willingness to pay is estimated.

Sadashivappa and Qaim (2009) estimated the WTP for the Bt cotton technology using a contingent valuation choice approach. They found that for 2002-03 growing season, mean WTP was Rs. 1633 per packet of Bt seeds, which was very close to the official market price. After the 2004-05 season, mean WTP even increased to Rs 2595. This reflects the farmer's satisfaction towards the new technology despite Bt seed prices been relatively high. They also estimated the mean WTP for 2006 season, the year when government seed price interventions began (seed prices were reduced from Rs 1600 to Rs 750 for a packet of 450 gms of Bt cotton seeds). Interestingly they found that the mean WTP estimated for 2006-07 is still much higher than the maximum retail price of Rs 750.

Ramaswami, Pray and Lalitha (2008), also estimated the mean WTP for both approved and unapproved Bt cotton seeds using a contingent valuation approach. Based on a survey of cotton growers in Gujarat in 2004, they found the mean WTP for approved Bt seeds to be Rs 778 and the median is Rs 880. These estimates imply that approved seeds are overpriced and therefore have not been adopted widely. However, the mean WTP for unapproved seeds was found to be Rs 3050.

Krishna and Qaim (2006) used a similar approach for ex-ante analysis of adoption of insect resistant Bt eggplant technology in India. They conducted interview based farm surveys in 3 major eggplant producing states of India—Andhra Pradesh, Karnataka and West Bengal in 2005, and estimated the farmers' willingness to pay using the contingent valuation method. They found that the average WTP for Bt hybrids was more than four times the current price of conventional hybrid seeds.

In contrast to the above studies, we analyze diffusion of technology in terms of actual acreage adopted under the new technology, and examine economic factors affecting them.[2] It is a panel data study that covers 9 major cotton growing states, viz. Punjab, Haryana, Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu over 2002 to 2008 period.

The studies estimating diffusion path have showed that the cumulative adoption path often behaves like a logistic curve. It is based on the premise that diffusion occurs through interpersonal contacts among a group of homogenous adopters. When a new technology is introduced, adoption increases slowly at first because initially only the most progressive and less risk averse adopt and then it increases more rapidly as

[2] The papers adopting such a methodology are Frisvold 2004, Fernandez-Cornejo 2002 and Jarvis 1981.

information spreads to other producers and finally it slows when nearly all producers who find the technology profitable have adopted, the process reaches a stable ceiling. This produces the classic ‘S-shaped’ diffusion curve, first introduced by Griliches in 1957. The logistic function is often used to represent the S-shaped diffusion process for agricultural innovations.

The rest of the paper is organized as follows. We begin by describing the dynamic logistic model used in the study and present the regression results. We then estimate percentage area under Bt cotton using the estimated coefficients. The estimated percentage area under Bt cotton from this model is then used to analyze the impact of price controls on gross revenue of seed providers. The second last section compares the profitability of seed providers under alternative cost conditions, and finally the last section contains conclusions and policy implications.

2. Model

The traditional models of diffusion treat diffusion parameters as scalar constants and directly estimate them as functions of time-varying exogenous variables. These are termed as static diffusion models. The functional form used is as follows

$$P = \frac{K}{1 + e^{-(a+bt)}}$$

where P measures the proportion of the innovation that is adopted. This can be expressed either as the percent of producers adopting the innovation or as the percent of acreage where the innovation is applied. K is the adoption ceiling or upper limit on P representing the maximum possible percentage area under Bt cotton in the long run equilibrium. The term t is a time trend, a represents origin parameter capturing the date of availability of Bt cotton. Variable b represents the slope coefficient or the relative speed of diffusion.

A limitation of static models is that they cannot be used to determine the impact of economic factors on the diffusion parameters, and thereby on diffusion paths. We, therefore, use a dynamic diffusion model that allows parameter of diffusion b to change overtime. It allows us to determine the impact of observed economic variables, such as prices, technology, etc., on the process of diffusion. In other words, the model assumes that the speed of adoption is a function of economic variables. Since the slope coefficient b is assumed to be a function of economic variables, the model is termed as variable slope dynamic logistic model (Frisvold 2004, Fernandez-Cornejo 2002 and Jarvis 1981).

The basic functional form of the variable slope dynamic logistic model is given by

$$P_{it} = \frac{K}{1+e^{-(a+b(z))t}} \tag{1}$$

where P denotes percentage area under Bt cotton and is computed as (area under Bt cotton/ area under cotton) multiplied by 100; K is the adoption ceiling or upper limit on P representing the maximum possible percentage area under Bt cotton in the long run equilibrium. The term t is a time trend, and a represents origin parameter capturing the date of availability of Bt cotton. Variable b represents the slope coefficient or rate of diffusion of Bt cotton. The vector z denotes economic variables that are influencing the rate of diffusion, b .

Using the variable slope dynamic logistic model described above, we first analyze the impact of economic factors like seed prices, varietal approval, and cotton prices on diffusion of Bt cotton in India (Arora and Bansal, 2012). We find that seed price controls have significantly impacted diffusion of Bt cotton in India. We also find cotton prices and varietal approval (defined in terms of number of Bt hybrids approved for commercialization) to be important factors impacting the diffusion rates. We then examine the impact of price intervention in Bt cotton seeds on gross revenue and profitability of seed providers. In contrast to the study by Pray and Nagarajan (2010), which relied on data from industry sources, our analysis is based on the area under Bt cotton estimated from the above model.

Equation (1) can be transformed to

$$\log\left(\frac{P}{K-P}\right) = a + b(z)t \qquad (2)$$

where b is a linear function of seed prices, cotton prices and number of approved Bt hybrids, that is,

$$b_{it} = \beta_1 p_{s_{it}} + \beta_2 p_{c_{it}} + \beta_3 T_{it} \qquad (3)$$

where $p_{s_{it}}$, $p_{c_{it}}$ and T_{it} denote seed prices, cotton prices and number of approved Bt hybrids, respectively, in state i in year t. The adoption ceiling K is fixed at 100 and the coefficient of diffusion b is allowed to be a function of exogenous factors. The origin parameter a is assumed to be fixed. The study uses a panel data that covers 9 major cotton growing states, viz., Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, Tamilnadu, Karnataka, Punjab, Haryana and Rajasthan over the period 2002-08.

Plugging (3) in (2) and introducing year dummies, the dynamic logistic model takes the following form[3]:

$$\log\left(\frac{P_{it}}{K-P_{it}}\right) = a + \beta_1 . p_{s_{it}} .t + \beta_2 . p_{c_{it}} .t + \beta_3 .T_{it} .t + \beta_4 .T_{05} .t + \beta_5 .D_{04} .t + \beta_6 .D_{05} .t$$
$$+ \beta_7 .D_{06} .t + \beta_{8.} D_{07} .t + \mu \qquad (4)$$

where D_{0j} is a dummy variable for *200j, j = , 4, 5, 6, 7,* and T_{05} is the interaction term $(T_{05} = d_{05} * T)$ where d_{05} is the dummy for the year *2005* and *T* denotes varietal approval.

[3] Refer to Arora and Bansal (2012) for a complete description and justification for the model used and results of variations of the above model.

The term $\frac{P_{it}}{K - P_{it}} \equiv y$ is the ratio of actual to potential percentage area under Bt cotton and can be considered as a proxy for diffusion. The above model is estimated using generalized least squares (GLS).

Data on the area under Bt cotton was taken from ISAAA Brief 41, Global Status of Commercialised Biotech/GM crops, James (2009); data on aggregate area under cotton cultivation was obtained from the Cotton Corporation of India (CCI). The data on seed prices for a packet of 450 gm was taken from internal Mahyco-Monsanto estimates. For some of the years the data represents an average rather than an exact price. For data on cotton prices, we have used the average price of kapas (raw cotton) for major varieties that include Bengal Desi, LRA, J-34, H-4, S-6 and DCH-32. These prices have been taken from the Statistics, published by Cotton Corporation of India limited (Government of India). The variable T_{it} denotes the number of cotton hybrids containing the cry 1 Ac gene approved for commercial cultivation in India. This data was taken from the Indian GMO Research Information System (Year wise list of commercially released varieties of Bt cotton hybrids by GEAC, IGMORIS).

The regression results are presented in Table 1. The results indicate that while seed prices significantly and negatively impact diffusion, cotton prices and varietal approval impact diffusion positively. The mean elasticity of diffusion with respect to seed prices is -1.8. We also find that the effect of varietal approval is stronger in 2005 than other years. This can be attributed to the introduction of around 20 new hybrids in 2005, some of which were specifically suited for the agro-ecological conditions of the northern zone. Further, the year 2006 dummy was significant, implying that apart from seed prices, varietal approval and cotton prices, some other factors impacted diffusion rates in 2006. Possible reasons include the approval of three other gene constructs approved for commercial release: Bollgard II, developed by MMB, and two others developed by JK Agri-Genetics Limited and Nath Seeds Limited. Another possible reason could be the change in the approval process of Bt hybrids from a case by case to an event based approval system. This may have stimulated the introduction of more hybrids, thereby resulting in wider choice for the farmers. Thus, although the government's seed price interventions were significant in impacting the increased percentage of area planted with Bt seeds, the dramatic increase in the percentage of area planted with Bt seeds in 2006 cannot be attributed entirely to the governmental seed price interventions.

Using the estimated coefficients from our regression, we compute $\log y$, antilog of which gives us the estimated y. Substituting $K = 100$ in the expression y, we obtain estimated percentage area under Bt cotton, P_{it}, for all the nine states under study. Table 2 presents the estimated percentage area under Bt cotton for 3 major cotton growing zones from 2002 to 2008. Using these estimates, we compute the seed price elasticity of demand in the next section.

3. Impact of Price Controls on Gross Revenue

From economic theory we know that the price elasticity of demand is crucial in determining the effect of a price change on gross revenue. Specifically, the gross revenue of a firm increases with a fall in the product price if the demand is elastic. To examine the effect of seed price control on revenue of seed providers, we first compute elasticity of percentage area under Bt cotton with respect to seed prices for individual states.

Differentiating the left hand side of equation (1) and rearranging, we obtain the expression for elasticity of percentage area under Bt cotton with respect to seed prices,

$$\eta_{Pp_s} = (\frac{K - P}{K})\beta_1 t p_s$$

where η_{Pp_s} denotes the elasticity of P with respect to p_s, and t is the time trend. This can be termed as the (seed) price elasticity of demand. The elasticity estimates are computed by plugging in estimated value of the coefficient of diffusion, β_1, the estimated percentage area under Bt cotton (from Table 2), and $K = 100$ in the above expression. Table 3 presents the seed price elasticity of demand for three major cotton producing states viz Maharashtra, Gujarat and Andhra Pradesh. Note that the elasticity estimates are varying overtime.

Our computations show that the seed price elasticity of demand for all three states for the year 2005 (the year preceding seed price interventions) is highly elastic, it is greater than 2 for Maharashtra and Gujarat and close to 2 for Andhra Pradesh. This suggests that a small fall in seed price from Rs 1600 would result in an increase in the gross revenue of firms. However, since there was a drastic reduction in seed prices from Rs1600 to Rs750, we need to explicitly compute gross revenues with seed price intervention and compare them with gross revenues if such interventions had not taken place. To predict gross revenue curve in the absence of seed price intervention, we use the model developed above.

Scenario I: Seed Price Intervention

Gross revenue is the product of price and quantity sold. Since the price of seed is for a packet of 450 gm of seeds, we need to express quantity in terms of number of packets of seed sold. We convert the estimated percentage area under Bt cotton into estimated area under Bt cotton in acres using the relation:

Estimated area under Bt cotton = {Estimated percentage area (P_{it}) *Total area under cotton}/100}. The estimated area under Bt cotton was then converted into estimated number of packets sold assuming that a 450 gm packet of Bt cotton seed is spread across one acre land (Murugkar, Ramaswami and Shelar, 2007). This was done for all the 9 states and over the years from 2002-08. The estimated number of packets sold were multiplied with seed prices to arrive at gross revenue estimates. The state wise estimates were then aggregated to compute the gross revenue of seed providers for India as a whole.

Scenario II: No seed price intervention

Since the focus of this paper is on determining the effect of seed price intervention on the gross revenue and profitability, the second scenario traces gross revenue if the government had not intervened in seed prices, and the seed prices had continued at the rate of Rs 1600 per packet. To be able to do that, we computed estimated percentage area under Bt cotton for all 9 states using the dynamic logistic model (equation 1) assuming seed prices to be Rs 1600 from 2002-08 keeping all other variables intact. The estimated percentage area without intervention was converted into estimated number of packets sold and multiplied by seed prices (Rs 1600) to arrive at state wise gross revenue estimates without intervention. The state wise estimates were then aggregated for India as a whole.

To compare the gross revenue curves under the two alternative scenarios we are assuming that except for the seed prices, the values of all other variables remain the same as in the base scenario. To be able to do so, the implicit assumption is that variables are not interrelated.

Table 4 presents the estimated gross revenue of seed providers with and without price interventions. These are illustrated in Figure 2. It can be seen from Figure 2 that gross revenue curve of seed providers with intervention lies above the gross revenue curve without interventions for 2006 and 2007. This shows that government seed price reductions resulted in increasing the revenue of seed providers in the short run which is also consistent with our elasticity estimates.

Comparing increase in gross revenue of seed providers from 2005 to 2006 for different states, we can also examine regional variation in the impact of seed price control. Our results show that the largest increase in gross revenue in 2006 as compared to 2005 was obtained from the state of Gujarat (Rs 647 million approx) followed by Maharashtra (Rs 547 million) and Andhra Pradesh (Rs 316 million approx). A state-wise comparison of gross revenue estimates reveals that although Maharashtra is the largest cotton producing state in India, Gujarat incurred the largest increase in revenues. This result is consistent with our elasticity estimates where we find that the seed price elasticity of demand for Gujarat in 2005 is highest among the three cotton producing states (Table 3).

The largest increase in gross revenue for the state of Gujarat as compared to other states for year 2006 could be attributed to a reduction in the spread of illegal Bt seeds in the state in the post intervention period. Illegal Bt seeds were priced between 800 and 1200 Rs per packet of 450 gm as compared to a price of Rs 1600 for official Bt cotton seeds

(Murugkar, Ramaswami and Shelar, 2007). Thus government price controls could have probably contributed to a reduction in the illegal Bt area and an increase in the availability of legal Bt cotton hybrids in the state which in turn generated more revenues for the seed providers.

4. Impact of seed price controls on the profitability of seed providers

To ascertain the effect of price controls on the profitability of seed providers apart from the gross revenue, we also need to take into account the changes in total costs. The profitability of seed providers would increase if the increase in gross revenue exceeds the increase in total costs. If the per unit price mark-up over costs increases then profits will definitely increase as there is an increase in the quantity sold. The profits, however, could also increase even if there is a fall in the per unit mark-up. This would happen if the increase in demand over-compensates the fall in the price mark-up.

We estimate the effect of price control on profitability by hypothetically constructing plausible cost scenarios as we could not obtain data on costs of providing seeds. Since the major costs of producing Bt cotton seeds are incurred at the R&D stage (which are fixed costs), we assume marginal costs of providing seeds to be constant (Qaim and de Janvry, 2003). The seed price before price control was Rs 1600 out of which a royalty of Rs 1200 was paid to Monsanto. After the seed price control, a royalty of Rs 150 was paid from a price ceiling of Rs 650 (Pray and Nagarajan, 2010). From both these observations, we deduce that it is unlikely that the marginal cost of providing seed exceeds Rs 400. Thus, we have estimated the profits of seed providers under three hypothetical cost scenarios of Rs 300 per acre, Rs 350 per acre, and Rs 400 per acre respectively.[4] For all the three scenarios, we have attempted to compare the profits of seed providers with intervention versus without intervention.

[4] Pray and Nagarajan (2010) have done the analysis assuming marginal cost of providing seeds went up by 35-40% from the 2006/07 crop year due to increased cost of production. They also didn't have data on cost of seed production for every year so they applied the increases in the cost of seed production from 2006/07 year.

Tables 5-7 depict the estimated profits of seed providers with and without intervention under different cost conditions. Table 5 compares the estimated profits with intervention with that of profits without intervention assuming marginal costs to be Rs 300 per acre. The figures clearly show that estimated profits have increased with intervention. We have depicted these profits in Figure 3. The gap between the blue and the pink line shows the change in the profitability due to price controls. It is evident that profits have increased with intervention for years 2006 and 2007. We have done the same exercise, assuming marginal cost of providing seeds to be Rs 350 per acre. Table 6 and Figure 4 depict the results of this exercise. Here also we find that profitability of seed providers have increased marginally with intervention for 2006 and 2007.

We, however, find that the profitability of seed providers is declining for both 2006 and 2007 if marginal cost of providing seeds is Rs 400. This can be clearly seen in Table 7. Also the profit curve without intervention in Figure 5 lies above the profit curve with intervention.

The above analysis suggests that the overall impact of price controls on profitability would depend on the cost conditions. If the marginal cost of providing seeds is less than Rs 400 per acre, price controls would increase the profits in the short run whereas if cost Rs 400 per acre or greater, firms' profits would decline with price reductions.

5. Conclusion and Policy Implications

In 2006, the government of Andhra Pradesh imposed a ceiling of Rs 750 on the price of a 450 gm packet of Bt cotton seeds. There is interest in the literature in analyzing the impact of price controls on the farmers as well as seed producing companies. We have analyzed the impact of such price reductions on diffusion of technology in India, the gross revenue and profitability of seed providers.

We find that price controls were significant in impacting diffusion of technology in India. We computed seed price elasticity of demand for three major cotton producing states and found it to be highly elastic in the year 2005. This suggests that a reduction in seed price would result in an increase in gross revenue for the seed providers. This indeed was the case. We found that the gross revenue of the seed providers increased for two consecutive years following the price controls, i.e., in 2006 and 2007. Comparing the gross revenue under two alternative scenarios—with and without seed price intervention, we find that seed price reductions have increased the gross revenue of seed providers, at least in the short run.

We have also attempted to study regional variation of the seed price control on gross revenue. We find that the largest increase in gross revenue in the post intervention period was incurred by Gujarat, although Maharashtra is the largest cotton producing state. This is an interesting result and could be attributed to the reduction in the spread of illegal Bt seeds in Gujarat in the post intervention period.

Regarding the impact of seed price controls on profitability of seed providers, our results suggest that it would depend on the cost conditions. If marginal costs of providing seeds exceed Rs 400 per acre then profits would decline with government price reductions. This result is close to Pray and Nagarajan (2010) who find that profits of both seed companies as well as technology providers have reduced in the post intervention period. This suggests that the price controls could hamper the incentive of the seed providers to innovate in future and thus could restrict the accessibility of Indian farmers to some important new technologies.

However, if cost of producing Bt seeds is less than Rs 400 per acre then profits would increase with price controls. In that case, the government imposed price control might have improved the access of beneficial technologies to farmers without curbing the incentive of the company to innovate in the future. The results of this case are closer to Qaim and Janvry (2003) where they find that reducing the seed prices for Bt cotton in Argentina are not only beneficial for farmers but also beneficial for the seed companies. This could be possible if the seed prices in the pre intervention period were not profit maximizing prices. Thus, the overall impact of price controls on the profitability of seed providers would depend on the cost of producing Bt seeds.

The excessive prices charged for the official seeds may strengthen the incentive to cheat. There was widespread adoption of illegal seeds in Gujarat, which were priced between Rs 800 and Rs 1200 per packet of 450 grams as compared to a price of Rs1600 for official Bt cotton seeds (Murugkar, Ramaswami and Shelar, 2007). Thus, the government imposed price control for legal Bt seeds could have probably contributed to a reduction in the illegal Bt seeds.

Apart from government interventions in the pricing of Bt cotton seeds, an alternative policy measure to increase the benefits for the farmers as well as seed providers would be to allow competition among alternative gene providers which could reduce the seed prices on its own (rather than the government doing it) and could ultimately increase the gross revenue as well as profitability of the seed providers as a whole. The government could also encourage competition in the seed market by supporting indigenous research by farmer scientists who develop their own hybrids.

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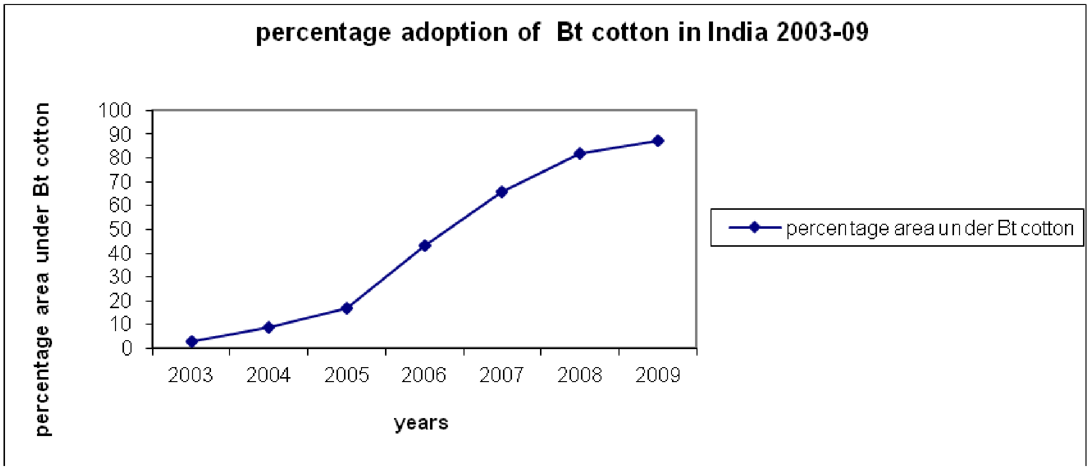
Appendix

Figure 1: Percentage Adoption of Bt cotton in India, 2003 to 2009



Source: James C (2009), Preview: Global status of commercial Biotech Crops: 2009, ISAAA Brief No.41. Ithaca, NY

Figure 2: Comparing Gross Revenue of seed providers under 2 alternative Scenarios

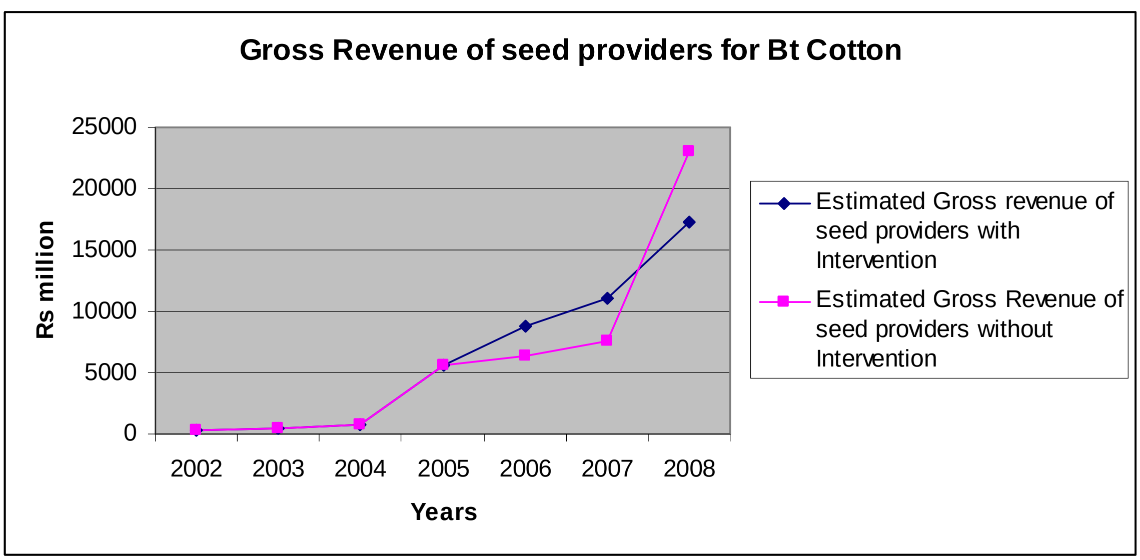


Figure 3: Profitability of seed providers (this includes seed firms and technology providers) with and without intervention under different cost scenarios

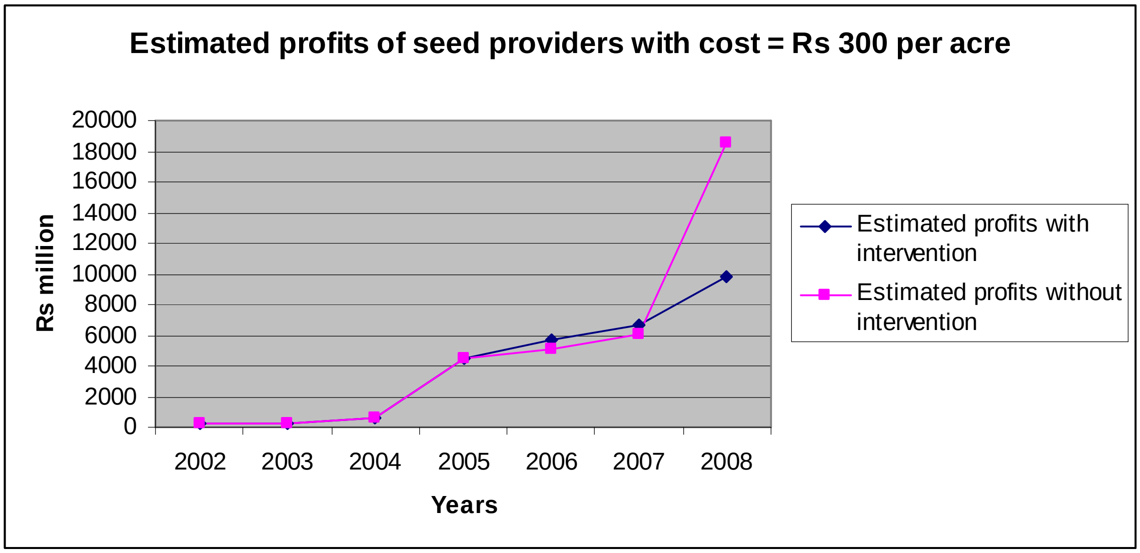


Fig 4: Profitability of seed providers with and without intervention assuming cost = Rs 350 per acre

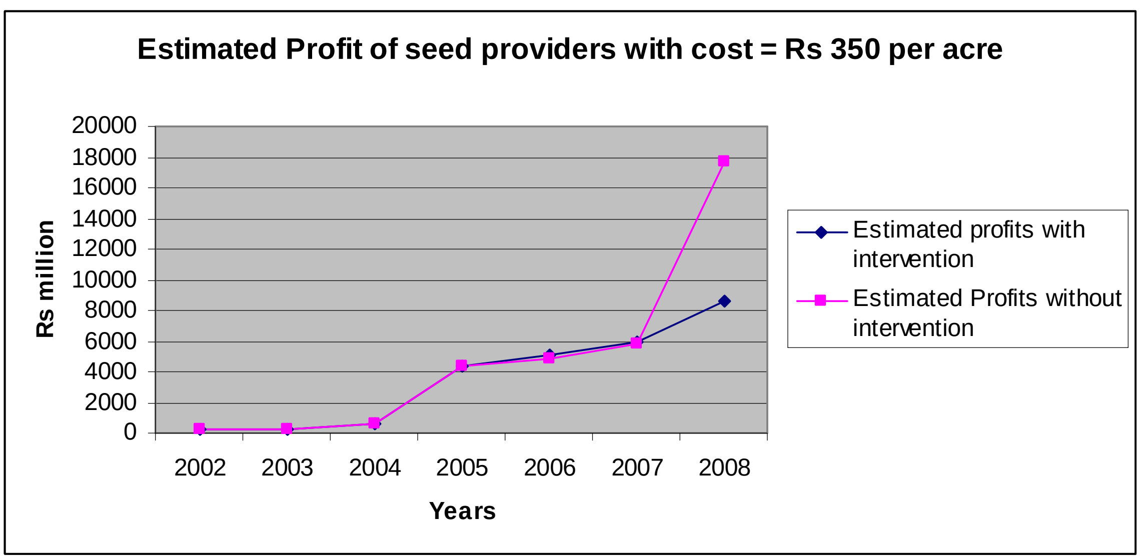


Fig 5: Profitability of seed providers with and without intervention assuming cost = Rs 400 per acre

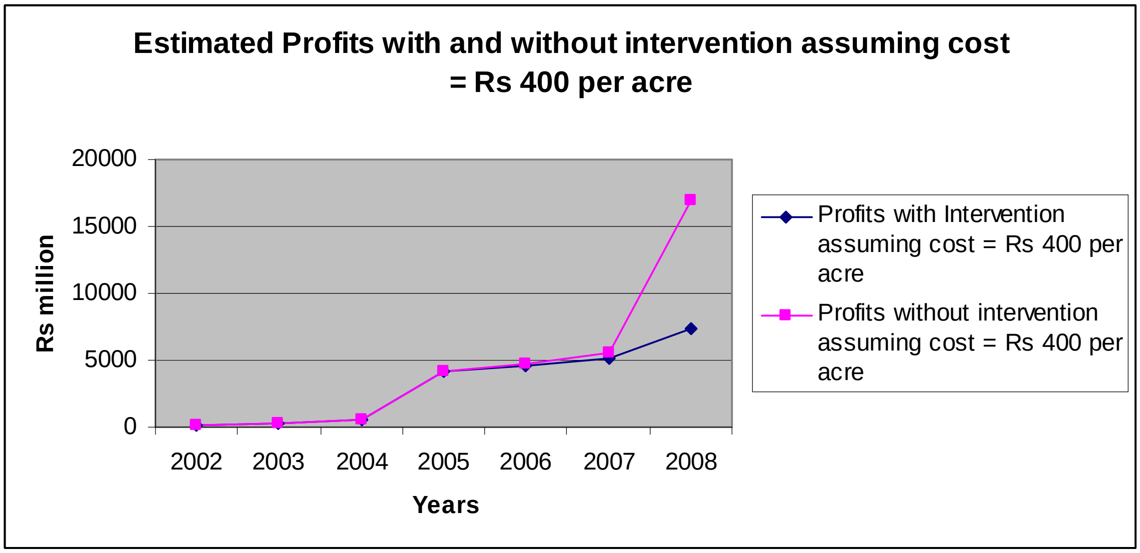


Table 1: Estimation results of dynamic logistic model

Dependent variable:	*Log(P_{it} / $K - P_{it}$)*
Independent variables	Model
Constant	-4.76895
$p_{s_{it}}.t$	-.00038* (.00021)
$p_{c_{it}}.t$	.00039*** (.00008)
$T_{it}.t$	.00367** (.00193)
$D_{04}.t$	.25570 (.21027)
$D_{05}.t$	.00595 (.31659)
M .t	.16428* (.10016)
n $D_{07}.t$	.10896 (.06986)
$\boldsymbol{T_{05}.T}$	.03952* (.02444)
R Squared	0.8267
Number of observations	54

Note: The figures in brackets denote the standard error.

***, **, * denote significance at 1 percent, 5 percent, 10 percent, respectively.

Table 2: Estimated percentage area under Bt cotton from dynamic logistic model

Years	Central Zone	Southern Zone	Northern Zone
2002	0.948909	0.948909	
2003	1.497824	1.497824	
2004	2.771498	2.771498	
2005	17.67088	11.04216	4.336979
2006	46.01904	43.74972	15.13269
2007	56.50644	52.68745	36.5168
2008	93.05993	91.53911	71.94022

Source: Estimated from the dynamic logistic model used for this study.

Table 3: Elasticities of percentage area under Bt cotton *(P)* w.r.t seed prices (p_s) for three major cotton producing states.

Year	**Maharashtra (Elasticity)**	**Gujarat**	**Andhra Pradesh**
2002	-0.60432	-0.60603	-0.60369
2003	-1.20629	-1.19286	-1.20495
2004	-1.70046	-1.71219	-1.71281
2005	-2.01428	-2.35189	-1.86127
2006*	-0.58278	-1.14808	-0.20878
2007	-0.1686	-1.07202	-0.07234
2008	-0.00166	-0.75831	-0.03719

Note: *Year when price controls began.

Table 4: Comparison of gross revenue of seed providers under 2 alternative scenarios

Years	Estimated Gross Revenue with Intervention (in Rs million)	Estimated Gross Revenue without Intervention (in Rs million)
2002	263.2	263.2
2003	424.93	424.93
2004	782.88	782.88
2005	5536.5	5536.5
2006*	8723.7	6380.7
2007	11051.34	7509.6
2008	17273.39	23029.9

Note: *Year when price controls began.

Table 5: Estimated profits with intervention versus without intervention at marginal costs equal to Rs 300 per acre over the years 2002-08.

Years	Estimated Profits with Intervention keeping cost = Rs 300 per acre (in Rs million)	Estimated Profits without intervention keeping cost = Rs 300 per acre (in Rs million)
2002	190.7399	190.7399
2003	300.9331	300.9331
2004	636.2993	636.2993
2005	4545.05	4545.052
2006	5661.167	5119.286
2007	6630.837	6025.539
2008	9793.924	18509.13

Table 6: Estimated profits with intervention versus without intervention with cost = Rs 350 per acre over the years 2002-08.

Years	Estimated Profits with Intervention keeping cost = Rs 350 per acre (in Rs million)	Estimated Profits without intervention keeping cost = Rs 350 per acre (in Rs million)
2002	183.22	183.22
2003	289.35	289.26
2004	611.73	611.73
2005	4378.59	4378.5
2006	5151.22	4908.5
2007	5886.94	5776.77
2008	8556	17751

Table 7: Estimated profits with intervention versus without intervention with cost = Rs 400 per acre over the years 2002-08.

Years	Estimated Profits with Intervention keeping cost = Rs 400 per acre (in Rs million)	Estimated Profits without intervention keeping cost = Rs 400 per acre (in Rs million)
2002	176.067	176.067
2003	277.7844	277.7844
2004	587.3532	587.3532
2005	4214.501	4214.502
2006	4640.274	4698.56
2007	5157.318	5530.488
2008	7300.548	17001.93