Chapter 23

Application of Economic Surplus Model for Impact Assessment: Case of Bt Cotton in India

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Introduction

In the annals of Indian agriculture, Btcotton is a major technological landmark after the advent of green revolutionin late 1960s. Since the official legal introduction of the technology in 2002, it transgressed sizes and agro-ecologies resulting in significant economic gains, and transformed the landscape of Indian cotton scenario (Ramasundaram*et al.,* 2011). The direct benefits ofBt cotton include reduced insecticide usage, lower farming risks and production costs, better yields and profitability, expanded opportunities to grow cotton and a brighter economic outlook for the cotton industry (Edge *et al.,* 2000; Gandhi and Namboodiri, 2006; Pray and Naseem,2007). These benefits have transformed into increased returns to labour and aggregate household income, thereby contributing to poverty reduction (Subramanian and Qaim, 2010).

The noticeable feature of the impact of Bt cotton in India is its regionalvariationsdue to the underlying agro-ecologic and socio-economic differences(Bennett*et al.,* 2006,Qaim*et al.,* 2006).These incidences would be more pronounced when the prescribed norms for Bt cotton cultivation- like maintenance of refuge crops- are not strictly followed, asoften observed in small-holder agriculture (Sadashivappa and Qaim, 2009). Further, Bt seeds in India are available only in hybrids produced and marketed by private firms. Accordingly, some of the state governments in India intervened in Bt cotton seed pricing by declaring maximum retail prices for cotton seed, again with some inter-state variations. These developments have affectedtherelative performance of cotton in terms of yield growth, pesticide saving and seed costs. However, there is a very limited literature that deals with *ex-post*assessment of impact of Bt cotton at national (aggregate) level in India, as in case of many other non-industrialised countries (Falk-Zepeda *et al.*, 2007). Even scarcer are studies that address regional variations on the technology adoption and agronomic performance.

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The present study attempts to estimate the welfaregains of Bt cotton in India and its distribution acrossregions (states in India). Our research contributes to the existing literature in twoways: first, as noted earlier, there are only a few *ex-post*studies in India that attempted to document the welfare gains of Bt cotton cultivation to come up with national level estimates, taking into account the regional variations.Those studies used trial data or field level data on agronomic and economic performances, collected from experimental farms or a limited number of farmers from a particular locationat a particular point of time. We, on the other hand, combine the field level data with the macro level data on actual performance of cotton using the databases of Ministry of Agriculture, Government of India, for all major cotton growing states. Second, the study updatesprivate sector surpluses taking into account the changes in the input (seed) markets.

In the following section, we present a brief overview of the extent of adoption of Bt cotton in Indiaand its economic impacts and related developments. This is followed by description of the general features of the economic surplus approach and the model used in the study. In the subsequent session results of the study and the discussion are provided, while the last sessionconcludes.

Extent of Bt cotton cultivation and its impact in India- Anoverview

In 2009-10, cotton occupied 10.3 million ha, sustaining about 4-5 million farm households, with a raw cotton production of 5.5million tonnes (GoI, 2010). It is cultivated in most of the agro-ecologies, mainly under rainfedconditions,except in northern states, where it is cultivated with assured irrigation (Sundaram*et al.*, 1999). But Maharashtra, Gujarat and Andhra Pradesh account for more than three-fourth of the total cultivated area. Cottonhas attracted attention of Governments, researchers and activistsdue to its sheer contribution to the national exchequer and livelihood of millions of farmers and textile workers, with significant political implications, and, therefore, has undergone continuous technology and policy shifts over a period of time(Ramasundaram*et al.*,2012).During these shifts cotton has witnessed compositional changes in species mix. At the dawn of the independence, about 96 % of the cotton area was under *desi* (indigenous) varieties (Sundaram*et al.,* 1999). Commercial hybrid in cotton in the world was first developed by India in late 1960s. By 2000, the area under the American cotton varieties and hybrids reached 75 %. However, the yield advantage associated with varietal changes started dissipating over years and it exhibited signs of fatigue in increasing the yield. One of the major reasons was increased biotic stress particularly, pest attack. The most economically important pest that infested cotton crop was the American cotton bollworm (*Helicoverpaarmigera*). Considering the damage potential, farmers had to maintain near zero tolerance against this pest. Central Institute of Cotton Research (CICR), under the Indian Council of Agricultural Research (ICAR), Government of India, reported that theinsect pests in general causedupto 50 % losses in cotton productivity (1998). In many states, the share of plant protection costs in total cost of cultivation increased tremendously. For example in Punjab, the share of pesticidesin operational costs four perc cent in TE 1978-79 to 34 per cent in TE 2001-02and to about 50 % in some endemic areas (Shetty, 2004). Researchers estimatedthat the total loss due to the infestation of bollworm was to the tune of Rs 20 billion to Rs120 billion[2](Wahab, 1997; Chandra 1998;Birthal*et al.* 2000),despite about half of India's total pesticide consumption going for cotton alone(Sundaram*et al.* 1999;Qaim2003), mainly targeting American cotton bollworm. The human health implications of high chemical use in cotton cultivation were also enormous. These developmentswere creating a perfect stage for the introduction of transgenic cotton in India. After the introduction of Bt hybrids in 2002-03 Kharif, its adoption at an exponential rate was invasive and unparalleled; a brief review of the economic impacts of which, is provided below.

Economic impacts of Bt adoption in cotton

Many recent studies have examined the economic impact of Bt cotton in developing countries including India (Qaim 2003;Qaim and Zilberman2003;Huang *et al.* 2004;Barwale*et al.* 2004; Bennett*et al.* 2006;Gandhi and Namboodiri 2006;Qaim*et al.* 2006;Dev and Rao 2007; Pray and Naseem 2007; Vitale *et al.*2007). Most of these studies employed either and / or enterprise budgeting technique, production function approach and its variations, social accounting matrix, economic surplus model using primary data (collected from the farmers/ plots), and came out with varying estimates of the impacts, mostly leading to conforming results of the positive impacts and attributed the increased farm level benefits to savings from insecticide use, higher effective yields, despite higher seed prices (Subramanian and Qaim, 2010). Since its introduction, the area under Bt cotton increased from about 29 thousandhectares in 2002 to over 9.4 million hectares in 2010 (James, 2010), accompanied by an increase in yield from 213 kg/ ha (triennium ending average in 2000-01) to 430 kg/ ha in (triennium ending average in 2008-09). Table 1 depicts the estimated area under Bt cotton in major states in India between 2002 and 2010. The replacement of areas under non-Bt cotton coincided with significant yield increase across all the states.

Figure 1 depicts the yield increase of cotton in major cotton growing states of India since 1970. It is clearly observable that all the states posted sharp yield increase post- Bt cotton introduction. This has causedcorresponding production increase - from1.83million tonnesto 4million tonnesat an aggregate growth rate of about 13 % per year for both production and yield. This contrasts with the growth performance during the previous decade at about negative one %for yield and 0.7 %for production. The contribution of yield effect in the total production increase during the Bt period was about 83 % at national level, and surpassed 100 % in case of four out of nine major cotton growing states (on account of negative area growth) (Ramasundaram*et al.*, 2012).This is the single major factor that contributed towards the growth in cotton production (James, 2008).Nevertheless, thereexisted wide regional variations in growth performance. Table 2 depicts the area, production and yield growths during the Bt period and the preceding decade.

Yield growth was significant during the Bt period (from 2002-03 onwards)- ranging from 3.2 % in Tamil Nadu to 17.4 % in Gujarat -resulting in significant

[2]The exchange rate for Indian currency, Rupees (Rs) is One US$ = Rs 48.6 in 2002

production growthas well in all but two states. The low production growths in some states as could be noticed in case of Karnataka and Tamil Nadu can be attributed to fall in the area. The impact of Bt technology on cotton yield increasehas been succinctly broughtby Gruère and Sengupta (2011), in their observation that the average cotton yield level reached almost 400 kg/ha in 2003-04 (for the first time in history, even though the area under Bt hybrids was very less) and that the yield level exceeded 500 kg/haonly three years later in 2006-07, whereas it took 15 years, from 1982 to 1997, for the national yield level to increase from 200 kg/hato an average of 300 kg/ha. It was also estimated that in the alternate scenario of continuing only historical growth rates, the production would have been around 13-14 million bales at the yield level of less than 300 kg/ha as against 526 kg/ha during 2009-10. The total pesticide consumption in Indian agriculture would have been around 60 thousand tonnes against 42 thousand tonnes during 2010-11 (Ramasundaram*et al.* 2011). It is pertinent to mention that the advances in pesticide technology too might have contributed to this reduction.

Many other studies have estimated the beneficial role of Bt cotton cultivation, deploying field level data. Qaim*et al.* (2006) used farm level data collected from the states of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu in 2002 and reported that Bt cotton yields were higher to the extent of 34 %with lower number of insecticide sprays (2.6 times less). Subramanian and Qaim (2009) surveyed the same farmers again in 2004-05 and in 2006-07, and reported that on an average Bt cotton recorded 37 % higher yields than the conventional cotton and 41 % lower insecticide applications. Narayanamoorthy and Kalamkar (2006) while examining the economic viability of Bt cotton cultivation at farm level, reported that the profit realized from the Bt cotton is substantially higher than that from the non-Bt cotton crop, to the extent of about Rs 14000, and the profit was about 80 % higher than that of the non-Bt farmers owing to higher productivity and cost efficiency than higher output price. Similar results were reported by some other researchers as well (Bennet*et al.*, 2006;Dev and Rao, 2007). But some other studies were rather skeptical about the impact of Bt technology in India. Kuruganti (2009) observed that the high yield growth in case of Gujarat was mainly due to the low incidence of the target pest, consistently good monsoon for a long period, increasing area under irrigation and high application of chemical fertilizers. Further, the author argued that the hybrid vigor brought about by the shift to cultivation of hybrids itself brought in large yield improvement. Large scale shift to hybrids (F_1 seed) was reported as an important after effect of Bt cotton cultivation in India (Khadi,2007). Naik*et al.* (2005),while exploring the paradoxes reported in some earlier studies on benefits of Bt cotton, found that on an average the technology generates overall economic benefits, but heterogeneity among farmers needs to be accounted for. The appropriateness of Bt technology depends on local pest pressure, individual crop management, local suitability of the germplasm into which Bt gene is transferred and the information flow. Gruère and Sengupta (2011), while agreeing to the proposition that the Bt cotton technology has played a significant role in raising the cotton production, also pointed to the differing marginal effects of the technology across states. Some researchers attribute such differences to the enabling paraphernalia of technology adoption like development of irrigation infrastructure (Shah *et al.*, 2009,Ramasundaram*et al.* 2012), besides the variations in the agro-ecological and socio-economic conditions (Bennett*et al.*, 2006;Qaim*et al.*, 2006). This fact becomes more evident while looking at the irrigation development *vis a vis* cotton yield (Figure 2). It is discernible that the yield of cotton was generally high in regions with larger area under irrigation.

Empirical methodology

Economic surplus model for welfare estimation

Economic surplus model has been widely used to quantify the welfare effects of genetically modified crops. It details how markets would respond to the introduction of the technology, by analysing new equilibriumusing a demand-supply framework. The model is governed by the well-established economic theory and assumes perfect competition as the basis for best outcome for the society. It is based on the premise that whenever new technologies are adopted on a large scale, the productivity increase will cause the crop supply curve to shift downwards, leading to changes in producer and consumer surpluses, which are measured in standard monetary units (Alston *et al.,*1995). The consumers derive their surplus from purchasing their bundle of goods at lower prices, whereas producers obtain surplus out of selling higher quantities in the market and by reducing production costs. Consumer surplus, in that context, represents the free resources that can be transferred to other sectors of the economy, whereas the producer surplus is the sum of additional rents that accrue to farmers' internal resources (Vitale *et al*, 2007). The magnitude and distribution of the economic benefits depend on factors such as price elasticities, volume of production, trade issues, and nature of innovative changes induced by the technology, innovator rent, and technology fee, among others. The model follows comparative statics approach, and doesn't detail the dynamics of establishment of the new equilibrium. One of the important features of the model is that, the early adopters will achieve large benefits that would dissipate as others follow (Vitale *et al.*, 2007).When the market for a single crop is considered, partial equilibrium models are used, whereas general equilibrium models are used when indirect effects and spillover to other markets and sectors are also of interest (Qaim, 2009). The present study covers only Bt cotton (although there could be some substitution effects between Bt and non-Bt cotton), and, therefore, adopt partial equilibrium model.The economic surplus model considers only the effects of the technology change in the market where the technical changes occurs, and disregards the effects in other markets, such as input markets. As the technology is developed and commercialised by the private sector, technology rent accrued tothem also needs to be considered (Moschini and Lapan, 1997) in estimating total welfare.The technology in India is developed by Mahyco-Monsanto Biotech, but the company have sub-licensed marketing rights to four other firms as well. Therefore, the appropriation of the benefits of the seed industry goes to all the firms involved in the entire business process, including the innovators and the marketing companies depending upon the license agreements and respective market shares. However, we restricted our analysis to the benefits accrued to the entire private sector without attempting to analyse the firm level benefit appropriation.

Model empirical structure

India is a net exporter of raw cotton and yarn. As on 2009, India exported 1.4 million tonnes of cotton (including raw cotton, cotton yarn, lint and waste) worth US

$ 2.0 billion. This accounts for 21 % of world cotton trade (FAO, 2011). On account of this significant share in export, we modelled the economic impact of Bt cotton in an open-economy framework with no technology spillovers (though, there could be some across the border transfer), and assumed linear supply and demand and a parallel shift in supply from the new technology (Alston *et al.*, 1995). The spillover effect is neglected considering the large size of India as an agrarian economy and negligent impact that the changes in factors of production would bring about in other sectors. The cotton market is regulated by Government of India, which guarantees purchase of cotton at minimum support prices. However, in practice, the domestic market price is higher than the minimum support price rendering the Government operations redundant in most of the years and states. The Bt cotton seeds in India is marketed by Mahyco-Monsanto, the holder of the patent for the technology and marketing rights. Due to this monopoly power the company enjoys, it could beableto set the seed prices above the marginal cost of production. Therefore, the welfare estimation undertaken in this model consists of two components, viz. the changes in the producer surplus and the monopoly profits. The change in producer surplus (Δ PS) resulting from Bt technology in the year t can be calculated as:

$$\Delta PS = PQK\,(1+0.5\,K\varepsilon) \qquad ...(1)$$

Where, P and Q are counterfactual cotton prices and quantities, respectively and ε is the price elasticity of supply. K is the technology induced supply shift of cotton, calculated based on the actual change in the yield level of cotton as indicated below:

$$K = \left[\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1+E(Y)}\right]\rho A_t(1-\delta_t) \qquad ...(2)$$

Where, E(Y) is the proportionate yield change per hectare, E(C) is the proportionate change in variable input costs per hectare to achieve the expected yield changes, ρ is the probability of the success of the research (assumed as one as it is *fait accompli* and the analysis is *ex-post*), A_t is the adoption of Bt cotton in percentage of total acreage and $\delta_t$isthe annual rate of depreciation. As the performance details of the technology were available, the field data with respect to yield advantage, cost reduction and adoption rate were used for estimation. The private sector benefit (PB) accruing to the innovators and marketers is analysed using the method propounded by Moschini*et al,*. (2000) as indicated below:

$$PB = A[(1-\theta)(P_{Bt} - P_{non\text{-}Bt})] \qquad ...(3)$$

Where, A is the coverage of Bt cotton in hectares, P_{Bt} is the price of the B_t seeds and $P_{non\text{-}Bt}$ is the price of non- Bt seeds. Here, it is safe to assume that the conventional seed market is competitive and cost of production of Bt cotton is equal to that of the non Bt conventional hybrids available in the market, and difference between these two prices is the gross technology revenue (GTR). However, distribution, marketing and extension cost of the Bt seeds is somewhat higher than that of the conventional hybrids, especially in the early years of adoption. Qaim*et al.* (2006) used a value of 0.1 to account for this expenditure and is represented by θ in the equation indicated above. By adjusting the GTR with θ, it translates intonet private benefit. Though this cost pertains to the initial years of the technology development, it is assumed that the expenditure under this head would continue to retain the market composition and introduction of new hybrids with Bt gene. The company R&D expenditure has not been accounted for in the analysis as they are considered as sunk costs. The analysis has been carried out for all the major cotton growing states of India. The producer and private sector surpluses were generated and summed up to arrive at the national figures.

Data and data sources

As reviewed earlier, many empirical studies have documented the economic benefits of Bt cotton cultivation in India, with mostly conforming results, leaving a few contradictions. Using meta analysis covering a fairly long period of 2003 to 2008, Gruère and Sengupta (2011) notedthat a majority of Indian farmers gained substantially by adopting Bt cotton; however, the gains in the Bt cotton cultivation cannot be generalised for all cultivators, regions and seasons. On an average,the number of pesticide sprays reduced by 30-36 % with associated cost reduction of 35-52 %. The yield increase ranged between 34-42 %, with no clear effect on seed cotton prices. The overall rise in net return was to the extent of 50-94 %. Significantly, there were considerable inter-state variationsas well. Notwithstanding the deficiencies of these studies, we have adapted the averages of the agronomic performance parameterscompiledbyGruère and Sengupta(2011) to computestate wise economic surpluses. The technology life reckoned for computation was assumed to be 14 yearsbased on discussions with crop scientists and seed companies.

Acharya and Agarwal (1994) reported that the price elasticity of supply for cotton in Southern India is 0.31 in the short run and 0.54 in the long run. Since the state-wise disaggregated elasticity of supply was not reported, we have taken the average elasticity of 0.43 as the medium-run elasticity, and this was used to calculate the reduction in marginal costs for all the states. The medium run supply elasticity of 0.43 was used by some other researchers also to estimate the economic impact (see, Qaim, 2003). One other important parameter used in the estimation process is the technology fee, which is the cost difference between the Bt seeds and non-Bt counterparts. Though the price of Bt seeds was on the higher side in the initial years, subsequent Government interventions, brought it down considerably (Sadashivappa and Qaim, 2009). Based on discussions with the seed dealers and farmers, it was assumed to be 52 %. The actual technology adoption rates were used for the estimation of benefits upto 2010 and the end year values were retained for the remaining period of 2011 to 2015. It is pertinent to mention here that this assumption seems quite tenable as the adoption of Bt cotton almost stabilised by the end of the last decade.

Another important parameter is the technology depreciation. Discussions and literature enable our assumption that the technology depreciation setinBt cotton since 2007 and would continue to decline during the projection period,even while retaining the edge over non-Bt counterparts[3]. The counterfactual cotton prices were calculated as the

[3] The technology depreciation in case of Bt cotton is noted in the form of emergence of non-target pests as the major pests thereby necessitating increased pesticide application. It is observed that once the Lepidopteron pests, like American cotton bollworm infestation diminished, new problems emerged in the form of increased infestation by various sucking pests.

three year weighted average prices based on the data during the pre-Bt period, 1999-00 to 2001-02. The impact assessment needs to take into account the growth not accounted for by the technology; therefore the output was adjusted for this by using the exogenous output growths. They were estimated based on business as usual principle, by compound annual growth rate of cotton production over a decadecovering 1990-91 to 2001-02, the period closer to the introduction of Bt cotton. Since thebenefits are accruing over a period, the future benefits needs to be discounted. Selection of proper discount rate assumes importance in this context. Kula (2004) reported that the social discount rate for evaluating agricultural projects as 5.2%. We have adopted this rate to calculate the present value.

Results and discussion

Welfare generation

The welfare generated across states is provided in Table 3. The total welfare amounted to Rs 220 billion, consisting of Rs188 billion producer surplus and Rs32 billion private sector surplus. On conversion of the benefits into US dollars at 2002 exchange rates, it turned out to be $ 5.67 billion with per annum benefit of $ 404 million. Similar results were reported for other countries as well. Price *et al.*(2003) reported annual surplus of about $ 164 million in case of United States and the percentage shareamong farmers, consumers and producing companies were37, 18 and 45, respectively. For China, the surplus accrued was $140 million in 2009 (Pray *et al.*, 2001). Qaim (2003) estimated total producer and innovator surplus in India to be Rs 15 billion during 2005, starting from Rs 0.30 billion for 2002, Rs 2.1 billion for the year 2003 and Rs 6.0 billion for 2004, when the area under the Bt cotton was very low.Ourestimates are pegged at slightly lower level- Rs0.64 billion for 2002, Rs0.85 billion in 2003 and Rs 1.37 billion in 2004. This deviation wasmainly due to less than expected reduction in the pesticide consumption in some states. The realisation of the surpluses across states varied widely in proportion to the penetration of Bt hybrids, their agronomic performance and variations in pre-Bt cotton performance (base effect). The highest was recorded inMaharashtra, with Rs74 billion, accounting for about one third of total surplus, followed by Gujarat withRs67 billion, accounting for about 31 %. These two states together accounted for 57% of total cotton area in India (as on 2008-09). Andhra Pradesh, with its meagre share of only two per cent in surplus (pegged at about Rs 6.3 billion) is conspicuous as its share in the crop acreage is as high as 15 % (1.4 million hectares). The stateappropriatedonly 0.29 % of total producer surplus generated in India, while its share in total private sector surplus was 14 %. The lower performance of the producer surplus despite higher adoption rates may be due tothenegligible cost reduction and high pre- Btgrowth performance experienced in the state. Punjab, a state where cotton is cultivated under assured irrigated condition realised a producer surplus of Rs37 billion accounting for about 19 % of the total producer surplus, despite a meagre area share of about 5.6 %. The introduction of Bt cotton hybrids fitted very well with the prevailing cotton- wheat crop rotation systemof the state (Ramasundaram,2005). Short duration cotton could be cultivated during the *kharif* season (summer, starting from June- July), and harvested by about October, when the land preparation of the succeeding wheat crop during *rabi*season (winter, starting from late October) could be undertaken. Punjab is a major wheat producing state in India with the highest per hectare yield contributingmore than 20%to the national production as on 2010. Before 2005-06, the hybrid cotton area in the state was less than 3-4 %as open pollinated varieties were more preferred. But Bt hybrids with synchronised flowering, limited picking and early termination, enabled timely sowing of wheat.Besides, the dismal pre-Btperformance of cotton - the yield growth during the previous decade being negative (–3.2 %)due to severe pest infestation (Ramasundaram*et al.* 2012)- also facilitated a higher surplus. Bigger reductions in pesticide costs and resultant high yield advantage during the post-Bt period helped the state to emerge as a high performer.

It may be noted that almost 85 % of the total surplus generated was accounted for by the producers, and the rest by the private sector. Barring Andhra Pradesh, the share of producer surplus ranged between 76 % in Haryana and 90 % in Rajasthan (Figure 3). It is worthwhile to recall that in both these neighbouring states cotton is cultivated under irrigated condition. Still, the better in performance of cotton in these two states can be adduced to the higheryield gains and the pesticide reduction post Bt-introduction. The extent of surplus realisation and distribution between producers and private sectorwouldhave been different, but for the state intervention in rationalising the seed prices (Ramasundaram*et al*, 2011). The administrative measures to reduce the per acre seed pricefromRs 1500 to Rs 750 in many stateshelpedits wider adoption, generating higher producer surplus, and boosting the private sector surplus through volume of trade.It can be surmised that the percentage of benefit appropriation was more than the corresponding area share under Bt cotton in three out of nine states (Gujarat, Punjab and Rajasthan). While in Punjab and Rajasthan, large yield increase and pesticide reduction favoured an increase in the benefits, in case of Gujarat it was triggered by large area increase. Though cotton is cultivated under full irrigation coverage in Haryana also, the percentage benefit realisation could not surpass the area share, probably due to the less than proportionate reduction in input application compared to the non-Bt era.

The distribution pattern of the cumulative surplusesat national level over years for the period under study is depicted in Figure 4. It can be noted that by 2007, total surplus realisation was about 10 %, which increased sharply to 21 % by 2008, and further to 33 % by 2009. The year 2010 saw the realisation of almost half of the total cumulative surplus, and itemerged as the turning point, with no further marginal increase in the annual realisations. This would be mainly due to technology depreciation and diminished scope and progress infurther technology adoption. This warrants further investments for technology re-invention. Already such efforts are on, primarily by private sector. One of the prime steps in this regard was transfer of Bt gene to better host hybrids/ varieties and incorporation of genes that can withstand some other pests as well (stacked genes).

Conclusions

It is a decade since Bt cotton has been introduced for commercial cultivation in India in 2002-03. This study is contextual in critically analysing the impact of the technology on Indian cotton economy through an economic surplus model and examining the welfare distribution over states. The study combines the field level data on the agronomic performance of Bt cotton with the macro data on technology adoption, seed prices and exogenous growth rates for all the major states.

Bt cotton phase has increased income and generated substantial social gains due to higher yield and lower cost of production through reduced cost of plant protection. The total benefit would be Rs 220 billion with 85 %accruing to producers. The wide inter-state variations are because of the differences in the penetration of Bt hybrids, their agronomic performance in the fields and variations in pre- Bt cotton performances. It was noted that the highest total surplus was recorded in Maharashtrafollowed by Gujarat. Andhra Pradesh and Punjab depicted contrasting performance because of the differences in agronomic performances and the exogenous technology growth. While the lower reduction in insecticide usage combined with positive exogenous technology growth yielded a reduced producer benefit (in absolute terms and in comparison with the acreage) in case of Andhra Pradesh, the significant reduction in insecticide usage and lower exogenous production growth yield higher and more than proportionate benefit in case of Punjab. The private sector benefit, though was Rs32 billion, constituted only 15 % of total benefit. One reason for this might be the seed market regulations brought about by the Government. It is also worthwhile to point out that the relatively stronger intellectual property rights regulations in India helped generation of substantial private benefits and innovation rents, thereby promoting further private investment in research and development. It may be recalled that in India the vehicle for Bt technology in cotton is hybrids, whereas in other countries Bt technology is incorporated in open-pollinated varieties obviating the need to purchase seed every year (Ramasundaram*et al.,* 2011). Development of the open pollinated Bt varieties may help in realisation of greaterbenefits to cultivators in resource poor regions not conducive to hybrids and enhancement of the producer surplus. It is pertinent to note that the entire welfare generated cannot be attributed to the Bt gene technology alone, but to a gamut of other factors like increase in crop area, hybrid area, input use,favourableagroclimate in terms of consistent good rainfall in some regions, increase in the irrigation coverage, to cite a few.Hence, the entire benefit is better viewed as the welfare generated during the Bt phase.

However, the benefit estimatemay be an under report by as much as the un-estimated positive externalities and indirect benefits in terms of health benefits due to reduction in pesticide use and reduced exposure to pesticides, possible surge in predators and parasites population, improvement of soil health and clean water bodies, reduction in greenhouse gases, increase in employment and reduction in poverty, which cannot be captured due to paucity of data and time. On the flip side, new challenges have emerged in cotton pest scenario in India in the past few years, in terms of negative externalities like surge in minor pests calling for more plant protection expenditure for their control than earlier, reduction in biodiversity by elimination of cotton open pollinated varieties, to cite a few. This study has not taken into account these complex changes at field level. There is scopeforfurtherincreasing the social gains through research in various aspects of the crop. They include cost cutting strategies like promotion of Bt varieties for resource poor regions, demand driven value addition in fiber traits, incorporating stress tolerance traits andmanipulation of crop duration, among many others.

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