Rural Poverty and Employment Effects of Bt Cotton in India

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Abstract

The impact of genetically modified (GM) crops on the poor in developing countries is still the subject of controversy. While previous studies have examined direct productivity effects of *Bacillus thuringiensis* (Bt) cotton and other GM crops, little is known about wider socioeconomic outcomes. We use a microeconomic modelling approach and comprehensive survey data from India to analyze welfare and distribution effects in a typical village economy. Bt cotton adoption increases aggregate employment with interesting gender implications. Likewise, aggregate household incomes rise, including for poor and vulnerable farmers, highlighting that Bt cotton contributes to poverty reduction and rural development.

1. Introduction

Several recent studies have analysed the impacts of genetically modified (GM) crops on farm productivity in developing countries (FAO, 2004; Huang et al., 2005; Zilberman et al., 2007). Many of these studies focused on insect-resistant *Bacillus thuringiensis* (Bt) crops, especially Bt cotton, because this technology has been adopted already by millions of small-scale farmers around the world, including in China, India, South Africa, Mexico, and Argentina (James, 2007). The available evidence shows that the concrete impacts vary seasonally and regionally, according to the underlying agro-ecological and socioeconomic conditions (Qaim et al., 2006; Bennett et al., 2006). On average, farmers growing Bt cotton benefit from insecticide savings, higher effective yields through reduced crop losses and net revenue gains, in spite of higher seed prices (Huang et al., 2002; Morse et al., 2004; Qaim and de Janvry, 2005; Gandhi and Namboodiri, 2006; Crost et al., 2007; Pray and Naseem, 2007). Using partial equilibrium displacement models, different authors also showed that these productivity effects entail significant gains in economic surplus (e.g., Pray et al., 2001; Qaim, 2003).

There are also studies that have analyzed welfare effects of Bt cotton and other GM crops for developing countries from a macroeconomic perspective, using computable general equilibrium (CGE) models (de Janvry and Sadoulet, 2002; Elbehri and Macdonald, 2004; Huang et al., 2004; Anderson et al., 2008). However, hardly any research so far has focused on analysing wider socioeconomic outcomes at the micro level, which is probably also the reason for the ongoing controversy surrounding the poverty and rural development implications of GM crops (Lipton, 2007; World Bank, 2007; Friends of the Earth, 2008). One exception is Subramanian and Qaim (2009), who have examined direct and spillover effects of Bt cotton adoption in India, using a village modelling approach. Building on census data from a particular village in the state of Maharashtra, they developed a micro social accounting matrix (SAM), disaggregating village households by land ownership. Simulation results with a multiplier model showed that small and large farms can benefit from Bt cotton adoption, although household income gains are somewhat bigger for the large farm category.

Here, we extend the approach by Subramanian and Qaim (2009), in order to analyze the impacts of Bt cotton on poor households more explicitly. We use the same data and SAM approach, but disaggregate village households by income groups, employing local poverty lines as differentiating criteria. Since this is the first attempt to assess the poverty effects of a GM crop application, the results can add new facts to the academic and public policy debate about the role of agricultural biotechnology for sustainable development.

The rest of the paper is organised as follows. In section 2, a brief overview is presented of the direct farm level effects of Bt cotton, using representative survey data from different states of India. Furthermore, the village data and household disaggregation are discussed. In section 3, we describe the general features of the village SAM, while in section 4, we run simulations to study the broader socioeconomic impacts of Bt cotton on farm and non-farm households. The last section concludes.

2. Farm Level Impact and Census Survey

In India, cotton is mainly grown on relatively small farms with less than 10 acres (Qaim, 2003). Bt cotton was officially commercialised for the first time in 2002, and since then adoption rates have increased rapidly, reaching 6.2 million hectares in 2007 (James, 2007). Qaim et al. (2006) had analyzed farm level effects of the technology in 2002-2003, using stratified random sample data collected in the states of Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu. These data are representative for cotton production in central and southern India. Subramanian and Qaim (2009) had surveyed the same farms in 2004-2005, and we conducted a third round of data collection in 2006-2007. A comparison of Bt and conventional cotton plots for all three survey rounds is summarized in Table 1. These results are consistent with other studies in India (e.g., Bennett et al., 2006; Gandhi and Namboodiri, 2006; Crost et al., 2007).

The difference in yield between Bt and conventional cotton increased from 34 per cent in 2002-2003 to 42 per cent in 2006-2007, while the reduction in insecticide quantities decreased from 50 per cent to 21 per cent. However, yield and insecticide effects vary from year to year with pest pressure, so that the differences should not be over-interpreted as a clear trend. Between 2002 and 2007, per-acre net revenues were on average 2000-3000 Indian Rupees (Rs.) (US $45-67) higher on Bt than on conventional cotton plots.

(Table 1 about here)

In order to analyze the broader socioeconomic effects, we use comprehensive data from a census survey that was carried out in one particular village in 2004 (Subramanian and Qaim, 2009). The study village, Kanzara, is located in Akola district of Maharashtra, the state with the largest area under cotton in India. Kanzara can be considered a typical setting for smallholder cotton production in the semi-arid tropics (Walker and Ryan, 1990). Interviews with village households captured all household economic activities and transactions for the 12-months period between April 2003 and March 2004. Of the total 305 village households, 102 are landless; the other 203 own land suitable for agricultural production. The average farm size of land-owning households in the village is 4.7 acres. All farm households cultivate at least some cotton, mostly next to a number of food and fodder crops for subsistence consumption and for sale. Fifteen farmers had adopted Bt cotton technology in the 2003-2004 growing season.[1]

Unlike Subramanian and Qaim (2009), who used a categorisation of households by land ownership, for the analysis here we classify village households according to their consumption expenditures, using the local rural poverty line of 10.62 Rs. per day

(Planning Commission, 2001). This corresponds to US $1.15 in terms of purchasing power parity (PPP), which is close to the $1.08 a day figure used by the World Bank to classify extreme poverty at the international level (Chen and Ravallion, 2007). Forty-eight per cent of the households in Kanzara fall below this poverty line. A second threshold of 21.24 Rs. per day ($2.30 PPP) is used to classify vulnerable households.[2] According to this definition, 38 per cent of the village households are vulnerable, that is, they fall in-between the Rs. 10.62-21.24 range.

3. Features of the Micro Social Accounting Matrix

The SAM we use here is based on Subramanian and Qaim (2009), but with a different household categorisation, as detailed above. Village SAMs have been developed and used previously in different contexts (Adelman, Taylor and Vogel, 1988; Subramanian and Sadoulet, 1990; Parikh and Thorbecke, 1996). Yet, this SAM is distinct in two respects. First, unlike previous SAMs, which are based on sample surveys, this SAM builds on a village census. Since a SAM by construction requires both receipts and payments of all transactions, availability of census data reduces the problem of unbalanced markets and thus of biased results. Second, this SAM explicitly considers Bt and conventional cotton as two different activities, which allows us to evaluate both technologies' distributional impacts.

The SAM for Kanzara village considers 156 agricultural and non-agricultural activities. Agricultural activities include the cultivation of cotton and numerous other crop and livestock enterprises. Non-agricultural activities include agricultural services (for example, hiring out machinery), village production (for example, construction and small-scale manufacturing), retail trade, private services (for example, barber, doctor), government services (for example, ration shop, post office) and transportation. An aggregate version of the SAM is presented in Subramanian and Qaim (2009). In 2003-2004, the gross domestic product of the village was about Rs. 24.54 million (US $0.55 million). Kanzara is a net exporter of commodities and a net importer of factor services. The local economy is characterised by extreme openness, with only 28 per cent of total crop production within the village being for subsistence purposes.

4. Simulations

The SAM as such is a static representation of the village economy. It does not allow making statements about income distribution effects of individual activities like Bt cotton. This requires simulations with a SAM multiplier model. The idea of a SAM multiplier simulation is to introduce an exogenous shock to the village economy and then observe how factor returns and household incomes change in comparison with the status quo. We use the multiplier model described by Subramanian and Qaim (2009), which largely builds on Pyatt and Round (1979).

For the analysis of Bt cotton impacts, we run two scenario simulations, both considering an expansion in the village cotton area by 10 acres. The first scenario assumes that the additional 10 acres are cultivated with Bt cotton, while the second assumes that the additional area is grown with conventional cotton.[3] Accordingly, differences between the two scenarios can be interpreted as the net impacts of Bt technology adoption. The 10 acres in each scenario are additional to the crop area already cultivated in Kanzara, and – as is common in SAM multiplier analyses – it is assumed that there are no constraints in the availability of other production factors. It should be noted that the magnitude of the area expansion does not matter for the essence of the results, as long as it is the same in both scenarios. Based on the existing structure of the village economy, the multiplier model simply simulates the direct and spillover effects resulting from the increase in a specific economic activity, in our case either Bt or conventional cotton production. All the resulting effects are proportional to the assumed area expansion, such that income distribution is not influenced by the choice of the concrete acreage.

We first discuss the Bt scenario separately, in order to explain the socioeconomic mechanisms underlying the results. Figure 1 demonstrates that 10 additional acres of Bt cotton would entail sizeable employment effects at the village level; aggregate returns to labour would rise by Rs. 39 thousand. Especially the employment of hired female labourers would increase. In the manual cotton production systems, hired women workers carry out most of the sowing, weeding, and harvesting operations, while men are mostly responsible for tillage, irrigation, and pest control. But also returns to non-agricultural labour would increase through employment effects in other village sectors that are linked to cotton production, such as transportation, trade, and other services.

(Figure 1 about here)

Aggregate household incomes in the Bt scenario increase by Rs. 106 thousand (Figure 2). This is the result of changes in the returns to the factors of production labour, capital, and land employed within the village. In addition, multiplier effects through spillovers to outside village markets and feedbacks are included. These are particularly important for a cash crop like cotton. For instance, higher cotton production and rising incomes within the village induce growth also in outside village sectors, which again leads to new employment and investment opportunities, including for village households. Figure 2 demonstrates that most of the aggregate income effects resulting from an increase in Bt cotton production would be captured by farm households, although landless village households would also benefit to some extent.

(Figure 2 about here)

Yet, employment and income gains would also result from an increase in conventional cotton production. Therefore, the second scenario simulation assumes that the additional 10 acres are cultivated with conventional cotton. The effects on employment and household incomes are similar to those in the Bt scenario (Figures 1 and 2), as one would expect given that both alternatives involve an increase in village cotton production. Nonetheless, there are also noteworthy differences, and these differences are particularly relevant for the comparative evaluation of both technological choices.

Overall, changes in the returns to labour are higher in the Bt scenario (Figure 1), demonstrating that Bt cotton generates more employment than conventional cotton in the local economy. The difference is especially notable for hired female agricultural labourers, which is due to significantly higher yields to be harvested in Bt cotton. For male members of the farm families, returns to labour are also higher in Bt than in conventional cotton, although this is largely driven by indirect effects. With reduced insecticide applications in Bt, some of the family male labour involved in pest scouting and spraying is saved, which means less employment in Bt cotton as a direct effect. However, the simulations show that this family labour saved in cotton production can be reallocated to other agricultural and non-agricultural activities, such that the overall returns to labour increase. Apparently, use of family male labour in cotton is associated with a significant opportunity income. Most of this opportunity income is realised in self-employed activities (that is own agricultural and non-agricultural businesses). In contrast, the returns to hired male agricultural labour are lower in Bt than in conventional cotton, suggesting that there are fewer alternative employment opportunities for this category of workers.

Total household income increases are 82 per cent higher under Bt than under conventional cotton (Figure 2). This implies a remarkable gain in overall economic welfare through Bt technology adoption at the village level. For landless households, the effects are relatively small. Especially the poorer landless households derive most of their income from employment as hired agricultural labourers, and the higher employment of female workers in Bt cotton is almost offset by the lower employment of male workers. However, all types of farm households – including those below the poverty line – benefit considerably more from Bt than from conventional cotton. Strikingly, vulnerable farm households are the main beneficiaries, with additional income gains in a magnitude of 134 per cent.

Beyond the direct impacts on cotton profits, labour market effects are an important component of the income changes caused by Bt technology. For poor and vulnerable farmers, higher returns to labour are due to more employment of female household members as hired workers on other farms, as well as higher returns to agricultural family labour in alternative employments. For rich farmers, hiring out female labour is rare, so that the increase is almost exclusively from higher returns to family male labour employed in alternative activities. Thus, the observed differences in household income increases between different types of farmers can largely be explained by different opportunity incomes. Poor farm households are dominant in non-agricultural village production activities such as construction and small-scale manufacturing (Figure 3), where positive spillover effects through Bt cotton adoption are relatively weak. Spillovers are more felt by vulnerable farm households, who receive a higher proportion of the village income from agricultural production and non-agricultural services, and for rich farm households, who account for the largest share of agricultural services (for example, hiring out machinery) and retail trade within the village.

(Figure 3 about here)

5. Conclusion

In this article, we have analysed the direct and spillover effects of Bt cotton on poor households in rural India. The results demonstrate that technology adoption entails important positive socioeconomic effects in the small farm sector. More specifically, we show that Bt cotton adoption increases rural employment with interesting gender implications. Compared to conventional cotton, Bt cultivation increases aggregate returns to labour by 42 per cent, while the returns for hired female agricultural workers even increase by 55 per cent. Likewise, total household incomes rise considerably, including for poor and vulnerable farm families that constitute the largest proportion of rural dwellers. Strikingly, the main beneficiaries are vulnerable farmers, whose household income gains are 134 per cent higher under Bt than under conventional cotton. This disproves the often heard argument that only wealthy farmers could benefit from GM crops.

While the exact findings presented here are specific to the study village, the social structure of the local economy is typical for the semi-arid tropics, comprising cotton production in central and southern India. So it is reasonable to conclude that Bt cotton produces important benefits in large parts of rural India. The technology is net employment generating and causes income gains for all types of households, including those below the poverty line. This highlights that Bt cotton contributes to poverty reduction and rural development.

Hardly any previous research has been carried out on the wider socioeconomic outcomes of GM crops at the micro level in developing countries. The resulting knowledge gap has contributed to uncertainty and to overly precautious attitudes in research and regulatory policies. Our results for Bt cotton in India cannot simply be generalised to other examples, because impacts always depend on the concrete technology and institutional framework. Nonetheless, the fact that GM crop applications can help reduce poverty as such has wider implications and might further the debate about the role of agricultural biotechnology for sustainable development.

The results presented here should be interpreted keeping in mind some of the inherent drawbacks of the SAM multiplier approach, such as the assumptions that output levels are solely driven by demand and prices are fixed (for a comprehensive discussion see Taylor and Adelman, 1996). We believe that the broad results will not change significantly by relaxing these assumptions. This, however, require a village CGE model, the construction of which we consider part of the future research agenda.

Endnotes

[1] 2003-2004 was only the second season in which Bt cotton was officially commercialised in India. The number of adopting farmers has increased significantly over time, including in Kanzara village. In 2007-2008, already 66 per cent of the total Indian cotton area was under Bt technology (James, 2007).

[2] The World Bank uses a $2.15 (PPP) a day value as a second threshold. This is considered to be more representative of what poverty means in middle-income countries (Chen and Ravallion, 2007).

[3] Technically, this is implemented as an exogenous increase in cotton demand by the value produced on the additional 10 acres. In SAM jargon, this is called the initial injection. Since yields in Bt are higher than in conventional cotton, the value of the injection is also proportionally higher in the Bt cotton scenario. We used the representative data in Table 1 to calibrate yield and insecticide use differences between Bt and conventional cotton in the simulations.

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Table 1. Comparison of mean insecticide use, yields, and net revenues between Bt and conventional cotton plots in India

	2002-2003		2004-2005		2006-2007	
	Bt	Conventional	Bt	Conventional	Bt	Conventional
Insecticide use in kg/acre	$2.07^{***} \pm 2.65$	4.17 ± 3.37	$2.05^{***} \pm 2.68$	4.19 ± 10.48	$1.22^{*} \pm 1.41$	1.55 ± 1.51
Yield in kg/acre	$658.82^{***} \pm 393.64$	490.86 ± 335.88	$742.94^{***} \pm 327.62$	550.52 ± 291.22	$841.65^{***} \pm 356.00$	589.93 ± 335.09
Net revenue in Rs./acre	$5294.22^{***} \pm 8117.19$	3132.99 ± 6773.89	$4921.83^{***} \pm 6290.90$	2152.08 ± 5476.80	$7120.82^{***} \pm 7654.80$	4181.26 ± 7563.07
Number of observations	133	301	165	300	317	56

Sources: Qaim et al. (2006) for 2002-2003, Subramanian and Qaim (2009) for 2004-2005 and authors' calculations for 2006-2007.

*, **, *** Mean values are different from those of conventional cotton in the same year at a 10 per cent, 5 per cent, and 1per cent significance level, respectively.

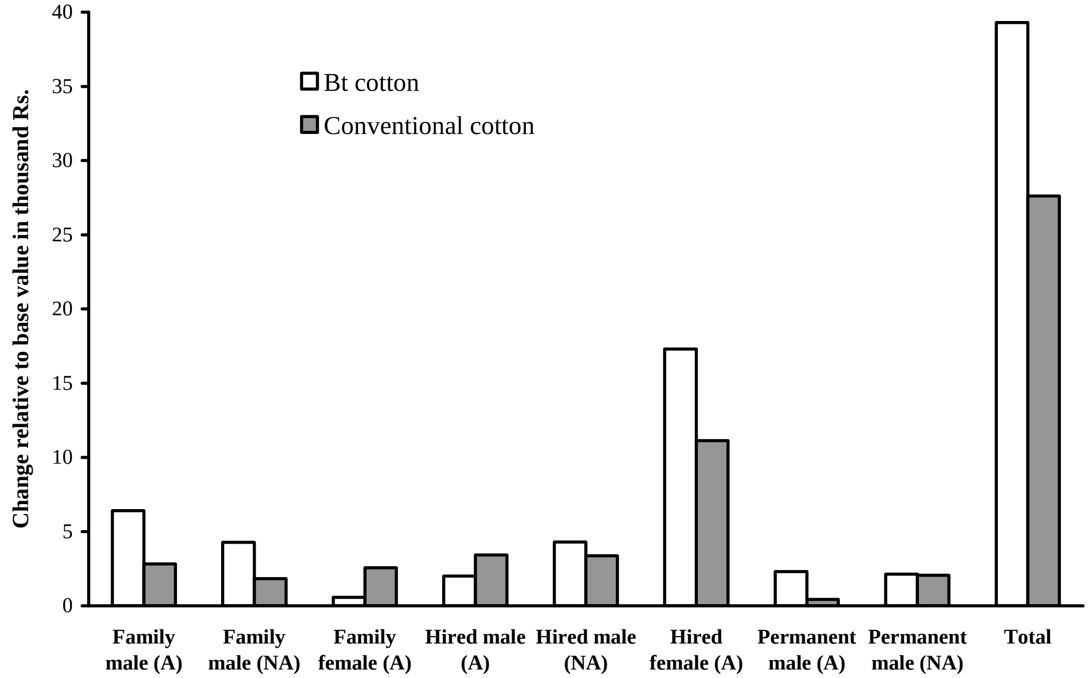

Figure 1. Changes in returns to labour from increased Bt and conventional cotton production

Note. “A” stands for agricultural and “NA” for non-agricultural labourers

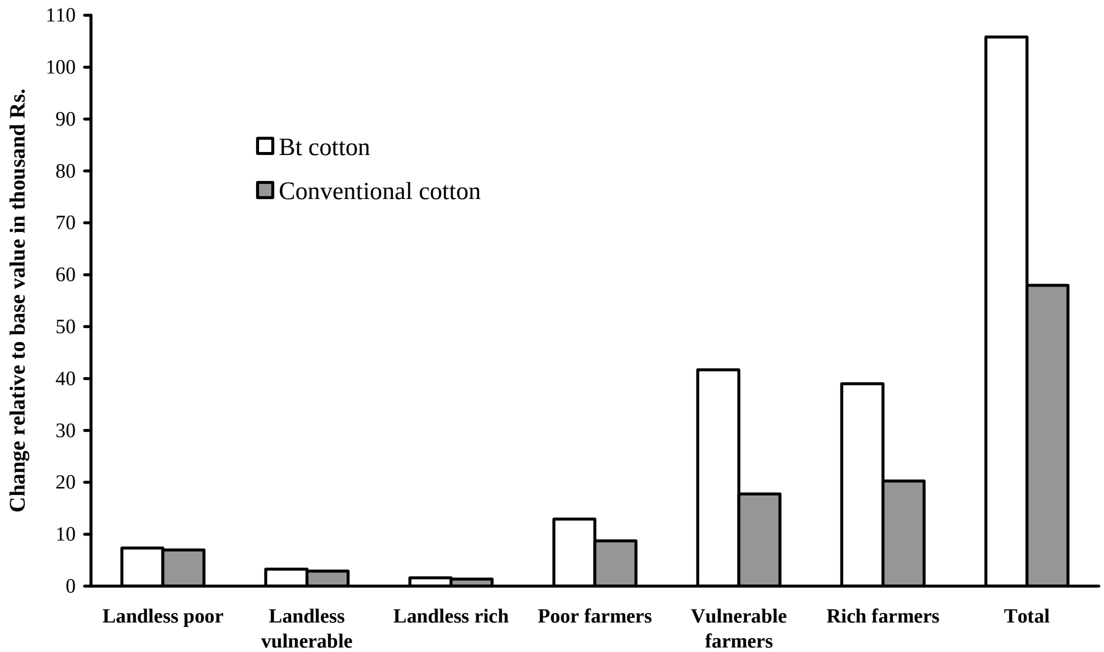

Figure 2. Changes in household incomes from increased Bt and conventional cotton production

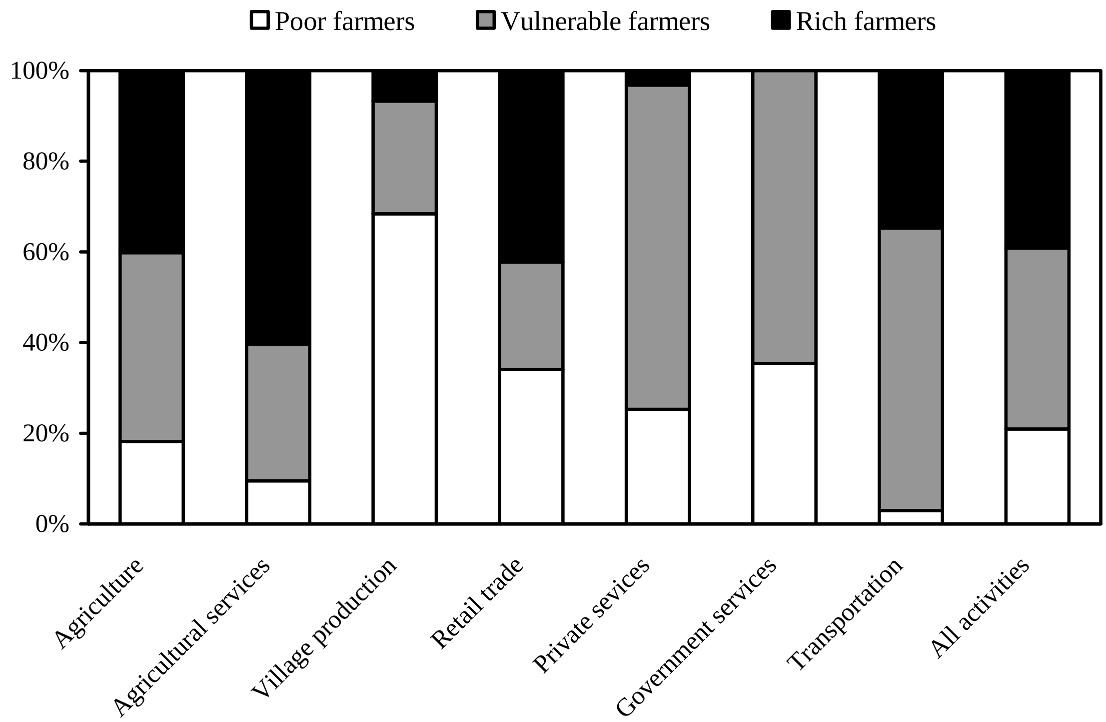

Figure 3. Contribution of farm household categories to different economic activities

Note. The contribution of landless households is not included.