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Abstract

The acreage under the transgenic Bt cotton seeds in India has risen significantly since its legalization in the year 2002. Discussions on the advantages from the technology have focused on increments in productivity and income, without much analysis on risk. We point out that claims on productivity gains seem to be misplaced, as appropriate counterfactuals do not exist for the same hybrids. In this article we analyse production costs and crop incomes in drought years to test a simplistic theory of risk based on first principles. We employ a mixed-methods framework to draw inferences by combining data from two cross-sectional surveys in Gujarat (Saurashtra and Southern-Plains) and Maharashtra (Western Vidarbha) for the period 2009-10 and compare it with unit-level data for the corresponding regions from a nationally representative sample for the period 2002-03. Empirical evidence, though limited, brings out the problem of how a high cost technology could be associated with higher risks and may be dominated by traditional alternatives under certain conditions. Ethnographic accounts from the field provide qualitative support to our understanding of potential risks and uncertainties associated with the new technology.

Keywords:

Bt cotton, agricultural risk, technology evaluation, mixed-methods, India

JEL Code:

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Abstract

The acreage under the transgenic Bt cotton seeds in India has risen significantly since its legalization in the year 2002. Discussions on the advantages from the technology have focused on increments in productivity and income, without much analysis on risk. We point out that claims on productivity gains seem to be misplaced, as appropriate counterfactuals do not exist for the same hybrids. In this article we analyse production costs and crop incomes in drought years to test a simplistic theory of risk based on first principles. We employ a mixed-methods framework to draw inferences by combining data from two cross-sectional surveys in Gujarat (Saurashtra and Southern-Plains) and Maharashtra (Western Vidarbha) for the period 2009-10 and compare it with unit-level data for the corresponding regions from a nationally representative sample for the period 2002-03. Empirical evidence, though limited, brings out the problem of how a high cost technology could be associated with higher risks and may be dominated by traditional alternatives under certain conditions. Ethnographic accounts from the field provide qualitative support to our understanding of potential risks and uncertainties associated with the new technology.

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1 Introduction

It is observed that in less than a decade since its legal introduction in 2002, there has been a remarkable diffusion of Bt cotton technology in India, with the genetically modified seeds being used to cultivate nearly 90 per cent of the total area under cotton in 2010 (Arora & Bansal, 2011; Choudhary & Gaur, 2010; Government of India, 2010). [4] During this period, the yields and overall production has increased on an average, and India, which is the second largest producer of cotton in the world, became a net exporter of cotton from being a net importer. Should we accept these trends as evident of a successful adoption of the technology? Or, is there something more than what meets the eye – like the dominance of the QWERTY technology for keyboard layouts (Liebowitz & Margolis, 1990)? In other words, can the increasing acreage under Bt cotton be solely attributed to inherent benefits of the transgenic seed technology or there are at work other mechanisms that demand explanation? More importantly, are we missing out on critical dimensions of assessing the technology amidst the 'deceptive rhetoric, spin, and soundbite science portraying the wonders or horrors of the new technology' (Stone 2002, p.611) propounded by the competing discourses of the pro and anti Bt camps?

The evidence on the performance of Bt cotton in India has been mixed. Several studies provide evidence on the positive and significant impacts of Bt cotton through increased crop productivity (yield), higher net returns, saved management time and savings on account of reduced insecticides cost (e.g. Rao & Dev, 2009a; 2009b; Subramanian & Qaim, 2009, 2010; Gruere, Mehta-Bhatt & Sengupta, 2008; Basu & Qaim, 2007; Ramasundaram, Venilla & Ingle, 2007; Qaim & Zilberman, 2003; also see James, 2009; and Naik *et al*., 2005 among others). The proponents of the new seed technology have been indicating that reduced pest attack on account of Bt seeds usage has a concomitant impact on improving yield. This, with no foreseeable price shocks (both input and output) and cost savings due to lower insecticide requirements have been argued to lead to greater economic returns.

On the other hand, the opponents of the technology mention about loss of seed sovereignty, adverse impact on health for livestock and people because of increased exposure to plant toxicity, insecticide resistance, emergence of new pests, and increased

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[4] Bt cotton is genetically engineered to produce a protein found in the soil bacterium Bacillus thuringiensis (Bt). The protein is toxic to lepidopterous insects, especially bollworms like *Helicoverpa armigera* (popularly known as American bollworm) and *H.zea*, and promises to protect farmers from losses due to pest attacks that damage cotton production and affect quality.

costs on account of seeds and additional requirements on account of the new technology (e.g. Kurungati, 2009; Herring, 2008; Qayum & Sakkhari, 2005; among others).

It should be borne in mind that there are several methodological differences in the analysis of Bt cotton impacts which could explain the spectrum of conclusions in the debate (Smale, Zambrano & Cartel, 2006; Smale *et al*., 2009). However, notwithstanding the conflicting findings in the discourse, there has been a perceptible bias in the narrative of genetically modified (GM) agricultural technologies. Glover (2009, 2010) critiques the 'pro-poor narrative' of the GM technology benefits on the grounds that a range of technical, socio-economic and institutional factors which are critical for the performance of GM crops are ignored. Similarly, arguments against Bt seeds tend to ignore the positive outcomes even though they are based on some restrictive assumptions and conditions. This lack of accommodating plural and competing explanations among the pro and anti Bt camp has rendered the Bt cotton debate reductionist, which motivates our analysis.

It can be argued that while some farmers, in some regions and/or in some seasons may have experienced benefits in some particular sense (higher income, production, or yield) from the use of Bt seeds, the genetic attribution of Bt seeds, that is, the Bt trait which causes a particular protein to be expressed does not guarantee any effects beyond protection against specific bollworm (like American bollworm) infestation under certain conditions.[5] Cotton being a risky cash crop, varieties with Bt gene are as susceptible to all the risks in cotton cultivation that non Bt varieties are (Herring, 2007), and ignoring such risks is a serious analytical flaw. Moreover, owing to the complex interactions in crop production, there are inherent uncertainties in the effects of any agricultural technology, and transgenic seeds are not an exception.

For a scientific evaluation of the hypothesized superiority of Bt cotton seeds in the causal sense, the use of these seeds should be the differentiating factor in attainment of higher yields and profitability in cotton production, ceteris paribus. Also, it should be borne in mind that in the absence of appropriate counterfactuals and adequate controls, any evidence that rejects the null hypothesis of Bt seeds not being superior to their non Bt counterparts, does not necessarily imply the superiority of Bt seeds, and vice versa. In the case of Bt cotton, the co-existence of scores of varieties with Bt genes and non Bt hybrids (e.g. Karihaloo & Kumar, 2009) complicates the separability of the effects of the Bt strain.

[5] Expression of insect-resistant cotton encoding the 'cry1Ac' toxin gene from Bacillus thuringiensis (Bt).

Unfortunately, the Bt cotton discourse has failed to acknowledge this fundamental logic while attempting to establish the positive or negative impacts.

In this article, we argue that an improved understanding of risk and uncertainty is central to the assessment of Bt cotton technology by analyzing outcomes in two drought periods, across two cross-sections. First, we use unit-level data from the Situation Assessment Survey of Farmers from the 59th round of the National Sample Survey (NSS), for the period 2002-03 across specific regions of Gujarat (Saurashtra and Southern Plains) and Maharashtra (Western Vidarbha).[6] Then we employ data from our surveys and ethnographic inquiries in the similar agro-ecological zones in the two states for the period 2009-10. Furthermore, the Gujarat sample provides interesting comparisons across Bt and non Bt growers and ethnographic findings from the field in Wardha district of Vidarbha allow us to draw critical inferences on the Bt technology.

By taking up the analysis in two drought periods – one at a time when the legal (official) commercial transgenic varieties were introduced, and the other at a time when the technological diffusion can be assumed to have played out well, the findings of this article attempt to sensitize Bt cotton analysis to issues of risk and technological uncertainty. We believe, this article has two important contributions to improving our understanding of the Bt cotton debate. First, we argue for the need to consider the fundamental aspect of risk in the evaluation of the impact of Bt seeds. This assumes significance at a time of crisis in the Indian agriculture and spate of farmers' suicides among predominantly cotton growers (e.g. Reddy & Mishra, 2009).

Second, our study is a contribution in mixed-methods research paradigm (Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 2003). In this context, we introduce a methodological innovation that combines quantitative and qualitative findings from the field with secondary data from a nationally representative sample that provides a rough baseline approximation in the context of Bt cotton evaluation for the two major cotton growing regions of the country, namely, Saurashtra and Southern Plains in Gujarat and Western Vidarbha in Maharashtra. It is quite likely that some farmers in the nationally representative sample would have already used illegal Bt seeds Nevertheless, the analysis can be safely assumed to be representative of non Bt usage scenario and hence a valid benchmark for conditions of cotton production in the relevant regions. For the current purpose we compare and contrast results from the NSS survey for the crop season of 2002-

[6] Western Vidarbha region in the NSS dataset comprises of the districts Akola, Amravati, Buldhana, Nagpur, Wardha, Washim and Yavatmal.

03 with that of some location specific and somewhat independent surveys in the above-mentioned two cotton growing regions during 2009-10.

The article is structured as follows. In Section 3 we discuss how risk has been treated in the context of agricultural technology evaluation and present a theoretical framework for assessment of risk in Bt cotton. Section 4.1 discusses the results of secondary data analysis for Saurashtra and Southern Plains in Gujarat and Western Vidarbha in Maharashtra. This is followed by discussion of findings from the field: an analysis of the field data from the two regions by focusing on riskiness for Bt and non Bt growers in Gujarat (section 4.2.1); and problems of uncertainty, deskilling and fads in Western Vidarbha (section 4.2.2). In Section 4.3, we discuss the aspects of risks in light of our empirical findings and ethnographic evidence from the field. Section 5 concludes the article. Now, in section 2, we discuss the data sources and method employed in this article.

2 Data and Methods

We conduct our analysis using two datasets. First, we use unit-level data from the Situation Assessment Survey (SAS) of Farmers in the 59th Round of the National Sample Survey (NSS), for the period 2002-03.[7] This survey is a rich source of information on the income, expenditure and investments by the farmer households. We confine our analysis to two specific sub-samples of the larger dataset and focus on cotton farmers of two agro ecological zones of Gujarat (Saurashtra and Southern Plains) as well as the Western Vidarbha region of Maharashtra – the two leading cotton producing states of India. Second, we use relevant evidence from our field surveys (microdata) and ethnographic inquiries among farmers of cotton growing villages of Saurashtra and Southern Plains in Gujarat (277 farmers across 15 villages) and in Wardha district of Western Vidarbha in Maharashtra (120 farmers across five contiguous villages) in 2009-10, which could be considered to be fair approximations for the regions analyzed using the secondary dataset mentioned above.[8]

The purpose of this methodological innovation is twofold. Firstly, in the absence of appropriate counterfactuals and inter-temporal variations, we approximate the production conditions in the pre-Bt period in our study regions by using the NSS dataset as the

[7] The SAS dataset provides detailed farm and farmer level information from 51,770 households spread over 6,638 villages across the country for the period 2002-03.

[8] The sample in the five villages of Wardha district in Vidarbha is part of an ongoing panel data designed by the first author's doctoral research and focuses on issues of risk and vulnerability of farm households in the region.

baseline approximations (corresponding to the period 2002-03). Both these periods being drought years, the findings provide an interesting approximation of conditions in worst off years. Secondly, given the lack of relevant datasets, we have attempt to understand the potential benefits and riskiness of the seed technology based on ethnographic (qualitative) and limited quantitative evidence from the field at a time when the technology effects can be assumed to have played out. This combination of secondary and primary datasets; and quantitative and qualitative information can be considered as a methodological departure.

As a caveat, although a cross sectional analysis is not appropriate for addressing these concerns, given the lack of relevant longitudinal datasets (e.g. Sadashivappa & Qaim, 2009) for the Bt cotton evaluation, we attempt at an analysis that is sensitive to the fact that farm and farmer fortunes fluctuate across time and space; and technological evaluations should incorporate these possibilities and pluralism of arguments and evidence rather than give a verdict based on reductionist ideologies and limited information.

Before discussing the results of our analysis, we explain the need for considering risk and uncertainty in agricultural technology evaluation in general, and Bt cotton in particular. Our treatment of risk and uncertainty in the context of Bt cotton is based upon the theoretical foundations discussed in the next section.

3 Risk in Bt technology evaluation: Theoretical Frameworks

Risk is integral to the performance of any agricultural technology due to the inherent uncertainties in crop production and the stochastic nature of crop outcomes. Since there are a host of factors that determine crop yield (e.g. rainfall, availability and quality of inputs, credit, capital, labour, farm characteristics, farming practices, pest attacks, crop disease, soil health), and a host of others that influence farm profitability for a given level of yield (e.g. input and output price volatility, storage conditions, policy uncertainty), it is not possible to net out the exact effects of specific factors on variability in yield or net returns. Risk can emerge from each of the components associated with the production process, making ex ante decision making under risk and uncertainty (e.g. Kurosaki, 1998; Feder, 1979) extremely complex. Moreover, downside risks have potential adverse effects on farmers' welfare, necessitating an improved understanding of the riskiness of the inputs in a stochastic production process.

Surprisingly, studies on impact of Bt cotton provide only ex post estimates of the effects of Bt cotton and remain silent on the aspects of risk and ex ante expected values from adoption of the new technology.[9] Studies on Bt cotton adoption at the farm level are limited by their ignorance of preference driven demand side factors. Most importantly, they have not looked into farmers' risk attitudes (e.g. Just & Pope, 2003) and cognitive biases (e.g. Cole *et al.*, 2009) in adoption of Bt cotton, which are central to technology adoption decisions in agriculture (e.g. Just & Zilberman, 1983). A difficulty with the inability to analyse such perspectives is that the increased acreage of Bt cotton, might well be driven by network effects, bandwagon effects or farmers preferring Bt to non Bt varieties because of fads, rather than by way of well informed rational choices or experiential factors.

Given the high adoption rate of Bt cotton among India's cotton farmers and a lack of consensus on the effects of the technology, it is imperative to assess the risks associated with Bt cotton technology and weigh the identified benefits, not only against the associated costs but also with the unmitigated risks embedded in the new technology. In this context, a fundamental question that remains to be answered is whether Bt cotton increases or decreases risk?[10]

The agricultural production literature provides some clues on whether an input (e.g. pest control) reduces or increases riskiness of the production process, depending on how the uncertainty associated with the input's potential (e.g. pest uncertainty) enters the production function (Horowitz & Lichtenberg, 1994; Pannell 1991); and there is empirical evidence on both cases (e.g. Horowitz & Lichtenberg, 1993). Farnsworth & Moffitt (1981) discuss risk in cotton production in California, USA and show the risk-reduction effect of labour, fertilizer and farm machinery.

Though there is no discussion of risk in the context of Bt cotton, a study by Hurley, Mitchell & Rice (2004) challenges the risk reduction attribute of Bt corn and argues that in some circumstances it is advisable to "subtract a risk premium from the "mean benefits" of Bt corn, because farmers will use it to increase, not decrease, risk." (Hurley *et al*., 2004, p.346). They derive the theoretical conditions under which Bt corn increases/ decreases risk or acreage or farmer's welfare. They highlight the importance of distinguishing between marginal and aggregate risk effects in evaluating the effect of Bt corn on risk and demonstrate that the effect of Bt corn on risk depends on the price paid for the technology.

An interesting finding of Hurley *et al*. (2004) is that Bt corn is not universally risk

[9] Fernandez-Cornejo & Jans (1999) discuss this aspect in the context of US Agriculture.

[10] An input is defined as risk decreasing (increasing) if a risk averse farmer uses more (less) than a risk neutral firm at a given price (Ramaswami, 1999).

increasing or decreasing, rather, conditional on the price paid for the technology and the expected value of loss it, it can be risk increasing even when its effect on risk improves farmer welfare. Their empirical findings show that conditional on the price, Bt corn can be marginally risk increasing or decreasing and can either increase or decrease corn acreage. Applying these perspectives to the case of Bt cotton, it can be argued that if planting cotton is optimal for farmers, Bt cotton can be considered risk increasing if the expected loss (by way of protection from crop losses due to pest infestation) it eliminates exceeds its price, but not if its price exceeds the expected loss.[11] Interestingly, understanding the riskiness of Bt cotton, could also help explain the acreage decisions of farmers, namely, what share of their cultivable lands would they allocate to Bt and non Bt hybrids.

Another simplistic yet intuitive theory of risk assessment developed in Mishra (2008) can be used to scrutinize the success of agricultural production techniques against the alternatives since some technologies while successful in increasing production as well as productivity, may also add to the risk simultaneously. The framework is as follows.

Let technique T_i be the one where inputs X_i lead to output Y_i; where i= 0, 1 indicates two possible techniques. In our case i= 0 could be assumed to reflect the traditional (non Bt) technique and i=1 be the new and improved Bt technology. According to this theory, we would consider T_1 as an improvement over T_0 if either $X_1 < X_0$ or $Y_1 > Y_0$. What these inequalities imply is that, a method would be preferred over another if either it is 'input-saving' (i.e. it uses les inputs for giving the same output) or 'output-enhancing' (i.e. it uses same inputs to give more output), or both.[12]

The arguments in favour of Bt cotton indicate the condition of $Y_1 > Y_0$ but what remains to be factored into the technology assessment is the concomitant condition of $X_1 > X_0$. There could have been more production and productivity (yield) due to Bt cotton, but the technique associated with it may be using more inputs to produce more output, this enhancement being indicated by a shift in the production function, *ceteris paribus*.

From a risk perspective, it is important to understand that it may so happen that the output is higher but the rate of increase in output could well be lower than the rate of increase in input i.e. $(Y_1/Y_0) < (X_1/X_0)$, indicating the adoption of the Bt technology as

[11] Following Hurley *et* al., (2004), a testable hypothesis in this context could be: Bt cotton increases (decreases) cotton acreage if the change in the expected marginal revenue of cotton acreage is greater (less) than the change in the marginal risk premium (Ramaswami, 1999; Kurosaki, 1998).

[12] Inputs can be measured by input costs (expenditures) while gross value of output (revenue) or net returns could be used as measures of output.

increasing the riskiness of cotton production. Our understanding of risk in this article will revolve around the empirical validation of this theory of risk using the data on production costs and net returns in cotton production for two drought years (one being relatively good compared to the other), for the two leading cotton producing states of India. Interestingly, this framework fits into Scott's (1976) 'subsistence ethic' argument in evaluating modern agricultural technology vis-a-vis traditional technology as it factors in farmers' preferences for reliability and stability in choice of technology. Moreover, considering risk perceptions of the competing technology (as long as farmers have an option to choose from alternative technology) is also crucial for a proper evaluation of agricultural technologies, and we incorporate these philosophies into our analysis by the use of stochastic dominance analysis (Hazell & Norton, 1986; Anderson, 1974) which has been developed in the literature to evaluate a modern technology vis-a-vis a traditional alternative. We now present the main results of our investigation and discuss the relevance of the findings.

4 Results and Discussion

4.1 Findings from NSS data for the period 2002-03: Baseline Approximations

In order to understand the conditions prevailing at a time when the Bt cotton seeds were legally introduced into farming systems, we look at the yield, production costs and net returns per acre, for farmers in the NSS sample for the year 2002-03. As evident from Table 1, seeds and fertilizer expenses are substantial in cotton production. While seeds comprise of 25.4 per cent of total cost in Gujarat and 25.9 per cent in Vidarbha, share of fertilizer expenses in production costs were higher than seed costs in both the regions, at 26.3 per cent and 31.6 per cent for Saurashtra and Southern Plains and Western Vidarbha respectively. While the share of pesticide costs are more or less same in both the regions – 11.6 per cent in Saurashtra and Southern Plains and 10.5 per cent in Western Vidarbha, the share of casual labour expenses in Western Vidarbha are relatively higher at around 22 per cent compared to 14 per cent in Gujarat. The yield in Gujarat (2.12 quintals per acre) is more than double that in the Western Vidarbha sample, which attributed to higher irrigation in cotton production in Saurashtra and Southern Plains in comparison with Western Vidarbha.[13]

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[13] Though both regions fall under the central zone of cotton production in India, which is predominantly rainfed of the rain-fed and is under black soil (vertisols) subjected to

Table 1. Production conditions for cotton farmers in study regions of Gujarat and Maharashtra, NSS, 2002-03.

Items	Gujarat (N=369)		Maharashtra (N=1392)	
	Mean	Share of total costs, %	Mean	Share of total costs, %
Seed	540.4	25.4	395.6	25.9
Pesticide	299.2	11.6	195.0	10.5
Fertilizer	526.8	26.3	537.5	31.6
Irrigation	274.4	8.6	77.6	3.0
Regular Labour	101.6	2.4	31.6	1.4
Casual Labour	346.3	14.4	408.8	22.0
Others	239.0	11.2	109.1	5.6
Total Cost	2327.5	100.0	1755.2	100.0
Net Returns	7139.4		3724.5	
Yield	2.12		1.03	

Notes: Seed, Pesticide, Fertilizer, Irrigation, Regular Labour, Casual Labour, Others, Total Cost and Net Returns are expressed in rupees per acre; reported means are unweighted averages.

The average net returns per acre in Saurashtra and Southern Plains of Gujarat is more than 90 per cent that in Western Vidarbha of Maharashtra even though the cost of production is only 30 per cent higher. What is of concern is that in Western Vidarbha total costs is nearly half that of the net returns. It should be borne in mind that the period under study being a drought year, farmers could have had a higher cost if they went in for a second or third sowing or reduced their investment in variable inputs given expectations of a bad crop, which could have contributed to the observed low yields, separately from the yield reductions purely due to the effects of the drought. It is impossible to decompose such effects from the current data. Nevertheless, the figures here could be considered as representative of a drought year, and not a normal year. The scenario can also be used to explain a baseline condition with little or no Bt cotton usage.

The observations from 2002-03 can be contrasted with field level observation in the period 2009-10, another drought year. This was also a time when the use of Bt seeds had become ubiquitous, which could provide important insights into the assessment of Bt cotton's impact. Before, discussing the findings from the field in Saurashtra and Southern Plains of Gujarat and in Western Vidarbha of Maharashtra in the next section, we would like to highlight a fundamental methodological point that has surprisingly been missed out

runoff, soil erosion and nutrient losses, tracts in Gujarat have a higher irrigation percentage than in Maharashtra.

in the Bt cotton debate, and which is integral to our interpretation of risk in agricultural production systems.

From a methodological viewpoint, for a causal interpretation of the impact of Bt cotton on profitability of cotton farming, it should be understood that in a pre-Bt environment, higher yield and higher prices could enhance net returns, given production costs. Hence, the channel through which the Bt cotton could increase net returns is through savings by way of specific pesticides and pesticides spraying costs (labour) given a pest pressure. The narrative of the pro Bt camp that the Bt technology provides yield gains (e.g. Qaim, 2003; Rao & Dev, 2009) should at best be interpreted as a reduction in yield gap from a potential because what the technology offers is mere protection against yield losses on account of specific pest incidence (cotton bollworms), rather than yield gains for a given pest pressure. This differentiation is crucial for understanding the true effects of Bt cotton because protection from yield losses is not same as yield increment in the sense that the Bt cotton seed technology can be considered as mitigating the risk of bollworm induced losses, instead of increasing yields in the presence or absence of bollworms. Keeping this distinction in mind, we discuss our findings from the field in Gujarat and Maharashtra in the following section.

4.2 Findings from the field in Gujarat and Maharashtra

As discussed earlier, for a proper evaluation of a new agricultural technology, it is imperative to factor in the dynamics of farmers' experiences with the new technology; the prevailing environmental, ecological and economic conditions of crop production; and aspects of risk and uncertainty associated with the new technology. In this section we discuss aspects of risk by delving into the differences in conditions of cotton production; and compare crop outcomes of two relevant groups – Bt users and non-users from the Gujarat sample, and discuss evidence from the field in Wardha district of Western Vidarbha to understand the uncertainty around the Bt technology and farmers' adjustment problems.

4.2.1 Risk in cotton production: Comparing Bt and non Bt users in Gujarat

Our field survey from Gujarat, for the period 2009-10 allows us to compare the crop economics and outcomes of those farmers who did not grow Bt hybrids with those who did, thus providing a good counterfactual to usage of Bt cotton. This dataset, though primarily generated with the objective of understanding farmer's participation in financial markets, is nevertheless unique in the sense that it lends us to understand crop economics of some non

Bt growers as well, providing a reasonable estimate of the variations across a sample of Bt and non Bt users. However, the Maharashtra sample does not provide us with this opportunity. Furthermore, the Maharashtra sample will help us understand a complete Bt scenario, with the non Bt growers in the Gujarat sample mimicking the counterfactuals. In light of the discussion of results of the analysis using NSS data for 2002-03, it is worth noting that those findings can be considered as baseline scenarios for Bt cotton evaluation in the study regions as it pertains to a period when both Gujarat and Maharashtra farmers could be assumed to be non Bt users.

The random sample of 277 cotton growers from three districts of Gujarat, namely, Amreli, Bharuch and Bhavnagar, for the period 2009-10 enables us to compare crop outcomes of Bt and non Bt hybrid growers. Interestingly, 56 per cent of the farmers in our sample are non Bt growers, quite representative of the general patterns of relatively lower adoption of Bt technology among Gujarat farmers (Arora & Bansal, 2011).

Table 2 reports the crop economics of Bt and non Bt growers.[14] Our cross-sectional findings bring out the relatively high cost of production for Bt growers. The non Bt hybrids growers in the sample have significantly lower cost of production and higher net returns, while the yield advantage of Bt over non Bt is not statistically significant (p-value 0.3356). The relatively higher net returns per acre can be attributed to lower production costs for the non Bt farmers. Furthermore, the cost of production for Bt growers is almost double that of the non Bt growers and this substantial difference is statistically significant (p-value 0.0000). From a risk perspective, lower input costs have relevance because the only factor that a farmer has control over, is the choice of inputs (e.g. Dercon, 1996). For a given level of revenue, the net returns and the associated risk that a farmer has on her (his) portfolio in any season is a decreasing function of the costs incurred.

Table 2. Economics of Production: Bt and Non Bt growers, Gujarat, 2009-10.

Item	Non Bt (N=154)		Bt (N=123)		All (N=277)	
	Mean	CV	Mean	CV	Mean	CV
Yield	2.89	0.69	3.01	0.78	2.94	0.73
Revenue	11798.4	1.99	9651.4	0.91	10845.02	1.7
Cost	6539.73	1.41	12747.5	0.75	9296.22	1.06
Net Returns	5258.64	4.84	-3096.1	-4.08	1548.79	13.64

Notes: CV denotes coefficient of variation.

[14] See Sadashivappa & Qaim (2009); Roy, Herring & Geisler (2007); and Gandhi & Namboodiri (2004) which also surveyed both Bt and non-Bt growers.

An interesting observation from the perspective of risk is that the yield variability of Bt cotton is higher. Assuming this as an indicator of inter-temporal variability in yield, farmers who have not yet chosen Bt cotton, may be inferred to have a preference for reliability of the yields which the non Bt varieties could be offering. If farmers chose stability and lower fluctuations in yield to higher expected returns (yield), their risk-avoidance behaviour in terms of not choosing Bt cotton seeds is indeed rational. This risk-aversion is also reasonable from Scott's (1976) 'subsistence-ethics' perspective as it would be very difficult for farmers with lower asset-base to recover from adverse production shocks which the use of new technology could be associated with. The losses experienced by the Bt cotton users as against the gains of the non Bt users (Table 2) and farmers' views from focus group discussions (FGDs) corroborates this argument.

Having had an idea of the general differences in crop outcomes, a look at the components of the cost of production should be informative about which variable inputs weigh heavy in the production costs. Table 3 brings out the differences among input costs of Bt and non Bt growers. There is a clear pattern of a costly external input system of production being undertaken by the Bt growers vis-a-vis their non Bt counterparts, which is a matter of grave concern given the unsustainability of returns to cultivation in India (Gaurav & Mishra, 2011). Except for draught (bullock) costs, the difference between variable input costs for Bt and non Bt hybrid growers is statistically significant at all levels, corroborating the earlier finding of relatively higher production costs of Bt technology. The seed costs, pesticide costs (on account of sucking pests) and labour costs of the Bt growers is more than twice that of the non Bt growers which is reflected in average production costs which are almost double that of the non Bt growers.

Concerns about high input costs in Bt cotton production have been raised in earlier studies. Sahai & Rahman (2003) found Bt seed costs to be four times the traditional varieties, and that the higher seed costs failed to be compensated by corresponding increments in yield or savings on account of reduced pesticide use, resulting in lower net profits for Bt cotton than non Bt cotton. Swaminathan & Rawal (2011) found that the Bt cotton varieties had higher expenditure on chemical pesticides and higher variability as in our Gujarat field sample. Bennet *et al*. (2004; 2006) identified the problem of higher seeds costs and overall cost of production associated with the Bt adopters.

From an agricultural technology perspective it should be borne in mind that no matter how effective or superior it might be, there would be times in agricultural production process when realized crop outcomes will fall short (or go beyond) of farmers' expectation or adverse (favourable) deviations from the normal values. In seasons when there are adverse realizations, the adopters of the costlier technology stand to lose more than their counterparts who did not adopt. At times of losses, the benefits or merits of the technology cannot come to their rescue as the loss event has occurred, rather it may push them down into deeper financial crisis on account of having incurred higher cost (also higher opportunity costs). Glover (2010) and Gruere *et al*. (2008) argue on similar lines and discuss how a Bt adopter is potentially even more vulnerable than a non-adopter in the face of such eventualities. This dimension also hints at the need to account for the dynamism of farm outcomes over a long period of time is pertinent in the Bt cotton discourse.

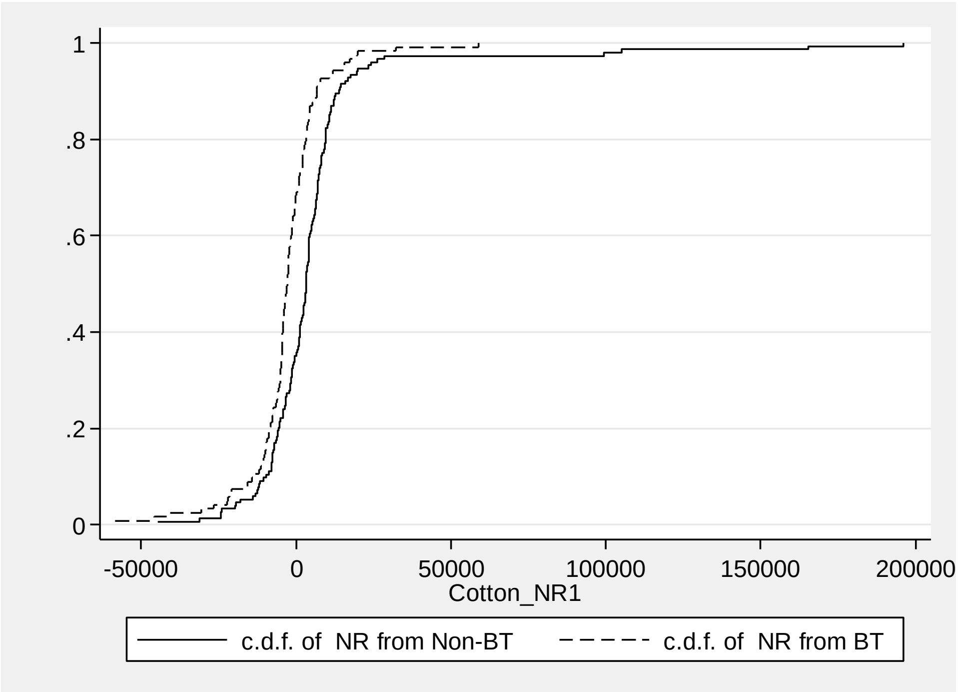
To further substantiate our argument of a costlier production technique being riskier, especially in bad crop seasons, we look at the cumulative distribution functions (CDF) of net returns from the two technologies. Risk perceptions in alternative technology evaluation are embodied in the CDF, which index the cumulative probability that the net returns fall below a given level. The lower cumulative density plot first order stochastically dominates (e.g. Anderson, 1974) the higher plot, indicating the lower CDF being superior in the sense that, for a given cumulative probability, we can always obtain a higher level of net returns. As depicted in Figure 1, we see that the Bt technology is first order stochastically dominated by the non Bt technology, which implies that for rational decision makers (farmers here) guided by the principle of local non-satiation (more is better), the non Bt technology is more risk-efficient and it is clearly preferred to Bt technology.

Table 3. Production costs per acre for Bt and Non-Bt growers, Gujarat (2009).

Farmer Type	Seed			Fertilizer	Manure	Pesticide	Irrigation	Labour	Draught	Tractor	Total
	Non-Bt	Bt	Varieties								
Non Bt (N=154)											
Mean	741.3	_	18.7	763.0	864.6	911.7	479.3	1540.3	577.7	643.2	6539.7
% Share	11.34	_	0.29	11.67	13.22	13.94	7.33	23.55	8.83	9.84	100.00
Bt (N=123)											
Mean	27.5	1358.9	_	1441.4	1811.8	1978.3	1105.0	3154.9	747.8	1122.0	12747.5
% Share	0.22	10.66	_	11.31	14.21	15.52	8.67	24.75	5.87	8.80	100.00
All (N=277)											
Mean	424.3	603.4	10.4	1064.2	1285.2	1385.3	757.2	2257.2	653.3	855.8	9296.2
% Share	4.56	6.49	0.11	11.45	13.82	14.90	8.14	24.28	7.03	9.21	100.00

Notes: Non Bt/Bt refer to Non Bt/Bt hybrids; Varieties refers to straight varieties.

Figure 1. Stochastic dominance between alternative seed technologies: Bt and non Bt hybrids, Gujarat sample: 2009.



Notes: c.d.f. stands for cumulative distribution function. NR stands for net returns expressed in rupees per acre; BT and Non-BT stand for Bt and Non-Bt hybrids; Cotton_NR1 represents net returns from cotton in rupees.

What this finding implies is that the farmers' present practices of using non Bt hybrids dominates the Bt technology in a risk-prone environment and this behaviour is reasonable as it would not be appropriate to experiment with a costlier and uncertain technology like Bt for farmers who are credit and liquidity constrained. This result of a traditional technology being perceived as better than a new technology that is claimed as 'improved' is similar to that of Dvorak's (1986; cited in Walker and Ryan, 1990) finding that applying inorganic fertilizer to post-rainy season sorghum grown in Sholapur villages of ICRISAT VLS (village level studies) is worse than no fertilizer applications as it adds to the production cost and risks without increments in potential benefits. It should be borne in mind that if the c.d.f. plots crossed once (or multiple times), we would have had to check for second (or higher) order stochastic dominance, which are scenarios where risk-aversion of the farmers becomes potentially important. Moreover, crossing does not necessarily indicate a trade-off between risk and expected profitability as one technology may be preferred to another in low probability and low returns events. If it is likely that persistently low or even negative returns is realized in the time of adversities, farmers may not prefer the new technology like Bt, as the expected profitability may be dominated by concerns for stability of returns (e.g. Perrin & Winkelman, 1976).

What this analysis brings out is that, farmers who do not have substantial experience of the returns from a particular cash-intensive technology in both good and bad crop years (i.e. subjective probability distribution of net returns from the new technology unlike the traditional technology), given their local conditions of farming, they can be expected to choose the traditional technology. Walker and Ryan (1990, p.225) provide an excellent example of this complexity: "In abnormally good years, hybrid cotton would significantly outperform local cotton, *mung* bean, or hybrid sorghum, but those years of ideal growing conditions are so few that they do not make up for hybrid cotton's inferiority in the more numerous years of less than ideal growing conditions". This argument is also sensitive to the fact that most cotton farmers in our study areas carry out cotton production by inter-cropping and ignoring this could be naive. Our ethnographic investigation in villages of Wardha district in Western Vidarbha is now taken up.

4.2.2 Technology uncertainty, deskilling and fads: insights from Vidarbha villages

The cash-crop oriented production systems in the five contiguous villages in Wardha district are representative of rainfed production in other parts of Western Vidarbha – cotton or soybean as main crops intercropped with *tur* (pigeon pea) as major intercrop during the Kharif season; and wheat and *chana* (chickpeas) in the Rabi season, for those who have access to irrigation.[15]

Table 4 reports the condition of crop production in 2009-10. We will contrast this information on costs and returns with the findings from the NSS sample for Western Vidarbha (2002-03) in the following section to get an idea of the riskiness in the production system. A similar calculation will also be done for the two Gujarat samples.

[15] Though the villages are characteristic of the risky cultivation under rainfed conditions, these villages are seeing active participation in the community based sustainable agriculture (CMSA) practices of a civil-society group. The randomly selected study sample can be considered to be representative of local conditions in the five villages.

Table 4. Cotton Production in five Wardha villages, 2009-10.

Items	Mean
Yield (quintal per acre)	3.32
Revenue (Rs. per acre)	10056.96
Cost (Rs. per acre)	3578.28
Net Returns (Rs. per acre)	6478.68
Seed Cost (Rs. per acre)	1038.28
Seed Cost %	29.02

Notes: Though the full sample comprises of 120 farmers, in 2009-10 only 104 farmers took up cotton production; All the cotton plots were a mix of Bt cotton hybrids intercropped with *tur* (pigeon pea). Seed Cost % refers to percentage share of seed costs in total costs.

For the farmers in our five study villages, the 2009-10 was one of the worst crop years they had faced in the last five years given prolonged dry-spells during the germination phase of the cotton and incidence of Spodoptera (leaf eating tobacco caterpillar) pest attacks on standing soybean plants. In spite of it being a relatively bad drought year, the average cotton yield of 3.3 quintals per acre fetched positive net returns (an average of Rs.6500) due to better price realizations in comparison to the previous year (an average of Rs.3029 per quintal as against Rs.2752 per quintal in 2008-09, which was also a drought year with a marginally higher yield of 3.4 quintals per acre and almost similar (lower) costs that gave average net returns of Rs.5876 per acre). The fact that farmers can receive positive returns despite poor yields and high costs brings out the role of output prices and price risk (in both inputs and output) in the determination of net returns from cotton production.[16] Such decomposition of price effects and yield effects are vital for a sound evaluation of the effects of Bt cotton, which has not been attempted here.

Related to this issue is the role of intercrops in influencing input decisions as well yield and returns given inherent complementarities and substitutabilities among multiple crops in an intercropped system. Swaminathan & Rawal (2011) discuss the importance of differentiating between mono cropped and inter cropped cotton in the context of Bt cotton evaluation in a village study in Vidarbha. Accounting for this distinction is critical because the inter crops could confer positive as well as negative externalities on yield and costs. For example, growing *tur* (pigeon pea) as an inter crop with cotton not only works as a pest distracter for cotton plants, but also plays an important role in nitrogen fixation and providing ecological benefits to the cotton production.Farmers' own labour allocation and

[16] See Baffes (2011) for the emergence of Bt cotton and the evolution of cotton output prices in India and other leading cotton producers in the world.

use of hired labour for farming activities is also dictated by the cropping patterns.[17] The presence of intercrops also influences the crop management practices and influences variables like availability of 'refuge land' for non-Bt varieties, for instance, which play a role in determining crop yields. From a price risk perspective (e.g. Newbery & Stiglitz, 1981), growing intercrops also works as a natural hedge to the downside risk in cotton prices and ensures nutritional security for the farm households (e.g. Parsuraman & Rajaratnam, 2011).

Farmers in our sample complained of the relatively higher seed costs. As shown in Table 4, seed expenses comprised of around 29 per cent of the total production costs, as against 26 per cent in 2002-03 (Table 1). Though this seed inflation may be attributed to the higher prices of Bt cotton seeds on an average, it becomes disproportionately penalizing for those farmers who incur substantial losses in bad crop years.[18] With around one-third of the farmers in our sample reporting substantial losses in crop production in 2009-10 compared to one-tenth in 2002-03, it is for these farmers that such high costs are symptomatic of higher risk in the production system as the relative increase in costs is likely to be higher than that of the net returns. Moreover, significantly large negative income shocks could also increase the likelihood of farm households falling into poverty traps (e.g. Carter & Barrett, 2006)

Another problem that complicates farmers' decision making process is the proliferation of seed varieties with Bt traits.[19] In recent years, there has been an increasing trend to adopt multiple genes (mostly two genes). The first two-gene event (second generation) MON15985, commonly known as Bollgard®II (BG®II) featured the two genes 'cry1Ac' and 'cry2Ab', and was approved for sale for the first time in 2006 – four years after the approval of the single gene event (BG®II) MON531 Bt cotton hybrids in 2002-03. Surprisingly, all the farmers in our sample were ignorant of the basic distinction between the single gene and multi gene technology and reported expectations about double yield from the costlier BG®II hybrids based on anecdotal evidence from some farmers in their social network or news of some progressive farmer in a neighbouring

[17] This includes draught, human and mechanized labour.

[18] Arora & Bansal (2011) discuss the implications of the high prices of Bt cotton seeds and the effect of price ceilings in some Indian states.

[19] The problem of proliferation of Bt cotton hybrids and dwindling alternatives remains unaddressed. Choudhary & Gaur(2010) mention that a total of 522 Bt cotton hybrids were approved for planting in 2009 compared with 274 Bt cotton hybrids in 2008, 131 in 2007, 62 in 2006, 20 in 2005 and only four Bt cotton hybrids in 2004.

village having experienced supranormal profits by its adoption. To further complicate farmers' seed purchase decisions, with episodes of higher weeding costs (labour costs) and pest resistance being reported from many regions which saw the higher adoption of hybrids with BG®II trait, the farmers reported rumours of a likely emergence of next generation Bollgard® seeds which could overcome such problems.

Closely associated with the proliferation of multiple gene seeds is the conspicuous unavailability of straight varieties and alternative cultivars in the sowing season. This has been reported to be a major concern for farmers in our study villages because the lack of affordable alternatives and inexperience with the new arrivals force them to make ill informed guesses while purchasing the seed mix every growing season. Moreover, a major source of uncertainty with the Bt seeds is the farmers' ignorance about the effect of Bt seeds on pest ecology, and hence the effect on optimal insecticide spray decisions of farmers.[20] This could be a result of the drastic transformation of cotton seed technology to Bt seeds. This transformation occurred at a time when the market for seeds had been undergoing unprecedented changes with the proprietary hybrid seeds flooding the market and crowding out the more regulated public hybrid seeds and straight varieties (Lalitha, Ramaswami & Viswanathan, 2009). The proliferation of the predominantly intra-hirsutum (intra-specific) proprietary hybrids had a complex interaction with the dynamics of pest ecology and crop's growth requirements, which resulted in the farmers being increasingly dependent on the market for their seeds (Stone, 2011).[21] Furthermore, with new varieties of seeds, there has been a concomitant emergence of new kinds of insecticides with declining natural resistance to many pests, which have been attributed to ecological imbalances on account of higher dosage of synthetic sprays (Kranthi *et al*., 2002).[22]

[20] See Pannel (1991) for the role of uncertainty about some variables, such as pest density and pest mortality, on optimal pesticide use under risk aversion.

[21] Interestingly, India is the only country to grow all four species of cultivated cotton *Gossypium arboreum* and *G. herbaceum* (Asian cottons), *G. barbadense* (Egyptian cotton) and *G. Hirsutum* (American upland cotton). *Gossypium hirsutum* represents more than 90 per cent of the hybrid cotton production in India and all the current Bt cotton hybrids are *G. hirsutum*.

[22] Synthetic insecticides have been observed to be rendered ineffective against most Lepidopterans (e.g. bollworms) and *Hemipteran* sucking pests like cotton aphid (*Aphis gossypii*), mealybug (*Phenacoccus sp.*, *Maconellicoccus sp.*), and mirid (*Creontiades sp.*), whitefly (*Bemisia tabaci*) and other aphids (Stone, 2011).

This market transformation also renders the evaluation of Bt genes difficult. The claim of significant yield increments and the role of Bt genes in the hybrids is problematic. It is impossible to account for the share of yield increments attributable directly to the Bt trait in the Bt hybrids. Also, attributing this causality to Bt cotton, without controlling for access to irrigation, weather variations and socio-economic characteristics is unscientific.[23]

Many Bt growers in our study villages revealed that they applied fewer insecticides to control sucking pests than non Bt growers in the early seasons assuming the Bt seeds to take care of the sucking pests as well. However owing to increasing sucking pest pressure as well as resistance from bollworms they eventually resorted to relatively more insecticides sprays and experienced losses or lower profits. Accounting for such differentiation in pesticide expenses is important for the evaluation of Bt cotton because what matters for the economic viability of the production process is how the savings due to reduced insecticides usage exceeds the higher seed cost. If there are instances of pest resistance or other effects on the cropping system, the positive effects of Bt cotton could be reduced and there could well be negative effects.

Hence, the evidence from the field in Vidarbha suggests that, left on their own to wade through the myriad of uncertainties looming large in the absence of effective extension and information (e.g. Fitzgerald, 1993), the informational gaps were filled in by local input dealers with vested interests of profiteering.[24] The farmers rely heavily on the advice of input dealers who promote the costlier seeds and unnecessary chemical inputs by a narrative that their use would lead to higher profits through cost savings associated with fewer sprays for controlling pests like Spodoptera as well as increasing yield significantly over single gene Bt hybrids.

Since, farmers rely on social learning and their preferences and decision making was shaped more by the opinions and actions of others, rather than experiential learning, their behaviour regarding adoption of new seeds and insecticides appears to be dictated by 'highly localized seed fads' driven by marketing and happenstance rather than local agroecology (Stone, 2011). The observed behavior of the cotton farmers could be thought of as 'informational cascades' or 'observational learning' (Bikhchandani, Hirshleifer &

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[23] This is akin to asking: Would the non Bt cotton not have registered the yield increments during the similar period, *ceteris paribus*?

[24] Incidences of supplier-induced demand were also observed in a study on farmers' suicides in Vidarbha by Mishra (2006a, 2006b), but the scenario depicts a situation when Bt seeds were not used much.

Welch, 1992) or ‘herd behavior’ (Banerjee, 1992) as prominent in the theory of psychology, economics and marketing. From a Bt cotton assessment perspective this is crucial because, herd mentality, information cascades or fads do not necessarily imply the superiority of the adopted technology.

In some sense, Bt cotton is akin to an insurance product, and hence, the premium the farmers are paying by way of higher seed costs to avert the losses on account of unanticipated bollworm attacks should also be actuarially appropriate or the reasons for the higher prices be rationalized.[25] The price of Bt cotton seeds should reflect the risk that is inherent in the technology as it is not proper for the farmers to be paying a premium on account of trait fees or charges of royalties without the knowledge of the scenarios under which the technology could fail or perform worse than expected. This implies that informational asymmetries on account of the lack of knowledge of the loss events and corresponding probabilities amplify the uncertainty associated with the technology. Moreover the germination rates and conditions for their success or failure, as well as side-effects should be properly communicated to the farmers like the 'red herring' or 'exclusion clauses' in insurance contracts. This would enable the farmers to properly evaluate the technology given their credit and liquidity constraints and then make a well informed buying (investment in seeds) decision.

The observed high production costs in both Gujarat and Maharashtra samples could also be a consequence of the problem of deskilling and unreasonable decision making by farmers that makes it a riskier proposition. In the following section, we discuss the riskiness of cotton production by combining data from the NSS for the period 2002-03 and from the field in 2009-10 for both Gujarat and Vidarbha.

4.3 Riskiness of cotton production

A formidable test of sustainability of an agricultural technology and its ability to protect farmers against downside risks is how it fairs in the eventuality of bad crop years or worse seasons. If Bt cotton does not perform well vis-a-vis non Bt hybrids in drought years, when the expected yields and returns are lower than normal years, then the utility of the technology should be brought under the scanner.

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[25] An added advantage of such a perspective is that it necessitates the knowledge of loss distributions of the Bt cotton seed technology, which could be used to communicate to farmers, the intensity of losses and associated probabilities of the loss events.

As discussed in Section 3, our perspective on risk in cotton production is motivated by the dynamics of costs and net returns associated with Bt cotton and its alternative production technology. With Y representing net returns, X representing input costs and the subscripts 0 and 1 representing non Bt and Bt technology respectively, a look at the relative change in net returns with relative changes in production costs should be indicative of the risk in the system. We undertake a methodological jump here assuming that 2002-03 represents a non Bt scenario as it was formally legalized that year and the NSS data would be capturing baseline conditions of cotton production where Bt adoption was near zero.[26] This is contrasted with microdata from the field for 2009-10 when the Bt diffusion had reached a high level in the study regions. In the absence of richer datasets for the relevant analysis, we focus on just two time periods and try to understand the relative change of costs and returns in cotton production given our assumption.

Using the notation developed earlier, it implies that even if $Y_1 > Y_0$ could hold, the rate of increase in net returns (gross value of output minus costs) could well be lower than the rate of increase in production costs (input) i.e. $(Y_1/Y_0) < (X_1/X_0)$, indicating an increment in risk.[27]

Table 5. Riskiness of cotton technology, Gujarat and Maharashtra.

Item	Gujarat	Maharashtra
X_0/Y_0	0.33	0.47
X_1/Y_1	6.00	0.55
X_1/X_0	3.99	2.04
Y_1/Y_0	0.22	1.74
Y_0	7139.40	3724.50
Y_1	1548.79	6478.68

Note: X and Y denote input costs and net returns respectively. The subscripts 0 and 1 denote non Bt and Bt scenario respectively.

From Table 5, it is clear that there has been an increase in riskiness of cotton production in both Gujarat and Maharashtra. In Gujarat, production costs have almost quadrupled and net returns have become one-fifth, resulting in an eighteen fold increase in

[26] Baffes (2011) confirms that this is a valid assumption given the relatively low adoption of Bt cotton in India in 2002-03 compared to other cotton growing countries and subsequent time periods.

[27] For a proper assessment of risk X should be cost in a bad year and Y be the net average savings from good years (net returns minus consumption). The value, X/Y, indicates that we need so many good years to make good a bad year. In the absence of consumption/net savings we take net returns as proxy and the measure being relevant only for $Y>0$ indicates that for zero or negative net returns farmers cannot make good the loss.

riskiness. In the meantime, Maharashtra saw a relatively lower increase in riskiness as costs doubled while net returns increased by around three-fourth. Even if both the periods are drought years, in 2009-10, Gujarat farmers experienced costs that were six times of the net returns; in fact, the net returns of the Gujarat farmers in our sample of 2009-10 is about one-fifth of that in 2002-03. In Maharashtra, the net returns were higher in 2009-10 compared to 2002-03, but the rate of increase in net returns was lower than the rate of increase in input (i.e.$Y_1/Y_0 < X_1/X_0$), as in Gujarat, thereby, increasing the risk in cotton production. In other words, having input costs as the basis for deriving a price index that the farmer faces, the net returns for cotton farmers both Gujarat and Maharashtra in 2009-10 are lower than that of 2002-03 in real terms.

In any case, the absolute value of the observed net returns in both Gujarat and Maharashtra is not sustainable from a livelihood perspective (Gaurav & Mishra, 2011), yet the case of Gujarat exemplifies the problem of a costly production system. In 2009-10, even $Y_1<Y_0$ (net returns is lower in absolute terms when compared with 2002-03) which implies that the riskiness of the cotton technology has increased since the introduction of Bt cotton to such an extent that in bad drought years, there are losses on an average for farmers in the region. Such situations could affect the welfare of farmer households adversely and it is imperative to include such possibilities while assessing the relative costs and benefits of Bt cotton technology.

5 Concluding Remarks

In this article we argue that the perceived benefits and costs of introduction of the genetically modified seed technology, needs to be re-evaluated from the perspective that by being a substantial addition to cost in the farmers input vector, it also has risk considerations that need to be analyzed. Its dynamic interaction with a host of other factors like changing pest ecology, price risks, multi crop systems and market dynamics needs attention.

Using data from the Situation Assessment Survey of Farmers of the NSS 59th round, for a drought period 2002-03, we derive baseline scenarios for regions in Gujarat and Maharashtra. Data from the field and ethnographic evidence in similar regions provide changes in conditions of cotton production in the drought year 2009-10. First, we show that Bt technology is first order stochastically dominated by non Bt technology for our sample of cotton growers in Gujarat and the Bt technology adds substantial input costs to the production system.

Second, findings from the village level study in Maharashtra provide evidence of technology uncertainty, rampant deskilling and sub-optimal production decision making by farmers with limited information. Widespread institutional failures in the market for seeds emerge as a major concern in the farmers' adjustment process and demands immediate attention.

Last but not the least, we provide the first evidence on the riskiness of Bt cotton technology by employing a simple risk framework (Mishra 2008) which takes the ratio of costs with that of net returns from cultivation of a specific crop. In this theoretical framework Bt technology can be both risk increasing or risk decreasing given the actual conditions under which the production occurs, but empirical evidence presented in this analysis indicate that Bt cotton has been risk increasing.

Even though our datasets are limited in terms of external validity and we employed a mixed-methods framework to address our core research question, we get substantive qualitative and quantitative confirmation on the Bt technology being associated with increasing risk in a drought year. This perspective is critical for the technology evaluation because the farmers stand to lose more in bad crop years than they would have in the case of traditional varieties. Moreover, if the net gains from Bt (at higher expected yields) are offset by the high intensity losses (frequent or otherwise), the yield advantage promised by Bt seeds should be taken with a pinch of salt because the absolute returns are so low that an increase in returns in such years would not lead to an increase in savings that can be used to compensate in a bad year. The riskiness of this technology becomes even more important from the fact that around 65 per cent of India's cotton is produced in rainfed conditions and 35 per cent is irrigated.

We would like to emphasize that this article is not an addition to the existing literature on the productivity or socio-economic impact of Bt cotton technology, rather it is an attempt to introduce a new perspective in evaluating the technology by analyzing farm level data from a nationally representative sample and field level data from an ongoing panel data based study in one of the most challenging socio-economic and institutional contexts where the merit of the technology could be put to test. The contribution of our paper is that it introduces an alternative perspective on how the inherent riskiness of a so-called innovation like Bt cotton should be identified, irrespective of its potential benefits or observed merits across different parts of the country and among different groups of farmers. We demonstrate how a neglect of the simple economics of crop production and the associated risk factors can play out against the farmers who make a conscious decision to adopt a particular technology given multiple constraints, with the hope that it will pay off well.

There are certain methodological issues in Bt cotton evaluation that have not been dealt with in this paper but could be taken up as future research. Bt hybrids outperforming the earlier non Bt varieties should not be taken as a positive increment in yield on account of Bt alone, and the separability of effects of the hybrid impacts from Bt traits in a seed should be strived at. Variability of yield and other dimensions like price risks need to be assessed rigorously. Moreover, Bt technology could also induce moral hazard in farming practices as the farmer would expect the superior technology to be causing higher yields. An analysis of the dynamic performance of the technology over an appropriate period of time across different agroclimatic conditions could throw more light and also help us study the associated effects on the ecology and environment. Despite these limitations, our analysis does suggest that the proposition – to Bt or not to Bt; demands more non reductionist analyses that take cognizance of the localized variations and institutional realities.

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