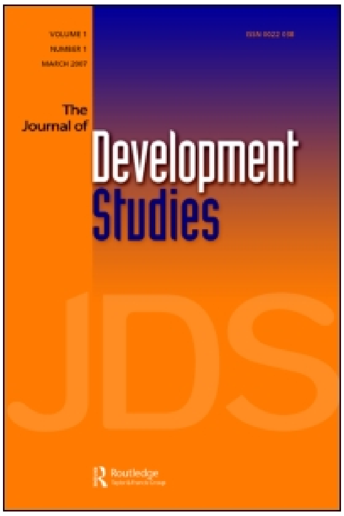

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Bt Cotton and Farmer Suicides in India: An Evidence-based Assessment

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Bt Cotton and Farmer Suicides in India: An Evidence-based Assessment

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ABSTRACT *Bt cotton is accused of being responsible for an increase of farmer suicides in India. In this article, we provide a comprehensive review of evidence on Bt cotton and farmer suicides. Available data show no evidence of a 'resurgence' of farmer suicides. Moreover, Bt cotton technology has been very effective overall in India. Nevertheless, in specific districts and years, Bt cotton may have indirectly contributed to farmer indebtedness, leading to suicides, but its failure was mainly the result of the context or environment in which it was planted.*

I. Introduction

In 2002, India officially approved its first genetically modified crop, Bt cotton, which expresses the toxin *Bacillus thuringiensis* to resist cotton bollworms. Five years later, India had the largest area in the world under Bt cotton with 6.2 million hectares (*The Hindu*, 2007). The rapid adoption of this technology by farmers clearly demonstrates its commercial success.

Yet, Bt cotton is also at the centre of a number of controversies. In particular, a number of groups have contested its effectiveness. Perhaps the most talked about controversy has been the reported accusation that Bt cotton was responsible for an alleged increase in farmer suicides in the country (for example, Krishnakumar, 2005; Nadal, 2007; Sahai, 2005).[1] Some of these reports focused on the relationship between Bt cotton and farmer suicides while others concentrated on conditions facing farmers and the context in which they committed suicides. Still, most reports tend to reflect the polarised views on Bt cotton itself, without providing a

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An Online Appendix is available for this article which can be accessed via the online version of this journal available at informaworld.com/fjds

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comprehensive understanding of the actual situation that led to the observed resurgence of farmer suicides in India and therefore the potential role (or absence thereof) of Bt cotton in this picture.

The objective of this article is to provide a critical review of evidence on the alleged links between Bt cotton and the observed growth in farmer suicides in certain regions of India. We formulate three hypotheses on the presence or absence of a resurgence of farmer suicides and the potential relationship it may have with the use of Bt cotton. We then use secondary data from multiple sources to evaluate these hypotheses. In so doing, we analyse the performance of Bt cotton in India, taking into account the competing evidence given by various studies. We also explore other plausible causes of farmer suicides and whether they have a direct relationship to Bt cotton cultivation.

This analysis is based on data collected from published official and unofficial reports, peer-reviewed journal articles, published studies, media news clips, magazine articles, and radio broadcasts, from India, Asia and international sources from 2002 to 2009. We also had the opportunity to obtain feedback on this specific topic from the Solution Exchange, an internet discussion group organised by the United Nations Development Program (UNDP) in India.

II. Linking Bt Cotton to Suicides: Reviewing the Links

As a basis of analysis, we propose to assess the following three hypotheses:

A. Farmer suicide is a long-term phenomenon; there is no clear evidence of a ‘resurgence’ of such suicides in the five-year period covered by this study (2002–2007).
B. Bt cotton is neither a necessary nor a sufficient cause of farmer suicides. In contrast, many other factors (not all related to agriculture) have likely played prominent roles.
C. In specific regions and years, where Bt cotton might have indirectly contributed to farmer indebtedness (via crop failure), potentially leading to suicides, its failure was mainly the result of the context or environment in which it was introduced or planted; Bt cotton as a technology is not to blame.

Hypothesis A is examined in section III, which reviews the empirical evidence on farmer suicides in India. Hypotheses B and C are mainly supported by the arguments in section IV, V and VI, which provide a comprehensive review of the effects of Bt cotton and an evaluation of its potential contribution, among other factors, to farmer suicides. We then provide a synthesis of our analysis in section VII and close the paper with some concluding remarks.

III. Farmer Suicides in India: Reviewing the Evidence

Two sources of official data have primarily been used to document the rate and number of farmer suicides in India. The first estimates are reported by IndiaStat (2006). This source is important because government officials in Parliament cited these data during question-and-answer sessions in the summer of 2006, and journalists and several researchers cited the data in their papers on Bt cotton or farmer suicides in India. Yet, we find that these data are inconsistent across states and years, that some data are missing, and that several point estimates are reported by crop year, while others are by calendar year.

The second source of data is the National Crime Records Bureau (NCRB) of the Ministry of Home Affairs, which publishes annual reports on accidental and suicidal deaths in India. The number of farmer suicides reported here is larger and more consistent across states and years than IndiaStat. Several authors have used this source, including Nagaraj (2008) and journalists such as Sainath (2007a, b) and Sengupta (2006).

We use the NCRB data as the main basis of this analysis, despite some reported limitations.[2] According to this source (Table 1), farmer suicides only represent a relatively limited and stable share of total suicides in India between 1997 and 2007. Annual national suicide numbers range between 95,800 and 118,200, while farmer suicides lie between 13,600 and 18,300 in the same time span (Figure 1). There is a slight rising trend in total suicides with growth accelerating during 1997–1999 and again during 2003–2007. The rate of farmer suicides is also relatively stable but slowly increasing over time. Figure 2 provides a time series of the share of farmer suicides in total suicides in the same period. This share fluctuates between 14.5 per cent and just above 16 per cent of total suicides. The series reaches its maximum point in 2002 and a secondary peak in 2004. These figures provide evidence that there has not been any recent acceleration (or resurgence) in suicides or farmer suicides at the national level.

Looking at a more disaggregated spatial level, the distribution of suicides and farmer suicides across states is not uniform. By studying trends in suicides for all Indian states, Nagaraj (2008) classifies states into four groups based on the size of their suicide numbers, their farmer suicide rates, their share of farmer suicides in total suicides, and the overall growth of farmer suicides during 1997–2006. The first group includes Andhra Pradesh, Karnataka, Madhya Pradesh and Maharashtra, which account for 52 to 65 per cent of the total reported farmer suicides in recent years and a significant number of total suicides (40% in 2001). Unlike other groups, states in this group form a contiguous zone which might suggest a cause for the higher incidence of suicides in this region.

Maharashtra has a higher share of total farmer suicides than the three other states and also a steadier annual increase (Figure 2). Karnataka and Madhya Pradesh initially had almost as many farmer suicides as Maharashtra, but the share of farmer suicides represented by these two states decreased considerably (Figure 2). In contrast, Andhra Pradesh started with lower farmer suicide numbers, but its suicide rate rose significantly to reach what looks like a plateau in 2005–2006 to decrease in 2007 (Table 1). Figures in Andhra Pradesh, Maharashtra and at the national level point towards three relative peaks in suicide numbers – in 2002, 2004 and 2006.

The importance of these cotton-producing states in observed suicides have been a key argument is supporting a possible link between Bt cotton and farmer suicides. But the link only stands if there is sufficient evidence that Bt cotton has indeed been a failing technology. The following section looks at the economic effects of Bt cotton.

Table 1. Farmer suicides in selected states and all India, 1997–2007

State	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Maharashtra	1,917	2,409	2,423	3,022	3,536	3,695	3,836	4,147	3,926	4,453	4,238
Andhra Pradesh	1,097	1,813	1,974	1,525	1,509	1,896	1,800	2,666	2,490	2,607	1,797
Karnataka	1,832	1,883	2,379	2,630	2,505	2,340	2,678	1,963	1,883	1,720	2,135
Madhya Pradesh	2,390	2,278	2,654	2,660	2,824	2,578	2,511	3,033	2,660	1,375	1,263
Gujarat	565	653	500	661	594	570	581	523	615	487	317
Other states	5,821	6,979	6,152	6,105	5,447	6,892	5,758	5,909	5,557	6,418	6,882
All India	13,622	16,015	16,082	16,603	16,415	17,971	17,164	18,241	17,131	17,060	17,131

Sources: NCRB reports 1997–2007.

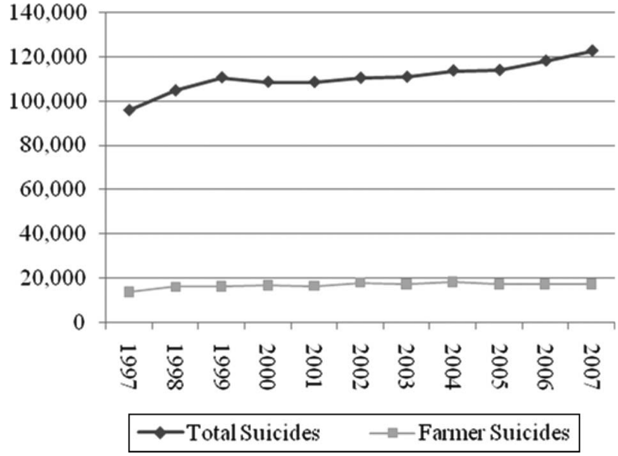

Figure 1. Farmer and total suicides in India, 1997–2007. *Source*: NCRB 1997–2007.

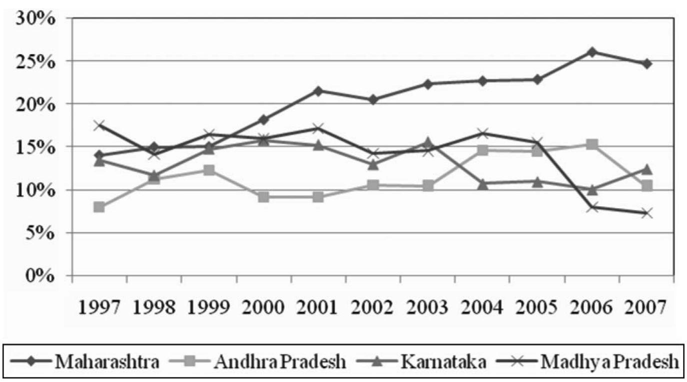

Figure 2. Shares of total Indian farmer suicides in the four states, 1997–2007. *Source*: NCRB 1997–2007.

IV. The Effects of Bt Cotton in India

Bt Cotton at the National Level: Observed Effects

As of 2008, Bt cotton was cultivated in more than 10 Indian states, with Andhra Pradesh, Gujarat and Maharashtra leading the rest of the States in total acreage. Table 2 gives the estimated area of adoption of Bt cotton by state between 2002 and 2008.

According to the Cotton Advisory Board, Bt cotton has been the major factor behind increased cotton production in the country, rising from 15.8 million bales in 2001/02 to 31.5 million bales in 2007/08 (James, 2008). Figure 3 shows the change in average cotton yields at the national level before the introduction of Bt cotton (1980/81–2001/02) and after, 2002/03–2007/08. The difference between the trend in national average yields before and after Bt cotton suggests a significant jump in productivity after Bt cotton introduction. Perhaps more striking is the fact that the

Table 2. Area of adoption of Bt cotton in ha, by state, 2002–2008

State/Region	2002	2003	2004	2005	2006	2007	2008
Maharashtra	12,424	21,854	161,475	508,692	1,840,000	2,880,000	3,130,000
Gujarat	9,137	41,684	125,925	149,258	470,000	908,000	1,360,000
Madhya Pradesh	1,488	13,355	86,119	136,221	310,000	500,000	620,000
Andhra Pradesh	3,806	5,463	71,227	90,419	830,000	1,090,000	1,320,000
Karnataka	2,186	3,035	34,304	29,345	85,000	145,000	240,000
Tamil Nadu	374	7,689	11,995	17,017	45,000	70,000	90,000
Northern Zone	–	–	–	83,503	215,000	682,000	840,000
Other	–	–	–	–	5,000	5,000	5,000
Total	29,415	93,080	491,045	1,014,455	3,800,000	6,200,000	7,605,000

Source: Indiastat (2005) for 2002–2005, James (2008) for 2006–2008.

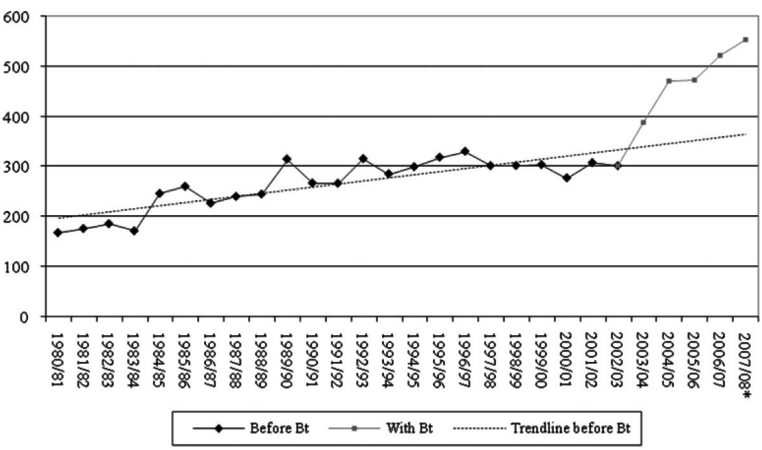

Figure 3. Average cotton yields in India (kg/ha), 1980–2007. *Source:* International Cotton Advisory Committee (2008). *Note*: Data for 2007/08 is an estimate.

average yield level reached almost 400 kilograms per hectare in 2003/04 for the first time in history and that the yield level exceeded 500 kilograms per hectare only three years later in 2006/07. In comparison, it took about 15 years, from 1982 to 1997, for the national yield level to increase from 200 kilograms per hectare to an annual average of 300 kilograms per hectare.

Interestingly, this evolution does not reflect uniform changes in all regions of India. Figure 4 shows the same evolution for selected states that have adopted Bt cotton, indicating that all states except Madhya Pradesh have reached record average yield levels in recent years. Among the central states, Gujarat shows the most striking upward trend in yields, from less than 300 kilograms per hectare in 2000/01 to more than 700 kilograms per hectare five years later. It is likely that crop year variation played a significant role, but in the absence of other structural changes in the sector, this state would be expected to reach an average level of just above 500 kilograms per hectare by 2007/08. Instead, the level of yields in Gujarat reached 750 kilograms per hectare in 2007/08 – 50 per cent higher.

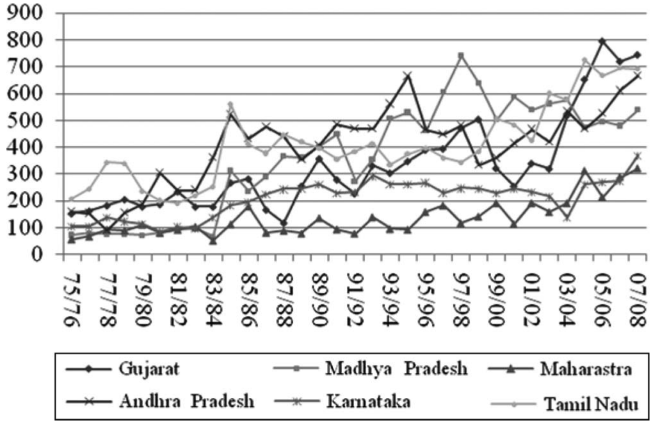

Figure 4. Average cotton yield level by state (kg/ha), 1975–2007. *Source*: Data provided by Directorate of Cotton Development, Government of India (2008); East India Cotton Association (2008).

Although measuring the actual net effects of the introduction of Bt cotton would require formal empirical analysis, our simple overview of the average yield levels helps us draw two conclusions. First, in the absence of other technical or climate shocks in the last five years, Bt cotton likely played a role in the large jump in productivity observed, leading to record high yield levels in India post 2002/03. Second, regional data show that Bt cotton may not have had the same marginal effects in each state. In particular, it seems to have had a larger effect in the central region, and in the central western states of Maharashtra and especially Gujarat.

The Bt Cotton Controversy: The Institutional Context

Farmers' lack of information on growing conditions, pesticide use, the importance of planting proper seeds and the earnings to be expected from using this technology seem to be behind the controversy shrouding Bt cotton's performance. Coupled with this the initial high price of Bt cotton gave rise to a booming spurious seeds market targeting farmers trying to save on seed costs (Herring, 2007). The increasing number of Bt cotton varieties released by the government added to the confusion between real seeds and fake seeds. The lack of agriculture extension and dissemination of knowledge about these new varieties from the government left farmers solely dependent on the companies for information regarding these varieties (SEMC, 2007). Hence they still used high-priced pesticides on Bt cotton, further increasing the costs of cultivation. In a survey of farmers in Maharashtra and Gujarat, Shetty (2004) found that farmers in Guntur and Warrangal districts sprayed cotton 20 to 30 times, when the optimum was 15 times.

According to Shetty (2004), this indiscriminate spraying led to development of resistance in the bollworm and hence pest infestation returned, lowering the yield from Bt cotton in these regions. Moreover, the controversy has been fuelled by the lack of consistent public information on the performance of Bt cotton (SEMC, 2007), which is the focus of the next section.

Economic Effects of Bt Cotton at the Farm Level

Since its introduction, many empirical studies have been published on the economic effects of Bt cotton at the farm level in India. Smale et al. (2009) provide an analysis of the methods used in all farm-level studies of Bt cotton in India up to 2007 and show that the reported effects of Bt cotton in India vary due to the extensive heterogeneity of the growing environment, pest pressures, farmer practices and the social context. The polarised views on the effects of Bt cotton may be reflected in some of the reported studies from groups that are vocal proponents or opponents of the technology. Smale et al. (2009) also emphasize the observed importance of the host germplasm in the literature in determining the effectiveness of Bt cotton.

These three factors, together with the presence of unofficial varieties, the data used and methodology employed provide a convincing explanation of the observed findings of existing studies. The overall conclusion from the literature is that the gains of Bt cotton cannot be generalised to all farmers, all states, and all years. This inconsistency in the results surely played a role in fuelling the controversy over Bt cotton and its benefits for Indian farmers.

We summarise the methods, data, and results of each distinct study in the Online Appendix (Table A1). We find that the location, season, sample, methods and varieties largely varied across studies, and so did the results. But there is also a clear converging trend from contradictory to consistent conclusions. On the one hand, a study of field trials in multiple states (Qaim and Zilberman, 2003) obtained very large and positive results. On the other hand, a study led by two NGOs in certain districts of Andhra Pradesh obtained large and negative results (Qayum and Sakkhari, 2003; Sahai and Rahman, 2003).

Later studies (such as Bennett, Ismael and Morse, 2004) use empirical analysis to show that there is no real controversy about the effects of Bt cotton in India because the variability in results can be explained. The loss observed in some studies is largely due to the lack of adequate Bt varieties (most Bt varieties performed well under irrigation, while cotton in India is grown mostly under rainfed cultivation), the lower quality of cultivar in which the Bt gene was infused, the high price of seeds compensating for the reduction in pesticide costs and the limited knowledge of the technology among cotton growers. At the same time, these later studies show that despite all these constraints, on average, a large majority of Indian farmers gained significantly by adopting Bt cotton varieties.

To test these conclusions, we conducted a simplified meta-analysis of the literature (from 2003 to 2008) on the farm level effects of Bt cotton in India.[3] Table 3 reports the average and weighted average effects of Bt cotton, based on the number of plots (or farms) for these two groups of studies. Each major outcome presented is the one-year percentage change in an indicator on Bt plots relative to non-Bt plots. For example, yields of 115 over 100 would be reported as a 15 per cent rise of 15 points with Bt cotton relative to non-Bt cotton. We find that the differences across average estimates do not differ much. According to these studies, on average, Bt cotton reduces the number of pesticide sprays by 30–36 per cent, reduces pesticide costs by 35–52 per cent, increases the total costs of production by about 15 per cent, has no clear effect on seedcotton prices,[4] increases yields by 34–42 per cent, and raises net returns by 50–94 per cent.

Table 3. Average effects of Bt cotton, compared with non-Bt cotton, based on all farm-level studies and only on peer-reviewed published studies (publications until 2008)

	Pesticide use	Pesticide costs	Total costs	Seedcotton price	Yields	Net returns
All studies						
Number of points	25	31	34	30	50	42
Average change	−36.4%*	−35.9%*	14.5%*	0.2%	34%*	84%*
Number of plots	12206	18836	13087	12285	20843	19018
Weighted average (of change)	−30.1%	−42%	15.0%	−2%	40.9%	93.4%
Peer reviewed studies						
Number of points	22	23	25	22	32	24
Average change	−36.0%*	−41.5%*	16%*	0.3%	36.2%*	58.1%*
Number of plots	11691	10749	10981	10563	12755	10931
Weighted average (of change)	−29.7%	−51.5%	15.6%	−2.4%	41.4%	50.1%

Notes: Each major outcome presented is the one-year percentage change in an indicator on Bt plots relative to non-Bt. *Significantly different from zero at the five per cent level.
Sources: Compiled by authors based on ASSOCHAM (2007), Barwale et al. (2004)**, Bennett et al. (2004)**, Bennett et al. (2005)**, Bennett et al. (2006)**, Dev and Rao (2007), Gandhi and Namboodiri (2006), Janaki and Raja (2009)**, Lalitha et al. (2009)**, Morse et al. (2005a)**, Morse et al. (2005b)**, Morse et al. (2007)**, Naik et al. (2005)**, Narayanamoorthy and Kalamar (2006)**, Orphal (2005)**, Pemsl et al. (2004)**, Qaim et al. (2006)**, Qayum and Sakkhari (2003), Qayum and Sakkhari (2005), Ramasundaram et al. (2008)**, Ramgopal (2006), Sahai and Rahman (2003)**, Sahai and Rahman (2004)**. Peer reviewed publications are noted with **. To avoid double counting, due to overlapping publications, we include results from each dataset once. See details in the Online Appendix.

It is important to note that a significant caveat of these results is that not only do these studies not share a methodology, but virtually all of the studies make no effort to correct for the potential presence of self-selection bias (Crost et al., 2007). Because adoption is a nonrandomized process, Bt cotton adopters may be more productive farmers than nonadopters, and neglecting this fact could result in overestimating the actual net effect of Bt cotton compared with non-Bt cotton. While we cannot correct this potential bias, we try to gauge the consistency across estimates by measuring whether average effects are significantly different from zero at the 5 per cent level. In all case except seedcotton price, we find effects that are significantly different from zero, positive, or negative depending on the variable.

The average effects of Bt cotton by state computed across studies are shown in Table 4. The results show that the surveyed states may be divided into three groups. In the first group of states, including Gujarat, Madhya Pradesh and Tamil Nadu, Bt cotton seems to be very successful. In the second group, including Maharashtra and Karnataka, Bt cotton is associated with higher production costs but it is offset by the yield advantage, resulting in significant net income gains. Andhra Pradesh represents the third group: there, Bt cotton did not reduce pesticide costs much and had a negative but insignificant effect on price. On the other hand, the yields increased on

Table 4. Average effects of Bt cotton relative to non-Bt cotton by state for all farm level studies

State	Number of estimates	Pesticide use	Pesticide costs	Total costs	Seedcotton price	Yields	Net returns
Andhra Pradesh	11	−41.7%*	−16.2%*	12.4%*	−3.8%	14.2%	46.1%
Gujarat	8	0%	−28.7%*	7.5%*	3.4%*	31.2%*	89.0%*
Madhya Pradesh	2	−72.0%	−46.5%	n.a	n.a	78.0%*	n.a.
Maharashtra	18	−30.8%*	−41.3%*	18.2%*	−1.4%	44.1%*	77.2%*
Karnataka	5	−40.5%*	−40.8%	20.0%*	1.8%	35.4%	56.6%
Tamil Nadu	4	−60.3%*	−61.9%*	10.7%	6.5%	27.4%*	219%*
Punjab	1	n.a	−32.1%	n.a	n.a	31.1%	58.4%
Haryana	1	n.a	−29.4%	n.a	n.a	23.5%	54.6%
Rajasthan	1	n.a	−58.2%	n.a	n.a	32.7%	67.9%
Average- all samples		−36.4%*	−35.9%*	14.5%*	0.2%	34%*	84%*

Source: Compilations based on studies cited under Table 3 (see the Online Appendix for detail).
Notes: Each major outcome presented is the one-year percentage change in an indicator on Bt plots relative to non-Bt; n.a. means not available. *Significantly different from zero at the five per cent level.

average by 14 per cent while net returns increased by 46 per cent, but these two effects are not significant. The largest variances across results were reported in Andhra Pradesh and Maharashtra, two suicide-prone states. We disaggregate the results by season of studies, ranges of effects and peer reviewed versus all studies in these two states in Table 5.

Andhra Pradesh shows a relative increase in net returns over time, going from negative to positive, apparently due to better average yield effects in the last two years. Sahai and Rahman (2004) argue that cotton growers progressively replaced MECH varieties (the official Bt varieties of Monsanto-Mahyco) with Navbharat unofficial varieties, which may have performed better under local conditions, but whose seeds also cost less than official Bt hybrids. The results also show a large variance in this state.

Results obtained in Maharashtra are more consistent across studies (Table 5). It is the state with the largest number of studies and the largest number of plots surveyed. Average effects in the three seasons reported are qualitatively similar. Yields and net return effects appear to be positive in all studies, but there is more variance in cost effects. It is clear that the discrepancy across results during the same season shows that the Bt cotton varieties adopted in these states had various effects on cotton productivity and farm income.

V. Bt Cotton in the Confluence of Other Factors

Many reports and studies have been written on the cause of farmer suicides in India. Although some focus on purely agricultural matters, others have taken a broader

Table 5. Detailed analysis of average effects of Bt cotton relative to non-Bt cotton in Andhra Pradesh and Maharashtra

	Pesticide use	Pesticide costs	Total costs	Seedcotton price	Yields	Net returns
Andhra Pradesh						
2002/03	−39.0%	−10.5%	12.0%	−2.2%	1.3%	−58.0%
2003/04	n.a	−14.5%	14.5%	−10.0%	−5.6%	−38.0%
2004/05	−47%	−16.4%*	11.8%*	−2.1%	25.3%	87.3%
2006/07	n.a	−30%	n.a	n.a	22.8%	217%
Minimum	−57.0%	−30.0%	5.0%	−10.0%	−35.0%	−142.0%
Median	−47.0%	−17.6%	13.0%	−3.0%	5%	−7.0%
Maximum	−21.0%	−2.0%	21.0%	2.3%	46.0%	380.0%
Average all studies	−41.7%*	−16.2%*	12.4%*	−3.8%	14.2%	46.1%
Weighted average all studies	−43.5%	−19.9%	13.2%	−1.7%	19.3%	98.4%
Average peer-reviewed studies	−39%	−14.7%	16.3%	−5.1%	8.2%	−37.3%
Weighted average peer-reviewed	−41.5%	−14%	15.9%	−4.4%	13.6%	−34.4%
Maharashtra						
2002/03	−38.2%*	−52.0%*	18.8%*	−3.6%	44.8%*	60.6%*
2003/04	−27.6%	−30.7%*	19.4%*	−0.2%	46.1%*	56.1%*
2004/05	−36.0%	−63.0%	12.0%	−1.0%	22.0%*	53.5%
2006/07	n.a	−28.9%	n.a	n.a	94.2%	376%
2007/08	−4%	n.a	n.a	n.a	19%	n.a
Minimum	−64.0%	−105%	−4.0%	−11.0%	−14.5%	−67%
Median	−38.5%	−48.0%	18.0%	0.1%	42.5%	73.0%
Maximum	31.0%	17.0%	49.0%	3.0%	94.2%	376.0%
Average studies	−30.8%*	−41.3%*	18.2%*	−1.4%	44.1%*	77.2%*
Weighted average	−31.2%	−50.9%	16.0%	−2.8%	46.7%	79.8%
Average peer-reviewed studies	−30.3%	−44%	19.3%	−1.2%	42.5%	55.8%
Weighted average peer-reviewed	−31.1%	−54%	16.2%	−2.8%	42.5%	49.6%

Source: Compiled by authors based on studies cited under Table 3. See the Online Appendix for details.
Notes: Each major outcome presented is the one-year percentage change in an indicator on Bt plots relative to non-Bt plots; n.a. means non-available.* Significantly different from zero at the five per cent level.

outlook, viewing farmer suicides as an indicator of a more systemic problem in agriculture and society, especially in the central and southern states.

In the conclusion of his report on farmer suicides in India, Nagaraj (2008) argues that a complex set of socioeconomic factors play a role, which is confirmed by our own literature review. However, one leading factor seems to connect several causes particularly related to agriculture: the heavy indebtedness of farm households, particularly in the suicide-prone states. Indebtedness, worsened by the agrarian crisis, has been cited as a primary cause of suicides (Asadi, 2000; Sharma, 2004; Rao and Suri, 2006; Mitra and Shroff, 2007; Nagaraj, 2008). Rising cost of cultivation, loss of competitiveness (Mitra and Shroff, 2007), breakdown of rural institutions (Asadi, 2000; Kumar, 2005) have also been reported as major causes of increased farmer suicides in the central region. Still, increased indebtedness and crop failure would not be problems if there were other options available to the farmers to make up for these losses. Given pre-existing conditions of high vulnerability in the region, the absence of alternate livelihood opportunities to mitigate losses might have exacerbated suicide rates in this group of states (Nagaraj, 2008).

The alleged link between farmer suicides and Bt cotton is based on the assertion that it may have contributed to higher costs of production and to crop failures, both increasing the chance of indebtedness and the likelihood of suicide. Here we specifically look at the evidence on the possible relationship between Bt cotton and farmer suicides and in the subsequent sections we examine more general factors that have been reported to be causing indebtedness or farmer suicides.

Farmer Suicides and Bt Cotton Adoption

There are no numbers on the actual share of farmers committing suicide who cultivated cotton, let alone Bt cotton, and among them, those who committed suicide because their Bt cotton crop failed. In this context, we can only provide a second-best assessment of the evidence. At the aggregate level, we combine data on the adoption of Bt cotton with the numbers of farmer suicides at the national level between 1997 and 2006 (Figure 5). We use this figure to compare the trend in farmer suicides with the spread of Bt cotton in the country.

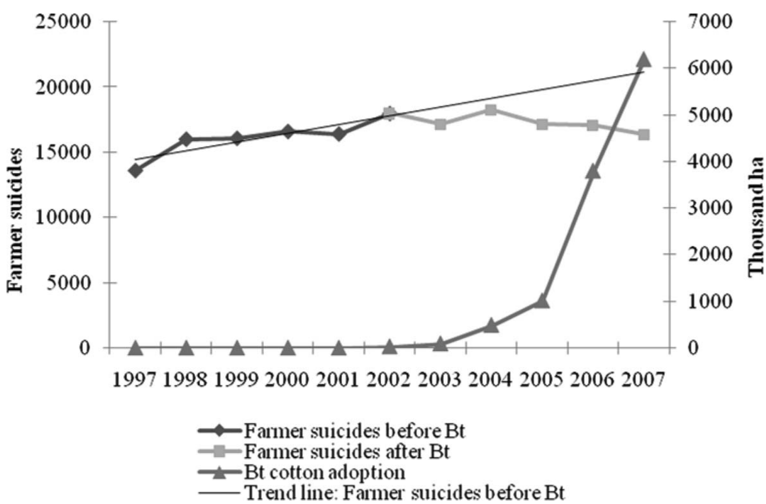

Figure 5. Farmer suicides and Bt cotton area in India, 1997–2007. *Source*: Combined data from Table 1 and Table 2.

Three clear conclusions emerge from Figure 5: (1) there is no observed correspondence (or causality) between the national Bt cotton adoption rate and farmer suicides, (2) the annual growth in suicides actually diminishes after the introduction of Bt cotton, (3) the two more recent peaks in farmer suicides are in 2002 and 2004, while the largest increase in adoption happened during years with reduced suicides. However, as in the case of suicide numbers, these aggregate results may not hold at a lower spatial level.

Maharashtra tends to be a good proxy for what happens at the aggregate national level, notably because of its important cotton sector (Figure 6). The growth in farmer suicides in this state started much before Bt cotton and actually slowed down in the years after the introduction of Bt cotton. Overall, at this level of analysis, it is clear that the overall adoption of this technology was not a driver of suicide growth.

The case of Andhra Pradesh is more ambiguous, because the farmer suicide numbers have followed a much less regular (and less linear) pattern during the period as a whole (Figure 7). The linear trend of suicides before Bt shows that the rate of suicide may have increased after the introduction of Bt cotton, even if there is a clear drop in 2007. Based on this evidence, we cannot reject a possible partial correlation between adoption of Bt cotton and suicide growth, even though there were many farmer suicides and a clearly increasing pattern much before Bt cotton was introduced. The year 2004 stands out as a peak in the suicides. In that year, Bt cotton had only been partially adopted. In the following two years, which saw a much larger acceleration in adoption of Bt cotton, relative changes in suicide rates in Andhra Pradesh were limited, but the total decreased significantly again in 2007, despite a clear increase in Bt cotton adoption.

To sum up, based on these simple insights, we can dismiss the possibility of Bt cotton being a necessary or sufficient condition for farmer suicides in India (confirming hypothesis B). It is evident that a high number of farmer suicides occurred much before Bt cotton was introduced and that the introduction of Bt cotton did not result in a clear leap in farmer suicides in India. What we cannot reject, however, is the potential role of Bt cotton varieties in the observed discrete

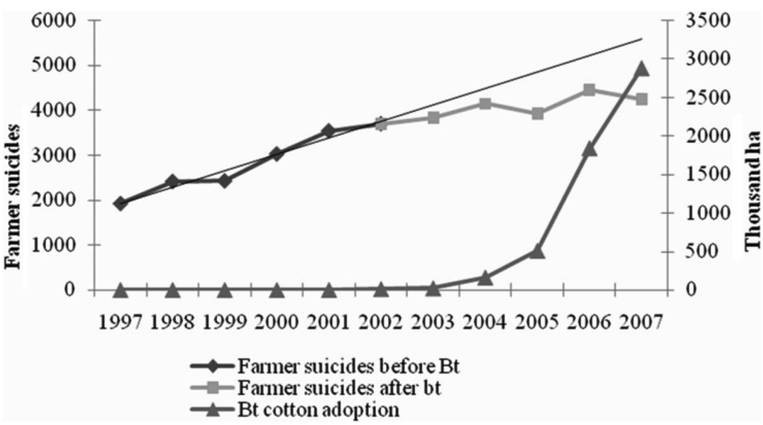

Figure 6. Farmer suicides and Bt cotton area in Maharashtra, 1997–2007. *Source*: Combined data from Table 1 and Table 2.

increase in farmer suicides in certain states and years, especially during the peaks of 2002, 2004 and 2006 in Andhra Pradesh and Maharashtra.

Weather and Market Factors in Andhra Pradesh and Maharashtra

While institutional factors likely played a role, climatic and economic factors, which are naturally more varying over time, may also have contributed to lower yields or crop failure and therefore negative net revenues in some of these particular years.

In Andhra Pradesh, there was a drop in rainfall in 2002/03 and 2004/05 in the suicide-prone districts and the state as a whole (see Figure 8). At the same time, the yield distribution is much more condensed and at a low level; 2002/03 was a bad year for cotton in most districts. 2003/04 is centred toward normal precipitation, but compared to the two earlier years, it presents a wide range of yield levels across dry

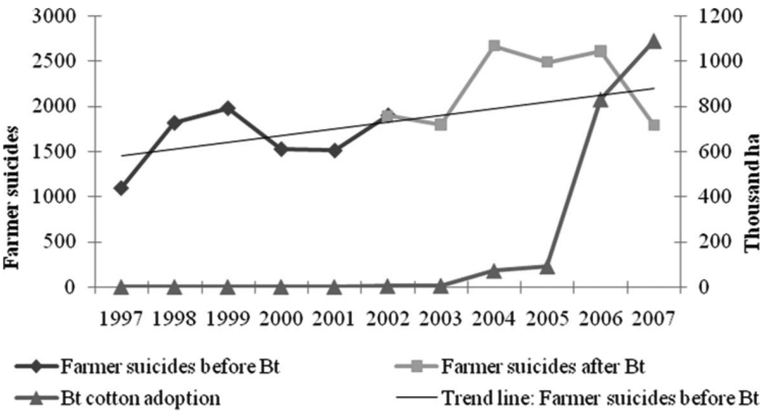

Figure 7. Farmer suicides and Bt cotton area in Andhra Pradesh, 1997–2008. *Source*: Combined data from Table 1 and Table 2.

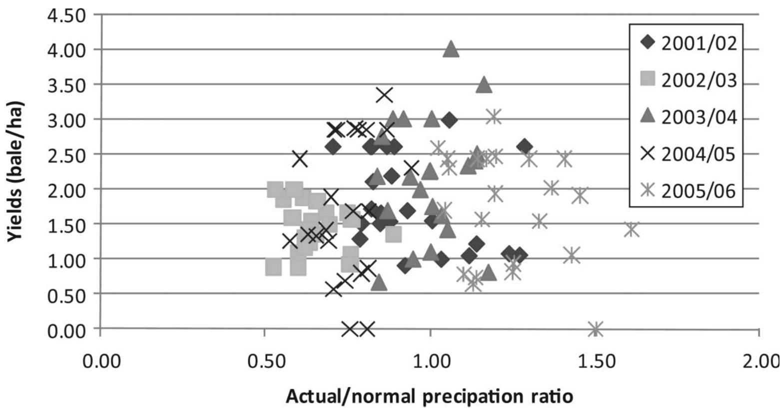

Figure 8. Precipitation and cotton yields levels in 23 districts of Andhra Pradesh, 2001–2004. *Source*: http://www.indiastat.com

or less dry districts. Yield levels also varied in 2004/05; although less than in the previous year, but precipitation was clearly lower than average. It was a rather dry year for many districts, and the highest yields were therefore lower, but it was still a much more productive year than 2002. Lastly, in 2005/06, precipitation was much higher than normal. The monsoon was particularly strong that year, which may have contributed to the moderately low and high yields observed in different districts.

The picture in Maharashtra is much more obscure (Figure 9). Perhaps the only visible feature for seasons before and after 2002 is the widespread rainfall estimates across districts – some having large excesses of rainfall, other large deficits. Both factors could have contributed to relatively low yields. Unfortunately we did not obtain data for 2004/05 or 2006/07; therefore we cannot comment on the role of rainfall in those particular years.

There is also evidence that cotton was sold at a low price during these seasons. The Cotlook A index (used for international cotton prices) decreased significantly at the end of the 1990s, reaching low points in 2001/02 and again in 2004/05. Indian varieties also reached a minimum price in 2001/02 and 2004/05. So if 2002/03 was a particularly dry season in Andhra Pradesh and Maharashtra, with low cotton yields in the former, it also followed a record year of low prices. Combined, these two successive 'bad' seasons, with cotton bringing low or even negative revenues, may have increased farmers' indebtedness significantly.

More General Factors and Trends Linked to Increased Indebtedness

Beyond weather and markets, more general factors can be linked to agriculture indebtedness and suicides. Agriculture in Andhra Pradesh and Maharashtra, which used to be dominated by rain-fed, low-cost food crops, has gradually moved toward cultivation of cash crops. The area under food crops has declined in both states (Mishra, 2006a; Shridhar, 2006). In Maharashtra, cash crops like oilseeds have significantly increased (Mohanty and Shroff, 2004). A comparison of cropping patterns in 1958 and 1998 in Andhra Pradesh shows a rising trend toward cash crops such as groundnuts and oilseeds. A change in the cropping pattern toward cash

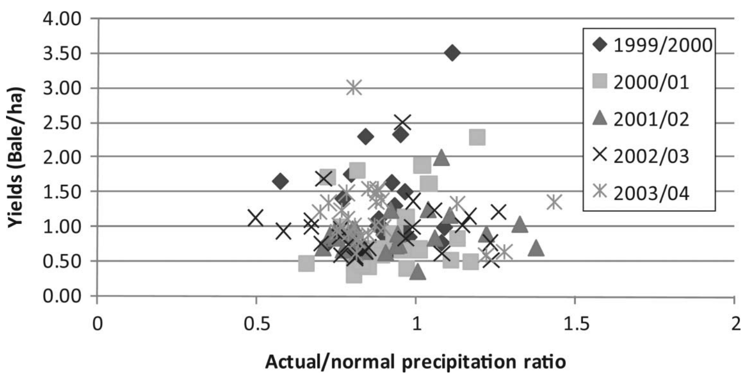

Figure 9. Cotton yields and precipitation ratio in 25 districts of Maharashtra, 2000–2004. *Source*: Indiastat (2006).

crops in itself would not be a concern if the crops had not failed in certain seasons, sinking farmers' investments. With dry conditions and inadequate irrigation systems in some parts of these states, farmers have been pushed toward financial distress.

Discounting polarized views, previous studies did not report a link between Bt cotton production and farmer indebtedness (Mitra and Shroff, 2007; Rao and Suri, 2007). Instead increased indebtedness of farmers is attributed to unprofitability of cotton due to decline in irrigated area under cotton and low rainfall (Mitra and Shroff, 2007; Rao and Suri, 2007). In fact, there has been an increased dependence on monsoons. Nationally, 66 per cent of the area under cotton was cultivated under rain-fed conditions in 2000/01 (Narayanamoorthy and Kalamkar, 2006). While there is evidence that Bt cotton has performed better under irrigated conditions (Naik, Qaim and Zilberman, 2005), Bt and non-Bt cotton are reported to have similar irrigation facilities (ASSOCHAM, 2007).

Surveys conducted to discover reasons for farmer suicides find failure of the wells to be a major cause of indebtedness among farmers in Andhra Pradesh (Sridhar, 2006). When wells fail, farmers not only lose the money spent in digging, but also may lose the cotton crop for lack of water (Government of Andhra Pradesh, 2004). In 2004, following a delayed release of water from the nearby Nagarjuna Sagar Dam, crop losses in parts of the state were not confined to cotton but also affected food crops (Rao and Suri, 2006). In Maharashtra, cotton growers are still dependent on the monsoons, as only 6–8 per cent of the net sown area is irrigated (Mohanty and Shroff, 2004).

Another factor enhancing indebtedness is the lack of access to institutional credit. Most of the farmers who committed suicide in both states had high, unpaid loans. In Maharashtra, the share of total credit utilization going toward agriculture declined from 20.2 to 11.2 per cent from 1991 to 2004 (Mishra, 2006b). In Andhra Pradesh, the share of moneylenders and other sources of credit going to agriculture is much higher, reaching about 68 per cent (Mishra, 2006b). A survey conducted by the government of Andhra Pradesh showed that 80 per cent of all agricultural loans come from non-institutional sources. In both states, many of the families directly affected by suicide accessed local moneylenders for credit (Government of Andhra Pradesh, 2004).

On the revenue side, Mitra and Shroff (2007) provide evidence of a general increase in cultivation costs, particularly in Maharashtra – an increase that was not compensated for by low or stagnating prices for cotton, therefore leading to negative net revenues. A survey conducted among the households of deceased farmers in Andhra Pradesh in 2003 found the same trend of unrecovered costs incurred in cotton and in high-yielding varieties of chillies (Rao and Suri, 2006). The Dandekar Report of 2005 claims that crops cultivated in the region were sold at a loss by farmers. According to this report, between 1996 and 2004, farmers' net losses were about 38 per cent for paddy, 38 per cent for cotton, 32 per cent for groundnuts, 37 per cent for soybeans, and 12 per cent for sugarcane.

Spurious seeds sold as Bt cotton seeds also added to crop loss. Greater demand for Bt cotton in the initial years coupled with high price of the seeds gave rise to a flourishing spurious seed market. In the absence of seed certification, farmers honestly mistook such seeds for approved Bt cotton (Herring, 2008). Failure of these crops cannot even be considered failure of Bt cotton as they might not have displayed the Cry protein (Herring, 2008).

While dealing with crop loss, farmers did not have any respite from repayment of the heavy debts they had accumulated. Farmers who committed suicide had consistently been harassed for immediate repayment of loans even after a crop failure (Mishra, 2006b). This factor is seen to contribute significantly to the feeling of loss of economic standing among farmers, along with the fact that they were continually relying on credit to get out of debt (Mishra, 2006b). This loss of social position was more prominent among small and marginal farmers who owned some land and hence some social standing. Farmers who lost crops and were in large debt often concealed this fact from their families (Hardikar, 2006). These observations show that the loss of social position was a concern that distressed farmers.

Another perhaps less talked-about factor, is the availability of toxic pesticides. Although not noted in the section on suicide above, the annual estimates of the National Crime Record Bureau attribute about 20 per cent of suicides to the absorption of toxic pesticides. This factor is even more important in rural areas. It is estimated that 300,000 people living in rural areas of Asia commit suicide every year by ingesting toxic pesticides; this may represent 60 per cent of all suicides in Asia (Gunnell and Eddleston, 2003; Konradsen et al., 2007).

Lastly, safety net policies may have had some unintended effects on suicides. Incentives from the government to combat suicides could also have increased suicides among indebted farm families. Ex-gratia payments for families of suicide victims may have caused suicides, especially during the suicide peak election year of 2004 (Herring, 2008). This concern has become even more prominent in 2007, when the Indian government announced a major rehabilitation package for the families of farmers who had committed suicide (Kennedy, 2007).

In March 2008, the Government of India also initiated a large loan waiver scheme (equivalent to $15 billion) to allow for the clearance of debts for small and marginal farmers. Although designed as a strong response to the debt issue, this plan was largely criticised. For instance, Swaminathan (2008) criticised the unified definition of small and marginal farmers to whom the plan was targeted. Second, targeted loans eligible for repayment are those provided by scheduled commercial banks, rural banks, and cooperative credit institutions. Yet moneylenders and traders provide a major share of the loans used by distressed farmers. Thus a large-scale targeted rural aid program was unfortunately not aimed at the households using the problematic informal loan sources.

VI. Discussion

We do not claim to have a sufficient understanding to provide a full picture of the reality behind farmer suicides. Still, our analysis is sufficiently well documented to discredit the possibility of a naïve direct causal or reciprocal relationship between Bt cotton and farmer suicides. First, adopting Bt cotton is not a sufficient condition for the occurrence of farmer suicides in India. It is estimated that about 5 million farmers have planted Bt cotton, whereas a cumulative total of 90,000 farmers are reported to have committed suicide between 2002 and 2007. The case of Gujarat, with high adoption and low and stable suicide rates clearly shows the lack of a clear general relationship between Bt cotton and farmer suicides. Moreover, the trend in farmer suicides in India appears to have slowed down since the first year with Bt cotton, which would certainly not have happened if Bt cotton were responsible for increasing farmer suicides. Second, the adoption of Bt cotton is not, nor has it ever been, a necessary condition for farmer suicides in India. Farmer suicides occurred in various states of India long before the introduction of Bt cotton.

Therefore, Bt cotton cannot be indicted as the primary cause of farmer suicides in India. In fact, our overview of the evidence suggests that Bt cotton has been quite successful in most states and years in India, contributing to an impressive leap in average cotton yields, as well as a decrease in pesticide use and an increase in farmer revenues. The reality is more complex, with the conditions surrounding the proper cultivation of Bt cotton, the resulting effects, and the socioeconomic constraints which might have pushed farmers in particular regions to commit suicide during some years.

Using more disaggregated data, we explored some of the complexity on the hypothetical link between Bt cotton and farmer suicides in two states (Andhra Pradesh and Maharashtra) and specific suicide peak years: 2002 and 2004. By using meteorological and economic data (see Online Appendix), we find that in Andhra Pradesh, low rainfall, leading to low yields and following a season with low minimum prices could have played a role in the observed relative peak in suicides in 2002. Bt cotton, which had just been introduced, is unlikely to have played any significant role that year. In 2004, low rainfall and low prices, with another drought, resulted in low or negative revenues for cotton, including in some cases Bt cotton. But available evidence suggests that, on average, Bt cotton still performed significantly better than non-Bt that year, even in suicide-prone districts.

In Maharashtra, the two peak suicide years of 2004 and 2006 are more difficult to comprehend, notably because of a lack of complete or consistent data. The 2004 season was clearly one of low prices and very dry weather, especially in the suicide-stricken districts of Vidharba and Marathwada. Bt cottonseeds were sold at a high price, and even if the technology was reportedly quite successful, there is insufficient evidence of its performance that year. Average yields of cotton did reach a historic record level in 2004/05, which suggests that cotton productivity increased in the state, weakening any link between cotton and suicides at the state level. Still, the few varieties of Bt cotton being sold that year, which were still not suitable for dry conditions, could have been adopted by rainfed farmers in arid or semi-arid districts of the state. In 2006, however, with the availability of many more varieties, this factor likely did not play a role. The only studies on 2006/07 found positive results with Bt cotton. Hence, more data would be needed to have a definitive conclusion but it is unlikely that the peak was related to Bt cotton.

VII. Conclusion

In this article, we reviewed the evidence on the alleged resurgence of farmer suicides in India and the potential relationship between the adoption of Bt cotton and suicides among Indian farmers. Using secondary data from multiple sources, we evaluated three hypotheses on the phenomenon of farmer suicides and Bt cotton in India.

We first showed that despite the recent media hype around farmer suicides, fuelled by civil society organisations there is no evidence in available data of a 'resurgence' of farmer suicide in India in the last five years. Moreover, even if there has been an increasing trend in total suicides, the reported share of farmer suicides has in fact been decreasing.

Second, we provided a comprehensive review of available evidence on the effects of Bt cotton in India and found that Bt cotton technology has been very effective overall. However, the context in which Bt cotton was introduced has generated disappointing results in some particular and limited cases. While on average Bt cotton has had a significant positive effect on cotton productivity in India, Bt cotton's results during the first three seasons varied across studies and locations. It did not always perform well in particular areas and seasons, partly because of climatic conditions, low cotton prices, inadequate farming practices fuelled by misinformation about the new technology and the widespread use of initial Bt varieties that were not adequate for all locations and farming practices. We also found that the institutional context likely played a significant role where the outcome with Bt cotton was not positive, including lack of or weak extension systems, lack of information on the different types of seeds and the presence of unofficial and spurious seeds sometimes being sold as official Bt.

Third, our analysis has shown that Bt cotton is not a necessary nor a sufficient condition for the occurrence of farmer suicides. Therefore, it should not be blamed for the resurgence of farmer suicides in the field. In contrast, other factors have almost certainly played an indispensable role in these cases.

The absence of irrigation systems in drought-prone areas (especially in Maharashtra), combined with specialisation in high-cost crops, low market and support prices, and the absence or failure of the credit system, is a clear recipe for failure. It is possible, therefore, that under the conditions in which it was introduced, Bt cotton, an expensive technology that has been poorly explained, often misused and initially available in only a few varieties, might have played a role in the overall indebtedness of certain farmers in some of the suicide-prone areas of these two states, particularly in its initial years. But none of these possible links has been explicitly demonstrated with a sufficiently robust analysis.

One implication of this study is the critical need to distinguish the effect of Bt cotton as a technology from the context in which it was introduced. Revealed preferences based on farmer adoption rates and official or unofficial data all point toward the overall success it has had in controlling pest damage and therefore raising average yields in India. In particular, the increasing adoption rate in two suicide-prone states, Andhra Pradesh and Maharashtra, indicates that farmers in these states found this technology economically beneficial.

In contrast, marketing constraints and institutional issues may have played a significant role. Our analysis suggests the need for a better extension system, more controlled seed marketing system, anti-fraud enforcement and better information dissemination among farmers in all regions, before the introduction of any costly new technologies like Bt cotton. Farmers should also be encouraged to diversify their farming and non-farming activities to spread the risks they may incur.

The second implication is that, as farmer suicides are not new or specific to recent cases or to the introduction of Bt cotton, they point toward the failure of the socio-economic environment and institutional settings in rural dry areas of India. This has nothing to do with cotton or the use of new technology and would suggest many potential policy changes. In several states, such as Karnataka and Andhra Pradesh, some policy changes have already been proposed. Lastly, much more and better federal and state investment could help prevent the 80 per cent or more other cases of suicides.

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Notes

1. We define suicides based on the following three properties (NCRB 1997–2007): i) it should be an unnatural death, ii) the desire to die should originate within himself/herself; and iii) there should be a reason for ending the life.
2. Some observers consider it an underestimate of actual number of farmer suicides (for example, Nagaraj, 2008). Among others, the strict definition used for farmers may have left out genuine farmers who are tenants and all those women farmers in cases where the land title is not in the woman's name.
3. For detailed information on each study, see Table A1 in the Online Appendix. We excluded Qaim and Zilberman (2003), because they were based on experimental field data.
4. Seedcotton prices are defined as the prices received by farmers for their harvested seedcotton, that is, before ginning.

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