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GM COTTON AND SUICIDE RATES FOR INDIAN FARMERS

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Abstract

The arguments for and against genetically modified (GM) crops are spread across the academic literature and in the media. This paper focuses on one of these disputes: has the introduction of GM cotton in India led, as some have claimed, to an increase in the suicide rate for Indian farmers? Evidence on the numbers of suicides and the numbers of farmers is assembled from several sources, by state and over time for both male and female farmers. This evidence is, faute de mieux, at an aggregate level. The short time series are modelled to test whether there is any evidence of a break in the series that corresponds to the adoption of GM cotton. The analysis reveals considerable variation in trends in suicide rates across the nine cotton-growing states. The data, although not ideal, and the modelling do not, however, support the claim that GM cotton has led to an increase in farmer suicide rates: if anything the reverse is true.

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Arguments continue to rage about the safety and costs of genetically engineered or genetically modified (i.e. GM) crops, and about their relevance to problems of world food production and the public health in developing countries. Those who promote them claim increased yields, fewer inputs, and economic and ecological benefits. The scientific consensus (e.g. The Royal Society, 2009) emphasises their advantages but does not regard GM as a panacea for all the agricultural problems of the world. Anti-GM campaigners (e.g. Antoniou et al., 2012) emphasise possible risks to health and to ecosystems, over-reliance on certain pesticides, and the dominant position of multinational companies in the GM seed market – which, they say, badly affects small farmers in poorer countries. Many of the arguments, for and against, rely on statistical data. But these data are very often not subject to critical assessment and analysis. Closer analysis can tell very different stories.

One example is the assertion that the introduction of GM cotton in India has led to a surge in farmer suicides. In 2008, HRH Prince Charles pointed to "the truly appalling and tragic rate of small farmer suicides in India, stemming in part from the failure of many GM crop varieties'' (Daily Mail, 2008). It is sadly true that thousands of Indian farmers commit suicide each year, often by ingesting pesticides and with far-reaching consequences for their families. On the other hand, there are many millions of farmers and so we should be concerned about the suicide rate as well as about the numbers. And, overall, male and female suicide rates in India are not notably high – higher than in the UK but lower than France according to the most recent data from the World Health Organisation (http://www.who.int/mental_health/prevention/suicide_rates/en/), although there are doubts about the accuracy of official data on suicides. But if suicide rates have indeed risen among farmers who have begun growing GM crops, it would be important evidence in the GM debate. Here, I throw some statistical light on trends in Indian farmer suicide rates over the last 15 years and whether there is any evidence to suggest that the trends have been affected by the introduction of GM cotton.

For many, the introduction of GM cotton to India is a resounding success story. Indeed, the proportion of farmers growing GM varieties since the official launch in 2002 has risen spectacularly: over 90% of cotton growing land (James, 2012) is now planted with one of over 800 varieties of what is usually known as *Bt* cotton. This is seed that has been genetically modified by adding genes from the soil bacterium *Bacillus thuringiensis* to provide resistance to cotton bollworm. More sceptical commentators (e.g. Coalition for a GM-free India, 2012) argue that the observed increase in yields is part of a longer-term trend brought about by better farming practices and irrigation, that *Bt* crops are prone to failure, and that the expense of the seeds allied to the need to buy new seed every year has contributed to rising farmer debt that eventually drives farmers to suicide. The Indian sceptics have gained ground recently and the introduction of GM food crops, notably *Bt* brinjal (aubergine/eggplant), has been postponed (although permission has been granted in Bangladesh).

There is evidence (Kathage and Qaim, 2012; Gruère and Sun, 2012) of a positive effect on profit for farmers growing *Bt* cotton arising both from higher yields and also from reduced pesticide costs. But it is also apparent that this effect varies across the nine states responsible for nearly all of India's cotton production. We can thus hypothesise that the endemic problem of debt faced by Indian farmers (National Sample Survey Organisation, 2005) has at least been alleviated by the introduction of *Bt* cotton. To the extent that debt is likely to be a cause (although certainly not the only cause) of farmer suicides, one might, in turn, suppose that the positive economic effects of *Bt* cotton would lower the risk of suicide. In addition, we might expect to find more marked reductions in suicide rates in those cotton-growing states where the effects on yields (and thus on profits) have been most marked.

I focus on self-employed farmers and make no distinction between farmers who own the land they farm and those who rent it. I ignore agricultural labourers on the grounds that it is their employers who make decisions about what crops to grow each year and how to grow them, and who borrow money to finance production. Although some agricultural labourers are likely to have small plots for growing food, I assume that agricultural labourers do not face the same circumstances as farmers if crops fail.

Previous research

There are two bodies of work relevant to the question of whether there is a link between the introduction of *Bt* cotton in India and a change in farmer suicide rates. The first body of work covers the evidence for the effect of *Bt* cotton on farmer profits. Perhaps the strongest study in this group is Kathage and Qaim (2012) who use panel data covering the period from 2002 to 2008 for a sample of 533 farmers (and 1655 plots), in four of the cotton-growing states (Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu). They show that there are positive effects of *Bt* adoption on yield (up 24%), profit (up 50%) and household consumption expenditure (up 18%). The strength of this paper is its use of panel data at the plot level, with household fixed effects that eliminate the problems associated with self-selection, i.e. more productive farmers choosing to adopt *Bt* seeds. It is not, however, entirely clear how the effects of plot, time and household were incorporated into the models used. The data only cover the initial period of *Bt* adoption and only for four states (the three states in the northern region – Haryana, Punjab and Rajasthan - are not represented, partly because *Bt* adoption was later in that region). Moreover, only 198 farmers were surveyed on all four occasions. (Kouser and Qaim (2011) use the same data to show that there are positive externalities of *Bt* adoption in terms of a reduction in cases of pesticide poisoning.)

Herring and Rao (2012), in a wide-ranging discussion of the GM arguments as they apply to *Bt* cotton, present data from a before-after study of *Bt* adoption by 186 farmers in Andhra Pradesh. They estimate a yield gain of 42% but do not do any modelling and do not have a control group of non-adopters. Gruère and Sun (2012) also focus on the effect of *Bt* adoption on yield. Their data cover the years from 1975 to 2009 for all nine states but only at the state level. Consequently, they are unable to control for measured and unmeasured characteristics of farmers. They too argue for a positive effect of *Bt* adoption on yield for India as a whole but do not do any formal analysis by state or region. There is some descriptive data that suggests that the effect might be driven by the effects in Gujarat, Maharashtra and Tamil Nadu. An interesting discussion about the ways in which evidence that relates to the effects on yield of *Bt* cotton is constructed and used by the academic community, and by anti-GM campaigners, can be found in Stone (2012).

Turning to the small group of studies that have looked at farmer suicides, the strongest is the article by Gruère and Sengupta (2011).They look at the numbers of farmer suicides from 1997 to 2007 by state and argue that, although the data are far from ideal, the evidence does not support a direct link between the adoption of *Bt* cotton and changes in the numbers of farmer suicides, especially given the positive effects of *Bt* cotton on yields, costs and profits. There are, however, some problems with Gruère and Sengupta's analysis. In particular, they analyse numbers of suicides and not suicide rates (this also a defect of the data presented by Nagaraj,2008) and so do not properly account for changes in the numbers of farmers or differences in state populations; the paper is descriptive without any formal modelling; they do not analyse males and females separately; there is a discontinuity between 2005 and 2006 for numbers of suicides in Madhya Pradesh with the data before 2006 appearing to include data from Chhattisgarh (which was created out of Madhya Pradesh in 2000) and, because *Bt* cotton was adopted later in the northern region, they exclude Haryana, Punjab and Rajasthan from their analyses.

Other studies have looked at suicides in India more generally and two of these stand out. Mayer (2011), as part of a sociological study of suicide, suggests (in Chapter 11) that farmer suicides are not especially high when compared with other occupations. Patel et al. (2012) have carried out what is probably the most detailed epidemiological study of suicide in India; I consider their results in more detail in the next section.

Data sources

(i) Suicide rates

We might be in a position to establish a causal relationship between farmer suicide rates and the introduction of *Bt* cotton if we could draw on data from a very large prospective study that covered all cotton-growing states and followed individual cotton farmers before and after their adoption (or non-adoption) of *Bt* cotton. Such a study was not carried out. Instead, we must rely on data from official sources at the state and national levels over time, with all their strengths and weaknesses, in order to get a better picture of (a) the trends in the rates of Indian farmer suicides; (b) whether there is any evidence of a discontinuity in the rates after *Bt* cotton was introduced; and (c) whether there is any association between trends in suicide rates and trends in cotton yields.

The National Crime Records Bureau (NCRB: http://ncrb.nic.in/statistics.htm) collates extensive data from state bureaux (which in turn collate data from district police forces) on suicides every year, broken down (since 1996) by state, occupation and gender and these are the data that were used by Gruère and Sengupta (2011). One of the occupations coded is "self-employed farming/agriculture" and these are assumed to be farmers or, as they are often referred to, cultivators (agricultural labourers are coded separately and are not considered in this paper). Table A1 gives some basic data on numbers of suicides by gender and cotton-growing state for 2011 (see data note 1). It shows that 78% and 80% of male and female farmer suicides, and 63% and 60% of all male and female suicides, fall within the nine states under consideration, and that the male:female ratios are similar for the cotton-growing states and all India. It is, however, suspected that not all suicides appear in the NCRB counts because of social stigma and fear of prosecution. In addition, occupational classifications are subject to error. This is a potentially important problem for women who farm land that is in a male relative's name as they might not be coded as farmers in those circumstances.

Despite these drawbacks, Mayer (2011) argues that the NCRB data are reasonably reliable. There is, however, a good source of cross-sectional survey data on suicides (Patel et al., 2012). These data come from a nationally representative survey of 95335 deaths (overall sampling fraction = 0.0067) occurring between 2001 and 2003 to people age 15 or more, of which 2684 (or 2.8%) were deemed to be suicides. The authors projected forward their rates to 2010 from which we can estimate that, for all occupations, the numbers of male and female suicides are, respectively, 35% and 47% higher overall for the nine cotton-growing states than they are in the NCRB data. These nine states account for 55% of male suicides and 52% of female suicides in the survey data. I apply these correction factors to the NCRB data and assume that they also apply to farmers, and that they do not vary over time or between states. It would be possible to relax the latter assumption and apply state-level corrections but these would be based on very few observed suicides in some states (e.g. only four female suicides in Punjab). See data note 2 for further discussion of the correction factor.

In order to analyse suicide rates, we need an estimate of the denominator – the number of farmers at risk. It is not easy, however, to establish just how many male and female farmers there are, state by state over time. There are two sources of data. The first is the Census of Population, conducted every 10 years with the most recent in 2011. The Census asks everybody for their main job but this can be unpaid work by females and children working on the family farm where decisions are made by men, and is therefore likely to over-estimate the number of cultivators (i.e. farmers), especially female cultivators. The Census also distinguishes between main and marginal workers within the main job, depending on how much of the year the person works. Table A2 gives this breakdown by state and gender for 2011 and shows that the proportions of marginal workers vary considerably between states for both males and females: Rajasthan has a high proportion of marginal cultivators whereas the proportion is low in Maharashtra. Data for main and marginal workers do not appear to be available by state for earlier Censuses and so main and marginal cultivators are combined in the analyses presented below.

The second source of data on the number of farmers at risk is the Agricultural Census, conducted every five years. The Agricultural Census does not collect data on farmers; instead it collects data on the number and size of agricultural holdings, broken down by state, size and gender. The holdings are categorized as individual, joint or institutional although data on different types of holdings are not yet available for the 2010/11 Agricultural Census. There is no direct link between the number of holdings and the number of farmers. So it is, at least in principle, possible for a farmer to have more than one holding in different villages which would mean that they would be counted twice. However, given that the definition of a holding encompasses non-contiguous plots, there are likely to be very few instances of double counting. In addition, we do not know the mean number of farmers in joint holdings; joint holdings are common in Gujarat, Haryana and Rajasthan but rare in the other six states (see data note 3). Joint holdings are categorized as male or female according to the basis of decision-making in their operation; they could include both male and female farmers. I consider a range of between two and four farmers per joint holding (2; 2.5; 3; 3.5; 4) and assume that they all have the same gender according to their classification. In addition, I assume that those who cultivate very small holdings (less than 0.5 hectares) do so as a supplement to their main income (possibly as agricultural labourers) and they are therefore excluded from the denominator, as are farmers who work on institutional holdings (see data notes 4 and 5). Table A3 gives the estimated numbers of male and female farmers for each cotton-growing state according to the assumptions made about joint holdings.

The estimates from the two sources for the number of male cultivators in 2011 are relatively close when the nine states of interest are combined: 41.3 million from the Census of Population and 43.1 million from the Agricultural Census when joint holdings are assumed to contain just two farmers. There are, however, marked discrepancies at the state level as shown in Table A4, with ratios varying from 0.69 (Andhra Pradesh; more farmers in the Agricultural Census even after omitting very small holdings) to 1.77 (Punjab; more farmers in the Population Census). Moreover, for some states, the time trends are different. For example, in Andhra Pradesh, the number of cultivators is decreasing according to the Census of Population but increasing according to my calculations from the Agricultural Census. It is, therefore, important to see whether conclusions about trends in farmer suicides are robust to assumptions about the numbers of farmers.

The discrepancies between the two sources of data for female farmers are much greater than they are for males. Again, they vary from state to state but, in all cases and as expected, there are more female farmers in the Census of Population than the estimates from the Agricultural Census – a ratio of 3:1 for all the cotton-growing states. It is reasonable to suppose that the estimates based on the Agricultural Census are the more accurate of the two and they are therefore used as the denominator when analysing female farmer suicide rates in subsequent sections of this paper.

In order to obtain suicide rates for each year between 1996 and 2011, estimates of the denominators for non-Census years were interpolated (the numerators are known). Quadratic curves for year were fitted to the data for each state from the 1991, 2001 and 2011 Censuses of Population and predicted values from the curves were used to estimate the numbers of male farmers for the inter-censal years. As data from the Agricultural Census were available for 1996, 2001, 2006 and 2011, cubic curves for year were fitted to obtain predicted values for males and females for each state and for each of the five assumptions about the numbers of farmers per joint holding.

(ii) Cotton yields

There are three sources of data on cotton yields, i.e. production divided by area and usually measured as kilograms per hectare. The most widely used data are those published by the Cotton Corporation of India and provided by the Cotton Advisory Board (CAB) by state and crop year (July to June). The data are based on arrivals at cotton mills and are subject to revision for up to two years. Doubts have been expressed about the reliability of the data at state level as, among other things, they are based on incomplete returns from ginning mills and do not allow for cotton produced in one state being processed in a neighbouring state (Sud, personal communication).

Cotton yield data based on so-called crop-cutting experiments are published by state and year by the Directorate of Economics and Statistics (DES) in the Ministry of Agriculture. These experiments are carried out on randomly selected plots and so the yield data are subject to sampling error. The methodology has been described as sound in principle but sometimes flawed in its execution (Sud, personal communication). The Ministry of Agriculture also publishes another set of yield data from their cost of cultivation surveys (CCS), again by state and year but with some gaps. The derivation of these yield data is not, however, entirely clear; they are also subject to sampling error. They have been used by Gruère and Sun (2012). See IS_cottonyield.xlsx for the raw data.

As there are gaps in the DES and CCS series, Table A5 compares mean yields over a 12 year period between 1999 and 2010 for the three sources of data. It shows that the CCS means are always substantially higher than those from the other two sources and that the CAB estimates are, except for Haryana and Punjab, higher than the DES estimates. As the

CAB data are based on the same estimates of area as the DES data, these are discrepancies in production. The ranks are not consistent across the data sources with notable discrepancies for the CAB series for Haryana, Madhya Pradesh, Punjab and Tamil Nadu. The provision of more accurate data on production and yield is the subject of a 2012 Bill – The Cotton Distribution (Collection of Statistics) Bill – under consideration by the Indian Parliament.

(iii) Adoption of Bt cotton

Data on the area under *Bt* cotton by year come from James (2012; Table 12, p.66). They are broken down by state except for the states in the northern region, where *Bt* adoption only started in 2005. It is not entirely clear how these data are collected and there is a degree of uncertainty about their accuracy as can be seen from Table A6 which gives *Bt* adoption percentages based on the James data as a percentage of the total area planted with cotton as given by CAB (which, in turn, are the same as the DES figures). In some years, percentage adoption exceeds 100% with the figure for Tamil Nadu in 2011 being particularly suspicious. The percentage (71) for Andhra Pradesh in 2009 is out of line with the percentages for 2008 and 2010. There are also suggestions in the literature (Gruère and Sun, 2012) that *Bt* seeds were used, especially in Gujarat, before it became legal to do so in 2002.

(iv) Data availability

All the data used in this paper can be found at:

http://www.ccsr.ac.uk/staff/ian_plewis_article.html

There are three Excel files and one STATA file. The Excel files are:

(i) *IS_corrfactor.xlsx*; this gives data on the correction factors for the NCRB data.

(ii) *IS_cottonyield.xlsx*; this gives data on cotton yields from the different sources.

(iii) *NONFARMSUI.xlsx*; this gives data on suicides for those who are not farmers.

The STATA file – *INDIANSUICIDES_SIG.dta* – contains all the data used to model suicide rates etc.

Results

(i) Suicide rates for farmers and non-farmers

Table A7 gives the range of suicide rates according to which denominator is used (see data note 6) for male and female farmers and non-farmers along with the total suicide rate, for the Census years 2001 and 2011 for the nine cotton-growing states combined (and these states account for 44% of the Indian rural population in 2011). The total suicide rate is substantially higher for men than for women (as it is in practically every country in the world), more so in 2011 than in 2001. We see that, for males, the rates for farmers are slightly lower than they are for non-farmers in 2001, more markedly lower in 2011. There are, however, some marked differences between states as we can see in Figure 1 for 2011. Male farmers were much less likely than non-farmers to commit suicide in Rajasthan and Tamil Nadu whereas the reverse is true for Maharashtra. The states are ordered, left to right, by region (north to south) in Figure 1 and this brings out the fact that suicide is generally more prevalent in the south of India.

The position is, however, different for female farmers. There is a lot of noise at the state level but, for the nine states as a whole, the rate for female farmers is twice the rate for non-farmers in 2001 with a slightly smaller gap in 2011 (Table A7).

An important caveat, when comparing these rates for farmers and non-farmers across gender, is that the rates are not standardised by age. We do not know whether the age distributions of male and female farmers and non-farmers differ. The data in Patel et al. (2012) indicate that, for all of India, suicide rates for men do not vary substantially by age but the rate for women is very much higher for the 15 to 29 year olds than in all other age groups.

(ii) Trends in suicide rates for farmers

If the introduction of *Bt* cotton has improved the livelihoods of Indian cotton farmers then we would predict that there would be a change in any time trend for suicide rates after (although not necessarily immediately after) 2002. But we would not expect this change to be the same across all cotton-growing states because the proportion of farmers who grow cotton of any kind varies from 26% in Punjab and Gujarat to just 5% in Karnataka (see data note 7); the adoption of *Bt* cotton also varies across states, averaging 33% in Gujarat to 57% in Andhra Pradesh since 2002 (see Table A6); and, as we see below, the effects on yields are not uniform.

In order to smoothe out random fluctuations over time, conclusions about trends are based on regressions fitted to the empirical logits (see data note 8) of the proportions of suicides against year (1996 to 2011) for each state (males only) and for all states combined (males and females), assuming a first-order autoregressive process for the residuals to allow for possible autocorrelation (i.e. ρ) in the farmer suicide rates (equation (1)). (An alternative approach, not used here, would have been to have modelled numbers of suicides with the population denominator as an offset.) The models were estimated using generalized least squares (Prais and Winsten, 1954) and implemented in the *Prais* procedure in STATA.

$$logit(p_t) = \beta_0 + \beta_1 t + u_t \ (1)$$

where p_t is the observed proportion of suicides in year *t* (*t* = -6, -5...9);

$u_t = \rho u_{t-1} + e_t\,;\; e_t \sim^{iid} N(0, \sigma_e^2).$

Four variants of the relation with year were considered: (i) a linear trend (as in (1)); (ii) linear and quadratic terms for year; (iii) log year; (iv) no trend (i.e. β_1= 0). In addition, each of these four variants were used with three assumptions about the denominator for the rates: (i) numbers of farmers based on agricultural holdings and assuming (a) two farmers per joint holding and (b) four farmers per joint holding; (ii) numbers of farmers based on the Census of Population. The Bayesian Information Criterion (BIC) was used to determine the best fitting model for each of the three assumptions about the numbers of farmers.

A disadvantage of this approach is that the variance of the empirical logits is not constant, especially as the proportions are small, and a weighted least squares approach for grouped logits (implemented in *glogit* in STATA) might be preferred (equation (2)).

$$logit(p_t) = \beta_0 + \beta_1 t + e_t (2)$$

where:

$$E(e_t e_{t-k}) = \frac{1}{n_t p_t (1 - p_t)}; k = 0.$$

$$= 0, k \neq 0.$$

In fact, the differences between the estimates and their standard errors from the two approaches were small when sandwich estimators for the standard errors were used with the *Prais* procedure. Tables A8 to A18 gives the BIC values, the estimated autocorrelations for the best-fitting models and the estimated coefficients and their standard errors for the Prais and grouped logit approaches.

Conclusions about trends rest on consistency of the predicted rates from the grouped logit models according to the assumptions made about the numbers of farmers. For male farmers for each state, we find that:

Andhra Pradesh: consistent evidence of an increasing suicide rate but no consistent evidence of a change after *Bt* adoption in 2002 (Figure 2).

Gujarat: consistent evidence of a declining suicide rate but no consistent evidence of a change after *Bt* adoption in 2002 (Figure 3).

Haryana: consistent evidence of an increasing suicide rate but no consistent evidence of a change after *Bt* adoption in 2005 (Figure 4).

Karnataka: no evidence of a trend.

Madhya Pradesh: no consistent evidence of a trend but some support for a decline after *Bt* adoption in 2002 (Figure 5).

Maharashtra: consistent evidence of an increase up to 2005 and a decline thereafter (Figure 6).

Punjab: some uncertainty as convergence was difficult to achieve for model (1) but evidence of a decline up to 2005 and then an increase after *Bt* adoption in 2005 (Figure 7).

Rajasthan: no evidence of a trend.

Tamil Nadu: no evidence of a trend.

Thus, for the northern region, we find that there is no consistent evidence for a change in the model-based suicide rate for male farmers in Rajasthan but, for Punjab, the rate appears to decline up to around 2004 but then increases whereas, for Haryana, it increases steadily. In the central region, the rate is declining in Gujarat, more or less constant for Madhya Pradesh but, in Maharashtra, it increases up to 2005 and declines thereafter. And in the south, the rate is constant for Karnataka and Tamil Nadu but increases steadily in Andhra Pradesh.

Figure 8 shows the predicted rates for male and female farmers for all the nine states (see Tables A17 and A18). We see an increase for men up to 2005 and a decline thereafter whereas, for females, we observe a consistent decline such that, from 2009 onwards, the male and female rates are essentially the same.

(iii) Trends in cotton yields

The expectation is that yields will rise in line with the adoption of *Bt* cotton. This is tested by treating the data as an interrupted time series and fitting the following model to the yearly data on yields for each state (omitting subscript *t* for simplicity):

$$yield = \beta_1\delta + \beta_2\gamma + \beta_3\delta.yearc + \beta_4\gamma.logbtadopt + e$$

where:

$yearc$ is year, centered at 2002;

δ and γ are 0/1 variables, with δ equal to 1 if $yearc$ <3 in the northern region, $yearc$ < 0 otherwise and γ = 1-δ.

$logbtadopt$ is the logarithm of percentage *Bt* adoption. A log transformation was used to model the possibility of self-selection: early adopters are likely to be the more efficient farmers who will enjoy the greatest gains from *Bt* adoption (Stone, 2012).

Essentially, this model fits a regression of yield on year before *Bt* cotton was introduced and a regression of yield on the log of the adoption percentage thereafter. Prais regressions (i.e. with the autoregressive structure specified in (1)) were fitted to each of the three measures of yield described above. Conclusions about whether the data are consistent with a causal effect of *Bt* adoption on yield were based on comparisons of the estimates of β_3 and β_4 for all three measures of yield. More weight was given to the estimates based on CAB estimates of yield as this was the only series that was complete for the years 1996-2011. In particular, if the estimate of β_3 was consistent with no or a negative trend before adoption and if the estimate of β_4 was positive and statistically significant for the CAB and one other measure of yield, than this was deemed a definite increase in yield after adoption. Similarly, if the estimate of β_3 was consistent with a positive trend before adoption and if the estimate of β_4 was zero or negative for the CAB and one other measure of yield, then this was deemed a definite decrease in yield after adoption. Otherwise, states were classified as either possible increases or decreases according to the estimates of β_3 and β_4 shown in Table A19.

The effect of *Bt* adoption on yield was deemed to be definitely positive in Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Rajasthan and for India as a whole; definitely negative in Punjab; and possibly positive in Madhya Pradesh and Tamil Nadu. Taking the estimate for β_4 of 31.8 for all India, using the CAB measure of yield, we find that yield is estimated to increase by 22 kg/hectare when *Bt* adoption goes up from 10% to 20% but by only 5.8 Kg/hectare when adoption goes up from 50% to 60%.

Discussion

As we have seen, it is difficult to reach definitive conclusions about the effects of the adoption of *Bt* cotton on trends in farmer suicide rates, more particularly cotton farmer suicide rates, over the last 15 years. The available data are not ideal and, even if they were better, it is never easy to reach causal conclusions from observational data.

There are four major components of the overall dataset: numbers of suicides, numbers of farmers, cotton yields and *Bt* adoption rates. We have seen that data for each of these components has defects although it is reasonable to suppose that the seriousness of these defects has been mitigated by being able to draw on data from a range of sources. The NCRB data, based on police reports of numbers of suicides, have been supplemented by the survey data from Patel et al. (2012). The numbers of farmers have been estimated using both the Census of Population and calculations based on the Agricultural Census. Three sources of data on cotton yields have been exploited. Although there are uncertainties about the only source of data for *Bt* adoption over time (James, 2012), their data are not out of line with small-scale studies in, for example, Andhra Pradesh (Herring and Rao, 2012).

It should also be recognised that conclusions from the statistical models are based on a relatively short time series of at most 16 observations per state, with only seven observations after official *Bt* adoption in the northern region and 10 for the central and southern regions. The series is too short for standard time series approaches (ARIMA modelling for example) and so inferences rely on appropriate estimates of parameters that reflect interruptions or breaks in the series and which account for autocorrelation and heteroscedasticity. It is, however, unlikely that data for years after 2011 would change conclusions substantially as *Bt* adoption rates are now so high.

Nevertheless, despite the caveats about the data and the models, we can reasonably conclude that these analyses do not support the view that farmer suicides have increased following the introduction of *Bt* cotton. Taking all nine states together, there is evidence to support the hypothesis that the reverse is true: male farmer suicide rates have declined after 2005 having been increasing before then. Of course, we do not know anything about suicide rates among cotton farmers: all our inferences come from overall farmer suicide rates. However, the fact that only a minority of farmers in the nine states grow cotton serves to strengthen our conclusions in that any suicide signal from growing *Bt* cotton has to compete with the noise from non-cotton growing farmers.

The picture at the state level is less clear-cut, especially the contrast between Maharashtra and Punjab. Can we bring any more evidence to bear to understand this contrast better? Both Punjab and Maharashtra have high proportions of farmers growing cotton (26% and 20%) and mean *Bt* adoption rates are similar (55% and 56%). However, when we model the effect of the introduction of *Bt* cotton on cotton yields, we find that they have risen in Maharashtra but have gone down in Punjab. There was a marked increase in yields in Punjab *before* the official introduction of *Bt* cotton in 2005, from 389 Kg./hectare in 2003 to 610 Kg./hectare in 2005. Perhaps some farmers were using illegal *Bt* seeds before 2005, as they did in Gujarat before 2002. And the yield in 2009 (432 Kg./hectare) was unusually low and this one observation might have had an unwarranted influence on the parameter estimates. It is also possible that the very different growing conditions in the two states contribute to the contrast: all cotton grown in Punjab is via irrigation (and yields are relatively high) whereas nearly all cotton grown in Maharashtra is rain-fed (and yields are relatively low). *Bt* seeds might be better suited to the conditions in Maharashtra than they are in Punjab although the variety of *Bt* seeds now available to farmers render this explanation unlikely. We can, however, say that the results for these two states are in line with our hypothesis that there is an economic component to the explanation of suicides although this might be coincidental.

Previous research has not analysed male and female farmers separately. There are six male farmers for every female farmer across the nine states of interest so conclusions about the relation between farmer suicides and *Bt* adoption will inevitably be driven by the data for males. Nevertheless, the convergence of male and female farmer suicide rates is noteworthy and it would be interesting to explore whether this is related to different adoption rates between male and farmer farmers and different trends in overall yields. This could only be done with survey or other micro data.

Conclusion

The Indian farmer suicide story has become received wisdom for some anti-GM campaigners. In fact, we find that the suicide rate for male Indian farmers is slightly lower than the non-farmer rate. And Indian suicide rates as a whole, although contested, do not appear to be notably high in a world context. The pattern of changes in suicide rates over the last 15 years is consistent with a beneficial effect of *Bt* cotton for India as a whole albeit perhaps not in every cotton-growing state. The widespread adoption of *Bt* cotton means that we will never have the opportunity to study this question in the depth that it merits but it might still be possible to do so in a different context if permission to grow GM vegetable crops is granted by the Indian government.

Acknowledgements

I would like to thank Tarani Chandola, Guillaume Gruère, Dougal Hutchison, Kunal Sen and Pauline Turnbull for comments on an earlier version of this paper, and the many statisticians in India who responded to my requests for further information and clarifications. A shorter version of this paper appears in *Significance* (Feb. 2014).

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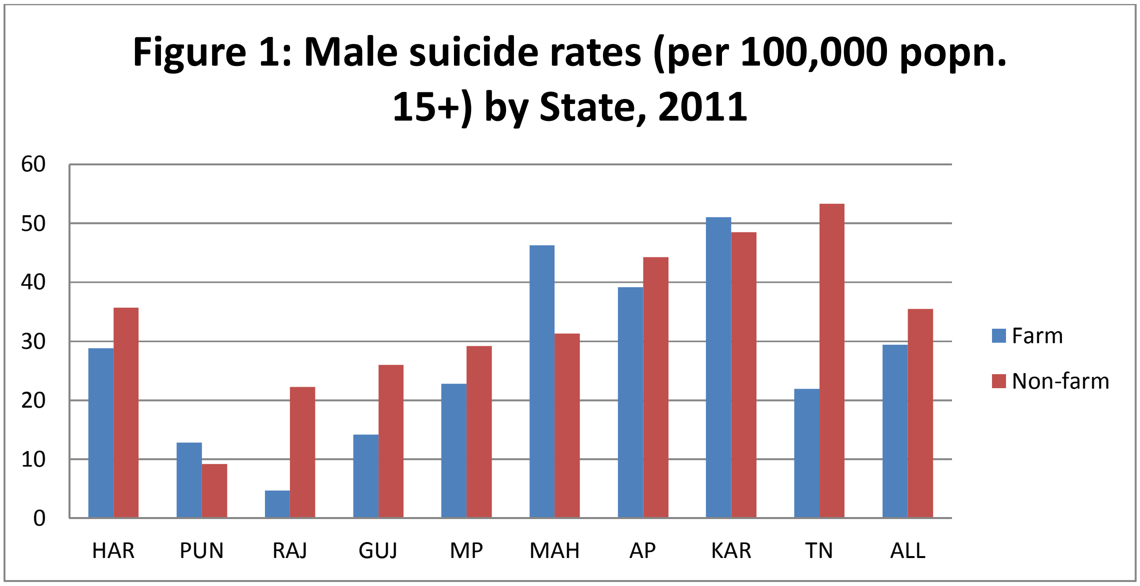
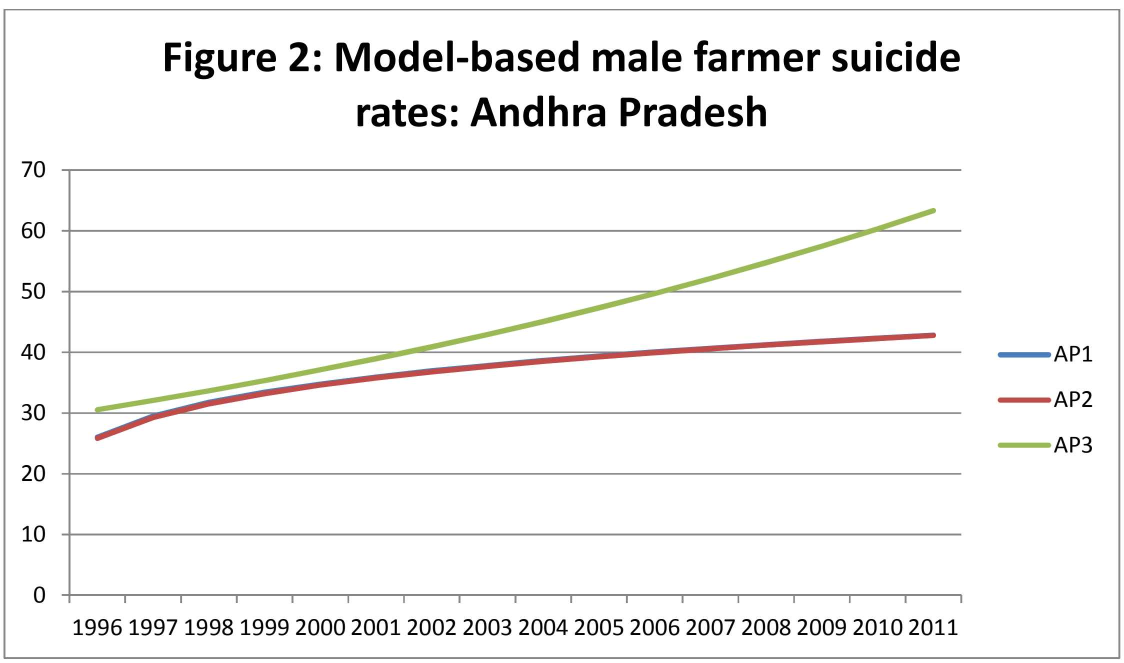


Note
1. These rates use estimated numbers of farmers from the Agricultural Census in the denominator, assuming two farmers per joint holding.



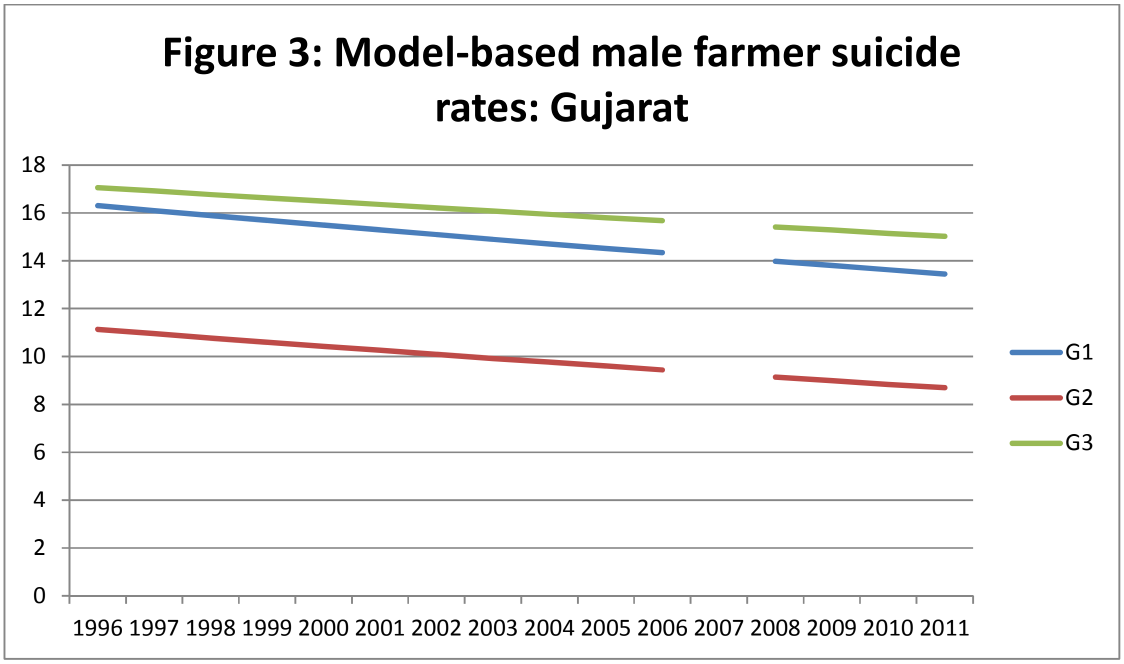


Figure 3: Model-based male farmer suicide rates: Gujarat

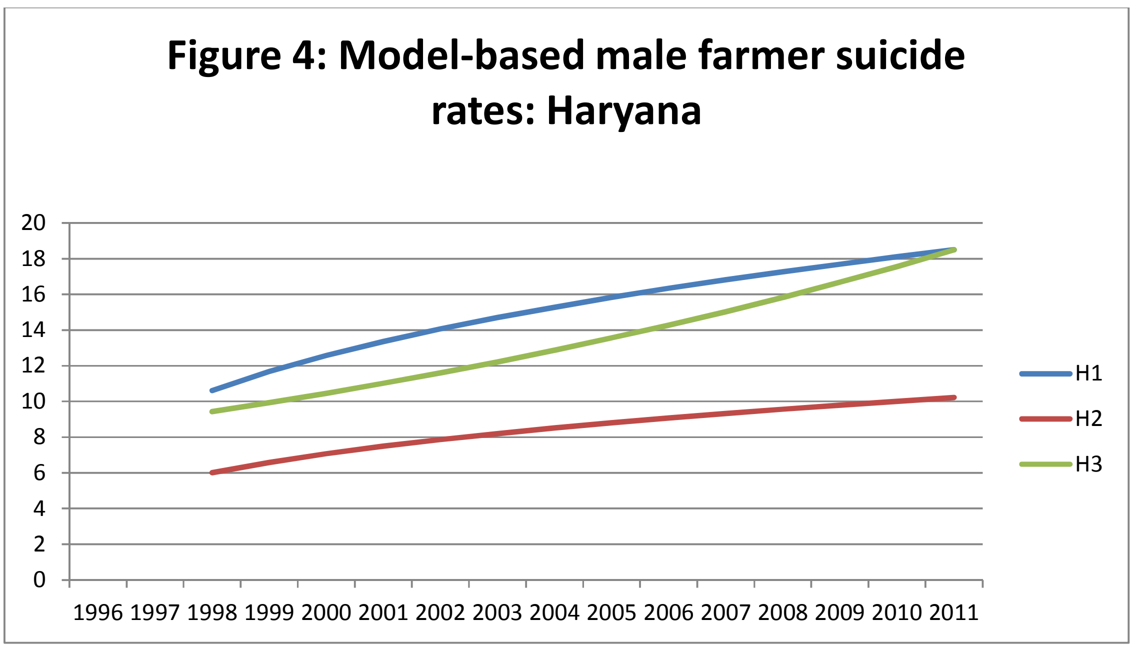


Figure 4: Model-based male farmer suicide rates: Haryana

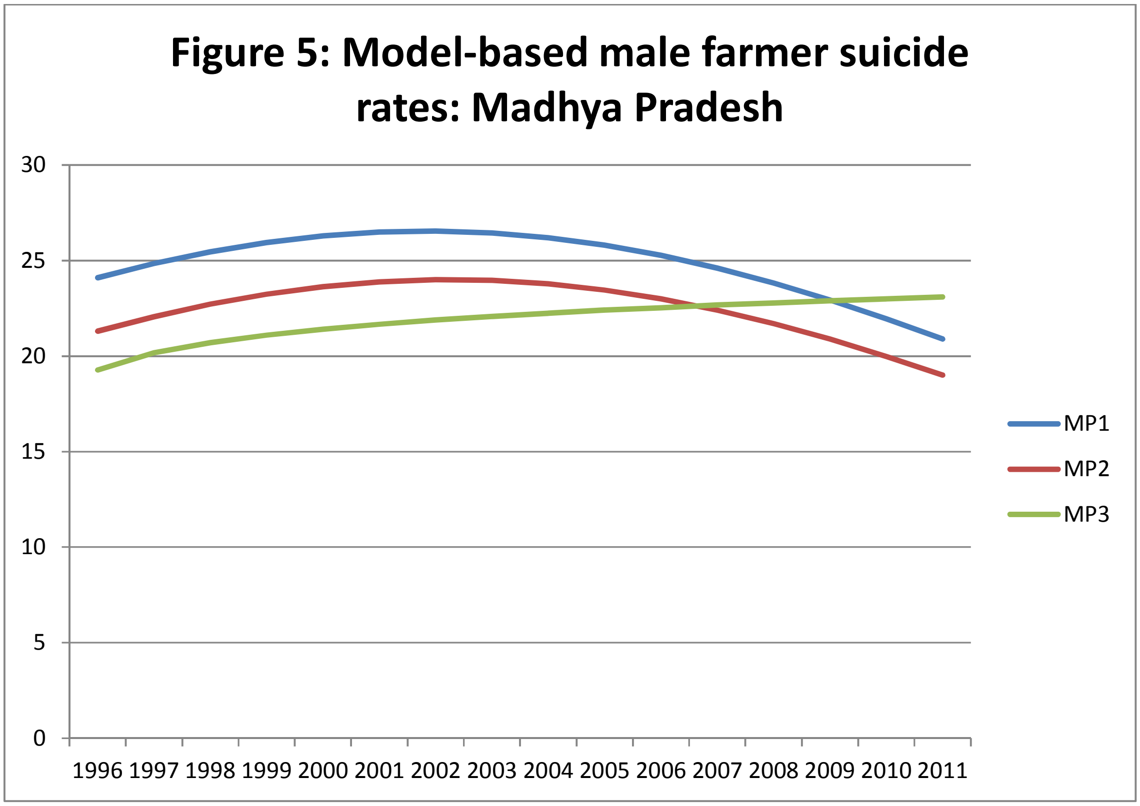


Figure 5: Model-based male farmer suicide rates: Madhya Pradesh
30
25
20
15
10
5
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
MP1
MP2
MP3

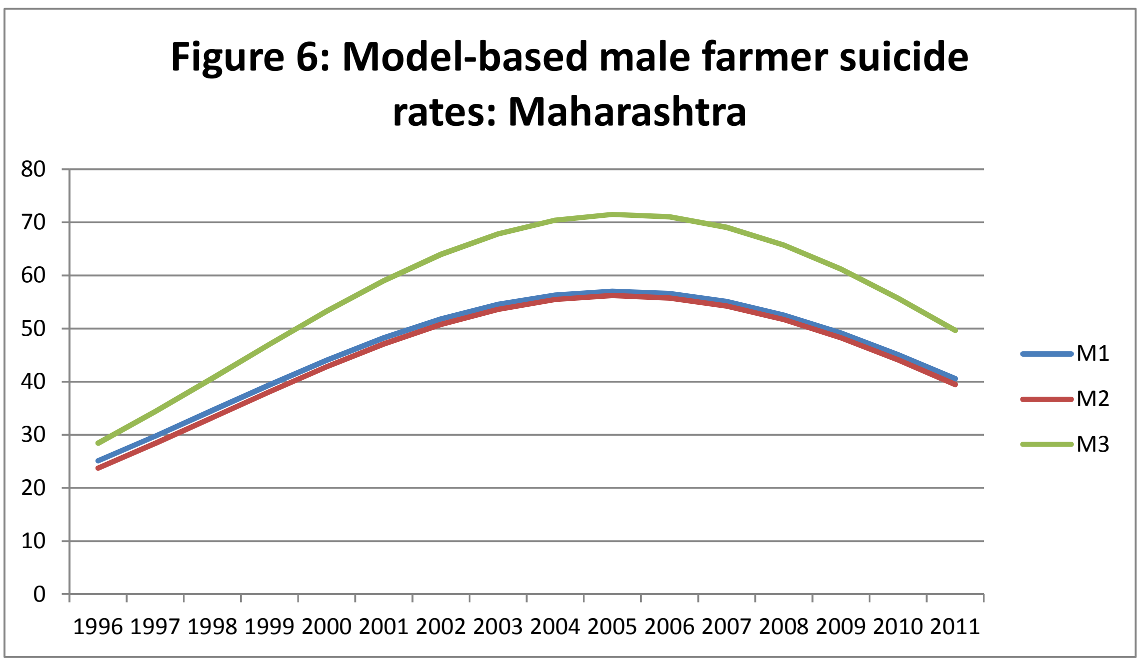
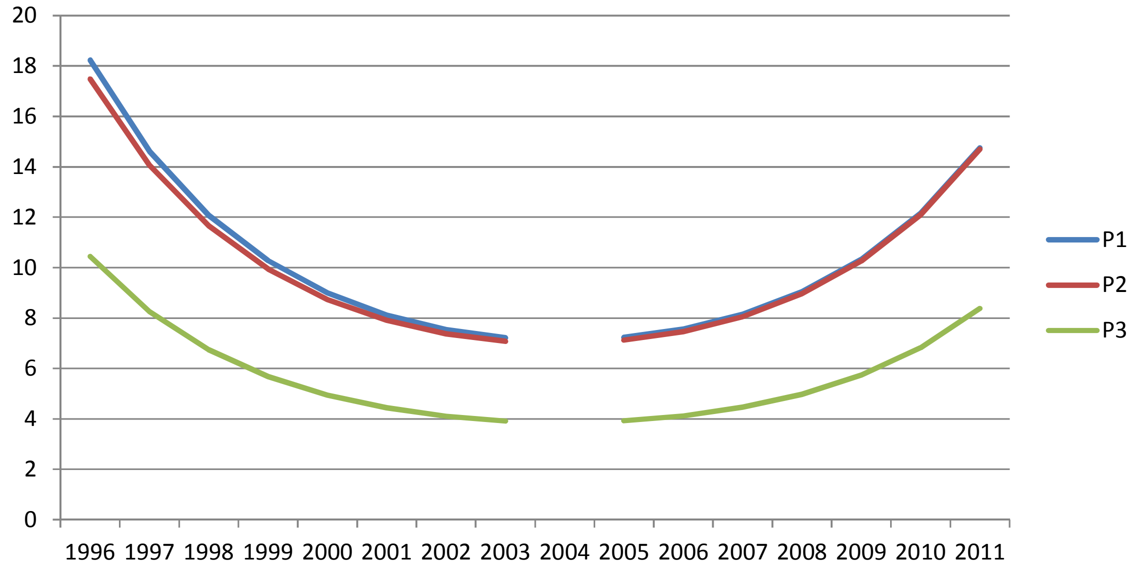


Figure 6: Model-based male farmer suicide rates: Maharashtra
80
70
60
50
40
30
20
10
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
M1
M2
M3

Figure 7: Model-based male farmer suicide rates: Punjab



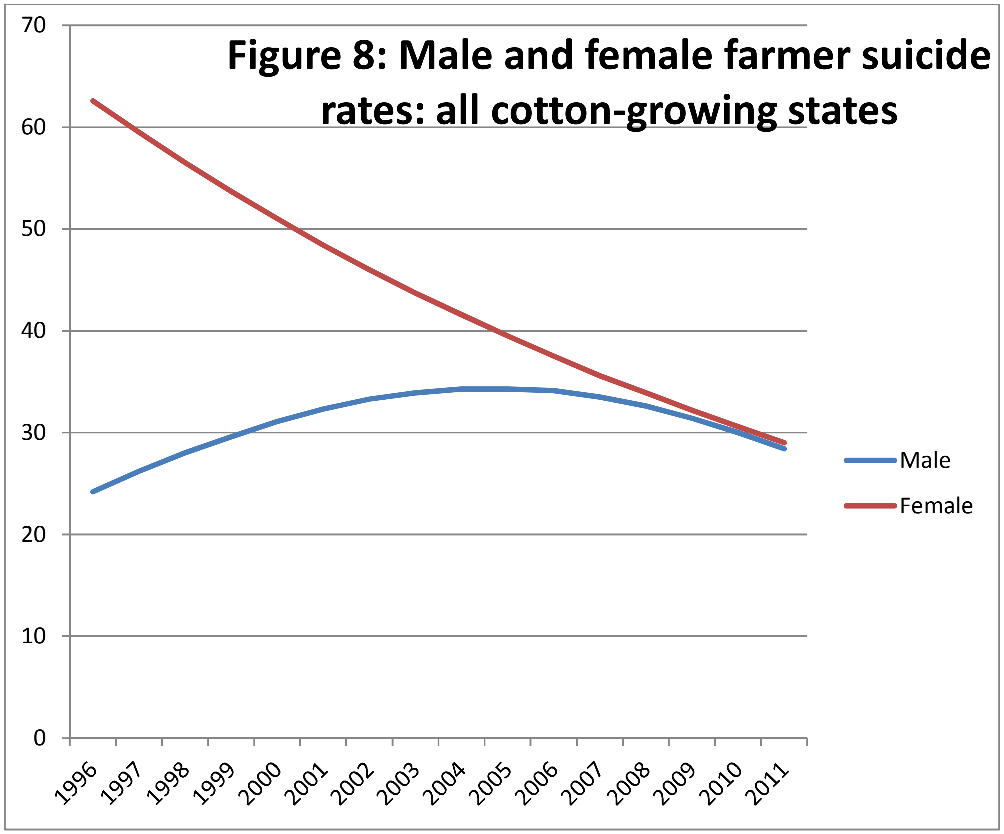


Figure 8: Male and female farmer suicide rates: all cotton-growing states
70
60
50
40
30
20
10
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Male
Female

Data notes

1. The boundary of Madhya Pradesh changed in 2000 when the state of Chhattisgarh was created. The population of Madhya Pradesh was 2.85 times the population of Chhattisgarh in the 2001 Census of Population. The overall suicide rate in Chhattisgarh was 1.75 times the suicide rate in Madhya Pradesh for the period 2001 to 2004. Hence, the numbers of suicides for Madhya Pradesh before 2000, as defined by its new boundaries, are assumed to be 61% of the reported total for Madhya Pradesh before 2000 in order to create a consistent series.

2. The correction factors based on weighted estimates for 2001 to 2003 (the years in which the data were collected) are 1.03 and 1.13 (in red on the spreadsheet) compared with 1.35 and 1.47 for the projected data for 2010 (in yellow on the spreadsheet). However, the uniform sample weights that are based on 1991 Census data may not be applicable to 2001 to 2003. File IS_corrfactor.xlsx gives more details, including state level correction factors.

3. In the Agricultural Census of 2005/6, the ratios of individual to joint holdings for males and females were:

AP: 1173 (M); 2645 (F)
G: 1.69 (M); 0.78 (F)
H: 0.54 (M); 0.36 (F)
K: 138 (M); 163 (F)
MP: 17.4 (M); 15.3 (F)
M: 98 (M); 92 (F)
P: 165 (M); No females
R: 2.7 (M); 6.7 (F)
TN: 108 (M); 152 (F).

For 2010/11, the assumed ratios of individual to joint holdings for Gujarat, Haryana and Rajasthan allow for trends from 1995/6 to 2005/6 and are:

G: 1.50 (M); 1.0 (F)
H: 0.50 (M); 0.33 (F)
R: 2.9 (M); 6.5 (F).

For the other six states, the 2005/6 numbers are used.

4. In the provisional results for the 2010/11 Agricultural Census, holdings of < 0.5 hectares and 0.5-1.0 hectares are combined into a marginal category. Hence, estimates of the numbers of holdings < 0.5 hectares to be omitted were based on trends from earlier years. The assumed ratios of <0.5 to 0.5-1.0 hectares for males and females, and for individual and joint holdings where applicable, are as follows:

AP: 1.55 (M); 1.78 (F)
G: 1.0 (IM); 1.0 (IF); 1.25 (JM); 1.0 (JF)
H: 1.6 (IM); 1.54 (IF); 1.6 (JM); 1.6 (JF)
K: 1.4 (M); 1.6 (F)
MP: 1.0 (M); 1.1 (F)
M: 1.06 (M); 1.08 (F)
P: 0.5 (M); 1.0 (F)
R: 1.0 (IM); 1.0 (IF); 1.0 (JM); 1.0 (JF)
TN: 2.64 (M); 2.85 (F).

5. The numbers of individual and joint holdings < 0.5 hectares in 2005/6 were:

AP: 3402 (M); 1168 (F)
G: 673 (M); 117 (F)
H: 414 (M); 60 (F)
K: 1676 (M); 442 (F)
MP: 1479 (M); 147 (F)
M: 2620 (M); 536 (F)
P: 49 (M); 1 (F)
R: 1012 (M); 61 (F)
TN: 3583 (M); 900 (F).

6. Suicide rates are calculated as follows:

Farmers: farm suicides as reported by NCRB, weighted by the correction factors (1.35 for males; 1.47 for females) and divided by estimates of the number of farmers from the Census and Agricultural Census.

Non-farmers: all suicides minus farm suicides minus suicides among children < 15 years weighted by the correction factors (1.35 for males; 1.47 for females) and divided by estimates of the number of non-farmers defined as the total population over age 14 minus the estimated numbers of farmers.

Total: all suicides minus suicides among children < 15 years weighted by the correction factors (1.35 for males; 1.47 for females) and divided by the total population over age 14.

See NONFARMSUI.xlsx for more details.

Using data from the Agricultural Census in 2000/1 for both Madhya Pradesh and Chhattisgarh (see data note 1), the estimated numbers of holdings in Madhya Pradesh for 1995/6 are, as a proportion of the totals reported:

	Individual	Joint
Male	0.69	0.96

Female 0.57 0.97

7. The percentages of farmers growing cotton for each state are based on the numbers of cotton farmers in “Cotton Statistics at a Glance”:
http://www.ncipm.org.in/ReportSystem/PDFs/Cotton%20Statistics%20at%20a%20Glance.pdf

divided by the estimated numbers of male and female farmers from the Agricultural Census. The estimates are as follows:

AP: 10%
G: 26%
H: 15%
K: 5%
MP: 7%
M: 20%
P: 26%
R: 6%
TN: 7%

8. The logit transformation is a non-linear transformation that stretches the probability scale (from 0 to 1) to ± infinity. A probit transformation would have the same effect. The estimates from the logit model are unlikely to be substantially affected by the correction factor applied to the suicide rates because these rates are small in absolute terms.

Table A1: Numbers and % of suicides by state and gender: 2011.

State	Male		Female		Male:Female	
	Farmers	Total	Farmers	Total	Farmers	Total
AP	1822 (18)	10120 (100)	384 (8)	4957 (100)	4.7	2.0
G	473 (12)	3912 (100)	105 (4)	2470 (100)	4.5	1.6
H	350 (14)	2464 (100)	34 (4)	781 (100)	10.3	3.2
K	1694 (20)	8472 (100)	406 (10)	4150 (100)	4.2	2.0
MP	1132 (22)	5240 (100)	194 (5)	4019 (100)	5.8	1.3
M	3093 (28)	10887 (100)	244 (5)	5060 (100)	12.7	2.2
P	94 (12)	755 (100)	4 (2)	211 (100)	23.5	3.6
R	224 (7)	3016 (100)	44 (3)	1332 (100)	5.1	2.3
TN	482 (5)	10282 (100)	141 (2)	5681 (100)	3.4	1.8
TOTAL	9364 (17)	55148 (100)	1556 (5)	28661 (100)	6.0	1.9
ALL INDIA	12071 (14)	87839 (100)	1956 (4)	47746 (100)	6.2	1.8

Notes
1. AP: Andhra Pradesh; G: Gujarat; H: Haryana; K: Karnataka; MP: Madhya Pradesh; M: Maharashtra; P: Punjab; R: Rajasthan; TN: Tamil Nadu.
2. Source: National Crime Records Bureau – http://ncrb.nic.in/CD-DSI2011/ADSIHome2011.htm

Table A2: Thousands (%) of main and marginal cultivators by cotton-growing state and gender: 2011.

State	Male		Female		Total	Male:female
	Main	Marginal	Main	Marginal		Main + marg.
AP	4183 (64)	174 (2.7)	1904 (29)	230 (3.5)	6491 (100)	2.0
G	4075 (75)	169 (3.1)	672 (12)	531 (9.7)	5447 (100)	3.5
H	1633 (66)	156 (6.3)	331 (13)	361 (15)	2481 (100)	2.6
K	4569 (69)	185 (2.8)	1470 (22)	357 (5.4)	6581 (100)	2.6
MP	6039 (61)	552 (5.6)	2176 (22)	1077 (11)	9844 (100)	2.0
M	7181 (57)	411 (3.3)	4297 (34)	680 (5.4)	12569 (100)	1.5
P	1692 (87)	62 (3.2)	112 (5.8)	69 (3.6)	1935 (100)	9.7
R	6366 (47)	1153 (8.5)	3480 (26)	2621 (19)	13620 (100)	1.2
TN	2512 (59)	220 (5.2)	1343 (32)	173 (4.1)	4248 (100)	1.8
TOTAL	38250 (61)	3082 (4.9)	15785 (25)	6099 (9.6)	63216 (100)	1.9

Notes
1. Main: worked in main job for at least six months in previous year. Marginal: worked but for less than six months in previous year.
2. Source: 2011 Census of Population, Primary Census Abstracts

Table A3: Thousands of farmers by cotton-growing state and gender estimated from 2010/11 Agricultural Census

State	Male					Female					Male:Female
	(2)	**(2.5)**	**(3)**	**(3.5)**	**(4)**	**(2)**	**(2.5)**	**(3)**	**(3.5)**	**(4)**	**(2)**
AP	6271	6273	6275	6277	6279	1870	1870	1870	1870	1870	3.4
G	4512	5122	5734	6341	6951	830	977	1123	1269	1415	5.4
H	1639	1973	2308	2642	2976	234	284	335	386	436	7.0
K	4488	4516	4543	4571	4598	975	979	982	986	989	4.6
MP	6717	6873	7029	7185	7342	673	692	712	731	751	10.0
M	9021	9062	9103	9143	9184	1532	1538	1545	1552	1559	5.9
P	992	993	994	995	996	9	9	9	9	9	110
R	6488	7137	7786	8435	9084	484	512	541	569	598	13.4
TN	2972	2984	2997	3009	3022	627	629	631	633	635	4.7
TOTAL	43100	44933	46769	48598	50432	7234	7490	7748	8005	8262	6.0

Notes

1. Numbers in bold (row 2) refer to the assumed numbers of farmers per joint holding.
2. The data for Punjab are based on a 20% sample; there is no sampling for the other eight states.

Table A4: Ratios of farmers from Census of Population and estimates from the 2010/11 Agricultural Census by cotton-growing state

State	Male	Female
AP	0.69	1.14
G	0.94	1.45
H	1.09	2.96
K	1.06	1.87
MP	0.98	4.83
M	0.84	3.25
P	1.77	20.1
R	1.16	12.6
TN	0.92	2.42
TOTAL	0.96	3.03

Notes

1. Assuming two farmers per joint holding in the Agricultural Census.

Table A5: Mean (SD) yields by cotton-growing state and data source, 1999-2010

State	DES		CAB		CCS	
	Mean (SD)	Rank	Mean (SD)	Rank	Mean (SD)	Rank
AP	357 (67)	4	533 (104)	3	1668 (429)	2
G	426 (196)	3	553 (201)	2	1398 (591)	4
H	502 (150)	2	404 (126)	6	1405 (493)	3
K	250 (75)	7	283 (79)	8	733 (268)	9
MP	214 (115)	9	520 (58)	4	974 (497)	8
M	221 (87)	8	250 (86)	9	1010 (249)	7
P	581 (155)	1	462 (147)	5	1703 (554)	1
R	325 (98)	6	396 (77)	7	1382 (442)	6
TN	335 (109)	5	670 (168)	1	1392 (376)	5

Notes

1. DES: crop-cutting experiments. CAB: arrivals at mills. CCS: cost of cultivation surveys.

Table A6: *Bt* adoption (%) by cotton-growing state and year

State	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
AP	1.0	1.2	6.4	27	85	96	94	71	92	97	57
G	0.6	2.2	6.4	7.9	22	37	58	64	68	65	33
H	-	-	-	3.8	15	51	66	88	85	75	54
K	0.8	1.3	3.5	7.3	22	36	59	60	68	103	36
MP	0.4	2.2	14	24	49	79	99	102	94	91	55
M	0.9	1.1	7.0	21	59	88	100	97	94	96	56
P	-	-	-	4.1	14	43	61	92	83	91	56
R	-	-	-	3.4	17	50	75	76	94	77	56
TN	2.4	6.8	3.8	19	45	71	83	105	90	165	52

Notes

1. Separate data for Haryana, Punjab and Rajasthan are not available so percentages are based on allocations proportional to mean area for 2005-2011.
2. The means are based on 10 years for states in the central and southern regions, 7 years for those in the northern region. Percentages greater than 100 are recoded to 100.

Table A7: Suicide rates by Census year, cotton-growing states combined.

	2001						**2011**					
	MALE			**FEMALE**			**MALE**			**FEMALE**		
	FARM	**NON-FARM**	**TOT.**	**FARM**	**NON-FARM**	**TOT.**	**FARM**	**NON-FARM**	**TOT.**	**FARM**	**NON-FARM**	**TOT.**
ALL	27.0 – 31.7	31.0 – 32.8	31.2	42.0 – 47.1	21.1 – 21.1	21.9	25.1 – 30.6	35.1 – 37.0	34.2	27.7 – 31.6	19.5 – 19.6	19.9

Notes

1. Rates are per 100,000 of the defined population.

Notes for Tables A8 to A18:

1. Chosen models, based on BIC, are shown in bold. Model estimates are for the chosen models.

2. Farmers (i) based on the Agricultural Census; farmers (ii) based on the Census of Population.

Table A8: Model estimates for suicide trend analyses: Andhra Pradesh.

		Farmers (i) (a)	**Farmers (i) (b)**	**Farmers (ii)**
BIC	**Linear**	-8.13	-8.1	**-8.88**
	Lin. + quad.	-6.73	-6.71	-6.9
	Log	**-8.18**	**-8.12**	-6.08
	Constant	-7.75	-7.76	-0.92
Auto-correlation		-0.17	-0.16	-0.13
Estimates (*Prais*)		0.18 (0.055)	0.18 (0.055)	0.050 (0.0077)
Estimates (*glogit*)		0.18 (0.055)	0.18 (0.055)	0.049 (0.0089)

Table A9: Model estimates for suicide trend analyses: Gujarat.

		Farmers (i) (a)	**Farmers (i) (b)**	**Farmers (ii)**
BIC	**Linear**	**-28.4**	**-28.8**	**-24.8**
	Lin. + quad.	-25.9	-26.8	-24.6
	Log	-25.8	-26.0	-21.8
	Constant	-20.7	-17.6	-22.9
Auto-correlation		-0.65	-0.66	-0.50
Estimates (*Prais*)		-0.012 (0.0027)	-0.016 (0.0026)	-0.0084 (0.0037)
Estimates (*glogit*)		-0.013 (0.0059)	-0.016 (0.0059)	-0.0085 (0.0060)

Notes

1. Data for 2007 omitted from the models as an outlier.

Table A10: Model estimates for suicide trend analyses: Haryana.

		Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
BIC	**Linear**	3.56	3.49	**2.99**
	Lin. + quad.	6.25	6.17	5.35
	Log	**2.78**	**2.77**	3.22
	Constant	3.46	4.03	4.66
Auto-correlation		0.48	0.48	0.47
Estimates (*Prais*)		0.38 (0.083)	0.36 (0.083)	0.060 (0.019)
Estimates (*glogit*)		0.33 (0.11)	0.32 (0.11)	0.052 (0.016)

Notes

1. Data for 1997 omitted from the models as an outlier.

Table A11: Model estimates for suicide trend analyses: Karnataka.

		Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
BIC	**Linear**	-11.5	-11.7	-11.0
	Lin. + quad.	-9.34	-9.68	-9.3
	Log	-11.7	-12.0	-11.6
	Constant	**-14.3**	**-14.5**	**-13.6**
Auto-correlation		0.34	0.32	0.36

Notes

1. Model estimates omitted as no evidence of a trend.

Table A12: Model estimates for suicide trend analyses: Madhya Pradesh.

		Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
BIC	**Linear**	-21.4	-20.5	-21.7
	Lin. + quad.	**-24.3**	**-23.7**	-23.2
	Log	-20.1	-19.9	**-24.6**
	Constant	-22.9	-22.6	-23.0
Auto-correlation		-0.15	-0.14	0.014
Estimates (*Prais*)		-0.0011 (0.0059) -0.0029 (0.0012)	0.0014 (0.0062) -0.0031 (0.0013)	0.070 (0.038)
Estimates (*glogit*)		-0.00097 (0.0068) -0.0028 (0.0013)	0.0016 (0.0069) -0.0031 (0.0013)	0.065 (0.034)

Table A13: Model estimates for suicide trend analyses: Maharashtra.

		Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
BIC	**Linear**	-19.1	-18.5	-18.0
	Lin. + quad.	**-27.0**	**-27.1**	**-26.0**
	Log	-21.2	-20.9	-19.8
	Constant	-18.6	-17.6	-17.9
Auto-correlation		0.09	0.08	0.17
Estimates (*Prais*)		0.060 (0.0062) -0.0092 (0.0012)	0.063 (0.0058) -0.0097 (0.0012)	0.066 (0.0080) -0.0099 (0.0017)
Estimates (*glogit*)		0.062 (0.0073) -0.0099 (0.0013)	0.065 (0.0073) -0.01 (0.0013)	0.070 (0.0075) -0.011 (0.0013)

Table A14: Model estimates for suicide trend analyses: Punjab.

	Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
Estimates (*glogit*)	-0.058 (0.016) 0.015 (0.0036)	-0.056 (0.017) 0.015 (0.0036)	-0.062 (0.017) 0.016 (0.0036)

Notes

1. Convergence difficult to achieve for the Prais models so estimates based on the grouped logit model with data for 2004 omitted as an outlier.

Table A15: Model estimates for suicide trend analyses: Rajasthan.

		Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
BIC	**Linear**	10.4	10.4	10.1
	Lin. + quad.	9.87	9.83	9.75
	Log	11.7	11.5	11.4
	Constant	**9.15**	**8.9**	**8.85**
Auto-correlation		0.52	0.50	0.50

Notes

1. Model estimates omitted as no evidence of a trend.

Table A16: Model estimates for suicide trend analyses: Tamil Nadu.

		Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
BIC	**Linear**	18.1	18.0	18.1
	Lin. + quad.	18.8	18.7	18.6
	Log	19.0	18.8	18.3
	Constant	**16.3**	**16.2**	**15.6**
Auto-correlation		0.37	0.36	0.29

Notes

1. Model estimates omitted as no evidence of a trend.

Table A17: Model estimates for suicide trend analyses: all cotton-growing states (males).

		Farmers (i) (a)	Farmers (i) (b)	Farmers (ii)
BIC	**Linear**	-36.2	-36.0	-34.9
	Lin. + quad.	**-46.3**	**-46.3**	**-46.7**
	Log	-41.5	-41.5	-40.4
	Constant	-36.8	-36.5	-35.3
Auto-correlation		0.15	0.15	0.12
Estimates (*Prais*)		0.025 (0.0036) -0.0047 (0.00063)	0.026 (0.0036) -0.0047 (0.00063)	0.029 (0.0035) -0.0052 (0.00062)
Estimates (*glogit*)		0.025 (0.0037) -0.0047 (0.00069)	0.026 (0.0037) -0.0048 (0.00069)	0.033 (0.0036) -0.0049 (0.00067)

Table A18: Model estimates for suicide trend analyses: all cotton-growing states (females).

		Farmers (i) (a)	Farmers (i) (b)
BIC	**Linear**	**-23.5**	**-22.8**
	Lin. + quad.	-20.8	-20.0
	Log	-16.1	-15.6
	Constant	-15.8	-15.9
Auto-correlation		0.22	0.27
Estimates (*Prais*)		-0.051 (0.0061)	-0.052 (0.0064)
Estimates (*glogit*)		-0.051 (0.0053)	-0.053 (0.0060)

Table A19: Model estimates for yield trend analyses.

STATE	β_3			β_4		
	DES	**CAB**	**CCS**	**DES**	**CAB**	**CCS**
AP	-30.6 (10.0)	-3.59 (10.8)	-1.30 (29.0)	24.7 (7.3)	30.7 (11.3)	-1.36 (50.6)
G	-113 (41.4)	-12.7 (18.8)	-137 (76.6)	73.0 (16.3)	72.9 (22.2)	184 (31.8)
H	38.7 (16.2)	-2.50 (21.6)	67.4 (50.3)	67.5 (12.9)	69.2 (13.6)	212 (40.5)
K	-1.36 (11.2)	-5.48 (3.57)	-25.8 (19.7)	41.9 (4.36)	42.1 (6.49)	121 (18.2)
MP	-162 (70.4)	-23.4 (11.0)	-60.5 (22.6)	43.7 (14.5)	-17.9 (4.70)	167 (22.4)
M	-4.93 (6.17)	1.73 (4.94)	-0.63 (35.2)	32.4 (6.56)	30.0 (4.41)	74.9 (27.6)
P	70.6 (11.8)	27.5 (14.6)	139 (59.5)	-21.9 (6.0)	-44.8 (16.7)	22.7 (46.3)
R	3.26 (9.93)	8.96 (8.67)	-7.38 (32.1)	36.9 (10.0)	51.6 (13.9)	135 (78.8)
TN	-34.0 (8.83)	28.9 (9.99)	21.9 (36.8)	49.2 (25.2)	74.1 (14.4)	177 (57.1)
ALL	4.33 (16.0)	6.40 (7.88)	33.2 (23.0)	40.6 (5.68)	31.8 (7.35)	123 (22.3)