Who Cares What Others Think (or Do)? Social Learning, Social Pressures and Imitation in Three Villages in India

Annemie Maertens*

20 September 2009 - Preliminary and Incomplete - Not for Citation

Abstract

In this paper, I look at the role of social networks in the adoption process of Bt cotton, a new type of (genetically engineered) cotton available on the Indian market since 2002. Unlike existing studies, the data that I collected allows me to parse out the various channels through which social interaction effects operate: social learning, imitation and social pressures. The results demonstrate the importance of knowledge about the profitability of a new technology in the adoption decision. This knowledge is established through experimentation, observing other farmers' past profits and talking to input dealers, company representatives and government extension agents. For first-time adopters, the last channel, i.e., talking to non-farmer sources is the most important channel to learn about the profitability of Bt cotton and the main driver of Bt cotton adoption, followed by learning from fellow farmers. I find strong evidence of social pressures inhibiting the adoption of Bt cotton and of farmers imitating the most successful farmers in the village, i.e., adopting Bt cotton without having observed the yield outcomes or profitability of these usually-successful farmers.

*The data for this working paper were gathered in India during August 2007 – November 2008, in collaboration with the International Crop Research Institute of the Semi-Arid Tropics (ICRISAT) in Patancheru, Andhra Pradesh, India. This research was funded through a combination of grants: a National Science Foundation Doctoral Dissertation Research Improvement Grant (Grant No. 0649330), an American Agricultural Economics Association McCorkle Fellowship, a Mario Einaudi Center for International Studies International Research Travel Grant, a Cornell University Graduate School Research Travel Grant and an International Student and Scholar Office Grant. I am grateful towards the American Institute of Indian Studies for administrative support, the Indian Statistical Institute in New Delhi for their hospitality and the Department of Applied Economics and Management and Chris Barrett for financial support. I thank the numerous research assistants and enumerators on the field: Sanjit Anilesh, Shraavya Bhagavatula, Pramod Bangar, Chayanee Chawanote, Sana Butool, V.D. Duche, Shital Duche, Madhav Dhere, Anand Dhumale, Meenal Inamdar, Shilpa Indrakanti, Navika Harshe, Sapna Kale, Jessica Lebo, Labhesh Lithikar, Nishita Medha, Ramesh Babu Para, Abhijit Patnaik, Gore Parmeshwar, Amidala Sidappa, Nandavaram Ramakrishna, K. Ramanareddy, P.D. Ranganath, Arjun Waghmode and Yu Qin. I have benefited considerably from discussions with Cynthia Bantilan, Reena Badiani, Chris Barrett, Kaushik Basu, Marc Bellemare, Larry Blume, Yann Bramoullé, Sommarat Chantarat, A.V. Chari, V.K. Chopde, Stephen Coate, Timothy Conley, Stefan Dercon, Xavier Giné, Ronald Herring, George Jakubson, Fernanda Leite Lopez DeLeon, Jack Meyer, Felix Naschold, K.P.C. Rao, Mohan Rao, Nageswara Rao, Paulo Santos, Russell Toth, Kumar Acharya Ulu, Alex Yuskavage and the comments of all seminar participants at ICRISAT (2008), Cornell University (2007-2009), ISI-New Delhi (2008), MIEDC (2009) and the AAEA Meetings (2009) and one anonymous referee. Finally, I would like to thank the following individuals for generously providing additional information and data regarding the Bt cotton technology in India: Raju Barwale, Ronnie Coffman, Neil Forrester, Milind Mugurkar, Matin Qaim, K.V. Raman, Joseph A. Shapiro, Mahendra Sharma and Frank Shotkosky. Any remaining errors and omissions are my own.

1 Introduction

When new agricultural technologies are introduced, adoption often does not occur immediately. Farmers instead follow a complex pattern of gradual adoption, non-adoption and sometimes disadoption, often resulting in an S-shaped adoption curve when plotting the number of adopters against time (Besley and Case 1993, Feder et al. 1985, Sunding and Zilberman 2001). While prices, income and individuals' attributes, such as risk aversion, are known determinants of adoption behavior, recent contributions in sociology and economics have pointed towards the importance of so-called social interaction effects, a general term encompassing both the pecuniary and non-pecuniary effects of individuals on each other. In this study, I focus on three social interaction effects: social learning, social pressures and imitation and study their role in agricultural technology adoption decisions.

Farmers learn about input and output prices, appropriate use of inputs and expected yields given these inputs from their own experimentation, the media, company agents, input dealers and the experimentation of others, the last being referred to as social learning (Baird 2003, Bandiera and Rasul 2006, Conley and Udry Forthcoming, Foster and Rosenzweig 1995, Moser and Barrett 2006, Munshi 2004). In addition, a farmer's choice could be directly influenced by the choices of fellow farmers through social pressures, i.e., deviation from standard agricultural practices may entail a non-monetary cost, for instance, social exclusion (Appadurai 1989, Moser and Barrett 2006, Rogers 1965, Vasavi 1994). Finally, a farmer's choice might directly depend on the behavior of other farmers, typically more the more successful farmers in the village through imitation (Bandiera and Rasul 2006, Pomp and Burger 1995, Rogers 1965). I distinguish behavioral imitation, motivated by a keeping-up-with-the-Jones' attitude, from imitation motivated through a learning story, which I will refer to as learning-imitation. In the latter case, a farmer, despite not observing the outcome of the other farmer's experimentation, makes inferences about the profitability of the technique if he observes another farmer using it.[1] In the former case, the farmer draws no such conclusions.

With the exception of Moser and Barrett (2006)[2] and Bandiera and Rasul (2006)[3]none of these studies consider multiple social interaction effects and attempts to parse out the various channels through which social interaction effects operate. However, differentiation along pathways is crucial from a policy perspective. The right strategy to stimulate increased and quicker uptake of promising technologies depends fundamentally on the structure of the technology adoption processes at the farm level. Different constraints and incentives imply different policy measures. If a lack of information is the constraining factor, agricultural extension services might be a first best response. But which farmers does one then target: the well-educated, richer farmers, or the less-educated, poorer farmers? If social pressures

[1] Note that a farmer may also draw inferences about the profitability as he receives information originating from outside of the village (i.e., from an input dealer) through another farmer. In practice, I will not be able to distinguish between this phenomenon and imitation.

[2] They look at the effects of social learning and social norms on the adoption of a new technique for rice cultivation in Madagascar. Their identification strategy runs as follows. Assume that a farmer's probability of initial adoption of a new technology is a concave function of the cumulative experience of village farmers. Then, the effect of the cumulative experience of village farmers up to $t-1$ should be larger than the effect of experience of village farmers at time t. They find this not to be the case and attribute this difference to social pressures.

[3] While their main interest is to look at the effects of social learning on the decision to adopt sunflower cultivation in Mozambique, they extend their basic analysis to incorporate imitation effects by including the behavior of a key individual in the village that could act as the focal point as a regressor. They find no evidence of imitation.

appear to impair the adoption of new technologies, giving information to a few selected farmers is unlikely to be a successful strategy.

Identifying social interaction effects is not without difficulties. Manski (1993), in a seminal paper, shows that in a regression model of behavior in large groups in which individual behavior is permitted to vary linearly with mean behavior in the group (expressing what he terms endogenous social interaction effects), with the mean values of exogenous attributes of group members (expressing what he terms contextual interactions effects), and with personal characteristics that may be similar across group members (expressing what he terms correlated effects), one is - under certain additional assumptions - unable to identify endogenous social interaction effects. Prospects of identification however improve if one relaxes one or more underlying assumptions of Manski's model. One could consider non-linear interaction effects instead of linear effects (Bandiera and Rasul 2006), impose time sequencing on the endogenous effects instead of considering contemporaneous endogenous effects (Conley and Udry Forthcoming, Moser and Barrett 2006), assume correlated and contextual effects are absent or move away from the assumption of global interaction (each individual interacts with the group as a whole) and consider network-based interactions.(Bandiara and Rasul 2006, Bramoullé et al. 2009, Conley and Udry Forthcoming). Note that while the latter solution might also represent a more realistic approach to human interaction, in practice, finding measures of the social relations of each individual in the sample is not an easy task due to the sheer multitude and multi-dimensionality of these relationships. The three most popular techniques of measuring social networks - respondent-driven snow-ball sampling, taking the "network of a sample", and using peer-reporting - all generate additional identification problems (as explained in Section 3). In addition, the presence of various endogenous social interaction effects, social learning, social pressures and imitation poses additional challenges beyond Manski's standard identification problem.[4]

The data I collected allows me to make use of a combination of the existing strategies and try to improve on them. I conducted a detailed survey of farmers in rural India during the period August 2007-November 2008 to learn about the adoption process of *Bacillus thuringiensis* (Bt) cotton, a new type of cotton that requires fewer pesticides and can increase expected yield, available on the Indian market since 2002 (Qaim 2003). I covered 267 farmers in three villages in India. Using a combination of experiments and questionnaires I elicited information on household composition, landholding, agricultural inputs and outputs, cotton adoption, production and marketing, perceived bio-safety hazards of Bt cotton in 2008, beliefs regarding the profitability of Bt cotton in 2008 and social networks. To construct the panel dataset that is used for this paper, encompassing 7 cropping years from 2001-02 to 2007-08, I add the data I collected to six rounds (2001-07) of the existing ICRISAT-VLS data (as explained in Section 3).

Using these data, I identify and distinguish between the influences of social learning, imitation and social pressures. To distinguish between social pressures from imitation I identified a set of "progressive farmers" in each village. These are farmers who are the earliest adopters of new technologies and whose adoption decisions by their own account is not influenced by social pressures or imitation. Equally important, these progressive farmers are more profitable, better educated and wealthier than the average village farmer

[4] Intuitively, parsing out the various channels through which these social interaction effects operate is not straightforward as they all will lead to the same reduced form effect in the data: correlated behavior. For instance, two farmers might be adopting a crop because they both learned from the same source about its profitability, or because one imitates the other, or because both feel that the pressures in their community which work against these new technologies have decreased.

and as such likely to be the object of imitation (see Section 4 and Appendix B).

As a preliminary step, I use the data collected on current beliefs regarding the profitability of Bt cotton versus non Bt cotton and the planned cropping pattern for the 2008-09 season. Any discrepancy between beliefs and planned cropping patterns, controlling for credit constraints and risk preferences, indicates the influence of non-monetary factors in the decision-process - these are either due to (behavioral) imitation effects or social pressures. Using the information on perceived bio-safety hazards, I investigate the hypothesis that these social pressures find its origin in bio-safety concerns with regard to Bt cotton: a farmer may be accused of endangering the health of the animals and people in the village as well as generating negative impacts on the soil fertility and water quality of neighboring plots.

To distinguish these effects further and examine the role of social learning in the formation of these beliefs, I use the panel dimension of the data. I hypothesize that farmers learn from experimentation, observing other farmers' past profits and talking to input dealers, company representatives and government extension agents. In addition, farmers might draw inferences from observing the progressive farmers' current behavior (without observing the yield outcome) and strategically delay their decision to adopt if they expect other farmers to adopt the new technology.

I construct controls for the usual unobservables that drive correlation between contacts through similar constraints, such as soil and climatic conditions, prices and the common sources of information of different farmers within each networks, and through the process of endogenous group formation where individuals associate with individuals similar to themselves, such as ability (proxied by education) and risk aversion. Given these controls, I can now focus on the endogenous social interaction effects: social learning, social pressures and imitation. Assuming that these interactions take place within the village boundaries, I construct measures of each individual's social network based on the relationship information I extracted from the results of an experimental game where I matched each individual - randomly - with a set of 10 other individuals in the sample. Using these measures, I then construct three variables capturing social learning, social pressures and imitation.

Social learning implies learning about the (initially unknown) production function of the Bt technology by observing the input choice and output of other farmers. To assess the importance of social learning for the adoption decision, I construct, for each farmer at each point in time, an aggregate measure of the information available to him on (historical) inputs and outputs of other farmers (whom he has observed).[5] Social pressures work through the contemporaneous behavior of fellow, i.e., non-progressive, farmers as, even though deviating from standard accepted practise might have a lingering effect in the next period, it's the contemporaneous behavior of these contacts that reflect how acceptable cultivating Bt cotton is in the farmer's network. Imitation effects are also of a contemporaneous nature, but imply a one-way interaction effect of the behavior of the progressive farmers in each farmer's network on the behavior of the farmer. To assess the importance of social pressure and imitation, I construct, for each farmer at each point in time, an aggregate measure of, respectively, the total number of fellow farmers and progressive farmers who cultivate Bt

[5] Concretely, I use the sum of the number of farmers each farmer knows each time period up to the previous period, who cultivated Bt cotton (at that time) and of whom the farmer (thinks he) knows the type of cotton used, the amount of pesticides used and the yield. I split these measures into two components, one component caputuring learning from fellow farmers and one component capturing learning from progressive farmers.

cotton (of whom he has observed the cultivar[6] choice) as a percentage of the total number of fellow farmers and progressive farmers who cultivate cotton (of whom he has observed the cultivar choice).[7]

The results demonstrate the importance of knowledge about the profitability of a new technology in the adoption decision. This knowledge is established through observing other farmers' profits and talking to input dealers, company representatives and government extension agents. For first-time adopters, the last channel, i.e., talking to non-farmer sources is the most important channel to learn about the profitability of Bt cotton and driver to switch to switch to Bt cotton, followed by learning from fellow farmers. I find strong evidence of social pressures inhibiting the adoption of Bt cotton and of farmers imitating the progressive farmers in the village, i.e., adopting Bt cotton without having observed the yield outcomes of these progressive farmers. In all specifications, the learning effect is concave, suggesting decreasing returns to new information coming in. I find weak evidence of the free rider hypothesis: i.e., farmers sometimes delay adoption and free ride on other farmers' experimentation.

The remainder of this article is structured as follows. The next section provides some background information on the Bt cotton technology, with a focus on India. Section 3 introduces the data. To set the stage for the analysis, Section 4 provides an informal description of the adoption process in the three villages, based on conversations with respondents. Section 5 outlines a simple theoretical model and the empirical identification strategy. Section 6 presents the results and Section 7 concludes.

2 Background

India produces almost twice as much cotton as the USA. In terms of yield however, India is at the tail-end of the global distribution. The average cotton yield in India is only one third of China's average yield. The main cotton producing states in India are Gujarat, Maharashtra, Punjab and Andhra Pradesh, producing over 80 percent of the total cotton production. In these regions, cotton is one of the main cash crops of farmers and supports a significant section of the population through the processing industries and trade.

[6] A cultivar is particular variety of plant species or hybrid that is being cultivated and/or is recognized as a cultivar under the International Code of Nomenclature of Cultivated Plants.

[7] Note that this measure of social pressures might suffer from endogeneity problems. Ideally, one would solve for the structural parameters of this problem, but the overlapping networks which I consider make it impossible to find an analytical solution for this fixed-point problem. Recognizing this problem, I use, substitute this current behavior of fellow farmers with either the expected behavior of others or the behavior of others in the previous period. Note that the latter does not conflict with the social learning measure, as the set from whom the farmer learns is a subset of the set of farmers whom could pressurize the farmer. Note also that even though I assume that Manski's contextual effects play no role in the decision making process, using the current properties of other farmers is unlikely to substitute as the variable which matter to the decision making process, land, irrigation and education level, vary little over time. Finally, note that while multiple equilibria are a possibility in binary choice models involving contemporaneous effects which impose correct expectations, I ignored this possibility in this paper. With regard to the imitation effects, note that the proposed measure implicitly ignores the effect of the past cultivar choices of the progressive farmers in each farmer's network of whom the farmer knows only the cultivar, but not the other input used and yields. This implies that this measure of imitation would capture the average effect of the current behavior of progressive farmers, across the various cultivation histories of these progressive farmers.

Table 1: Basic cotton statistics of China, US and India

	Cotton production[1]					Cotton exports[1]	Average cotton yields[2]
	1985	1990	1995	2000	2008	2008	2008
China	4,137	4,507	4,768	4,420	7,947	16	1,325
USA	2,924	3,376	3,897	3,742	2,985	2,830	951
India	1,964	1,989	2,885	2,380	5,443	1,328	579

Source: United States Department of Agriculture, PSD Online. Updated 10/10/2008.
Notes: [1]in thousand metric tons; [2]in kg/ha (ginned) cotton

Losses in cotton production in India are mainly due to its predominant cultivation under rainfed conditions and its susceptibility to 166 species of insects, pests and diseases. Today, nearby 50% of pesticides used in India are used on cotton (ISAAA 2005). The major pests affecting cotton are jassids, aphids, white fly and bollworms.[8]

As a response to bollworm pest problems, Monsanto, an agricultural company with headquarters in the US, developed the Bt GM (Genetically Modified) technology during the 1980s. In collaboration with the Maharashtra Hybrid Seed Company (Mahyco), the technology was then introduced into several of Mahyco's hybrid[9] breeding lines during the 1990s. In 2002, the Genetic Engineering Approval Committee (GEAC), an Indian government body, approved the commercial release of three Bt cotton cultivars of Mahyco. As of August 2008, 225 cotton cultivars with one of the Bt constructs had been approved by GEAC. These Bt cultivars contain a gene (*cry gene*) sourced from the soil bacterium *Bacillus thuringiensis* in their DNA sequence.[10] This gene produces a protein that is toxic to the bollworms.[11] The Bt gene does not effectively control against all bollworms and provides no protection against other pests and diseases. Also, when a Bt gene is inserted in the DNA of a plant it only affects its pest resistance. It does not affect its duration, drought resistance, or fiber length, etc. These properties are determined by the genetic properties, i.e., the germplasm, of the cultivar in which the gene was inserted. The effect on pesticide use, yield and hence profits from switching from any non-Bt to any Bt cultivar can therefore be decomposed into two effects: the Bt effect and the germplasm effect.

Data from trials on Bt cotton and its isogenic non-Bt counterpart in India show that in high bollworm pressure years, independent of soil and climatic conditions, profits from Bt cotton are higher than profits from non-Bt cotton.[12] If the bollworm pressure is low (and hence few pesticides are needed) and the price of the Bt seed is high this result might not hold. Pemsla et al. (2004), using farm data from non-isogenic Bt and non-Bt cultivars in

[8]The cotton bollworm complex encompasses the American bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*), spiny bollworm (*Earias insulana*) and spotted bollworm (*Earias vittella*) (ISAAA 2005, Asia-Pacific Consortium of Agricultural Biotechnology 2006).

[9]A hybrid is a plant produced from a crossing of two plants with different genetic constituents.

[10]This protein, when entering the gut of the insect in the larvae phase, meets a receptor protein, binds with it and punctures the wall of the intestine, which leads to paralysis and eventually death of the insect. This receptor protein is only found in insects of the Lepidoptera order. This implies that Bt cotton is has no impacts on humans or other mammals.

[11]I.e., the protein is toxic to several insects of the Lepidoptera order, among others the American bollworm, the spiny bollworm, the spotted bollworm and to a lesser extent, the pink bollworm.

[12]Data from Qaim and Zilberman (2003) from trials conducted in 25 districts on 175 farms in Maharashtra, Tamil Nadu and Madhya Pradesh during 2001-02, a high bollworm pressure year, show that the cumulative distribution function of the profits of Bt cotton first-order stochastically dominates the non-Bt function. I am grateful to Matim Qaim for sharing the data with me.

Karnataka during 2002-03, a low bollworm pressure year, conclude that, irrespective of soil and climatic conditions, non-Bt cotton outperforms Bt cotton.[13]

3 Data

I use two primary sources of data to construct the dataset for this paper. The first source is six rounds of the ICRISAT-VLS data, covering six cropping seasons from 2001 up to 2007. These data are collected by the International Crop Research Institute of the Semi-Arid Tropics (ICRISAT) in Hyderabad as part of their Village Level Studies (VLS) program.[14] Of the ICRISAT-VLS data, I use the modules on household composition, landholding, plot-level inputs used and output produced, machinery, income and wealth of three villages in rural India: Aurepalle in the Mahbubnagar district in Andhra Pradesh and Kanzara and Kinkhed in the Akola district in Maharashtra.

To obtain information on social networks and beliefs regarding Bt cotton, I resurveyed the households in the VLS sample in 2007-08.[15] In this supplementary survey I also elicited each household's cultivation plans for the year 2008-09 and past cotton adoption, production and marketing decisions covering the period 2001-08[16], in addition to administering a more standard household questionnaire. In addition to the VLS households, I also collected data among 21 additional progressive farmers as I expected the progressive farmers to play a central role in the dispersion of information and some of them to be role models for the farmers and as such the object of imitation. As such, omitting these progressive farmers from the analysis could cause correlation among farmers who are connected to the same progressive farmers and be a potential source of bias when measuring the learning from other farmers and the effect of social pressures. Of the ICRISAT-VLS farmers, 22 farmers were also labelled "progressive farmers", totalling 43 progressive farmers. I identified this set of progressive farmers in collaboration with the village leaders and the VLS investigators who have been living in the village since 2001 at the beginning of the survey. The tables in Appendix B show how these progressive farmers are different from the remainder of the sample. On average, the progressive farmers are higher educated and own more land, of which a larger share is irrigated, compared to the remainder of the sample. The progressive

[13] More specifically, the cumulative distribution function of the profits of non-Bt cotton first-order stochastically dominates the Bt cotton function.

[14] In this program, ICRISAT followed 300 households from six villages during the period 1975-1985 every three weeks. This dataset, known as the first generation VLS, contains detailed household (income, wealth, consumption and labor) and plot level (input/output) data. In 2001, ICRISAT restarted the panel, revisiting 185 of the first generation VLS households and their split-offs, in addition to 261 newly added households, to make the sample representative for each village in terms of land-holding size. The first three years, 2001-04 data were collected on a yearly basis, in 2004-05 they switched to a bi-yearly basis and during 2005-07 data were collected on a 3-weekly basis. For an overview of the goals, methods and outcomes of respectively the first and generation VLS see (i) Singh et al. (1985) and Walker and Ryan (1990), (ii) Bantilan et al. (2006) and Rao and Charyulu (2007).

[15] Of the 199 households covered in 2001-02 by the ICRISAT-VLS, 92% were still in the sample in 2007-08. The households that dropped out were, on average, smaller in terms of household size, higher educated, with less total land, but more irrigable land compared to the household that remained in the sample. I interviewed these 184 households plus some of their split-offs and newly added households, a total of 246 households. This sample is representative for the village in 2007-08 (see Bantilan et al. 2006 and Rao and Charyulu 2007). Of these, 68% have data for all seven cropping years. Of the 32% of the households who are included in the sample from a later date onwards, 30% are households that have split off from sample households during 2001-2008. These split-off households are included from their date of split-off. See also Appendix A.

[16] This section partially overlaps with the data collected in the 2001-07 ICRISAT-VLS.

farmers are far more likely to adopt Bt cotton and, conditional on adoption, adopt the new technology earlier compared to the remainder of the sample.[17]

Finally, I completed a village questionnaire, including information on climate and village infrastructure, with the assistance of the *sarpanch*[18], three knowledgeable people in each village, the *Mandal/Tehsil* Revenue Office[19] and the District Collector's Office. In terms of climate data, I use three different daily rainfall series: from June 2005 onwards, I use the daily rainfall data as measured by the VLS resident investigators in the villages; before June 2005, I use the daily rainfall data of Amangal (gauge data) as provided by the Tehsil office at Madgul for Aurepalle and the daily rainfall data of Murtizapur (gauge data) as available from the Maharastra State government website http://www.mahaagri.gov.in/. I obtained the bollworm pressure data from various AICIP and GEAC reports and double-checked this information with the perceived bollworm pressure as recorded in the village questionnaires.

The format of my resurvey combined experiments and questionnaires, including quantitative and qualitative, objective and subjective and closed- and open-ended questions. The household questionnaire includes sections on household composition, landholding (including soil characteristics), agricultural machinery and income, all pertaining to the 2007-08 season.[20] In addition, I elicited information on current beliefs regarding the profitability of Bt and non-Bt cotton and social networks within the village using an experimental approach. For the former, I used a yield distribution game, based on Lybbert et al. (2007). In this game, I first elicited the minimum and maximum yield (per acre) of two Bt and non-Bt cultivars of the respondent's choice conditional on the respondent's soil characteristics, irrigation status and expected input use. Then I made five boxes, evenly distributed between this minimum and maximum and I asked the respondent to use 20 stones (each stone representing a 5% probability) to form a yield density function. After each yield distribution game, I asked the respondent how much he expects to pay i) for the seed (per acre), and ii) for pesticides and for other inputs (per acre). During the interview, I explicitly linked the number of stones to percentages.[21]

I measured social networks using three different methods. The first method asked the respondent how many farmers he knew in each year since 2001-02 in different social groups (total, village, relatives) that adopted Bt cotton in that year and what the experience of these farmers was on average with Bt cotton. This method has the advantage of capturing most information links of the respondent, but, as we know little about these contacts, provides little information on the nature of these links. Let's denote a contact of the respondent by X. Ideally, one would like to take into account certain aspects of X's production (input and output) and the relationship between the respondent and his contact X. However, due to time constraints, one can not ask the respondent for information regarding the behavior of every one of their peers. In addition, it would not be reasonable to ask the respondent

[17]Note that there is a possibility that I might have missed the progressive farmers who have migrated from the village, but who used to be a role model and important in terms of spreading information. I do not expect this to be a serious issue as, looking at the characteristics of the households who have left the VLS sample since 2001, only one was a larger farmer household that used to cultivate cotton.

[18]A *sarpanch* is a democratically elected head of a village level statutory institution of local self-Government called the *Gram* (village) *Panchayat* in India.

[19]*Mandal* refers to the third-level administrative area in Andhra Pradesh, below state and district. The equivalent in other states is *tehsil* (or *taluka*).

[20]Note that this information is also collected during the standard ICRISAT-VLS survey, but as 2007-08 data would not be available in time, I added this standard module, based on the ICRISAT-VLS survey, to my resurvey.

[21]See also Delavande et al. (2008) for the various methods that can be used.

to recall the details of their peers behavior up to seven years ago.[22]

This implies that one needs to think about sampling the social network of each respondent. Two of the most popular techniques are respondent-driven "snowball sampling" (i.e., a technique where existing study subjects recruit future subjects from among their acquaintances, thus the sample group appears to grow like a rolling snowball) and taking the “network of a sample”.The first technique, "snowball sampling" is useful when one is interested in properties of the network itself, but as it results in a non-representative sample of the households, it is not a useful technique for the economic analysis of the effects of social networks on behavior (Scott 1991). The second technique, taking the "network of a sample", artificially truncates the network and is not representative of the “network of the population”. This technique might result in biased estimates of micro-economic behavior in the presence of structured networks as unobservables influence both the probability of a link and, independently, the behavior of interest (Santos and Barrett 2007). In addition, due to time constraints, one can not ask the respondent for information regarding his relationship with every other individual in the sample. I therefore opt for a third technique, the "random matching within sample" method based on Conley and Udry (2001) and Santos and Barrett (2007).[23]

Through the "random matching within sample" method, I elicit the details of the relationship between two randomly drawn respondents from the VLS sample. Each respondent is matched with six randomly drawn VLS respondents and four ex-ante identified fixed progressive farmers.[24] Appendix C comments on the selection of these 4 fixed progressive farmers**.** The questions in the random matching within sample game include: how long have you known person X?, how frequently do you talk to person X?, how risk averse are you compared to person X?, how profitable are you on your farm compared to person X?, and a set of questions on the knowledge of X’s farming activities in terms of inputs and outputs. As I know the characteristics of person X drawn, this method can shed more light on the nature of learning, social pressures and imitation.

One can use the information elicited through the random matching within sample game in two different ways. First, one can extrapolate the information obtained through the random matching within sample game to the population level as the percentage of links in the game provides an unbiased estimate of the percentage of links in the population. Assuming the absence of unobservables which influence both the probability of a link and the probability to adopt Bt cotton, one can then use this estimate to examine the effect of these links on the adoption decision. Second, one can regress the probability of a link on the attributes of the respondent and the match, and use the results of this regression to predict out-of-sample (i.e., out of the random matching within sample game) the probability of a link between any two individuals in the sample. the advantage of the latter method is that

[22] In addition, respondents often incorrectly report their peer’s behavior. This might or might not be a problem depending on what drives the respondent’s action: the actual behavior of X or the perceived behavior of X (Hogset and Barrett Forthcoming).

[23] Note that both the "network of a sample" and the "random matching within sample" will provide biased estimates of the effects of social networks in the presence of star-shaped network structures. The reason for this bias is that if a "source" in the network, i.e. someone who has many links compared to others, is not sampled, its absence generates an omitted variable bias, in the same way as excluding information from seed dealers and company agents generates spurious correlation between the farmers.

[24] Aurepalle consists of two separate sub-villages: the main village of Aurepalle and the sub-village of Nallavaripalle. I presented the respondent with 4 out of 6 matches from the same village and 2 out of 6 from the other villages. Similarly, for the progressive farmers, 3 out of 4 were from the same village and 1 out of 4 from the other village.

it strips the independent variable "link" of its unobservable part and as such avoids the potential bias. However, if the set of attributes poorly predict these links, there might be too little variation left in the predicted link variable to asses the effects of the links on the adoption decision.

The third method of measuring social networks asks the cotton farmer who he would approach for information if he had problems with his cotton crop, eliciting some characteristics of person X's farming activities and the relationship between the respondent and person X.

In order to be able to take into account the information that the respondent receives from non-farmer sources, I added a section on the information obtained since 2001-02 from contacts with extension agents, NGOs, input dealers and ICRISAT.[25]

I asked one question that directly relates to social pressures. As social pressures seem to arise from health and environmental concerns, i.e. a farmer might be accused of the health problems of a sick animal/human when cultivating Bt cotton, I collected data on the farmers' views and the perceived views of different social groups on the effects of Bt cotton on animal health, human health and the environment. More specifically, I asked the respondent "To what degree do you think (or that "others" think) that Bt cotton is hazardous for (1) animal health, (2) for human health, (3) for the environment", where the "others" refers to, in several sub-questions, other farmers, relatives, company agents, government extension agents, seed dealers and ICRISAT. Each of these three questions has five possible answers, ranging from "strongly disagree" to "strongly agree" and a "don't know" option.

4 Setting

Table 2 introduces the three villages considered for this study. Aurepalle, with 925 households, is the largest of the three villages. It is situated in the drought-prone, poor, Telangana region of Andhra Pradesh. The soils in this region are generally sufficient for good crop production, but as they are acidic in nature, require fertilizers and tend to be prone to erosion. Kanzara and Kinkhed, with respectively 319 and 189 households, are located in the somewhat less drought-prone Akola district of West Maharashtra. The soils in this region with their high clay content and poor physical condition are susceptible to erosion, but as their chemical properties are excellent, can give produce yields if properly managed.

The average education level of the respondent (i.e. the main decision-maker with regard to agriculture) is low, especially in Aurepalle (2.31 years). The average size of a household is between 4 and 5 members in all three villages.

[25] Not all respondents could recall the month in which they received the information. I reconstructed the month (before/after June) based on the adoption history of the farmer and knowledge of visits of extension agents etc. from the village questionnaire.

Table 2: Basic descriptive statistics of Aurepalle, Kanzara and Kinkhed

	Aurepalle	Kanzara	Kinkhed
Number of households in village	925	319	189
Number of households in sample	128	63	55
Average rainfall (mm/year)[1]	542	1140	1052
Distance to nearest town (km)	10	9	12
Phone service in the village (year establishment)	1978	2002	1993
Average education level of respondent (in years)	2.31	6.61	6.89
Average number of household members	4.23	4.87	4.50
Average yearly income (Rs)[2]	43,543	53,720	38,087

Notes: [1]2005-2007; [2]2004-2005; As the VLS has changed the way in which income is measured in 2005 income is not comparable across years. Before 2005-06 income was measured through a direct question to the respondent who is asked to recall his/her income one year back. From 2005-06 onwards, income is measured through a set of modules as the difference between production valued at market prices and expenditures valued at market prices including family labor on a three weekly basis of the different production activities. I opted here to report the annual income, as reported by the household in 2004-05.

Tables 3, 4 and 5, respectively, present selected descriptive statistics regarding the Bt cotton adoption process, future cultivation plans and the (current) knowledge and beliefs about Bt cotton. Figure 1 plots the number of farmers cultivating Bt cotton as a percentage of the total number of cotton farmers (the "adoption curve"). As the acreage under Bt cotton as a percentage of area under cotton gives a very similar picture, I omit this figure. In the remainder of this section, I discuss these tables and tell the story of the adoption process using qualitative interview evidence thereby previewing the main results of the quantitative analysis.

In Aurepalle cotton farming is a relatively recent phenomenon. Since the last seven years, the acreage under cotton has been on the increase. Aurepalle is situated in a drought-prone region, with a falling water table, where farmers often make large investments in agriculture, such as borewells, and have developed an elaborate system of risk management that includes income diversification.

In Andhra Pradesh, one out of three of the Bt cotton cultivars was not on the market during the first two cropping seasons (2002-04). Throughout the first three years NGOs and subsequently the Andhra Pradesh government challenged the decision of GEAC with regard to the approval of Bt cotton, resulting in a dis-continuation of the permission for commercial cultivation of the MECH Mahyco cultivars in 2005.[26] The legal battle and controversy around GM crops in the early years in Andhra Pradesh affected the farmers in Aurepalle in the sense that even though the Bt seeds were available in the urban areas, company agents did not actively go around the country side to promote the new Bt technology. Only one of the progressive farmers in Aurepalle learned about Bt cotton from non-farmer sources (seed dealers, company agents and media) as early as 2002 and started to cultivate Bt cotton in 2003. The majority of the remaining progressive farmers heard first about Bt cotton from media and each-other in 2003-2004 and the other cotton farmers heard about Bt cotton from the progressive farmers and company agents visiting the village in 2006-07. The large majority of the farmers, 91%, adopted Bt cotton in the same year that they heard

[26]Sources: The list of approved hybrids as released by GEAC and personal communication with Mahyco, dated 7 September 2009.

about Bt cotton for the first time, having observed only a handful of experiences with Bt cotton in person and displaying great confidence (by their own account) in the judgement of the progressive farmers and relying heavily on the advice of company agents and seed dealers. The few farmers who delayed adoption mentioned high seed cost, unavailability of the seed with their dealer and the need to observe the results for themselves as the main reasons. Farmers who did not adopt up to 2007-08 mentioned lack of land, family labor, credit, knowledge and high seed costs as the main reasons. No disadoption occurred in Aurepalle. Two farmers adopted the technology partially in 2006, cultivating both Bt and non-Bt cotton while all other farmers planted only Bt cotton.

Overall, Bt cotton was a success in Aurepalle. Before the introduction of Bt cotton, cotton farmers sprayed 7 to 8 times per season to control for bollworms. After the introduction of Bt cotton, several farmers who did not farm cotton before, switched to Bt cotton and sprayed the recommended 2 to 3 sprays per season. As bollworm pressure was low in Aurepalle in 2006 and 2007, farmers who switched to Bt cotton in the later years, felt confident that no more sprays were needed. As the seed price had dropped in 2006 to 40% of the initial price, Bt cotton proved to be both a cost saving as well as a yield improving technology. In 2007-08, the average profit of Bt cotton farming stood at 7,760 Rs/acre (and st. dev at 6,055 Rs/acre).[27] In 2006-07, a low bollworm pressure year in Aurepalle, the cumulative distribution function of the profits of Bt cotton First Order Stochastically Dominates the cumulative distribution function of the profits of non-Bt cotton in Aurepalle (see also Appendix E). Today, farmers in Aurepalle perceive Bt cotton to be less labor intensive and to need fewer sprays compared to non-Bt cotton. Assuming a step-wise distribution with the minimum and maximum of the distribution as specified by the respondent, I calculated the mean of the perceived conditional yield distribution of Bt cotton and non-Bt cotton for each respondent. In Aurepalle, the mean of the distribution is, on average, 7.6 quintal/acre for Bt cotton and 4.8 quintal/acre for non-Bt cotton. The variance of the distribution is, on average, 1.57 quintal/acre for Bt cotton and 0.64 quintal per acre for non-Bt cotton. The current adoption rate stands at 100% of the cotton farmers.

The Aurepalle farmers have little to no safety concerns regarding Bt cotton. Only 13% of the respondents "agreed" or "strongly agreed" with (at least) one of the following statements: "Bt cotton is hazardous for animal health: they might get sick or die when they eat it", "Bt cotton is hazardous for human health: if you touch it too much, you might get sick" and "Bt cotton is hazardous for the environment: it damages crops and soils". As such, social pressures due to bio-safety concerns play little to no role in the decision making process of the Aurepalle farmers.

Kanzara is located in the Akola region of Maharashtra which is traditionally a cotton-growing region where cotton is grown intercropped with other crops such as pigeonpea, greengram and blackgram. The acreage under cotton has been decreasing since 2005. The Bt adoption process has been smooth, characterized by partial adoption, strategic delays and disadoption. Disadoption of Bt cotton is between 14% and 27% each year and the percentages of Bt farmers who are partial adopters ranges from 31% to 80%. The progressive farmers in the villages learned about Bt cotton from company agents, media and each other as early as 2001 and started cultivation as early as 2002. The other village farmers heard first about Bt cotton from company agents, seed dealers and progressive farmers. Most farmers, even the progressive farmers, did not adopt Bt cotton in the year that they first heard

[27] As none of the farmers cultivated non-Bt cotton in 2007-08, the average profit of non-Bt cotton is unknown.

about Bt cotton. The reasons mentioned for this delay are lack of experience, including the experience of others in their network, lack of irrigation facilities, high seed cost and lack of credit availability.

Before the introduction of Bt cotton many farmers did not spray any pesticides at all on non-Bt cotton.After switching to Bt cotton, most farmers sprayed about 4-5 times per season. This is a bit more than recommended by the scientists and seed dealers. This does not reflect ill communication between the seed dealers and farmers, but rather is the result of farmers trusting their own judgement in the face of moderate bollworm pressure during 2004-06.[28] Due to a high seed cost during 2002-06, excessive spraying and an increased use of other inputs, such as fertilizers and labor, the Bt cotton technology was a yield improving technology but not always a cost saving technology in Kanzara. When switching from non-Bt to Bt cotton, several farmers, at a more fundamental level, switched from a low-input agricultural system to a high-input agricultural system. In 2007-08, a high bollworm pressure year in Akola, the average profit of Bt cotton farming stood at 7,760 Rs/acre (and st. dev. at 5,299 Rs/acre) versus 1,367 Rs/acre (and st. dev. at 3,056 Rs/acre) for non-Bt cotton and the cumulative distribution function of the profits of Bt cotton First Order Stochastically Dominates the cumulative distribution function of the profits of non-Bt cotton in Kanzara. In 2006-07, a low bollworm pressure year in Akola, the cumulative distribution function of the profits of Bt cotton First Order Stochastically Dominates the cumulative distribution function of the profits of non-Bt cotton in Kanzara. Today, farmers in Kanzara perceive Bt cotton to be more labor-intensive, less prone to bollworm attacks but in need of more sprays compared to non-Bt cotton. In Kanzara, the mean of the perceived yield distribution is, on average, 6.8 quintal/acre for Bt cotton and 3.8 quintal/acre for non-Bt cotton. The variance of the distribution is, on average, 2.12 quintal/acre for Bt cotton and 0.79 quintal per acre for non-Bt cotton. The current adoption rate stands at 54% of the cotton farmers.

About 51% of the respondents have serious concerns regarding the bio-safety of Bt cotton, resulting in moderate social pressures due to bio-safety concerns. While none of the progressive farmers have any concerns regarding bio-safety of Bt cotton, one can expect it to take time before these concerns completely disappear.

Kinkhed is located only a couple of miles from Kanzara. Traditionally a cotton growing village, the acreage under cotton has been on the decrease since 2006. Despite the fact that the progressive farmers in the village heard about Bt cotton from media, company agents, seed dealers and progressive farmers outside of the village as early as 2002, the progressive farmers displayed a 'wait and see' attitude and the adoption process started only in 2006. In the earlier years, farmers heard first about Bt cotton from input dealers and farmers outside of the village. It was only in later years that the progressive farmers within the village played a role in disseminating information about the new technology.

As in Kanzara, before the introduction of Bt cotton, farmers sprayed little to no pesticides on non-Bt cotton crops. After the introduction of Bt cotton, farmers who switched used the recommended amount of 2-3 sprays per season. In 2007-08, the average profit of Bt cotton farming stood at 1,176 Rs/acre (st. dev.3,842) versus 153 Rs/acre (st. dev. 2,762) for non-Bt cotton. As in Kanzara, Kinkhed farmers perceive Bt cotton to be more

[28] A technical aside: In the case of non-Bt cotton, a bollworm attack can destroy an entire field in 3-4 days if no pesticides are used. In the case of Bt-cotton, the bollworm attack is visible, and it typically takes 1-2 days for the Bt protein to become effective as the worms need to eat sufficient leaf tissue for them to die. As such, it might take a farmer a couple of years to trust the technology and not to overspray when the worms are visible.

labor-intensive, less prone to bollworm attacks but in need of more sprays compared to non-Bt cotton. In Kinkhed, the mean of the perceived yield distribution is, on average, 5.4 quintal/acre for Bt cotton and 3.7 quintal/acre for non-Bt cotton. The variance of the distribution is, on average, 1.49 quintal/acre for Bt cotton and 0.87 quintal per acre for non-Bt cotton.The current adoption rate stands at 14% of the cotton farmers. In fact, only one farmer classified as a non-progressive farmer has adopted the technology. The reasons for non-adoption mentioned by the farmers are: lack of information, irrigation, land, the high price of the seed and no credit availability and the danger Bt cotton poses to farm animals.

Social pressures are strong in Kinkhed with 53% of the respondents having serious bio-safety concerns, and these safety concerns are mentioned as one of the reasons for non-adoption by several farmers. Even the progressive farmers in the village attach some belief to these. The low adoption rate implies that these beliefs will not easily get disproved.

Table 3: Adoption of Bt cotton 2001-08

	Aurepalle	Kanzara	Kinkhed
Acreage under cotton, 2007-08 (Acre)	221	124	110
% of households that farm cotton, 2001-08	60	84	82
% of cotton farmers that adopt Bt cotton, 2001-08	77	51	11
% of cotton farmers that adopt Bt cotton, 2007-08	100	54	14
% of cotton acreage under Bt cotton, 2007-08	100	55	15
% of cotton acreage under Bt cotton, 2002-03	0	9	0
% of Bt cotton farmers that disadopt Bt cotton, 2007-08	0	14	0
% of Bt cotton farmers that partially adopt Bt cotton, 2007-08	0	31	40

Table 4: Future plans for Kharif 2008-2009 (as a % of total households)

	Aurepalle	Kanzara	Kinkhed
Not cultivate cotton	37.5	60.3	25.5
Don't know whether to cultivate cotton	3.9	3.2	9.1
Cultivate cotton	58.6	36.5	65.5
- Cultivate Bt cotton	50.0	25.4	21.8
- Cultivate Bt cotton and non Bt cotton	7.0	1.6	12.7
- Cultivate non-Bt cotton	0.0	9.5	27.3
- Not yet decided	1.6	0.0	3.6

Note:the rows might not add up to 100% due to rounding errors

Table 5: Current knowledge and beliefs regarding Bt cotton

	Aurepalle	Kanzara	Kinkhed
Never heard of Bt cotton (as % of cotton farmers)	4	0	0
Average perceived mean of Bt cotton distribution (Q/acre)[1]	7.60	6.82	5.45
Average perceived mean of non-Bt cotton distribution (Q/acre)[1]	4.79	3.88	3.72
Average perceived price of Bt cotton seed (Rs/acre)	1280	929	1200
Average perceived price of non-Bt cotton seed (Rs/acre)	653	412	636
Average perceived number of pesticide sprays needed for Bt cotton	3.4	4.7	2.9
Average perceived number of pesticide sprays needed for non-Bt cotton	7.6	2.1	1.24
% of respondents with safety concerns regarding Bt cotton	13	51	53

Notes: [1]1 quintal=100kg; the differences between Bt cotton and non-Bt cotton in perceived mean, perceived price and perceived number of sprays needed is significant in all three villages

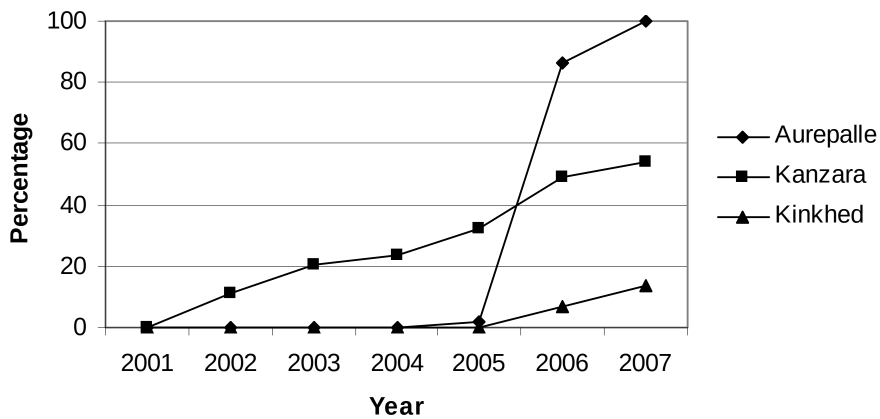

Figure 1: Adoption of Bt Cotton

What are the underlying factors driving these markedly different adoption processes? First, there are the usual constraints: credit, land and irrigation which are markedly different across villages. For instance, Aurepalle farmers, using groundwater, have typically access to irrigation during the rainy season, while Kanzara and Kinkhed farmers, using surface water, do not. The physical environment is different in terms of climate, expected bollwormpressure and soils and while the distance to the first urban hub is similar in all three villages, the different in state policies and attitudes with regard to genetically modified crops implied that Aurepalle was not visited by company agents until 2005. The education level is higher in the Akola villages, and the Kanzara farmers have, on average, a better access to media sources. And last, but not least important, the underlying network structures of who-communicates-with-whom are very different.

In 2007-08, the respondents in Aurepalle, Kanzara and Kinkhed (on average) knew, respectively, 85, 38 and 34 farmers who cultivate Bt cotton in 2007-08.[29] In Aurepalle,

[29] In case that a range was given by the respondent, the mean was taken. If the respondent answered "don't know" I assumed they knew no Bt cotton farmers. Note that a "don't know" can be interpreted in two ways: 1) I do not remember how many farmers I knew that year that adopted Bt cotton, or 2) in that

Kanzara and Kinkhed (on average), respectively, 78%, 85% and 57% of the Bt farmers known to the respondent live in the village. Table 6 presents some selected results of the random matching within sample game. I use the results of this game to identify and predict the set of farmers from whom each farmer might learn. Recall that each respondent draws 6 name cards of VLS respondents and is given a set of 4 fixed cards with names of progressive farmers. Denote the individual on the card by X. One can see that in a small village like Kinkhed, literally everyone knows everyone. In Aurepalle, only 87.8% of the cards are known. Conditional on knowing cotton farmer X, the respondent thinks he knows the pesticide use, cultivar choice and yield of farmer X in 2007-08 in, respectively, 21.9%, 27.8% and 63.6% of the cases in Aurepalle, Kanzara and Kinkhed.

In, respectively, 7.4%, 5.7% and 12.4% of the cases in Aurepalle, Kanzara and Kinkhed the knowledge about yield, pesticide use and cultivar is correct.[30] Incorrect knowledge about other farmers' activities might be one of the factors underlying dis-adoption, i.e., a farmer could adopt Bt cotton based on the perceived knowledge that x number of sprays are needed, on average, to give y quintal/acre, but once the farmer has adopted Bt cotton, he experiences a lower yield than he expected and decides to disadopt. While the figures on yield in the Akola villages of Table 6 should be taken with a grain of salt, as the respondent had to convert the yields from an intercropping system to quintal/acre, note that Kanzara, where the knowledge of the respondents was most frequently incorrect, is also the village with the highest disadoption rate.

Table 6: Knowledge about others' activities
(Results of the random matching within sample game)

	Aurepalle	Kanzara	Kinkhed
1. Know X? (%)	87.8	99.2	100.0
2. Does X farm? (% of 1)	82.3	83.7	91.6
3. Does X farm cotton? (% of 2)	57.2	70.2	90.0
4. Know X's yield? (% of 3)	30.2	39.1	68.6
5. Know X's pesticide use? (% of 3)	29.5	31.1	75.9
6. Know X's cultivar? (% of 3)	69.3	85.8	75.4
7. Know X's yield, pesticide use and cultivar? (% of 3)	21.9	27.8	63.6
8. Know X's soil?(% of 3)	89.1	95.6	98.0
9. Know X's irrigation status? (% of 3)	63.9	82.0	96.3
10. X's yield correct (% of 4)	31.4	21.2	16.3
11. X's pest correct? (% of 5)	14.6	25.1	61.1
12. X's cultivar correct? (% of 6)	86.0	81.9	77.3
13. X's yield, pesticide use and cultivar correct (% of 7)	7.4	5.7	12.4
14. X's soil correct?(% of 8)	40.7	29.0	45.4
15. X's irrigation status correct?(% of 9)	55.1	76.6	16.6

Note: In (4), (5), (6) and (7) "knowing" means that the respondent was able to name the cultivar, the amount of pesticides used, the yield per acre obtained etc of match X

year, I did not know whether any farmers that I knew adopted Bt cotton. From my conversations on the field, it appears that the second interpretation was far more common.

[30]Knowledge of yield and pesticide use was considered correct of the believed value was within a 10% range of the actual value. If X cultivated multiple cultivars, the believed value of the average yield of Bt and non-Bt was compared with the actual average. In case of pesticide use the discrete decision was often known (whether X uses pesticides or not) but not the exact number of sprays. In this case, knowledge was considered incorrect.

Recall that in this random matching within sample game one only obtains information about the various links between the respondent and 6 randomly selected VLS farmers and 4 fixed progressive farmers. In order to obtain a link variable for any two randomly drawn VLS respondents, I use a probit regression of the link variable of interest on a set of attributes and the respondent and the match drawn, including only the links of which the match cultivates cotton in 2007-08. I then use the results of this regression to predict out-of-sample, i.e., out of the random matching within sample game but within the VLS sample.[31] The results of this regression suggest that the probability of knowing X's yield, pesticide use and cultivar use increases when either respondent or match are a progressive farmer, the respondent and match belong to the same caste, either respondent or match are of the male gender, a higher education level of respondent or match and the respondent and match live in the same sub-village. Unfortunately, I cannot include the two variables with the largest predictive power, "living in the same neighborhood" and "having a field next to each other " as I only have this information on the respondents and matches drawn in the random matching within sample game. However, as one can see from from Table 7, the model still performs reasonably well with between 72% and 88% of the links correctly predicted.

Table 7: Percentage of links correctly predicted

	Link no. 6 Know cultivar	Link no. 7 Know cultivar, pesticide and yield
Aurepalle	80	88
Kanzara	77	83
Kinkhed	80	72

5 Model and empirical identification strategy

The simple model outlined below focusses on the decision to cultivate Bt cotton, conditional on having decided to cultivate $A_{i,t}$ acreage of cotton. Regarding notation, four kinds of subscripts are employed, the first subscript denotes the individual i or the contacts of individual i, denoted $-i$; the second subscript denotes the crop (c refers to cotton, b to Bt cotton and n to non-Bt cotton) and the third subscript denotes time t. Vectors are indicated in bold.

Assuming a time-separable utility function and discrete time steps, a farmer i at each time period t who possesses a certain knowledge about Bt cotton, denoted $K_{i,t}$, chooses the acreage under Bt cotton, denoted $A_{i,b,t}$, and a vector of inputs for Bt cotton and non-Bt cotton, denoted, respectively, $\mathbf{x}_{i,b,t}$ and $\mathbf{x}_{i,n,t}$ to maximize the discounted flow of instantaneous utility over an infinite horizon:

$$V(K_{i,t}) = \max_{\{\{A_{i,b,t},\mathbf{x}_{i,b,t},\mathbf{x}_{i,n,t}\}\}_{\forall t}} E\left[\begin{array}{c} \sum_{t=0}^{\infty}\delta^t u_i(\pi_{i,b,t}(\cdot)+\pi_{i,b,tn}(\cdot))+ \\ s(A_{i,b,t},\{A_{-i,b,t}\}_{\forall -i\in N_{P_i}},\{A_{-i,b,t}\}_{\forall -i\in N_{Ii}}) \end{array}\right] \quad (1)$$

[31] Concretely, I use a per-village probit regression with two-way clustering (the first cluster is the respondent and the second cluster is the match) and each variable entered up to the third degree. Denote an arbitrary correlate with x, then the suffix "add" and "min" refer, respectively, to $x_{respondent} + x_{match}$ and $x_{respondent} - x_{match}$. The list of correlates included is: "being a progressive farmer" (PFadd, PFmin), "being a laborer" (laboreradd, laborermin), "belonging to the same caste", "having the same family name", "acreage of land owned" (landadd, landmin), "years of education obtained by the decision-maker" (educationadd, educationmin), gender (genderadd, gendermin), "income per capita in kharif 2007-08" (incomeadd, incomemin), "number of children" (childrenadd, childrenmin), "value of agricultural machinery" (machineryadd, machinerymin) and "living in the same (sub)-village". The results are available upon request.

In 1,$V(\cdot)$ is the value function of the constrained maximization problem at time t, $\delta \in (0,1)$ is the discount rate, summarizing preferences over time and E is the expected value operator. The farmer's per-period well-being is a function of the farmer's consumption, as captured by the standard individual-specific $u_i(\cdot)$ Bernoulli utility function and a non-material satisfaction term, denoted $s(\cdot)$ included to capture the influence of social pressures and the (behavioral) imitation. The set of fellow farmers relevant to farmer i in terms of social pressures is denoted N_{P_i} and the set of progressive farmers relevant to farmer i in terms of imitation is denoted N_{I_i}.[32]

The profit of Bt cotton and non-Bt cotton are, respectively, defined as:

$$\pi_{i,b,t} = Pc_{i,t}.F_b(A_{i,b,t}, x_{i,b,t}, \epsilon_{i,b,t}|K_{i,t}) - \mathbf{Px}_{i,b,t}.x_{i,b,t} \tag{2}$$

$$\pi_{i,n,t} = Pc_{i,t}.F_n(A - A_{i,b,t}, x_{i,n,t}, \epsilon_{i,n,t}) - \mathbf{Px}_{i,n,t}.x_{i,b,t} \tag{3}$$

where $Pc_{i,t}$ denotes the individual-time specific price of cotton[33], $\mathbf{Px}_{i,b,t}$ and $\mathbf{Px}_{i,n,t}$, respectively, denote the individual-time specific vector of prices for Bt cotton and non-Bt cotton, $\epsilon_{i,b,t}$ and $\epsilon_{i,n,t}$, respectively, denote a random variable capturing unexpected shocks caused by weather fluctuations and bollworm pressure (distributed according to H_{ϵ_i}) and F_b and F_n denote, respectively, the production function of Bt cotton and non-Bt cotton. Denote the realization of F by f. The production function of Bt cotton is a function of the the knowledge the farmer i has about about Bt cotton, $K_{i,t}$, and is subject to the following law of motion:

$$K_{i,t+1} = K\left(K_{i,t}, f_{b,i,t}, \{f_{-i,b,t}, x_{-i,b,t}\}_{\forall -i \in N_{L_i}}, \{A_{-i,b,t+1}\}_{\forall -i \in N_{I_i}}, O_{i,t}\right) \tag{4}$$

where N_{L_i} denotes the set of farmers whose inputs and output choices farmer i has observed in period t and $O_{i,t}$ the information farmer i has received from non-farmer sources, such as company agents and seed dealers in period t. Thus, according to (4) farmer i updates his knowledge regarding the profitability of Bt cotton through experimentation, observing other farmers' input and output choices, observing the progressive farmers input choices, i.e., learning-imitation, and interactions with non-farmer sources.

And, the control variables in this dynamic optimization problem are subject to a non-negativity constraint and the state variables to a set of initial conditions:

$$A_{i,t} \geq A_{i,b,t} \geq 0 \tag{5}$$
$$\mathbf{x}_{i,b,t}, x_{i,n,t} \geq 0 \tag{6}$$
$$K(0) = K_0 \tag{7}$$

Equations (1) - (7) jointly specify a structural dynamic behavioral model. Rewriting this dynamic optimization problem as a Bellman equation (not shown), one can derive the relevant first-order conditions and solve for the policy functions describing the farmer's choice conditional on $K_{i,t}$, $A_{i,t}$, preferences and prices faced.

[32] Note that the model assumes that farmer i has an idea of the other farmers' choices $\{A_{-i,b,t}\}$ connect to farmer i at time t. According to the farmers' own account, this assumption is correct, as the choice of cultivar is an important topic of discussion during the months of April-May (before the decision has to be made in June).

[33] Note that the price of cotton is assumed to be the same for Bt cotton and non-Bt cotton. Using the 2007-08 input-output data, I show in Appendix D that this assumption is correct.

Without imposing any learning model or preferences, write the reduced form equations for the choice of interest $A^*_{b,i,t}$ at time period t as:

$$A^*_{b,i,t} = A(A_{i,t}, K_{i,t}, Pc_{i,t}, \mathbf{Px}_{i,n,t}, \{A_{-i,b,t}\}_{\forall -i \in N_{P_i}}, \{A_{-i,b,t}\}_{\forall -i \in N_{I_i}}, H_{\epsilon_i}, \delta, RISK) \quad (8)$$

where $RISK$ captures the preferences with regard to uncertainty. Plugging (4) in (8) this yields:

$$\begin{aligned} A_{b,i,t} = \; & A(A_{i,t}, K_0, \{f_{b,i,t}\}_{\tau=0}^{\tau=t-1}, \left\{\{f_{-i,b,t}, x_{-i,b,t}\}_{\forall -i \in N_{L_i}}\right\}_{\tau=0}^{\tau=t-1}, \\ & \left\{\{A_{-i,b,t}\}_{\forall -i \in N_{I_i}}\right\}_{\tau=0}^{\tau=t}, \{O_{i,t}\}_{\tau=0}^{\tau=t-1}, \\ & Pc_{i,t}, \mathbf{Px}_{i,n,t}, \{A_{-i,b,t}\}_{\forall -i \in N_{P_i}}, \{A_{-i,b,t}\}_{\forall -i \in N_{I_i}}, \delta, RISK) \end{aligned} \quad (9)$$

In order to bring (9) to the data, one needs to determine, for each farmer, the set of farmers N_{P_i}, N_{I_i} and N_{L_i} and decide on a aggregation rule to aggregate the experiences and actions of the different farmers $-i$?

Ideally, one would like to include all the information contacts of farmer i in N_{P_i}, N_{I_i} and N_{L_i}. This is exactly what the first social network question does, asking the number of farmers farmer i knew each year since 2001-02 who cultivated Bt cotton. This method however does not provide any information on the relationship between farmer i and his contacts $-i$ or the profit of the contacts when using Bt cotton and as such, one needs to take the total number of adopters farmer i has known up to $t-1$ as a proxy for what farmer i has learned regarding the production function of Bt cotton and the current number of adopters known as a measure of the aggregate effect of (behavioral) imitation, social pressures, learning-imitation and free-rider effects. As I expect the role of social pressure and imitation to be different once one has cultivated Bt cotton, let's focus on the decision of the first-time adopter (and drop the own experience $\{f_{b,i,t}\}_{\tau=0}^{\tau=t-1}$ in (9)):

$$P(A_{b,i,t} > 0) = \Phi \begin{bmatrix} A_{i,t}, K_0, \sum_{\forall -i \in N} \sum_{\tau=1}^{t-1} I_{A_{-i,b,\tau}>0} \\ \sum_{\tau=1}^{t-1} O_{i,\tau}, Pc_{i,t}, \mathbf{Px}_{i,n,t}, \sum_{\forall -i \in N} I_{A_{-i,b,\tau}>0}, \delta, RISK \end{bmatrix} \quad (10)$$

where N denotes the total set of farmers farmer i interacts with, i.e., $N = N_{P_i} \cup N_{I_i} \cup N_{L_i}$ and I denotes the indicator function taking the value of one if $A_{-i,b,\tau} > 0$ and zero otherwise. In the empirical specification, instead of $A_{i,t}$, I use the acreage of land owned and the Mills ratio predicted by a regression modelling the decision to cultivate cotton to capture selection effect. In addition, I add education (as education might help in processing new information) and measures of soil fertility, irrigation and credit constraints.

Using the results of the random matching within sample experiment, one can take into account certain aspects of the relationship between farmer i and his contact $-i$ and $-i$'s production decisions and outcomes:

$$P(A_{b,i,t} > 0) = \Phi \begin{bmatrix} A_{i,t}, K_0, \sum_{\forall -i \in N_{L_i}} \sum_{\tau=1}^{t-1} I_{A_{-i,b,\tau}>0}, \sum_{\forall -i \in N_{I_i}} I_{A_{-i,b,\tau}>0}, \\ \sum_{\tau=1}^{t-1} O_{i,\tau}, Pc_{i,t}, \mathbf{Px}_{i,n,t}, \sum_{\forall -i \in N_{N_i}} I_{A_{-i,b,t}>0}, \delta, RISK \end{bmatrix} \quad (11)$$

where N_{L_i} is the set of farmers for whom farmer i knows the cultivar, yield and number of pesticide sprays. This set includes both fellow farmers and progressive farmers. In the case of the fellow farmers this set equals the set of fellow farmers for whom farmer i (thinks) he knows the cultivar, yield and number of pesticides sprays as predicted by the random matching within sample game and scaled up to the village level taking into account the sampling percentage and size of the village. In the case of the progressive farmers, the same measure can be used, or, alternatively, the set of progressive farmers who, according to their own account, believe that the respondent knows their cultivar use and yield output. In the econometric specification, I will parse out the effects of past experiences of the fellow farmers and progressive farmers. N_{N_i} is the set of fellow farmers for whom farmer i (thinks he) knows the cultivar as predicted by the random matching within sample game and scaled up to the village level taking into account the sampling percentage and size of the village. N_{I_i} is the set of progressive farmers for whom farmer i knows the cultivar choice. This set either equals the set of progressive farmers for whom farmer i (thinks he) knows the cultivar as predicted by the random matching within sample game and scaled up to the village level taking into account the sampling percentage and size of the village or the set of progressive farmers who, according to their own account, talk on an at least monthly basis to farmer i. Note that specification (11) does not include the past cultivar decisions of the progressive farmers. This simplification does not entail any loss of information. As none of the progressive farmers dis-adopt, both current adoption and past adoption (without observing yields) gives the same information to farmer i: "progressive farmer x believes Bt cotton will increase his profits compare to non-Bt cotton". In the econometric specification, I tried both the imitation component and the social pressure component as specificied in (11) and as a ratio of the total number of fellow/progressive cotton farmers known.

I use (10) and (11) to estimate the effects of social learning, social pressures and imitation using the panel data. For the cross-sectional data I can directly use the information of subjective beliefs regarding the profitability of Bt cotton versus non Bt cotton and the (perceived) strenght of the concerns of other farmers with the variable $OTHER\_BIOSAFETY$, which is constructed as the average of the answers to: "To what degree do you think that other village farmers think that Bt cotton is hazardous for (1) animal health, (2) for human health, (3) for the environment"). Assuming that the effect of social pressures is proportional the average strength of the beliefs that Bt cotton is hazardous ($OTHER\_BIOSAFETY$) and inversely proportional with the probability of being blamed when something would go wrong (1/total Bt cotton adopters in the next period).Rewriting (8)

$$P(A_{b,i,t} > 0) = \Phi\left[A_{i,t}, M_{i,b,t}, V_{i,b,t}, M_{i,n,t}, V_{i,n,t}, \{A_{-i,b,t}\}_{\forall -i \in N_{I_i}}, \frac{OTHER\_BIOSAFETY}{\sum_{\forall -i \in N} I_{A_{-i,b,t+1}>0}}, \delta, RISK\right] \tag{12}$$

where $M_{i,b,t}$, $V_{i,b,t}$, $M_{i,n,t}$, $V_{i,n,t}$ denote the mean and variance of the subjective conditional distribution of profits of Bt and non-Bt cotton, respectively imitation. Note that as the prices are included in this profit calculation, there is no need to include additional prices in (12).

6 Results

In this section, I present the main results of the cross-sectional analysis of the future adoption decisions regarding the 2008-09 cropping year and the panel data analysis, encompassing the period 2001-2007. In order not to interrupt the flow of this section, I have relegated most comments regarding data quality, construction of control variables and assumption checks to either footnotes or appendix.

Throughout the analysis, the main population of interest is the cotton farmers, i.e., we will look at the decision to cultivate Bt cotton conditional on cultivating cotton. This choice seems logic as it is only for the cotton farmers that the preference ordering between Bt-cotton and non-Bt cotton is revealed through their choice, and on a more practical level, the profitability of non-cotton crops can be ignored (conditional on controlling for risk aversion).[34] In order to extrapolate the influences of the social interaction effects to the village population, I will take into account the 'self-selection' of the respondents into this 'cotton-farming' status. According to the respondents' own account the choice between cotton and non-cotton crops depend on many factors, notably, soil quality, weather expectations and access to irrigation, soil fertility/pest management and the need for crop rotation, the need for cash, the availability of labor and how labor intensive each crop is and the prevailing input and output prices.[35]

By using the social networks and the beliefs of the respondent, I implicitly assume that the respondent interviewed is also the decision maker of the household in terms of agricultural decisions. During the fieldwork, I set up interviews each time with the person who the resident VLS investigators thought makes the agricultural decisions in the household. During the interview, several open questions were asked regarding the decision making process, among others "in year X, who decided on the cultivar". In the few cases that the answers to these questions did not correspond to the person being interviewed, the interview was repeated with, this time, the correct respondent. As such, this assumption can be considered correct.[36]

With regard to measurement of social networks and risk aversion, two remarks are in order. First, by using measures based on the random matching within sample game, which was conducted in 2008, I implicitly assume that the nature of the relationship between two randomly drawn individuals has not changed in the last seven years.[37] During the trial round, I tested this assumption, and went back in time with the set of questions regarding the relationship between the respondent and the match, i.e., how long have you known X? How frequently do you talk to X?, etc. Only a couple respondents mentioned a recent change in the relationship, in all cases caused by a quarrel between families. I could not test the set of questions regarding the knowledge the respondent has about his match's

[34] As farmers do not change their intercropping arrangement after switching to Bt cotton, including only the price of cotton as the output price is sufficient after having controlled for the cotton selection effect.

[35] Among these, the need for crop rotation, which is not observable, might potentially bias the social interaction effects of interest when one includes only the cotton farmers in the analysis. An example can make this clear. Imagine that the (reduced form) true model of social learning is the following: for each farmer one has observed adopting Bt cotton, the probability of adoption goes up with 10%. Imagine that a farmer has observed 5 farmers and would like to adopt Bt cotton, however due to crop rotation rules (an unobservable), the farmer delays his decision to adopt with one year, after which he has observed an additional three farmers. If this happens at a large scale, the effect of social learning might be biased downward. As such, in the panel data analysis, I dropped the ten households that according to their own account practice crop rotation and switch in and out of cotton farming.

[36] Even though in theory the landlord might have a say in the input choices of a farmer who shares-in land, in practice, this appears not to be the case in the three villages I consider. In 2007-08, 4.5% of the plots were shared-in or shared-out and only 2.3% of the cotton plots were shared-in or shared-out. In only one case, the respondent mentioned that the landlord had a say in choices of inputs, and this household did not farm cotton at any point in time and was not planning to farm cotton in 2008-09.

[37] Note that using the results of the random matching within sample method directly implies that I have no link for the pairs which involve a match that did not cultivate cotton in 2007-08. These links were set at zero, i.e., "no link". As 25% of the respondents who have farmed cotton in the last 7 years did not farm cotton in 2007-08, this might be a potential source of bias depending on the nature of this measurement error. This is not a problem for the regressions using the predicted links.

farming activities as the respondent could not recall the yield, pesticide use and cultivar choice of the match several years ago. However, using the predicted links based in the results of the random matching within sample game, I constructed an estimate of the year when the respondent heard first about Bt cotton and compared this with the year the respondent stated he heard first about Bt cotton. For the respondent who farm cotton in 2007-08, I correctly predict this year using the link "know the cultivar of X" (i.e., link no. 6 in Table 6), but have an estimate which is too early in 37.5% of the cases using the link "know the cultivar, pesticide use and yield of X" (i.e., link no. 7 in Table 6). This issue might cause the social learning coefficient to be biased downwards in the regressions based on the results of the random matching within sample game. Similarly, I constructed a measure of risk aversion based on a risk experiment that I conducted in 2007-08. By using the same coefficient across years, I assume that the risk preferences of the decision maker have not changed over time.[38] Second, the network measures based on the random matching within sample game also implicitly assume that the social network of farmers from whom each farmer learns, whom the farmer might imitate and by whom the farmer might feel pressurized does not exceed the village boundaries. The descriptive statistics suggest that this assumption is relatively innocious in the case of Aurepalle and Kanzara where, respectively, each year, on average, over 85% of the Bt farmers known to the respondent live in the village.[39] However, in Kinkhed, over 40% of the farmers known to the respondent who cultivate Bt cotton do not live in the village. The results of the random matching within sample experiment however suggest that one is unlikely to learn from these farmers about the profitability of Bt cotton as the two largest determinants of "knowing the pesticide use and yield" conditional on "knowing the cultivar" are living in the same neighborhood in the village and having a field neighboring X's field.

Finally, I assume that for all farmers both Bt and non-Bt cotton seeds are available in the market where they usually buy inputs. As only 11 farmers mentioned that they were unable to purchase the cultivar they intended to purchase with their usual seed dealer, availability of seeds does not seem to be a problem in the villages.[40] In addition, I assume that the profitability of non-Bt cotton[41] and the prices of all inputs and outputs are well known.[42]

[38] Using the results of the risk experiment, I calculate a risk aversion measure as the difference in willingness-to-pay for a bag of cotton seeds when moving from a baseline yield distribution to a yield distribution with the same mean but a higher variance (see Maertens and Just 2009). A larger coefficients indicates a higher degree of risk aversion.

[39] The village of Aurepalle consists of two sub-villages. Using the results of the random-matchin-within-sample one can compare the links between the residents of these two sub-villages. These show that conditional on knowing the cultivar of a match X, the respondent is almost 3 times as likely to know the yield of a match X that lives in the same sub-village versus a match that lives in the other sub-village.

[40] I deleted the three households from the panel data analysis who could not find a Bt or non-Bt cultivar of their choice and ended up buying, respectively, a non-Bt and Bt cultivar.

[41] This is a reasonable assumption as the large majority of the farmers who switch to Bt cotton have been farming cotton for several years. Only ten farmers make the switch from no cotton to Bt cotton directly, but even in these cases it is possible that these farmers have farmed cotton before 2001. At the minimum, these ten farmers have observed other farmers for minimum of ten years, which should be sufficient to establish their beliefs with regard to these well-known non-Bt cotton cultivars.

[42] This might be a strong assumption, especially with regard to the seed prices of Bt and non-Bt cotton. Even though I elicited expected price of seeds in 2008 and have the actual price paid in 2007-08, I cannot compare these two directly as the former was elicited on a per acre basis while the latter is in kg or bag, and the majority of the farmers did not stick to the recommended 1 bag per acre (most farmers use 2 to 8 bags per acre). Extrapolating their 2007-08 use to 2008-09, about 40 percent of the farmers who plan to grow cotton in 2008-09 correctly knew the price of the Bt cultivar. I however expect this figure to underestimate the

Starting with the results of the cross-sectional analysis, recall that to identify non-monetary effects I exploit the data on current beliefs regarding the profitability of Bt cotton versus non Bt cotton and compare these beliefs with the planned Bt cotton cultivation decisions for the 2008-09 season.

Using the results of the yield distribution game, and assuming a uniform distribution within each yield category, I calculated the expected profits and reconstructed the CDF of the profit of each cultivar (per acre) for each respondent at the time of the interview in 2008.[43]

Table 8 compares the plans to cultivate Bt cotton in 2008-09 with the subjective beliefs regarding the profitability of Bt cotton.[44] The results are presented as a percentage of the total number of farmers who plan to grow cotton in 2008-09 in, respectively, Aurepalle, Kanzara and Kinkhed. In Aurepalle, all 75 farmers who plan to grow cotton in 2008-09, plan to grow Bt cotton. All of these farmers expect a higher average profit for Bt cotton compared to non-Bt cotton. In Kanzara and Kinkhed, respectively, 13% and 3% of the farmers who plan to grow cotton in 2008-09, plan to grow Bt cotton despite the fact that they expect a lower average profit for Bt compared to non-Bt. As, in absolute terms, the variance of the Bt distribution is lower than the variance of the non-Bt distribution in 2 out of 4 of these cases, this result cannot be interpreted as a concern with the second-order moment of the distribution. In none of these cases the profit CDF of non-Bt cotton FOSD the profit CDF of Bt cotton. On the flipside, in Kanzara and Kinkhed, respectively, 22% and 45% of the farmers who plan to grow cotton in 2008-09, plan to grow non-Bt cotton despite the fact that they expect a lower average profit for non-Bt cotton compared to Bt cotton. In, respectively, 60% and 33% of these cases the profit CDF of Bt-cotton FOSD the profit CDF of non-Bt cotton.

Table 8: Beliefs versus future plans for 2008-09

knowledge of the farmers in this regard as the prices change from year to year, and the farmers, according to their own account, are generally well aware of these new prices. In addition, the prices are publicly advertised on boards in front of the shops in the mandal capital which is frequently visited by most farmers.

[43] The profit is defined as the output price multiplied by the output minus the paid out input costs. These paid out inputs do not include own labor. Using the 2007-08 data I checked that this input does not differ much between Bt cotton and non-Bt cotton. Note that the results of the yield distribution game provide values for all these variables except for the output price of cotton. To construct an individual-level output price, I use the 2007-08 input-output data collected and regress the output price of cotton on village dummies, the number of adult family members, the education level of the decision maker (years), the acreage of owned land, the square acreage of owned land and whether or not the household had a functional irrigation source in 2007-08. I determined the choice of these variables based on the analysis presented in Table D1 in the Appendix. By using this predicted price, I avoid the potential bias cause by unobservables correlated with both price and social interaction effects. It must be noted that the results did not change much when using the actual price (in combination with a village-average price for the respondents who did not farm cotton in 2007-08) instead of this predicted price. Note that, in the case of Aurepalle, the total amount expected to be paid for other inputs (all inputs excluding pesticides) was not recorded. I used the total amount paid for other inputs per acre in 2006-07 as a measure for the Bt cultivars and this amount minus 1671 Rs (the average difference in cost between Bt and non-Bt cultivars in 2006-07) as a measure for the non-Bt cultivars. It should be noted that the results presented here are robust with respect to this particular number '1671 Rs'. Two farmers could not answer all of the questions needed to conduct this analysis.

[44] In practice, as I have data on 2 Bt cultivars and 2 non-Bt cultivars, the expected profit of one of the Bt cultivars should be larger or equal to the expected profit of the two non-Bt cultivars in order to chose for Bt cotton.

	Aur	Kanz	Kink
(1) Cultivate Bt and $E[\pi_{BT}] > E[\pi_{NON-BT}]$	100.00	65.22	51.52
(2) Cultivate Bt but $E[\pi_{BT}] < E[\pi_{NON-BT}]$	0.00	13.04	3.03
(2') Cultivate Bt but $F\pi_{NON-BT}$ FOSD $F\pi_{BT}$ (% of 2)	NA	0.00	0.00
(3) Do not cultivate Bt but $E[\pi_{BT}] > E[\pi_{NON-BT}]$	0.00	21.74	45.45
(3') Do not cultivate Bt but $F\pi_{BT}$ FOSD $F\pi_{NON-BT}$(% of 3)	NA	60.00	33.33
Total (1+2+3)	100.00	100.00	100.00

Notes: (2') as a % of (2), (3') as a % of (3); NA = Not Applicable

Table 9 presents the average and variance of some selected characteristics of the groups introduced in Table 8. Note that group 1, group 2 and group 3 are three mutually exclusive groups that together include all cotton farmers of 2008-09. The $KNOWN$ variable refers to the "number of village farmers known that plan to cultivate Bt cotton in 2008-09" , the $OTHER\_BIOSAFETY$ variable is constructed as the average of the answers to: "To what degree do you think that other village farmers think that Bt cotton is hazardous for (1) animal health, (2) for human health, (3) for the environment").[45] The *sws_predicted* variable refers to the number of progressive farmers predicted to be known by cultivar name using the results of the the random matching within sample game (i.e., link no. 6 in Table 6) who plan to cultivate Bt cotton in 2008-09 as a % of the number of progressive farmers known who plan to cultivate cotton (see Appendix E for alternative measures of the number of progressive farmers known who plan to cultivate Bt cotton) The $CREDIT$ variable refers to whether or not the respondent believes he has access to credit from an input dealer[46] and the $wouldCREDIT$ variable refers to whether or not the respondent would (did) consider buying inputs on credit.

Table 9 shows that farmers in group (1), on average, know more village farmers that plan to cultivate Bt cotton in 2008-09 than farmers in group (2). Farmers in group (3), on average, know fewer village farmers that plan to cultivate Bt cotton in 2008-09 and are surrounded by farmers who are, on average, more concerned with bio-safety issues. Farmers in group (2) know, on average, according to *sws_predicted*, more progressive farmers who plan to cultivate Bt cotton as a % number of progressive farmers known who plan to cultivate cotton, compared to farmers in group (1). Disregarding the access to credit and the willingness to obtain credit, which is lower for farmers in group (3) compared to farmers in the other two groups, these results point at the existence of social pressures and (behavioral) imitation.

Table 9: Characteristics of the groups in Table 8 (mean and st. dev.)

	KNOWN	OTHER_BIOSAFETY
(1) Cultivate Bt and $E[\pi_{BT}] > E[\pi_{NON-BT}]$	34.35 (28.77)	2.73 (0.63)
(2) Cultivate Bt but $E[\pi_{BT}] < E[\pi_{NON-BT}]$	58.75 (37.05)	2.75 (0.16)
(3) Do not cultivate Bt but $E[\pi_{BT}] > E[\pi_{NON-BT}]$	16.95 (12.22)	3.00 (0.69)
(3') Do not cultivate Bt but $F\pi_{BT}$ FOSD $F\pi_{NON-BT}$	13.87 (12.78)	3.29 (0.89)

Table 9 (continue): Characteristics of the groups in Table 8 (mean and st. dev.)

[45] Reacll that all of these have five possible answers and a "don't know" option. The range of this aggregate variable is $[1, 5]$ with higher numbers refering to an increased concern with biosafety issues.

[46] As it appears that all farmers have access to some kind of credit, I constructed this alternative measure of credit access. This measure makes sense as there is little to no variation between the interest rate at which the various input dealers give loans within each region.

	sws_predicted	CREDIT	wouldCREDIT
(1) Cultivate Bt and $E[\pi_{BT}]>E[\pi_{NON-BT}]$	0.90 (0.14)	0.68 (0.47)	0.71 (0.45)
(2) Cultivate Bt but $E[\pi_{BT}]<E[\pi_{NON-BT}]$	0.97 (0.05)	1.00 (0.00)	0.75 (0.50)
(3) Do not cultivate Bt but $E[\pi_{BT}]>E[\pi_{NON-BT}]$	0.87 (0.11)	0.31 (0.47)	0.52 (0.51)
(3') Do not cultivate Bt but $F\pi_{BT}$ FOSD $F\pi_{NON-BT}$	0.93 (0.05)	0.37 (0.51)	0.62 (0.51)

Notes: CREDIT: 0=no access to credit from input dealer, 1=access to credit from input dealer; wouldCREDIT=0 would not (did not) consider buying inputs on credit, wouldCREDIT=1 would (did) consider buying inputs on credit

Continuing with the cross-sectional analysis of the 2008-09 data, Table 10 presents the results of a probit analysis (with robust standard errors) estimating the parameters of (12) using *sws_predicted* to capture the effect (behavioral) imitation and $OTHER\_BIOSAFETY/KNOWN$ to capture the influence of social pressures due to bio-safety concerns.[47] Both the probit coefficient and the marginal effects at the average are presented. The dependent variable is the discrete decision to plan to cultivate Bt cotton in Kharif 2008, conditional on cultivating cotton. This regression is preceded by a first-stage regression (results not reported) explaining the decision to cultivate cotton. The selection effect is captured by the Mills-ratio.[48] The analysis includes all Kanzara and Kinkhed households that had decided to cultivate cotton in the 2008-09 Kharif season, except for the progressive farmers.[49] As this regression excludes Aurepalle, I opted to use *sws_predicted* as this variable does not suffer from the potential correlated unobservable bias as *sws_actual* and the random matching within sample correctly included the most important progressive farmers in the village. The variable $OWN\_BIOSAFETY$, similar to the variable $OTHER\_BIOSAFETY$, is constructed as the average of the answers to "To what degree do you think that Bt cotton is hazardous for (1) animal health, (2) for human health, (3) for the environment".

The coefficient on $OTHER\_BIOSAFETY/KNOWN$ is significantly different from zero, and large and with a negative sign, pointing at the presence of social pressures. The coefficient on *sws_predicted* is not significantly different from zero, pointing at the absence of behavioral imitation. All the other variables, except for $CREDIT * Income$ have the expected sign, but only few are significantly different from zero. Due to the limited number of observations, the results of this regression necessarily need be taken with a grain of salt. Using the results of Table 10, one can look at the decision how many acreage to cultivate under Bt cotton, given that a farmer has decided to cultivate Bt cotton (i.e., the partial versus complete adoption decision). The results are reported in Table G1 Appendix G. The mean and variance of Bt cotton are significant, with the expected sign, and - as expected - the coefficient on $OTHER\_BIOSAFETY/KNOWN$ is no longer significantly different from zero and small, pointing at the fact that, conditional on adoption, social pressures due to bio-safety concerns do no longer matter.

[47] The mean of the profit of Bt is calculated as the average of the means of the profit of both Bt cultivars (and vice versa for non-Bt). Similarly, the variance of the profit of Bt is calculated as the average of the variances of the profit of both Bt cultivars (and vice versa for non-Bt).

[48] The results of the first stage regression, which in addition includes various measures of wealth, soil fertility, irrigation availability, weather expectations and the predicted prices of all crops, are available upon request.

[49] This analysis does not include the Aurepalle households as the measure of other input use is not comparable across states due to a mistake during the data collection stage. The respondents who said that they might cultivate Bt cotton in Kharif 2008 were given a 0.5 as a dependent value. Among the 132 farmers who plan to adopt Bt cotton in 2008-09, 22 did not cultivate cotton in 2007-08 and of these 22 farmers, 5 farmers have never cultivated cotton before, but as I am controlling in this analysis for the subjective beliefs regarding non-Bt cotton, I do not expect this lack of experience with farming cotton to influence the results.

Table 10: Probit regression plan to cultivate Bt cotton in 2008-09 with robust standard errors (N=47, Adj R2 0.57)

	Coeff.	dF/dx
Mean profit Bt (in 1,000 Rs)	0.385 (0.328)	0.00049 (0.00160)
Mean profit Bt square	-0.011 (0.023)	-0.00001 (0.00005)
Mean profit non-Bt cotton (in 1,000 Rs)	-0.388 (2.637)	-0.00050 (0.00397)
Mean profit non-Bt cotton square	-0.107 (0.266)	-0.00014 (0.00052)
Variance Bt cotton (in 1000,000 Rs)	-0.417 (0.310)	-0.00054 (0.00185)
Variance Bt cotton square	0.015 (0.012)	0.00002 (0.00007)
Variance non-Bt cotton (in 1000,000 Rs)	0.426 (1.346)	0.00055 (0.00251)
Variance non-Bt cotton square	0.003 (0.132)	0.00000 (0.00017)
sws_predicted	-0.748 (0.473)	-0.00096 (0.00311)
OTHER_BIOSAFETY/KNOWN	-3.086 (1.300)**	-0.00396 (0.01313)**
OWN_BIOSAFETY	-0.236 (0.507)	-0.00030 (0.00137)
Risk aversion coeff.	-0.001 (0.001)	0.00000 (0.00000)
Income (in 1,000 Rs)	0.055 (0.023)**	0.00007 (0.00024)**
CREDIT*Income (in 1,000 Rs)	0.076 (0.033)**	0.00010 (0.00031)**
wouldCREDITt*Income (in 1,000 Rs)	-0.044 (0.020)**	-0.00006 (0.00019)**
Mills ratio	-2.831 (1.436)**	-0.00364 (0.01180)**
Constant	9.670 (6.431)	

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% levelI

Moving on with the panel data analysis covering the period 2001-07, one remark is in order. Recall that both the ICRISAT-VLS data and the recall data collected in 2008 provide information on the binary decision to cultivate Bt cotton and the acreage under Bt and non-Bt cotton. I opt to use the recall data for the descriptive statistics and the analysis as the ICRISAT-VLS data does not always contain information on which cultivar is used (in terms of Bt versus non-Bt) and, in addition, the input-output information is sometimes missing for households classified as agricultural laborers and/or households who lease in land.[50]

Table G2 and G3 in Appendix G present the results of, respectively, a "naive" regression assuming global interactions, i.e., everyone interacts with everyone, in the village and a regression based on the total number of farmers known cultivating Bt cotton in each time period using specification (10). These analyses includes all cotton farmers up to (and including) the first year they adopt Bt cotton. The self-selection effect into the cotton-farming status is captured by the Inverse Mills ratio in the case of Table G3.[51] These regressions exclude the progressive farmers as these not subject to any imitation or social pressure effect and thereby ensuring a one-way interaction effect between the farmer and

[50] Comparing the two sources of data reveals that in 80% of the cases the binary cotton cultivation decision in the recall data corresponds with the ICRISAT-VLS data, and conditional on cultivating cotton according to the recall data, in 77% of the cases the binary Bt cotton cultivation decision in the recall data corresponds with the ICRISAT-VLS data. As I collected data on the binary cotton and Bt cotton decision in several modules of the questionnaire and these are consistent with each other, I am confident of a high quality of the recall data, as far as these binary decisions are concerned.

[51] In case of split-off households or households that have been recently added to the ICRISAT-VLS, households were considered for inclusion in the analysis from the date of split-off or inclusion in the ICRISAT-VLS onwards. Recall also that the households facing seed availibility or crop rotation constraints are not included in the analysis.

the progressive farmer and avoiding issues of endogeneity in this regard. Both the probit coefficient and the marginal effects at the average are presented. The prices used are individual-level predicted prices for each period t.[52]

The variable "soil fertility" refers to the number of plots the farmer has access to (owned, leased/shared in, leased/shared out) larger or equal to one acre of "good" or "very good" quality (as perceived by the farmer). The measure for credit constraints and risk aversion are constructed in the same way as in the cross sectionaly analysis, as such I assume that these attributes of the individual do not change over time. The variable "irrigation-constraint" is an individual-level effect captures whether or not the farmer, in the past seven year, ever has faced a situation where he wanted to give additional irrigation to his cotton crop, but there was insufficient water available to him. The selection regressions contains additional measures of wealth, weather expectations, output prices, soil fertility and irrigation constraints.[53]

From the "naive" regression in Table G2, one can see that the cumulative number of

[52] The input-output and Y-modules of the ICRISAT-VLS 2001-07 data contain a year, individual, plot and activity specific price for each input and output, not including the cost of credit. In case no market transaction took place the price provided is an estimate by the enumerator or respondent on the field. Simularly, the 2007-08 data contains also individual, plot and activity specific prices, but only for the items for which a market transaction took place. I selected a set of input and output prices, relevant to the cotton cultivation decision. The choice of which output prices to include is complex, as the competing crops change each year. I based my choice on the number of farmers who cultivate a certain crop in 2007-08 and included cotton, blackgram, greengram, sorghum, rice, cowpea, pigeonpea, soyabean and castor. Note that as the output prices are not know per crop in 2001-02 in the input-output schedule, I used the production and utilisation schedule instead for this year. In terms of fertilizers and pesticide prices, I compute the 'average price' of fertilizers (pesticides) for each individual as follows: the sum of the total value spent on fertilisers (pesticides) divided by the total amount of fertilsers in kg (liter), excluding farm yard manure and the price of labor. Note that these prices are a function of the input choice of farmers in terms of fertilisers (pesticides). Constructing this average price for fertilizers and pesticides is necessary as the available fertilizers and pesticides change each year and for 2004-05 and 2002-03 no information is available on the type of fertilizers and pesticides used. In terms of other input prices, as the Bt plots -as evident from the 2007-08 input-output data - on average receive more inputs, the set of relevant prices must include all other input prices, namely the price of female, male and bullock labor and the rent of a tractor. I then compute an year/individual specific average using the various plot and activity specific prices of the kharif seaon (except for 2001-02 and 2002-03 which use both kharif and rabi prices as they cannot be separated out), I then predict the price that each individual farmer faces each year using the following OLS regression $p_{ijt} = \beta_0 + \beta_1 L_{ijt} + \beta_2^2 L_{ijt}^2 + VT_{jt} + IRRI_{ijt} + \epsilon_{ijt}$, where L stands for the acreage of land owned, $IRRI$ is a dummy variable capturing whether or not the farmer has irrigable land and VT stands for a time-village level fixed effect. In terms of seed costs, as the seed costs are not always known per crop in 2001-04 and the unit is not always recorded in the later years, I used the medium price for non-Bt cotton seeds, excluding the outliers in this calculation, and the official Bt price for Bt seeds. Finally, I deflate the price series using the State-wise Consumer Price Index Numbers for Agricultural Labourers in India available from INDIASTAT. The units of the prices are kg for the output prices, liters for pesticides, kg for fertilizers, kg for seeds, days for manual labor (a day of labor is 6 hours in the Akola villages and 8 hours in Aurepalle) and hours for the use of a tractor.

[53] As not all the VLS years contain data on the value of soil in Rs/acre, I construct a soilfertility measure based on the perceived quality of soil in the VLS panel data. The soilfertility1 measures whether or not the farmer has access to (owned, leased/shared in, leased/shared out) a plot of "good" or "very good" quality. The soilfertility2 equals the number of plots larger or equal to one acre of "good" or "very good" quality, and is also used in the main equation. As no landholding module was included in the 2002-03 and 2003-04 round, I extrapolated the information of, respectively, 2001-02 and 2004-05. As it is important to distinguish irrigable land from irrigated land, I included two variables capturing the actual irrigation status of a plot. The actualirrigation1 variable equals to 1 if a cotton plot was irrigated and 0 if a cotton plot was not irrigated. The actualirrigation2 variable equals the percentage of cotton plots (of all cultivated cotton plots) that did not require any additional irrigation (as perceived by the respondent). These two variables are calculated from the recall data collected in 2008 as no such measure was available in the VLS panel data.

past adopters in the village positively affect the farmer's propensity to cultivate Bt cotton. The current behavior of others in the village, captured through the mean acreage of owned land in the village, also positively influence the farmer's propensity to cultivate Bt cotton, pointing at positive contemporaneous social-interaction effects.

From Table G3, one can see that the coefficients on the total number of adopters known from the village and from outside of the village are not significantly different from zero.[54] The effect of non-farmer information on Bt cotton adoption is significant, positive, concave and large. Hearing from one input dealer, company agent or government extension agent about Bt cotton (ignoring the concavity) increases the probability of adoption with almost 4%.[55] The other social effect including social pressures, imitation and free rider effects, have a significant, positive effect, indicating that positive social pressure and imitation effects dominate negative free rider effects, if present. But the effect is small in size. Note however that this effect might be biased due to the fact that the farmers in the village make their decision simultanous and, as such, the current behavior of other farmers is endogenous. The effects of the irrigation constraint, cotton price and pesticide price are significant with the expected sign. The effects of owned land and the price of non-Bt cotton seed are also significant, but have the opposit sign as expected. The Aurepalle village fixed effect, capture the difference in bollworm pressure between the two regions, is significant, negative and large. Note that 99 observations were dropped after the inclusion of an Aurepalle*before2005 fixed effect (which I included to capture the difference state level policies in the pre-2005 period).

Tables 11 and 12 presents the results of the panel data analysis using specification (11). Again, this analysis includes all cotton farmers up to (and including) the first year they adopt Bt cotton, excluding the progressive farmers and conditional on cotton cultivation. Both the probit coefficient and the marginal effects at the average are presented. As Aurepalle is included in this analysis, and the random matching within sample game did not include the most important progressive farmers in Aurepalle, I opted to define the set of progressive farmers from whom the farmer might learn as the set of progressive farmers who, according to their own account, believe that the respondent knows their cultivar use and yield output. Similarly, the ratio of progressive farmers adopters at t equals the set of progressive farmers who, according to their own account, talk on an at least monthly basis to farmer i.

Table 12 presents the results using the current behavior of fellow farmers to measure the effects of social pressures, but as this behavior might be endogenous to the model, Table 13 shows the results of an instrumental variable approach, using the behavior of fellow farmers in the previous period instead.

[54] Including an interaction term of learning with the average experience of other farmers up to $t-1$ does not significantly change the results. Note that including an interaction term using an ordinal variable measuring experience of a group of other farmers ("very positive" up to "very negative") poses an aggregation problem across years. I use the average experience of the other farmers over time up to $t-1$.

[55] In all specifications, the non-farmer information excluded the information received from input/seed dealers in May/June to avoid problems of endogeneity.

Table 11: Probit, 2001-07, cultivate Bt cotton, first-time adopters, specification (10). (N=408, Pseudo R2=0.69)

	Coeff.		dF/dx	
	Coeff.	St. Error	dF/dx	St. Error
Non-farmer information up to t	1.62071***	0.49395	0.02674***	0.02358
Non-farmer information up to t square	-0.92213***	0.25961	-0.01521***	0.01281
Total number of PF adopters known up to t-1	0.12049	0.16942	0.00199	0.00312
Total number of PF adopters known up to t-1 square	-0.00357	0.01536	-0.00006	0.00026
Total number of fellow farmers adopters known up to t-1	0.01727***	0.00650	0.00028***	0.00028
Total number of fellow farmers adopters known up to t-1 square	-0.00002**	0.00001	0.00000**	0.00000
Ratio of PF adopters at t	4.37440*	2.30556	0.07218*	0.07457
Ratio of PF adopters at t square	-2.02385	2.21196	-0.03339	0.05300
Ratio of fellow farmers adopters at t	-0.16156	2.76702	-0.00267	0.04535
Ratio of fellow farmers adopters at t square	0.49924	2.87170	0.00824	0.04670
Risk aversion coeff.	0.00003	0.00072	0.00000	0.00001
Education head (years)	0.05095	0.04785	0.00084	0.00113
Owned land (acre)	-0.08211	0.06582	-0.00135	0.00151
CREDIT*owned land	0.06145	0.05810	0.00101	0.00106
wouldCREDIT*owned land	0.05131	0.05733	0.00085	0.00130
irrigationconstraint	-0.57645*	0.29988	-0.01451*	0.01482
soil fertility	0.13768	0.15484	0.00227	0.00298
P male (predicted) (day)	-0.39516**	0.16682	-0.00652**	0.00488
P female (predicted) (day)	0.62938***	0.17575	0.01038***	0.00780
P bullock (predicted) (day)	0.06689***	0.02571	0.00110***	0.00072
P tractor (predicted) (hour)	0.00629	0.01862	0.00010	0.00034
P cotton (predicted) (kg)	0.47064**	0.20916	0.00777**	0.00510
P fertilizer (predicted) (kg)	-0.02206	0.22335	-0.00036	0.00365
P pesticides (predicted) (l)	0.00444**	0.00214	0.00007**	0.00005
P non-Bt seed (kg)	0.00260	0.00324	0.00004	0.00006
P Bt seed (kg)	0.00139**	0.00060	0.00002**	0.00002
Andhra Pradesh dummy	-0.98675	2.43610	-0.00992	0.01897
Inverse Mills Ratio	0.23573	0.36754	0.00389	0.00607
Constant	-26.04182***	5.44059		

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level

Tables 11 and 12 show that farmers learn from the experiences of fellow farmers but not from the experience of progressive farmers. Disregarding the concave effect, for every ten fellow farmers known who adopted Bt cotton in the past, on average, the probability of adoption increases with 24%. The influence of non-farmer sources is much larger than the influence of fellow farmers, with a coefficient about 26 times the size of the coefficient on "total number of fellow farmers adopters known up to t-1".

The effect of the current behavior of progressive farmers, is positive, significant (at the 1% level) and very large: if all progressive farmers a farmer know would adopt Bt cotton in the current period, the farmer would, according to the predictions, also switch to Bt cotton according to Table 12. The effect of the current behavior of fellow farmers in Table 11 is not significantly different from zero. Similarly, the effect of the behavior of fellow farmers in the previous period is not significantly different from zero. This might imply neither free-rider effects or social pressures are present, or that that free-rider effects counteract social pressure effects. The results from the qualitative interviews and the cross-sectional analysis point at the latter explanation.

Table 12: Probit, 2001-07, cultivate Bt cotton, first-time adopters, IV specification (11). (N=408, Pseudo R2=0.69)

	Coeff.		dF/dx	
	Coeff.	Std. Error.	dF/dx	St. Error
Non-farmer information up to t	1.64020***	0.50194	0.63501***	0.37037
Non-farmer information up to t square	-0.92124***	0.25809	-0.35666***	0.20196
Total number of PF adopters known up to t-1	0.06210	0.18194	0.02404	0.07160
Total number of PF adopters known up to t-1 square	0.00329	0.01788	0.00127	0.00693
Total number of fellow farmers adopters known up to t-1	0.02421***	0.00876	0.00937***	0.00553
Total number of fellow farmers adopters known up to t-1 square	-0.00006*	0.00003	-0.00002*	0.00002
Ratio of PF adopters at t	4.81970**	2.42929	1.86596**	1.30667
Ratio of PF adopters at t square	-2.40761	2.39622	-0.93211	1.04245
Ratio of fellow farmer adopters at t-1	-40.05902	26.41166	-15.50890	17.47913
Ratio of fellow farmer adopters at t-1 square	244.24150	186.83440	94.55840	117.72260
Risk aversion coeff.	0.00008	0.00071	0.00003	0.00027
Education head (years)	0.06980	0.04837	0.02702	0.02549
Owned land (acre)	-0.06823	0.07014	-0.02642	0.02615
CREDIT*owned land	0.03414	0.06302	0.01322	0.02284
wouldCREDIT*owned land	0.05428	0.05544	0.02102	0.02350
irrigationconstraint	-0.60065*	0.31312	-0.23511*	0.12982
soil fertility	0.18131	0.16124	0.07019	0.06711
P male (predicted) (day)	-0.32417	0.16754	-0.12550	0.07958
P female (predicted) (day)	0.53467	0.18059	0.20700	0.11342
P bullock (predicted) (day)	0.06773	0.02754	0.02622	0.01452
P tractor (predicted) (hour)	0.00064	0.01877	0.00025	0.00726
P cotton (predicted) (kg)	0.49342**	0.21339	0.19103**	0.11851
P fertilizers (predicted) (kg)	-0.10472	0.21658	-0.04054	0.08259
P pesticides (predicted) (l)	0.00495**	0.00222	0.00191**	0.00116
P non-Bt seed (predicted) (kg)	0.00299	0.00326	0.00116	0.00140
P Bt seed (official) (kg)	0.00118*	0.00063	0.00046*	0.00031
Andhra Pradesh dummy	-0.74307	2.55270	-0.26235	0.81499
Inverse mills ratio	0.16302	0.37932	0.06312	0.14728
Constant	-25.68171	5.76040		

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level

7 Conclusion

The results demonstrate the importance of knowledge about the profitability of a new technology in the adoption decision. This knowledge is established through observing other farmers' profits and talking to input dealers, company representatives and government extension agents. Using panel data covering seven cropping seasons, I show that for first-time adopters, the last channel, i.e., talking to non-farmer sources is the most important channel to learn about the profitability of Bt cotton and driver to switch to switch to Bt cotton. This makes sense, as the farmer learns about the the general properties of the new technology (mean, variance) and proper input use through these conversations. The second most important source of information for first-time adopters is fellow farmers in the village. Surprisingly, the past adoption behavior of the progressive farmers one is connected to matters little.

I find strong evidence of farmers imitating the progressive farmers in the village, i.e., adopting Bt cotton without having observed the yield outcomes of these progressive farmers. This imitation effect takes the shape of learning-imitation and is a function of the the number of progressive farmers known who currently cultivate Bt cotton as a ratio of the total number of progressive farmers known who currently cultivate cotton. In all specifications, the learning effect is concave, suggesting decreasing returns to new information coming in.

Using the data on current beliefs regarding the profitability of Bt cotton versus non Bt cotton and the planned cropping pattern for the 2008-09 season, I find little evidence of the presence of (behavioral) imitation but strong evidence of the presence of social pressures inhibiting the adoption of Bt cotton. These social pressures find its origin in bio-safety concerns with regard to Bt cotton: a farmer may be accused of endangering the health of the animals and people in the village as well as generating negative impacts on the soil fertility and water quality of neighboring plots. Using the panel data, I do not find any evidence of social pressures. This is probably due to the fact that the free-rider effects and social pressures counteract each other.

References

Antle, John M. and Prabhu L. Pingali. 1994. "Pesticides, Productivity, Farmer Health: A Philippine Case Study." *American Journal of Agricultural Economics*, 76:3, pp. 418-30.

Appadurai, Arjun. 1989. "Transformations in the Culture of Agriculture," in *Contemporary Indian Tradition: Voices on Culture, Nature and the Challenge of Change*. Carla M. Borden ed. Washington and London: The Smithsonian Institution Press, pp. 173-186.

Asia-Pacific Consortium of Agricultural Biotechnology. 2006. *Bt Cotton in India - A Status Report*. New Delhi.

Baird, Sarah. 2003. "Modeling Technology Adoption Decisions: An Analysis of High Yielding Variety Seeds in India During the Green Revolution." Working Paper. Department of Agricultural and Resource Economics, University of California at Berkeley.

Bandiera, Oriana and Imran Rasul. 2006. "Social Networks and Technology Adoption in Northern Mozambique." *Economic Journal*, 116:514, pp. 869-902.

Bantilan, M.C.S., P. Anand Babu, G.V. Anupama, H. Deepthi, and R. Padmaja. 2006. "Dryland Agriculture: Dynamic Challenges and Priorities." Research Bulletin No. 20, GT-IMPI, ICRISAT.

Barrett, Christopher B. 2005a. "Smallholder Identities and Social Networks The Challenge of Improving Productivity and Welfare," in *The Social Economic of Poverty: On Identities, Communities, Groups and Networks*. Christopher B. Barrett ed. London and New York: Routledge, pp. 214-43.

Barrett, Christopher B. ed. 2005b. *The Social Economics of Poverty. On Identities, Communities, Groups and Networks*. London and New York: Routledge.

Basu, Kaushik. 2000. *Prelude to Political Economy: A Study of the Social and Political Foundations of Economics*. Oxford University Press.

Bertrand, Marianne and Sendhil Mullainathan. 2001. "Do People Mean What They Say? Implications for Subjective Survey Data." MIT Economics Working Paper No. 01-04.

Besley, Timothy and Anne Case. 1993. "Modeling Technology Adoption in Developing Countries." *American Economic Review*, 83:2, pp. 396-402.

Binswanger, Hans P. 1980. "Attitudes toward Risk: Experimental Measurement in Rural India." *American Journal of Agricultural Economics*, 62:3, pp. 395-407.

Borelli, Sara. 2009. "Social Aspects of Drug Use in Djibouti: The Case of the Leaf of Allah." *Journal of African Economies*, 18:4, pp. 555–591.

Bramoullé, Yann, Habiba Djebbari, and Bernard Fortin. 2009. "Identification of peer effects through social networks." *Journal of Econometrics*, 150, pp. 41-55.

Chamley, Christophe P. 2004. *Rational Herds, Economic Models of Social Learning*. Cambridge University Press.

Conley, Timothy G and Christopher Udry. Forthcoming. "Learning About a New Technology: Pineapple in Ghana." *American Economic Review.*

Crost, Benjamin, Bhavani Shankar, Richard Bennett, and Stephen Morse. 2007. "Bias from Farmer Self-Selection in Genetically Modified Crop Productivity Estimates: Evidence from Indian Data." *Journal of Agricultural Economics*, 58:1, pp. 24-36.

David, G. Shourie and Y.V.S.T. Sai. 2002. "Bt Cotton: Farmer's Reactions." *Economic and Political Weekly*, November 16, 2002.

Delavande, Adeline, Xavier Giné, and David McKenzie. 2008. "Measuring Subjective Expectations in Developing Countries: A Critical Review and New Evidence." Policy Research working paper World Bank no. WPS 4824.

Dev, S. Mahendra and N. Chandrasekhara Rao. 2006. "Socio-Economic Impact Assessment of Transgenic Cotton in Andhra Pradesh." Working Paper. Center for Economic and Social Studies, Hyderabad.

Doherty, V.S. 1982. "A Guide to the Study of Social and Economic Groups and Stratification in ICRISAT's Indian Village Level Studies." Working Paper GT-IMPI, ICRISAT.

Engle-Warnick, Jim, Javier Escobal, and Sonia Laszlo. 2006. "Risk Preference, Ambiguity Aversion and Technology Choice: Experimental and Survey Evidence from Peru." Presented at NEUCD 2006 at Cornell University.

Marcel Fafchamps and Flore Gubert, forthcoming. "Risk Sharing and Network Formation" . *American Economic Review Papers and Proceedings*.

Feder, Gechon and Sara Savastano. 2006. "The Role of Opinion Leaders in the Diffusion of New Knowledge: The Case of Integrated Pest Management." *World Development*, 34:7, pp. 1287-300.

Feder, Gechon, Richard Just, and David Zilberman. 1985. "Adoption of Agricultural Innovations in Developing Countries: A Survey." *Economic Development and Cultural Change*, 32:2, pp. 255-97.

Floyd, C.N., A.H. Harding, D.P. Paddle, D.P Rasali, K.D. Subedi, and P.P. Subedi. 1999. "The Adoption and Associated Impact of Technologies in the Western Hills of Nepal." Agricultural Research and Extension Network Paper No. 90.

Foster, Andrew D. and Mark R. Rosenzweig. 1995. "Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture." *Journal of Political Economy*, 103:6, pp. 1176-209.

Griliches, Zvi. 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica,* 25:4, pp. pp. 501-522.

Hogset, Heidi and Christopher B. Barrett. Forthcoming. "Social Learning, Social Influence and Projection Bias: A caution on inferences based on proxy–reporting of peer behavior." *Economic Development and Cultural Change.*

Hubbell, Bryan J., Michele C. Marra, and Gerald A. Carlson. 2000. "Estimating the Demand for a New Technology: Bt Cotton and Insecticide Policies." *American Journal of Agricultural Economics*, 82:1, pp. 118-32.

ISAAA, International Service for the Acquisition of Agri-Biotech Applications 2005. "The Story of Bt Cotton in India - Video."

Jackson, Matthew O. and Brian W. Rogers. 2007. "Meeting Strangers and Friends of Friends: How Random Are Social Networks." *American Economic Review*, 97:3, pp. 890-915.

Krishnan, Pramila and Emanuela Sciubba. 2009. "Links and Architecture in Village Networks." *Economic Journal,* 119:537, pp 917-949.

Leibenstein, H. 1950. "Bandwagon, Snob, and Veblen Effects in the Theory of Consumers' Demand." *Quarterly Journal of Economics*, 64:2, pp. 183-207.

Liu, Elaine. 2008. "Time to Change What we Sow: Risk Preferences and Technology Adoption Decisions of Cotton Farmers in China." Job-Market Paper. Department of Economics. Princeton University

Lybbert, Travis J. 2006. "Indian Farmer's Valuation of Yield Distributions: Will Poor Farmers Value 'Pro-Poor' Seeds?" *Food Policy*, 31:5, pp. 415-41.

Lybbert, Travis J. and David R. Just. 2007. "Is Risk Aversion Really Correlated with Wealth? How Estimated Probabilities Introduce Spurious Correlation " *American Journal of Agricultural Economics*, 89:4, pp. 839-1224.

Lybbert, Travis J., Christopher B. Barrett, John G. McPeak, and Winnie K. Luseno. 2007. "Bayesian Herders: Updating of Rainfall Beliefs in Response to External Forecasts." *World Development* 35:3, pp. 480–97.

Maertens Annemie and David Just. 2009. "Marginal Versus Average Risk Aversion." Working Paper, AEM, Cornell University.

Manski, Charles F. 1993. "Identification of Social Interaction: The Reflection Problem." *Review of Economic Studies*, 60:3, pp. 531–542.

Moscardi, Edgardo and Alain de Janvry. 1977. "Attitudes toward Risk among Peasants: An Econometric Approach." *American Journal of Agricultural Economics*, 59:4, pp. 710-16.~

Moser, Christine M and Christopher B. Barrett. 2006. "The Complex Dynamics of Smallholder Technology Adoption: The Case of SRI in Madagascar." *Agricultural Economics*, 35:3, pp. 373–388.

Naik, Gopal, Matin Qaim, Arjunan Subramanian, and David Zilberman. 2005. "Bt Cotton Controversy: Some Paradoxes Explained." *Economic and Political Weekly*, April 9 2005, pp. 1514-17.

Narayanamoorthy, A and S. S. Kalamkar. 2006. "Is Bt Cotton Cultivation Economically Viable for India Farmers? An Empirical Analysis." *Economic and Political Weekly*, June 30, 2006, pp. 2716-24.

Pemsla, D., H. Waibela, and J. Orphalb. 2004. "A Methodology to Assess the Profitability of Bt-cotton: Case Study Results from the State of Karnataka, India " *Crop Protection*, 23:12, pp. 1249-57.

Pingali, Prabhu L., Cynthia B. Marquez, and Florencia G. Pelis. 1994. "Pesticides and Philippine Rice Farmers Health: A Medical and Economic Analysis." *American Journal of Agricultural Economics*, 76:3, pp. 587-92.

Pomp, Marc and Kees Burger. 1995. "Innovation and Imitation: Adoption of Cocoa by Indonesian Smallholders." *World Development* 23:3, pp. 423-31.

Qaim, Matin and David Zilberman. 2003. "Yield Effects of Genetically Modified Crops in Developing Countries." *Science*, 299: 7 February 2003, pp. 900-902.

Qaim, Matin, Arjunan Subramanian, Gopal Naik, and David Zilberman. 2006. "Adoption of Bt Cotton and Impact Variability: Insights from India." *Review of Agricultural Economics*, 28:1, pp. 48-58.

Qaim, Matin. 2003. "Bt Cotton in India: Field Trial Results and Economic Projections." *World Development*, 31:12, pp. 2115–27.

Rao, K.P.C, 2008. "Documentation of the Second Generation Village Level Studies 2001-2004". GT-IMPI, ICRISAT.

Rao, K.P.C. and Kumara D. Charyulu. 2007. "Changes in Agriculture and Village Economies." Research Bulletin no 21, GT-IMPI, ICRISAT.

Rogers, Everett. 1962. *Diffusion of Innovations.* New York: Free Press.

Saha, Atanu, C. Richard Shumway, and Hovav Talpaz. 1994. "Joint Estimation of Risk Preference Structure and Technology Using Expo-Power Utility." *American Journal of Agricultural Economics*, 76:2, pp. 173-84.

Santos, Paulo and Christopher B. Barrett. June 2007. "Understanding the Formation of Social Networks." Working Paper Cornell University.

Scott, John. 1991. *Social Network Analysis: A Handbook.* London - Newburry Park - New Delhi: Sage Publications.

Singh, R.P., Hans P. Binswanger, and N.S. Jodha. 1985. "Manual of Instructions for Economic Investigators in ICRISAT's Village Level Studies (Revised)." GT-IMPI, ICRISAT.

Stephens, Emma C. August 2007. "Feedback Relationships between New Technology Use and Information Networks: Evidence from Ghana." Working Paper Pitzer College.

Stone, Glenn Davis. 2007. "Agricultural Deskilling and the Spread of Genetically Modified Cotton in Warangal." *Current Anthropology* 48:1, pp. 67-103.

Subramanian, Arjunan and Matin Qaim. 2009. "Village-wide Effects of Agricultural Biotechnology: The Case of Bt Cotton in India." *World Development*, 37:1, pp. 256-267.

Sunding, David and David Zilberman. 2001. "The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector," in *Handbook of Agricultural Economics*. Bruce L Gardner and Gordon C. Rausser eds: Elsevier Science, pp. 207-61.

Vasavi, A. R. 1994. "'Hybrid Times, Hybrid People': Culture and Agriculture in South India." *Man*, 29:2, pp. 283-300.

Walker, Thomas S. and James G. Ryan. 1990. *Village and Household Economies in India's Semi-Arid Tropics*. Baltimore and London: John Hopkins University Press.

Appendix A

In 2007-08, I interviewed 128 households in Aurepalle, 63 households in Kanzara and 55 households in Kinkhed. Not all of these households were part of the VLS sample in 2001-02. Table A1 lists the number of households in the sample, by date included in the ICRISAT VLS. In Kinkhed, for instance, of the 55 households currently in the VLS, only 29 were in the VLS in 2001-02, 2, 22, 1 and 1 were added, respectively, in 2003-04, 2005-06, 2006-07 and 2007-08.

Table A1: Number of households included in the sample, by date included in VLS

	Aurepalle	Kanzara	Kinkhed
From 2001-02 onwards	94	46	29
From 2002-03 onwards	0	0	0
From 2003-04 onwards	5	0	2
From 2004-05 onwards	0	0	0
From 2005-06 onwards	18	13	22
From 2006-07 onwards	11	4	1
From 2007-08 onwards	0	0	1
Total sample	128	63	55

Appendix B

In 2007-2008, I interviewed 246 ICRISAT-VLS households and an additional 21 progressive farmers that were not part of the ICRISAT-VLS at the time of the interview. Of these 246 ICRISAT-VLS farmers, I labelled 22 as "progressive farmers". As such, in total, there are 43 progressive farmers in the sample. Tables B1 to B3 show how these progressive farmers are different from the other households. On average, the progressive farmers are higher educated, own more land, of which a larger share is irrigated, compared to the remainder of the sample. The progressive farmers are far more likely to adopt Bt cotton and, conditional on adoption, achieve a higher profit per acre, adopt the new technology earlier compared to the remainder of the sample. The exceptionally low profit per acre of the Kinkhed progressive farmers is due to the crop failure of two progressive farmers in the village due to floods.

Table B1: Progressive farmers characteristics (Aurepalle)

	Non-progressive farmers			Progressive farmers		
	N	Mean	St. Dev.	N	Mean	St. Dev.
Per acre profit of Bt cotton	48	6,588	6,753	11	10,349	3,422
First year of adoption	49	2006.22	0.47	21	2006.20	0.89
Number of household members	116	4.15	1.55	28	4.29	2.66
Education level decision maker	116	2.24	3.98	28	4.2	4.77
Owned dry land (acre)	116	2.10	2.42	28	7.10	8.40
Owned irrigated land (acre)	116	0.64	1.36	28	7.31	8.76
% adopted Bt cotton at any point in time	116	42		28	75	

Note: All variables, except for the first year of adoption and the % adopted Bt cotton at any point in time relate to the year 2007-08

Table B2: Progressive farmers characteristics (Kanzara)

	Non-progressive farmers			Progressive farmers		
	N	Mean	St. Dev.	N	Mean	St. Dev.
Per acre profit of Bt cotton	15	4,783	5,240	4	6,183	1,1691
First year of adoption	23	2004.48	1.56	6	2003.67	1.97
Number of household members	59	4.86	1.78	6	6.67	4.27
Education level decision maker	59	6.34	3.98	6	10.50	2.81
Owned dry land (acre)	59	2.17	4.46	6	0.00	0.00
Owned irrigated land (acre)	59	20.06	3.79	6	18.37	6.23
% adopted Bt cotton at any point in time	59	38		6	100	

Note: All variables, except for the first year of adoption and the % adopted Bt cotton at any point in time relate to the year 2007-08

Table B3: Progressive farmers characteristics (Kinkhed)

	Non-progressive farmers			Progressive farmers		
	N	Mean	St. Dev.	N	Mean	St. Dev.
Per acre profit of Bt cotton	1	3,959	NA	4	-214	2,311
First year of adoption	1	2007.00	NA	7	2005.85	0.75
Number of household members	49	4.53	1.86	9	4.44	1.24
Education level decision maker	49	6.35	3.61	9	11.56	2.70
Owned dry land (acre)	49	2.20	4.44	9	7.13	6.25
Owned irrigated land (acre)	49	1.49	2.91	9	13.08	7.71
% adopted Bt cotton at any point in time	49	2		9	77	

Note: All variables, except for the first year of adoption and the % adopted Bt cotton at any point in time relate to the year 2007-08; NA=not applicable

Appendix C

Regarding the selection of the progressive farmers for the random matching within sample game, recall that only 4 progressive farmers were selected for each village out of these 43 progressive farmers. In the case of Aurepalle, 2 different sets of progressive farmers were identified, one for the main village of Aurepalle and one for the sub-village of Nallavaripalli. Each Aurepalle farmer was then matched up with the three main progressive farmers of Aurepalle and the main progressive farmers of Nallavaripalle and vice versa. The idea was to select all progressive farmers who could play a central role in the dispersion of information and potentially be role models for the farmers and as such the object of imitation.

In order to get a sense of how successful this selection was, I compare the result of two social network questions, one from the perspective of the non-progressive farmers, the other from the perspective of the progressive farmers, with the farmers selected for the game.

From the perspective of the non-progressive farmers, Table C1 presents the results of the question "If you, today, would have a specific problem with your cotton crop who or where would you go to (up to 5 answers allowed)?"[56] Of all the village farmers mentioned by the respondents, I could retrieve data for 80% to 92% of the cases[57] and 63% to 91% were labelled as "progressive farmer" before the data collection started. In Aurepalle and Kinkhed about 40% of the farmers mentioned by all the VLS respondents of these were selected for the random matching within sample game. The low percentage in Aurepalle is due to the fact that several Aurepalle farmers in case of trouble would approach a progressive farmer located in Nallavaripalle. This was confirmed by the ICRISAT-VLS resident investigators in Aurepalle who mentioned that "Aurepalle does not have any real progressive farmers, these are all in Nallavaripalle". The low percentage in Kinkhed, on the other hand, is due to the fact that many respondents would approach farmers that were not labelled progressive farmers

Table C1: Selection of progressive farmers for the random matching within sample game (as % of village farmers mentioned by all VLS respondents)

	Data available	Labelled PF	Selected for game
Aurepalle	79.65	76.21	37.29
Nallavaripalle	92.30	90.38	78.85
Kanzara	89.74	78.21	70.51
Kinkhed	89.09	62.73	40.00

From the perspective of the progressive farmers, Tables C2 mentions the rank of the 4 progressive farmers selected for the game in terms of the variable "pf_TALK". This variable "pf_TALK" indicates the number of VLS farmers the progressive farmers talks to on an at least monthly basis. Thus the progressive farmer with rank one talks to the largest number of VLS farmers (compared to the other progressive farmers)[58] In the case

[56] This question was asked to all the respondents who ever cultivated cotton since 2001-02 or who plan to cultivate cotton in the future.

[57] The remainder of the farmers referred to were not part of the ICRISAT-VLS or the set of progressive farmers identified before the data collection started.

[58] I asked each progressive farmer (both VLS and non-VLS) to tell us, for each VLS respondent, whether he talks daily, weekly, monthly, yearly, twice a year or never to this person. The variable "TALK" was constructed as the sum of the number of individuals each progressive farmer talks to on a daily, weekly and monthly basis.

of Kinkhed the four top farmers were also the ones selected for the game. In the case of Aurepalle, only one of the top five progressive farmers based in Aurepalle was selected for the game and in the case of Nallavaripalle, three farmers from the top four farmers based in Nallavaripalle were selected for the game.

Table C2: Rank of 4 progressive farmers selected for the game in terms of "pf_TALK"

	Rank	Total number of PF
Aurepalle	7,9,12,17	28
Nallavaripalle	2,5,6,26	28
Kanzara	1,2,5,6	6
Kinkhed	1,2,3,4	9

To conclude, it appears that I did a relatively good job in identifying the most important progressive farmers ex-ante in Nallavaripalle, Kanzara and Kinkhed but failed to include the most important progressive farmers in Aurepalle. As such, I repeat the analysis using two different sets of measures of the imitation and social learning from progressive farmers component. The first set of measures is based on the random matching within sample game. The second set of measures includes all progressive farmers who, according to their own account, talk on a at least monthly basis to the respondent in case of the imitation component and all the progressive farmers who, according to their own account, believe that the respondent knows their cultivar use and yield output in case of the social learning component.[59]

[59] With regard to the latter measure - it must be noted that four progressive farmers in Aurepalle could not answer the question "Do you think the following person (show VLS respondent) knows which cultivars you have sown and how much yield you got from each cultivar this year" and answered "don't know" for all the VLS respondents.

Appendix D

Table D1 presents the results of a OLS regression of individual prices (in Rs/quintal) received for cotton in 2007-08 on variables representing the who, when and where aspects of the sales of cotton using the 2007-08 data of cotton price (in Rs/Quintal). Note that the price of Bt cotton is not significantly different from the price of non-Bt cotton. The location and time of sale matter and selling in the village yields a lower price compared to selling at the market. Note that the location of sale is responsible for the large majority of the variation in output price. The difference in price received when one sells in the market versus whether one sells in the village reflect the transportation costs between market and village (it would cost about 50 Rs to hire a small three-wheeler truck). When a farmer sells his produce will depend on in the first place on the duration of the cultivar (as cotton is a perishable product), i.e., how many weeks it takes for the crop to mature and in the second place on whether he needs to reimburse a seed dealer or money lender urgently. In general a farmer will pick a short-duration cultivar if he plans to cultivate crops during the summer season (March-May), and this in turn will depend on whether he has access to a functional irrigation source during the summer.

Table D1: OLS cotton price in 2007-08 (N=427, Adj R^2=0.30)

	Coeff.	St. Error
Quantity (quintal)	1.45	1.30
Aurepalle	-194.33***	32.47
Kinkhed	-10.63	30.04
Weeks since 1 October	7.74***	1.34
Dummy Bt cultivar	47.10	34.61
Sold to trader/agent in the village	-43.34**	17.00
Sold to farmer in the village	-51.70***	15.86
Sold to same person from whom input was bought	3.78	11.16
Constant	2077.41***	33.61

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level

Appendix E

In 2006-07, a low bollworm pressure year in all the villages, the cumulative distribution function of the profits of Bt cotton First Order Stochastically Dominates the cumulative distribution function of the profits of non-Bt cotton in Aurepalle and Kanzara. Little can be said about Kinkhed as there are so few Bt cotton farmers. In 2007-08, a high bollworm pressure year in the Akola villages, the cumulative distribution function of the profits of Bt cotton First Order Stochastically Dominates the cumulative distribution function of the profits of non-Bt cotton in Kanzara. Nothing can be said about Aurepalle as no cotton farmers cultivated non-Bt cotton in 2007-08. Figure E1 shows the cumulative distribution functions of the 2007-08 cropping year.

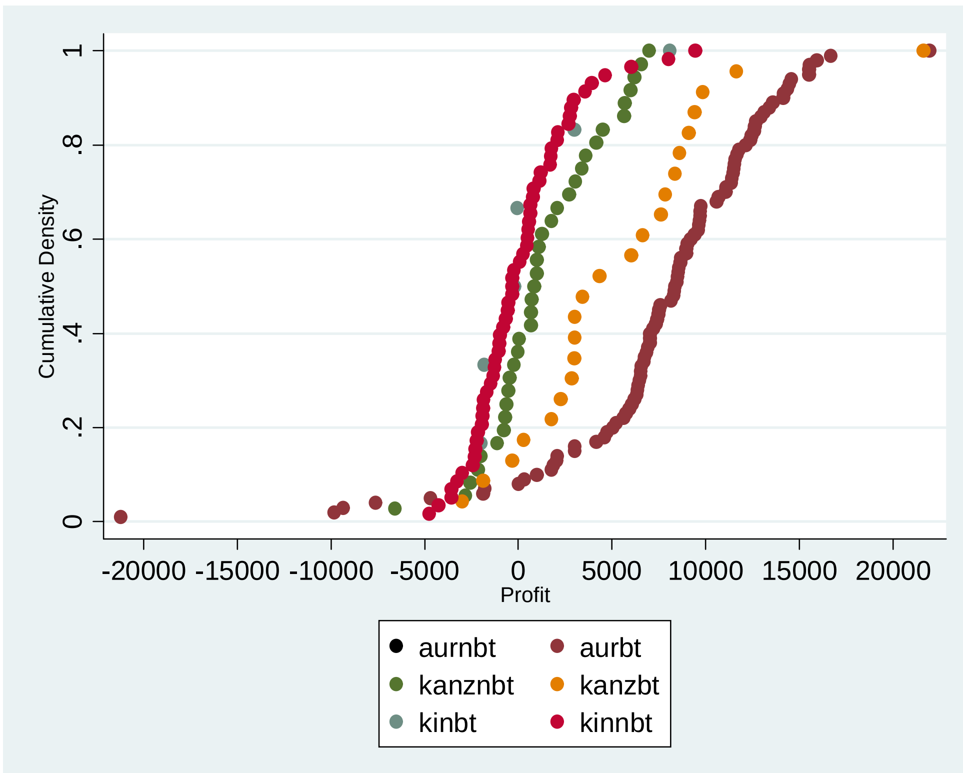

Figure E1: Cumulative distribution of profits of Bt cotton and non-Bt cotton in Aurepalle, Kanzara and Kinkhed in 2007-08

Appendix F

Table F1 continues Table 9 and presents the average and standard deviation of the various measures of number of progressive farmers known to the respondent who plan to cultivate Bt cotton in 2008-09 of the groups introduced in Table 8. The first two columns use the results of the random matching within sample game, and present, respectively, the number of PF who plan to cultivate Bt cotton in 2008-09 based directly on the results of the game and the number of PF who plan to cultivate Bt cotton in 2008-09 based on the results of the predicted links, both as a % of the PF "known by cultivar" (i.e., link no. 6 in Table 6) who plan to cultivate cotton. Column three and four use the information of the progressive farmer questionnaire and present, respectively, the total number of progressive farmers who, according to their own account, talk on an at least monthly basis to the respondent and who plan to cultivate Bt cotton in 2008-09, and the total number of progressive farmers who, according to their own account believe that the respondent knows their cultivar use and yield output and who plan to cultivate Bt cotton in 2008-09, both as a % of the PF known who cultivate cotton. If behavioral imitation is present, one would expect the average of group (2) to be larger than the average of group (1). This is the case using sws_actual, $sws\_predicted$ and pf_TALK. The differences between the two groups are significant at the 10% level for the first two measures.

Table F1 (continue Table 9): Characteristics of the groups in Table 8
(number of PF who plan to cultivate Bt cotton in 2008-09 as % of PF known)

	Based on the random matching within sample game	
	sws_actual	sws_predicted
(1) Cultivate Bt and $E[\pi_{BT}]>E[\pi_{NON-BT}]$	0.72 (0.21)	0.90 (0.14)
(2) Cultivate Bt but $E[\pi_{BT}]<E[\pi_{NON-BT}]$	0.93 (0.12)	0.97 (0.05)
(3) Do not cultivate Bt but $E[\pi_{BT}]>E[\pi_{NON-BT}]$	0.70 (0.25)	0.87 (0.11)
(3') Do not cultivate Bt but $F\pi_{BT}$ FOSD $F\pi_{NON-BT}$	0.75 (0.23)	0.93 (0.05)

Table F1 (continue): Characteristics of the groups in Table 8
(number of PF known who plan to cultivate Bt cotton in 2008-09)

	Based on the links from the PF perspective	
	pf_TALK	pf_CULT
(1) Cultivate Bt and $E[\pi_{BT}]>E[\pi_{NON-BT}]$	0.84 (0.09)	0.71 (0.45)
(2) Cultivate Bt but $E[\pi_{BT}]<E[\pi_{NON-BT}]$	0.88 (0.87)	0.50 (0.57)
(3) Do not cultivate Bt but $E[\pi_{BT}]>E[\pi_{NON-BT}]$	0.87 (0.07)	0.65 (0.48)
(3') Do not cultivate Bt but $F\pi_{BT}$ FOSD $F\pi_{NON-BT}$	0.85 (0.08)	0.50 (0.53)

Appendix G

Table G1: Tobit regression acreage to cultivate under Bt cotton in 2008-09 (0-1 range) with robust standard errors (N=29)

	Coeff.	St. Error.
Mean profit Bt (in 1,000 Rs)	0.088**	0.039
Mean profit non-Bt cotton (in 1,000 Rs)	-0.152	0.165
Variance Bt cotton (in 1000,000 Rs)	-0.082**	0.046
Variance non-Bt cotton (in 1000,000 Rs)	0.046	0.107
sws_predicted	-1.874	1.534
OTHER_BIOSAFETY/KNOWN	-0.081	0.306
OWN_BIOSAFETY	-0.058	0.086
Risk aversion coeff.	-0.001	0.001
Income (in 1,000 Rs)	0.013	0.013
CREDIT*Income (in 1,000 Rs)	-0.002	0.002
wouldCREDITt*Income (in 1,000 Rs)	-0.008	0.012
Mills ratio	0.522	0.660
Constant	2.797***	0.869
lnsigma	-0.716***	0.210
sigma	0.489	0.103

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level; 7 uncensored observations

Table G2: Probit, 2001-07, cultivate Bt cotton, first-time adopters (N=507, Pseudo R^2=0.66)

	Coeff.		dF/dx	
	Coeff.	Std. Error.	dF/dx	St. Error
Total number of adopters in village up to t-1	0.2310***	0.0799	0.0013***	0.0016
Total number of adopters in village up to t-1 square	-0.0030**	0.0014	0.0000**	0.0000
Average owned land in village at t	4.0120**	1.9622	0.0224**	0.0313
Risk aversion coeff.	-0.0002	0.0006	0.0000	0.0000
Education head (years)	0.0525	0.0373	0.0003	0.0006
Owned land (acre)	-0.1049	0.0657	-0.0006	0.0008
CREDIT*owned land	0.0723	0.0597	0.0004	0.0006
wouldCREDIT*owned land	0.0095	0.0674	0.0001	0.0004
irrigationconstraint	-0.1424	0.2803	-0.0009	0.0027
soil fertility	0.1168	0.1447	0.0007	0.0013
P male (predicted) (day)	-0.0034	0.1346	0.0000	0.0008
P female (predicted) (day)	0.1998	0.2064	0.0011	0.0023
P bullock (predicted) (day)	0.0623**	0.0245	0.0003**	0.0004
P tractor (predicted) (hour)	-0.0108	0.0187	-0.0001	0.0001
P cotton (predicted) (kg)	0.4582*	0.2570	0.0026	0.0032
P fertilizers (predicted) (kg)	-0.3025	0.2359	-0.0017	0.0022
P pesticides (predicted) (l)	0.0031	0.0021	0.0000	0.0000
P non-bt seed (predicted) (kg)	0.0073**	0.0032	0.0000**	0.0000
P bt seed (official) (kg)	-0.0003	0.0006	0.0000	0.0000
Andhra Pradesh first three years dummy	5.7410	3.5730	0.7586	0.6807
Constant	-44.2888***	14.0997		

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level

Table G3: Probit, 2001-07, cultivate Bt cotton, first-time adopters, specification (10). (N=408, Pseudo R^2=0.72)

	Coeff.		dF/dx	
	Coeff.	Std. Error.	dF/dx	St. Error
Non-farmer information up to t	1.7101***	0.5909	0.0370***	0.0250
Non-farmer information up to t square	-0.9231***	0.2997	-0.0200***	0.0137
Total number of adopters known up to t-1 (village)	-0.0193	0.0152	-0.0004	0.0004
Total number of adopters known up to t-1 square (village)	0.0001	0.0001	0.0000	0.0000
Total number of adopters known up to t-1 (outside village)	-0.0081	0.0338	-0.0002	0.0008
Total number of adopters known up to t-1 square (outside village)	-0.0001	0.0003	0.0000	0.0000
Total number of adopters known at t	0.0622**	0.0252	0.0013**	0.0011
Total number of adopters known at t square	-0.0001	0.0003	0.0000	0.0000
Risk aversion coeff.	-0.0010	0.0008	0.0000	0.0000
Education head (years)	0.0711	0.0449	0.0015	0.0016
Owned land (acre)	-0.1870**	0.0737	-0.0040**	0.0032
CREDIT*owned land	0.1489	0.0715	0.0032	0.0025
wouldCREDIT*owned land	0.0016	0.0842	0.0000	0.0018
irrigationconstraint	-0.5974**	0.3001	-0.0196**	0.0173
soil fertility	0.2261	0.1705	0.0049	0.0044
P male (predicted) (day)	0.0218	0.1339	0.0005	0.0029
P female (predicted) (day)	0.1349	0.1762	0.0029	0.0044
P bullock (predicted) (day)	0.0349**	0.0172	0.0008**	0.0005
P tractor (predicted) (hour)	-0.0318**	0.0177	-0.0007**	0.0005
P cotton (predicted) (kg)	0.5510***	0.1899	0.0119***	0.0073
P fertilizers (predicted) (kg)	-0.0443	0.1859	-0.0010	0.0041
P pesticides (predicted) (l)	0.0052***	0.0016	0.0001***	0.0001
P non-Bt seed (predicted) (kg)	0.0068***	0.0023	0.0001***	0.0001
P bt seed (official) (kg)	-0.0007	0.0005	0.0000	0.0000
Andhra Pradesh dummy	-3.8081**	1.5275	-0.0556	0.0485
Inverse mills ratio	0.3846	0.3442	0.0083	0.0089

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level