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The role of Farmer Training in the Diffusion of Biotechnology in Cotton in China: A Multi-period analysis

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Abstract

This paper applies a "difference in difference" model to analyze the effect of the introduction of genetically modified cotton varieties and of farmer training using the farmer field school approach. The model uses a three period panel data to measure the direct and indirect (exposure) impact of farmer field schools (FFS) on major economic indicators such as yield and insecticide use. Particular emphasis is given to explore the interaction between farmer education and Bt-cotton. Data were collected from over 480 farm households in three provinces in China. Results showed that the effect of farmer training is more pronounced than those of the technology alone. Significant impacts of FFS on both yield increase and pesticide reduction was observed shortly after the training took place. These effects were sustained up to the end of the observation period. Spill over effects to neighbouring farmers also were observed for pesticide reduction during the first period but these effects diminished thereafter. No significant exposure effect on yield could be concluded in this case. Compared to FFS the sole effect of Bt on yield increase insignificant and the effect on pesticide reduction is lower than previously observed. A significant interaction between biotechnology and training was shown suggesting that training could reinforce the potential pesticide reduction effect of Bt varieties by changing farmers cotton bollworm spraying practices.

Introduction

Among the developing countries, China was one of the first to introduce genetically engineered insect-resistant Bt cotton on a large scale. After first approved for cultivation in 1997, Bt-cotton experienced a double digit increase in the area sown until 2004 equal to 3.7 million hectares in 2004 or two thirds of the cotton area (James, 2004). Some economic studies, conducted by the same group of authors were highly enthusiastic about the merits of the technology for Chinese farmers (see for example Huang et al., 2002a, 2002b, 2002c, 2003, and 2005; Pray et al., 2001, and 2002). These studies claim more than 60% reduction in the spraying frequency and over 80% reduction in pesticide expenditures. Additionally, adoption of Bt-cotton reportedly contributes to a significant decrease in labor input and even a 10 % increase in yield in spite of the already high level of cotton yields in China. Other studies were more cautious (e.g. Keeley, 2006; Pemsl et al., 2005, and 2007; Fok et al., 2005; Yang et al., 2005a, 2005b) and found lower impacts or ambiguous results. Also questions have been raised with regard to potential resistance built-up of target pests against the Bt toxin (e.g. Tabashnik et al., 2003; Wu et al., 2002) and increased pest pressure from secondary pests (e.g. Xue 2002, Wang et al., 2006), as well as problems with illegal seeds with substandard quality (e.g. Pemsl et al., 2005 & 2007).

Recent studies observe Bt-cotton farmers are in mounting need of better knowledge about this new technology (Yang et al. 2005c). Hence further research is needed to examine whether farmer education on integrated pest management can enhance the impact of Bt cotton.

This paper is based on a study conducted in three counties in China, namely Lingxian in Shandong Province (Yellow River Cotton Region), Dongzhi in Anhui Province and Yingcheng in Hubei province (both belong to Changjiang River Cotton Region). Those counties were part of the FAO/EU IPM Program in Cotton at its inception in 2000. By 2004 a total of 209, 132 and 94 Farmer Field Schools had been carried out in the three counties respectively.

Bt-cotton was first introduced into Lingxian in 1995 (two years before official approval for commercial use of Bt-varieties), and then spread to Dongzhi in 1998, Yingcheng in 1999. Bt-varieties were 100 percent adopted in Lingxian in 2001. In the two other counties adoption of transgenic cotton has been partial.

Objectives

The overall objective of this study is to extend Difference in Difference model (DD model) to make unbiased and consistent assessment of dynamic impacts of FFS in a context of explosive diffusion of biotechnology. According to the existing literature, farmer field school and Bt-cotton might generate an array of impacts transcending socio-economic, environmental and health spheres (Pray *et al.*, 2001; van den Berg *et al.*, 2006). As a result, impact assessment of FFS impacts requires a mixture of approaches and disciplines (Waibel *et al.*, 1999). However, this study, as many others in this area, has to trade off between the need to be rigorous and the need to be comprehensive (van den Berg *et al.*, 2006). Recognizing the fact that the yield and pesticide use are primary indicators, on which many other social, environmental and health impacts largely depend, this study concentrates on those two aspects. Under the circumstance in China, the insecticides account for around 95% of total pesticide use, and most high toxic compounds are insecticides, we further narrow our research focus to insecticide use. Based on those considerations, we set our specific objectives as follows:

1) To measure the short term and medium term impact of IPM-FFS on yield and insecticide use within different farmer groups.
2) To discover the dynamic change of the impact of IPM-FFS on yield and insecticide use within medium time span.
3) To explore the interaction between FFS education and biotechnology particularly Bt-cotton adoption.

The Data

Six villages including three FFS villages and three control villages were selected in every aforementioned county. The FFS villages were randomly selected, while the control village selection was purposively done based on the analysis of secondary data. Factors such as cotton production distance from the city and village infrastructure were compared to achieve necessary representativeness of those villages and similarity between the FFS and control villages. In all the FFS villages, a farmer field school was conducted in 2001. No FFS has been conducted in the control villages so far. In order to avoid the diffusion effect of FFS on the farmers in the control villages, when designing the survey the two village groups in every county were set to be at least 35 kilometers apart. But with the expansion of the IPM program, some FFS were opened in-between, which reduced the distance from the control villages to the nearest FFS village to 20 kilometers. In every FFS village, 20 FFS participants and 20 exposed farmers were randomly selected for the survey. Owing to dropout and some missing data, a total of 480 complete observations were included in the study. The sample composition is given in table 1.

The data were collected by surveys organized in 3 years. The baseline survey was carried out at the beginning of the cotton season in 2001 to collect retrospective data for the year of 2000. The two impact surveys were based on season long monitoring of input and output data on cotton production in 2002 and 2005 respectively. Farmers were asked to keep a detailed diary of their cotton production activities in standard form. The recording was checked by enumerators during their monthly visit to farmer households. The data set includes detailed information on the timing, volume and value of various inputs including seed, fertilizer, pesticide and labor *etc.*, amount and revenue of outputs, characteristics of farmers and households and knowledge on pest control.

Table 1. Sample size and location of FFS impact study

County	No. of FFS Participants	No. of Exposed farmers	No. of Control Farmers	Total
Lingxian	46	50	57	153
Dongzhi	55	51	58	164
Hubei	54	57	52	163
Total	155	158	167	480

Notes: FFS Participants = farmers who participated in the farmer field school.

Exposed Farmers = farmers who did not participate in the program but live in the same village as FFS participants.

Control Farmers = farmers in a non-program village with similar conditions as the FFS village.

Model Specification

In order to eliminate the possible biases caused by non-random project placement and farmer self selection, this study extends the difference in difference model to fit the three period panel data. The model follows the basic concept outlined in the previous work of Feder et al. (2004a) and Praneetvatakul and Waibel (2006). A Difference in Difference model is developed starting from taking exponential growth of farmer performance as the dependent variable:

$$\ln(Y_{ijt}) = \alpha + \alpha_2 d2_t + \alpha_3 d3_t + \beta D_{Nijt} + \mu D_{Gijt} + \gamma_1 B_t + \gamma X_{ijt} + \delta Z_{jt} + \lambda_i + \eta_j + \varepsilon_{ijt} \qquad (1)$$

Y stands for farmer performance (yield and insecticide use in this study), D_G and D_N are dummy variables for FFS participants and exposed farmers. Bt denotes the adoption rate[1] of Bt-cotton in each farmer household, $d2_t$ and $d3_t$ is the dummy for periods 2 and 3 respectively. X and Z denote vectors of household and village observable characteristics, while λi and ηj are time constant unobservable effects resulting from household and village features respectively. The time varying error ε_{ij} represents all the unobserved factors that change over time and affect Yijt.

Since nonrandom participant selection can lead to correlation between D_N, D_G and λi, nonrandom program placement results in correlation between D_N, D_G and ηj, the orthogonality assumption of OLS is violated (Wooldridge, 2003, Feder et al., 2004a). To avoid this problem the model can be modified by subtracting period 1 from period 2 and period 2 from period 3. This results in equation 2:

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[1] The proportion of Bt-cotton acreage to total household cotton acreage.

$$
\begin{aligned}
\Delta\ln(Y_{ijt}) = {} & \alpha_2 + \alpha_3 d3_t + \beta[D_{Nijt} - (D_{Nijt} \times d3_t)] + \beta_1(D_{Nijt} \times d3_t) + \mu[D_{Gijt} - (D_{Gijt} \times d3_t)] \\
& + \mu_1(D_{Gijt} \times d3_t) + \gamma_1 \Delta Bt + \gamma_{1N}(\Delta Bt \times D_{Nijt}) + \gamma_{1G}(\Delta Bt \times D_{Gijt}) + \gamma\Delta X_{ijt} + \delta\Delta Z_{ijt} \\
& + \Delta\varepsilon_{ijt}
\end{aligned} \tag{2}
$$

By first differencing, λi and ηj no longer appear as they are constant over time. For further specification an interaction between the time period dummy $d3_t$[2] with program intervention dummies D_N, D_G is included. This allows probing the trajectory of IPM-FFS impacts over time. Of particular interest is the interaction between FFS training and Bt adoption, hence the interaction terms between D_N, D_G and Bt are added to the model.

Results

Descriptive Analyses

Table 2 reports the longitudinal and horizontal comparison of cotton yields and insecticide costs by time period and farmer group. Prior to the training program in 2000, there was no significant difference among all three farmer groups. After the training, substantial disparity in favor of the participants emerged in 2002. This gap remained there in 2005. FFS participants had bigger gains in 2002 and smaller losses in 2005. As compared to farmers in the control group, exposed farmers also had significantly higher yields in 2002 and 2005. For insecticide use the picture is different. With a higher initial level, the FFS participants experienced a significant drop in 2002. The same s true for exposed farmers. On the other hand insecticide use increased between 2002 and 2005 but least for FFS farmers.

Table 2: T test of outcome indicators and labor costs by farmer category

	2000	Difference 2002/2000	2002	Difference 2005/2002	2005
Yield (kg/ha)					
Participants	3262,92	657,80**	3920,71^{c}	-79,31**	3841,40^{c}
Exposed	3195,70	447,36**	3643,07^{b}	-138,43**	3504,64^{b}
Control	3196,64	300,05**	3496,69^{a}	-105,10**	3391,59^{a}
Insecticide Cost (US$/ha)					
Participants	128,92	-78,70**	50,22^{c}	7,16**	57,39^{a}
Exposed	128,11	-63,94**	64,17^{b}	10,59**	74,76^{b}
Control	113,96	-35,35**	78,61^{a}	10,93**	89,54^{c}

Note: **significant at 0.01. Superscript capital letters denote results of Duncan's test (0.05). Rural retail price index of material inputs and agricultural products are used to inflate the 2000 and 2002 value to 2005. The exchange rate between US$ and Chinese currency used in this table is 1:8.26 for 2000 and 2002 and 1:8 for 2005.

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[2] For convenience we drop the dummy for time period two and keep only one dummy for time period three.

Multivariate Analysis

The results of the yield growth model are summarized in table 2. For brevity only variables at the center of interest are reported here. The high level significance of the variable "participant" indicates that participation in FFS training enables farmers to increases their cotton yield. Ceteris paribus, FFS participants achieve 8.4% higher yields as compared to farmers in control villages. The parameter for the interaction term between FFS participation and time period is insignificant. Hence it seems that t farmers do not retain their knowledge they gained from FFS over time. For exposed farmers, the yield effect on the short term is not significant. Furthermore the negative coefficient of the interaction term between the variables "FFS exposure" and "Period" suggests that within-village spillover effects are non sustainable. Contrary to the findings of other authors (e.g. Huang 2002) we did not find a significant yield effect of Bt. On the other hand, based on the robust standard error, which corrects for selection bias, there is also no significant effect of the interaction between training and the Bt technology. In conclusion there seems to be some tendency that the yield effect of Bt is questionable during the observation period. This is not implausible as bollworm infestation remained low after 2000. On the other hand, FFS training helps farmer to improve their crop management skills and thus enables them to increase productivity by optimizing input and management decisions.

Table 3: Impact of FFS on Cotton Yield

Dependent variable: Yield N=960, R^2=0.36, F=30.45			
Variable	Coefficient	Robust Std Error[3]	t-value
Exposed	0.03369	0.02249	1.49800
Exposed×Period	-0.01252	0.01031	-1.21435
Participant	0.08086	0.02500	3.23440***
Participant×Period	0.00085	0.00931	0.09130
Insecticide	0.00006	0.00012	0.50000
Bt	0.00396	0.01865	0.21233
Bt×Participant	0.04153	0.02694	1.54157
Bt×Exposed	0.02823	0.02633	1.07216

Note: *** significant at 0.01

Table 4 reports the estimates of insecticide use function. The participation dummy has a coefficient of -0.61826, equivalent to a 46% reduction in insecticide use. There also seem to be spillover effects to non-participants in the FFS villages as the coefficient for "exposed" is also significant. In fact exposure leads to a 40% decline in insecticide use. It therefore appears that to some extent exposed farmers imitate the pesticide use practices of the trained farmers. However the pesticide reduction effect disappears in the second period and exposed farmers even increase their insecticide use relative to farmers in the control village. Unfortunately no judgments can be made on the continuation of more benign pesticide use practices. Hence some doubts regarding the sustainability of the training effects can be raised.

Analyzing the role of the Bt technology shows that Bt-cotton varieties also lead to a significantly reduction in insecticide use. However the rate of reduction is lower than those found in the

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[3] Most Difference in Difference papers ignore the bias in the estimated standard errors that serial correlation induces (Bertrand, 2004).Heteroscedasity may also cause problem to difference in difference model (Wooldridge, 2002). Tests following Wooldridge (2002) detect border significance of serial correlation and heteroscedascity in this case. Therefore robust standard errors are used for correction.

studies of Huang et al. (2002b, 2002c). On the other hand pesticide reduction is reinforced by interaction with FFS participation. Bt-varieties planted by FFS participants further contribute to a 15.5% decline in insecticide use as compared to those grown by the control farmers. However such effect does not exist for the exposed farmers as the coefficient of the interaction term is non-significant. The significant interaction between training and technology suggests that enhancing the understanding of farmers about the potential contribution of new technology can help to use technology more effectively. Some concern remains regarding the long term effects. As found by (Wang et al 2006) it is possible that emergence of secondary pests in the course of the introduction of Bt varieties may contribute to an increase in insecticide use. It is not clear if FFS training can help to rationalize this process.

Table 4: Impact of FFS on Insecticide Use

Dependent variable: Yield N=960, R^2=0.57, F=78.99			
Variable	Coefficient	Robust Std Error	t value
Exposed	-0.51812	0.08203	-6.31623***
Period×Exposed	0.14447	0.05446	2.652773***
Participant	-0.61826	0.09248	-6.68534***
Period×Participant	-0.00501	0.05159	-0.09711
Bt	-0.10703	0.06314	-1.69512*
Bt×Exposed	-0.08668	0.08769	-0.98848
Bt×Participant	-0.16785	0.09194	-1.82565*

Note: * significant at 0.1, ** significant at 0.05, *** significant at 0.01

Conclusions

The results of this study demonstrate that there is a significant impact of FFS on both yield increase and insecticide reduction for trained farmers on the short term. However impacts can only be proven for the short term but may not be retained over a longer period. This is also the finding s of Feder et al (2004) from the IPM program in Indonesia. On the other hand, substantial diffusion impact on pesticide use is also identified in the short term suggesting some within village spillover effect of farmer training. However, there is no such effect for yield. This seems plausible as yield improvements require in-depth knowledge of crop management while pesticide use practices are more easily observable..

Another finding from the multi-period panel data analysis is that impact of biotechnology (Bt cotton) was found to be less distinct than proposed by other studies. The fact that no yield effect of Bt could be demonstrated however is consistent with the observation that cotton bollworm infestation has declined since 2000 and that no major outbreak took place. Also as an alternative technology to chemical pesticides, the adoption of Bt-cotton is found to contribute to only a modest reduction in insecticide use. In addition there seems to be a positive interaction between technology and learning. Hence the potential for the reduction of insecticide use of Bt varieties can be augmented by farmer training and vice versa farmers who adopted Bt varieties may be more willing to experiment with lower pesticide rates.

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