Farmer Field School and Bt Cotton in China – An Economic Analysis

Wu Lifeng

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To my beloved daughter Wu Zhuoxuan and wife Liu Yaping for their sacrificial love,
and to all the people who offered me guidance, support and encouragement

“The ideas that have lighted my way and, time after time, have given me new courage to face life cheerfully have been Kindness, Beauty, and Truth.”

Albert Einstein

Preface

Some fifty years ago, scientists were enthusiastic about the widespread introduction of synthetic pesticides in agriculture to solve the world's food problem. Since about 25 years scientists and policy makers are voicing optimism about the prospects of pest resistant genetically modified crop varieties. While many negative effects of pesticide use have become known, intriguingly some see biotechnology in crop protection now as a solution to the very problems that pesticide use created. However, regulatory decisions about the commercialization of biotechnology products must consider uncertainty over bio-safety issues and consumer resistance and possible constraints on trade. For an industrial crop like cotton, China was the first among the developing countries to introduce genetically modified (GM) varieties on a large scale. Since its approval for cultivation in 1997, Bt-cotton experienced double digit growth in terms of area sown until early 2000. In spite of numerous studies to assess the impact of Bt cotton in China questions remain, e.g. to what extent farmers have really benefited from this technology. While it is clear that the assumption Bt could offer a simple solution to pest problems in cotton was wrong, two issues remain, namely: (1) the development of secondary pests and (2) seed quality problems as a result of market imperfections in the seed delivery systems. In China, a large number of breeder and seed organizations generate an array of products with very little information on their performance. Furthermore, local seed dealers minimize costs by adopting sales strategies that include mixing of varieties with different degrees of quality. Thus effective cotton bollworm control is not just a matter of planting transgenic seeds.

The research of Dr. Wu Lifeng is carried out against the background of this uncertainty in the information environment of cotton pest management technology. His study builds on the earlier works of Dr. Diemuth Pemsl in Shandong province in China also published in this series (PPP No. 11). Dr. Wu Lifeng is adding the farmer knowledge aspect together with the Bt technology question to the agricultural economics literature in crop protection. Looking at these two aspects simultaneously is challenging but at the same time potentially very rewarding. It significantly adds to a better understanding of the institutional arrangements that can facilitate a realization of the potential of new technologies such as Bt cotton.

Results of this study provide information for future investment decisions in IPM extension and can help policy makers to adjust resource allocations for better targeting of extension programs in developing countries. The cost-benefit analysis at farm-level and the welfare analysis at the macro-level were based on conservative assumptions.

The study of Dr. Wu offers a rich blend of information also on some of the institutional problems that underlie pesticide use and at the same time may contribute to increase the likelihood of pest outbreaks and other pesticide externalities in cotton and other crops in China. The perhaps most interesting part of this research is the evidence that challenges the popular believe that Bt cotton alone has solved the cotton bollworm problem in China. The sample includes 93 FFS villages with over 1100 farmers distributed over nine counties in China. It is therefore a unique set of data in the literature on FFS. The very impressive data set that includes nine counties in three different provinces in China allows drawing conclusions which makes the research particularly valuable. Hence the study nicely complements to the dominantly case study-based evidence presented in the literature so far. In particular, the inclusion of an additional time period allows the author to extend the standard FFS impact model to a multi-period “difference in difference” model. He also formulates the model in such a way that the interaction between Bt cotton and the improvement in farmer knowledge as induced by FFS can be captured. The author carefully describes the econometric procedure applied including the required statistical tests. The results are interesting and underline the insecticide reduction effect of FFS both in the short and in the medium term.

Overall, the study shows that FFS training in cotton in China can enhance the effectiveness of Bt cotton varieties. In addition FFS farmers can retain their new knowledge in the course of up scaling China’s national program on integrated pest management using FFS as a major tool provided there is strong government commitment. Undoubtedly, the study has generated several important messages relevant for decision makers in plant protection. At the same time it also raises new questions that call for continued interdisciplinary research in integrated pest management.

Hannover, February 2010

Hermann Waibel

Acknowledgement

Working as a Ph.D. candidate in Hannover was a magnificent as well as challenging experience to me. In all these years, many people were instrumental directly or indirectly in shaping up my academic career. It was hardly possible for me to thrive in my doctoral work without the precious support of those personalities. Here is a small tribute to all those people.

First of all, I wish to thank my supervisor, Prof. Dr. Hermann Waibel, for introducing me from a world of plant protection to a fresh and fantastic domain transcending natural and social sciences. It was only due to his valuable guidance, professional dedication, cheerful enthusiasm and ever-friendly nature that I was able to complete my research work in a respectable manner. I am very grateful to my second supervisor, Assistant Prof. Dr. Suwanna Praneetvatakul in Kasetsart University in Thailand, who took care of me at the very beginning when I had probationary courses in Bangkok and always gave me timely support whenever I needed. Sincere thanks are given to Prof. Dr. Ulrike Grote for her profound professionalism which always brought me enlightenment and inspiration at the frequent academic activities in our seminar room.

My deepest gratitude also goes to the leading group, especially Mr. Xia Jingyuan, Pan Xianzheng and Zhong Tianrun in the National Agro-technical Extension and Service Center (NATESC) within the Ministry of Agriculture of China. Without their support, I would have been tied to office desk in Beijing and could only imagine study abroad in luxury dreams. I am deeply indebted to my colleagues, particularly Mr. Wang Fuxiang and Wang Chunlin in the Division of Plant Quarantine and Administrative Office in NATESC. My work on Ph.D. through years was built on their sacrificial assumption of my workload in office. Their understanding, tolerance and encouragement are the greatest gifts I ever had and I will treasure all my life. Heartfelt thanks are due to Dr. Yang Puyun for sharing his profound expertise as an enthusiastic practitioner of participatory extension. Sincere appreciation is extended to many other colleagues in NATESC who have given me valuable support in one or another way.

I am grateful to numerous staff in the Plant Protection Stations of Anhui, Hubei and Shandong Provinces and the nine sample Counties, represented by Mr. Wang Mingyong, Wang Shengqiao and Lu Zengquan at provincial level and Mr. Tang Yinlai, Ni Xianwei and Mrs. Wang Lanying at county level. I will never forget their excellent cooperation in facilitating data collection and endless patience to answer queries about local conditions. The enumerators are warmly thanked for their dedication to the field work. Every figure in the thesis is the crystallization of their sweat in the fields. Thanks go particularly to more than 1500 farmers who willingly participated in the surveys. Their unflagging pursuit for better future on small cotton plots was the strongest motivation for me to struggle for the true story behind cotton production.

This study could not have been possible without the FAO-EU IPM Program for Cotton in Asia. The self-evaluation launched by the program had laid a sound foundation for this study. Special thanks are conveyed to Dr. Gerd Walter-Echols, the formerly Environmental Impact Expert and Dr. Peter A.C. Ooi, the formerly Chief Technical Advisor of the FAO-EU IPM Program for Cotton in Asia for helping access voluminous background documents and for enlightenment by their informative publications.

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Very special thanks are reserved for my family. I want to express my appreciation to my parents, Wu Jinrong and Chen Airong, and parents in law, Liu Enfu and Ru Xiuzhi, for their endless support and encouragement in all my professional endeavours. I am greatly indebted to my daughter, Wu Zhuoxuan, who was just a little child in kindergarten at the outset of my Ph.D. journey but is now a sensible girl in senior grade in primary school. I owe immeasurable debt to my beloved wife, Liu Yaping, who has shared with me all the burdens, anxieties and pleasure of this study. Her courage to take up the heavy responsibilities of life and work with frail shoulders is the powerful source of my ambition to persist in the pursuit of a new career.

Hannover, February 2010

Wu Lifeng

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List of Abbreviations

Bt	*Bacillus thuringiensis*
CAAS	Chinese Academy of Agricultural Sciences
CBW	Cotton Bollworm
DD	Difference in Difference
e.g.	For Instance (*exampli gratia*)
EIQ	Environmental Impact Quotient
et al.	And Others (*et alii*)
etc.	And Others (*et cetera*)
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FFS	Farmer Field School(s)
GDP	Gross Domestic Product
GMM	Generalized Method of Moments
Ha	Hectare
HH	Household
ICAMA	Institute of the Control of Agro-chemicals, Ministry of Agriculture
IMR	Inverse Mills Ratio
IPM	Integrated Pest Management
ISAAA	International Service for the Acquisition of Agri-biotech
JSCN	Jiangsu Chemical Industry Net
Kg	Kilogram
Km	Kilometer
MVPs	Marginal Value Products
MOA	Ministry of Agriculture
NATESC	National Agro-technical Extension and Service Center
NBSC	National Bureau of Statistics
NDRC	National Reform and Development Commission
OBAGE	Office for the Bio-safety Administration of Genetic Engineering
OLS	Ordinary Least Squares
PGMU	Program Management Unit of the FAO-EU Cotton IPM Program for Cotton in Asia
PPS	Plant Protection Station(s)

RSM	Red Spider Mite
PBW	Pink Bollworm
SSTC	State Science and Technology Commission
TOF	Training of Facilitators
T&V	Training and Visit
Viz	Namely (*videlicet*)
WHO	World Health Organization
2SLS	Two Stage Least Squares
US$	United States Dollar

Abstract

Both agricultural extension and biotechnology are taken by China as major strategies to meet the challenge of increasing natural resource scarcity in agriculture. Farmer Field School (FFS) as a participatory extension approach was introduced into China in 1989. Bt cotton as a major biotechnology product was commercialized later in 1997. At present, Bt cotton takes up a lion’s share of the total area sown to the crop in the country. The introduction of FFS has also been quite impressive albeit on a smaller scale mainly depending on the availability of external sources of finance. Both interventions however raise questions regarding their impacts on productivity and sustainability of agriculture. Especially in looking at the joint impact of those two interventions, there is a lack of rigorous studies and exist methodological challenges to conduct such studies.

This study is among the first initiatives that undertake an in-depth case study of the economic impacts of both FFS and Bt cotton. The main objective of this thesis is to contribute to a better understanding of the role of FFS and Bt cotton in agriculture in China while addressing methodological challenges for impact assessment.

With a considerable mobilization of macro data collected by responsible agencies, this thesis was largely built on the empirical data collected from nine counties in three provinces in China. A group of 540 farmers were surveyed for the cotton seasons of 2000, 2002 and 2005 including farmers who were trained by FFS in 2001. As a result, this three-period panel data set allows for a comparison of not only “with and without” FFS training but also “before and after” the training took place. Apart from the farmers included in the panel survey, another sample of over 1,000 farmers was interviewed in 2005. Hence, a cross-sectional data set with larger sample size was also available for this study. Retrospective data were collected in 2001 for the 2000 cotton season, while the other two surveys in 2002 and 2005 were in effect season long monitoring. In addition to the detailed account of input and output information, the household and village attributes and farmer knowledge on pest control were also collected in the surveys.

As compared to rice, wheat and maize, cotton is the major field crop with more severe pest problems and receiving more intensive pesticide treatment. Cotton farmers in

China faced tremendous difficulties in selecting suitable pesticides from a huge number of products, including a high proportion of unidentified ones. Although Bt cotton had been widely adopted, pesticide use remained at a very high level with a large proportion targeting cotton bollworm. Red spider mite, aphids, mirids and some other pests also took up considerable shares of pesticide use, indicating a change of the pest pattern. Great variation of pesticide use between areas and remarkable divergence between pesticide use and pest infestations were also identified, implying the existence of substantial overuse of pesticides in many areas.

Econometric analysis was conducted to investigate the immediate impacts of FFS. A two-period “difference in difference” (DD) estimator was constructed and applied to the panel data set to purge the possible selection bias caused by time-constant unobserved factors. It is revealed that immediately after FFS were conducted, the training generated significant impacts on yield increase and pesticide reduction, and consequently led to an increase in gross margins of cotton production among the FFS participants. No significant improvement of the growth rates of yields and gross margins were identified for the exposed farmers, but the pesticide use among them was considerably reduced as compared to that in the control group.

In order to capture the dynamics of FFS impacts, the “difference in difference” (DD) model was then extended to fit the three-period panel data. Efforts were also undertaken to explore the interaction between the FFS training and Bt cotton. FFS was found to have significant impacts on yield increase and insecticide reduction for the participants. Such impacts developed shortly after the training took place and were sustained up to the medium term. A substantial impact on insecticide reduction was also identified for the exposed farmers in the short term, but such impact was found to have diminished to some extent over time. No significant exposure effect on yields was concluded. In the process of increased adoption, Bt cotton per se was found to contribute to a modest reduction in insecticide use but no substantial yield gains. When the FFS dimension was added to Bt cotton cultivation, the substitution effect of Bt cotton for agrochemicals was strengthened. In addition, some productivity gains were achieved in the Bt cotton plots managed by those farmers who ever undertook the FFS training.

Based on the careful check and control of important econometric problems related to the cross-sectional data, efforts including the application of damage control concept and estimation by two stage least squares were undertaken to study the impacts of FFS in the context of program scale-up and Bt cotton before the background of wide adoption. The participants reduced insecticide use significantly and at the same time realized substantially higher yields. No apparent difference was found between the FFS conducted in earlier and later years, indicating not only the sustainability of the impacts of FFS conducted in earlier years but also the maintenance of the training quality during the program scale-up. For the exposed farmers, some improvement of the insecticide use was identified as the benefit from the exposure to FFS, but no evident gains in yields were discernable. However, it was found by one model specification that the more recently the farmers were exposed to FFS the stronger the exposure impact on pesticide reduction was. And hence, the sustainability of the exposure impact was once again cast into doubt. No significant contribution to insecticide reduction and yield increase could be attributed to Bt cotton in this case.

In conclusion, FFS have significant impacts on the performance of its participants which can be maintained over time and also during the scale-up of the program, while the indirect impacts on the exposed farmers are much more limited in scope and are likely to diminish. It is also concluded that there is a desirable interaction between FFS and Bt cotton and the impacts of Bt cotton during its expansion can be strengthened by FFS training.

It is recommended that in order to better use the participatory extension approach and biotechnology as development tools, efforts should be undertaken to (1) synchronize the expansion of biotechnology with the extension of the knowledge on the proper use of the technology, and (2) foster the follow-up activities of participatory extension initiatives to enable the knowledge gained by some farmers from the participatory training to be effectively diffused to other farmers in a similar manner.

Keywords: Farmer Field School, Bt Cotton, Impact Assessment, China

Zusammenfassung

Landwirtschaftliche Beratung und der Einsatz genetisch veränderter Pflanzen, die eine Resistenz gegen bestimmte Insekten aufweisen, werden in China als zwei Hauptstrategien angesehen mit deren Hilfe dem Problem der zunehmenden Knappheit natürlicher Ressourcen in der chinesischen Landwirtschaft begegnet werden kann. Das Konzept der Farmer Field School, eine partizipatorische Form der landwirtschaftlichen Beratung, wurde 1989 in China eingeführt. Bt-Baumwolle, eine bedeutende genetisch veränderte und dadurch gegen bestimmte Insekten resistente Baumwollsorte, wurde etwas später im Jahr 1997 kommerzialisiert. Gegenwärtig wird ein Großteil der chinesischen Baumwollanbaufläche mit Bt-Baumwolle bepflanzt. Die Einführung der Farmer Field Schools (FFS) ist bis zum heutigen Zeitpunkt ähnlich beeindruckend verlaufen, wenn auch in einem kleineren Gesamtausmaß, bedingt durch Beschränkungen bei der Verfügbarkeit von externen Finanzierungsquellen. Es stellt sich jedoch die Frage welche Auswirkungen beide Formen der Intervention auf die Produktivität von Landwirten und die Nachhaltigkeit landwirtschaftlicher Produktion haben. Insbesondere hinsichtlich der gemeinsamen Auswirkungen beider Eingriffe besteht ein Mangel an anspruchsvollen Studien welcher mit methodischen Herausforderungen bei der Durchführung von entsprechenden Wirkungsstudien einhergeht.

Die vorliegende Studie gehört zu den ersten Fallstudien welche sich eingehend mit den ökonomischen Auswirkungen sowohl von Farmer Field Schools als auch von Bt-Baumwolle beschäftigen. Das Hauptziel der vorliegenden Dissertation ist, zu einem besseren Verständnis der Rolle von Farmer Field Schools und Bt-Baumwolle in China beizutragen und sich dabei mit methodischen Herausforderungen hinsichtlich der Wirkungsanalyse zu befassen.

Die vorliegende Dissertation basiert zum Teil auf Makrodaten, die von den verantwortlichen chinesischen Behörden gesammelt wurden, überwiegend jedoch auf empirischen Primärdaten, die in neun Verwaltungsbezirken in drei chinesischer Provinzen gesammelt wurden. Zur Erhebung dieser Primärdaten wurden 540 Landwirte in der jeweiligen Baumwollanbauperiode der Jahre 2000, 2002 und 2005 befragt, einschließlich solcher Landwirte die 2001 an einer Farmer Field School teilgenommen haben. Der resultierende Panel-Datensatz ermöglicht nicht nur einen

Vergleich von Landwirten mit und ohne Farmer Field School-Erfahrung sondern auch einen Vergleich von Landwirten vor und nach ihrer Teilnahme an einer Farmer Field School. Zusätzlich zu den in der Panelstudie befragten Landwirten, wurde eine Stichprobe von über 1,000 Landwirten im Jahr 2005 befragt, wodurch ein Querschnittsdatensatz mit größerer Stichprobengröße zur Verfügung steht. In der Erhebung im Jahr 2001 wurden retrospektive Daten über den Baumwollanbau im Jahr 2000 gesammelt, wohingegen die Befragungen in 2002 und 2005 als saisonübergreifende Beobachtungen durchgeführt wurden. Zusätzlich zu detaillierten Informationen über Einsatzmengen von Produktionsfaktoren und den erzeugten Ernteertrag, wurden Informationen über Haushalts- und Dorfeigenschaften sowie das Wissen der Landwirte über Schädlingsbekämpfung erhoben.

Im Vergleich zu Reis, Getreide und Mais ist Baumwolle die Anbaupflanze mit den größten Schädlingsproblemen und wird deshalb am meisten mit Pestiziden behandelt. Chinesische Landwirte, die Baumwolle anbauen, haben große Schwierigkeiten aus einer Vielfalt von Pestizidprodukten, darunter viele nicht eindeutig gekennzeichnete, das für ihre Verhältnisse geeignete Produkt auszuwählen. Obwohl sich der Anbau von Bt-Baumwolle zu weiten Teilen durchgesetzt hat, werden weiterhin große Pestizidmengen verwendet, darunter auch viele zur Bekämpfung des Baumwollkapselwurms. Die anderen verwendeten Pestizidarten werden zur Bekämpfung der Spinnmilbe, der Blattlaus, der Blindwanze und einiger weiterer Schädlingsarten eingesetzt, was auf eine Veränderung des Schädlingsmusters schließen lässt. Große Unterschiede in den verwendeten Pestizidmengen zwischen den betrachteten Gebieten sowie nennenswerte Diskrepanzen zwischen Pestizidnutzung und Schädlingsbefall können beobachtet werden, was auf einen stark überhöhten Gebrauch von Pestiziden in vielen Gebieten hindeutet.

Mittels einer ökonometrischen Analyse wurden die unittelbaren Auswirkungen der Farmer Field Schools untersucht. Ein zweiperiodiges “difference in difference” (DD) Modell wurde konstruiert und auf den Paneldatensatz angewendet. Hierdurch wurde eine mögliche Verzerrung der Ergebnisse durch die nicht randomisierte Auswahl der Farmer (selection bias) bereinigt, indem unbeobachtete Faktoren über die Zeit konstant gehalten werden. Es zeigte sich, dass die Farmer Field Schools signifikante positive Auswirkungen auf die Baumwollernte sowie senkende Auswirkungen auf die Menge an verwendeten Pestiziden unmittelbar nach Durchführung des

Trainingsprogramms hatten, und dementsprechend der Bruttogewinn aus der Baumwollproduktion unter den teilnehmenden Landwirten anstieg. Keine signifikante Verbesserung der Ernteerträge und des Bruttogewinns konnte hingegen unter solchen Landwirten festgestellt werden, die zwar in denselben Dörfern wie die Farmer Field School-Teilnehmer wohnen, allerdings nicht selbst am Training teilgenommen hatten (exponierte Landwirte). Jedoch war der Gebrauch von Pestiziden in dieser Gruppe deutlich vermindert im Vergleich zur der Gruppe von Landwirten die in Dörfern wohnen in denen kein Farmer Field School-Training stattgefunden hatte (control group).

Um die Dynamik der Auswirkungen der Farmer Field Schools erfassen zu können, wurde das DD-Modell erweitert, so dass es auf den dreiperiodigen Paneldatensatz angewandt werden konnte. Dabei wurden auch mögliche Wechselwirkungen zwischen Farmer Field Schools und dem Anbau von Bt-Baumwolle erforscht. Es stellte sich heraus, dass Farmer Field Schools die Ernte signifikant erhöhen und die Menge an verwendeten Pestiziden signifikant senken. Solche Auswirkungen zeigten sich kurz nach der Durchführung des Trainings und hielten über eine mittelfristige Dauer an. Unter den exponierten Landwirten konnte ebenfalls eine beträchtliche Senkung der verwendeten Pestizidmenge beobachtet werden, wobei der Effekt sich in dieser Gruppe jedoch über die Zeit verringerte und keine signifikanten Auswirkungen auf die Ernte festgestellt werden konnten. Im Hinblick auf die Auswirkungen des Anbaus von Bt-Baumwolle konnte eine geringe Senkung der Pestizidnutzung im Verlauf der zunehmenden Ausbreitung dieser Baumwollsorte festgestellt werden, jedoch keine nennenswerten Erntesteigerungen. In Verbindung mit der Teilnahme an einer Farmer Field School verstärkte sich der Substitutionseffekt von Bt-Baumwolle für landwirtschaftliche Chemikalien und es konnten Produktivitätssteigerungen unter den Farmer Field School-Teilnehmern festgestellt werden.

Abschließend wurden unter Verwendung des Schadensvermeidungskonzepts (damage control concept) und einer zweistufigen Kleinste-Quadrate-Schätzung die Auswirkungen von Farmer Field Schools im Kontext der Vergrößerung des FFS-Programms und die Effekte des Anbaus von Bt-Baumwolle vor dem Hintergrund der weiten Verbreitung dieser Technologie untersucht, wobei sorgfältig wichtige ökonometrische Probleme überprüft und eliminiert wurden. Die Ergebnisse zeigen, dass Farmer Field School-Teilnehmer signifikant niedrigere Mengen an Pestiziden verwenden und höhere Ernteerträge erzielen. Keine Unterschiede wurden entdeckt zwischen den Auswirkungen der Farmer Field Schools, die in früheren und späteren Jahren durchgeführt wurden, was nicht nur die Nachhaltigkeit der Trainingseffekte unterstreicht, sondern auch die gleich bleibende Qualität der Maßnahmen im Verlauf der Vergrößerung des Farmer Field School-Programms. Eine Verbesserung hinsichtlich der Pestizidmengen konnte für die Gruppe der exponierten Landwirte festgestellt werden, wohingegen keine eindeutigen Steigerungen der Ernte nachgewiesen werden konnten. Zudem zeigte sich in einer der Modellspezifikationen, dass je stärker der Kontakt von Landwirten ohne Training mit Farmer Field School-Teilnehmern kurz nach der Teilnahme an dem Programm war, desto stärker waren die Verringerungen der Pestizidmengen von exponierten Farmern. Somit kann die Nachhaltigkeit der Auswirkungen von Farmer Field Schools auf exponierte Landwirte in Frage gestellt werden. Keine signifikanten Auswirkungen von Bt-Baumwolle auf Insektizidmengen und Ernteerträge konnten in diesem Fall nachgewiesen werden.

Schlussfolgernd kann gesagt werden, dass Farmer Field Schools signifikante Auswirkungen auf die Leistung der Teilnehmer haben können, die auch über einen längeren Zeitraum und während einer Vergrößerung des Programms anhalten. Die indirekten Auswirkungen auf exponierte Landwirte sind hingegen weitaus beschränkter in ihrem Umfang und es ist wahrscheinlich, dass diese im Zeitverlauf nachlassen. Es bestehen wünschenswerte Wechselwirkungen zwischen Farmer Field Schools und Bt-Baumwolle und die Vorteile des Anbaus von Bt-Baumwolle können während der weiteren Verbreitung dieser Technologie durch Farmer Field Schools verstärkt werden.

Um eine effektivere Nutzung des partizipatorischen Beratungsansatzes und von Biotechnologie zu erreichen, wird empfohlen, die Expansion von landwirtschaftlicher Biotechnologie mit der Verbreitung von Wissen über die richtige Anwendung dieser Technologie zu synchronisieren, sowie Folgeaktivitäten zur besseren Weiterverbreitung des an Farmer Field Schools erworbenen Wissens an andere Landwirte zu fördern.

Schlagwörter: Farmer Field School, Bt-Baumwolle, Wirkungsanalyse, China

1 General Introduction

This thesis carries out an economic analysis of two recent innovations adopted in cotton production in China, namely the Farmer Field School (FFS) approach and the transgenic Bt cotton varieties. The study was conducted under the partial sponsorship of the FAO-EU IPM Program for Cotton in Asia. It was also a cooperative project between the Leibniz University of Hannover, Germany and the National Agro-technical Extension and Service Center (NATESC), Ministry of Agriculture, P.R. China.

From a methodological point of view the thesis extends the “difference in difference” (DD) model and uses both panel and cross-sectional data sets. Also the damage control functions were integrated into a production function framework to quantify the economic impacts of the two innovations, and efforts were especially undertaken to look at the interaction between the application of a new extension approach like FFS and the adoption of a biotechnology product, namely Bt cotton. This chapter first describes the background, and then explains the overall and specific objectives of the study. In the last part of this chapter, the organization of the thesis is presented.

1.1 Background

After decades of rapid development, China has reached the stage of an emerging market economy and is at the verge to enter the intermediate stage of industrialization. The share of agriculture in GDP declined from 28.1% in 1978 to 11.3% in 2007 (NBSC, 2008). However, the diminishing contribution of agriculture to national wealth does not eliminate its fundamental position in national economy. To the contrary, agriculture in China is not only a crucial industry for feeding a huge population of 1.3 billion people, but also a vital sector to assure the well-being of 730 million rural residents and to provide job opportunities for over 300 million workers (NBSC, 2008). For this very reason, agriculture and rural development remain as top priorities for China in the process of modernizing its economy (Huang et al., 2008).

The ambition of China to modernize its agriculture is facing daunting challenges. Land and water resources have been stretched to their limits; widespread overuse of inorganic fertilizers and chemical pesticides has created serious problems of soil degradation and environment pollution (Hamburger, 2002; Williams, 2005; Lohmar et al., 2009). Given those constraints, it is widely recognized that any further gains in the agricultural output in China will have to come from the new technologies that foster a sustainable increase in agricultural productivity and the improvement of the extension system to effectively disseminate appropriate technologies to millions of small-scale farmers (Lohmar et al., 2009).

Among the recently developed new technologies, the modern biotechnology in plant protection with herbicide and insect resistant varieties has generated high expectations for productivity increase and sustainable development. In fact, the adoption of transgenic crops has been called as one of the most rapid cases of technology diffusion in the history of agriculture (Borlaug, 2000). With alien genes engineered in, the expectation is that the transgenic crops can be endowed with new properties such as resistance to pests, diseases and other stressful conditions like drought, salinity or water logging (Datt, 2001). However, among the transgenic crops currently in commercial use the herbicide tolerant varieties have been the dominant products and mainly used in the industrialized countries (Wu et al., 2004; James, 2008). The second dominant transgenic trait, currently under commercial use is the insect resistance with the Bt (Bacillus thuringiensis) gene introduced mainly in cotton, maize and soybean but increasingly also in vegetables (e.g. eggplant) which is also applied in developing countries (ISAAA, 2008; Chakravarty, 2009).

Biotechnology is viewed by Chinese policymakers as a strategic element for increasing agricultural productivity and improving national food security (James, 2007). From 1980s, China started to invest heavily in biotechnology research and development and has now built the largest biotechnology capacity outside of the USA (Pemsl, 2006). Owing to its economic importance and severe pest problems, cotton received intensive research attention, and a modified Bt gene fragment was successfully transferred into cotton in early 1990s by the scientists in the Chinese Academy of Agricultural Sciences (CAAS) shortly after the first debut of Bt transgenic plant in the USA in 1987 (Wang, 2001; Jia et al., 2004). At that moment, province wide outbreaks of cotton bollworm (CBW) (*Helicoverpa armigera*) were common in China (Wu et al., 2008) and cotton area shrank sharply under the fierce attack by that pest (Huang et al., 2002c). Addressing the harsh challenges for cotton production, Bt cotton was approved for commercial use in 1997 and from then on more and more domestic and imported Bt varieties became officially available to farmers in China (OBAGE, 2007). With the Bt trait resistant to CBW, the Bt varieties were quickly embraced by the cotton farmers in

China and by 2007 the area planted to Bt varieties had reached 3.8 million hectares, which accounted for 64% of the total cotton area in the country (James, 2007).

Extending the research outputs from the research institutes to 200 million small farmer households (HH) is a tremendous task, and hence China maintains a vast agricultural extension system with more than 0.33 million staff employed in the cropping sector from the central to township level (Lohmar et al., 2009; Hu et al., 2009). However for a long time, the system has been criticized for poor efficiency partially owing to its typical “top down” approach to carrying out the duty (Shao et al., 2002; Kamphuis et al., 2003). As a remedy for the deficiency problem with traditional extension, the FFS was introduced into China by the FAO in 1989 to extend the knowledge on integrated pest management (IPM) (Zhang et al., 2008b). In contrast to the traditional “top down” ideology, the FFS approach emphasizes the concept of “farmer driven” and the respect for farmer knowledge. It is expected that the FFS empowers the participants[1] to make their own decision first and then relay the knowledge to other farmers (Fleischer et al., 1999). With the passage of time, the FFS approach gradually gained ground throughout the extension system and up to date more than 130,000 farmers have been trained in thousands of FFS conducted in more than 10 provinces with the majority in principal rice and cotton producing areas (Yang et al., 2002; Ooi et al., 2004; NATESC, 2005). In that process, the scope of the FFS has been broadened to cover not only IPM, but also biodiversity management, soil conservation and even animal production (Zhang et al., 2008b). In the FFS with focus on IPM, Bt cotton as an IPM measure was also included as an important component of the curriculum (NATESC, 2003c).

Worldwide, Bt cotton has received tremendous research attention. In China, a series of studies were conducted by Huang et al. (e.g. 2002a, 2002b, 2002c, 2003a) which document Bt cotton as a considerable success. According to their findings, Bt cotton adopted by the small-scale farmers in China contributed to a yield increase up to 10% and pesticide reduction by around 60% on average, with positive effects for the environment and farmers’ health. However, there are also research results which question the unconditional success of Bt cotton in China. For example, a study by

1 The farmers sampled for this study were categorized into three groups, namely the participants mentioned here and the exposed and control farmers who will be addressed later. Participants are those farmers who had ever participated in the FFS training before the surveys were conducted. Exposed Farmers refer to the farmers who had not participated in FFS but lived in the same villages as participants, and hence might indirectly benefit from the training. Control Farmers are those farmers who lived in the villages where no farmer had received FFS training.

Cornell University reveals that those early positive trends are now reversing, and in their sample of a few hundred farmers in five Chinese provinces the net revenue of Bt cotton farmers was significantly lower than that of non-Bt cotton farmers in 2004 (Wang et al., 2006). In terms of the pesticide reduction benefits of Bt cotton, some studies (e.g. Keeley, 2006; Pemsl et al., 2005, 2007a & 2007b; Fok et al., 2005; Yang et al., 2005a, 2005c) suggest that the impact of Bt cotton might be lower than claimed by other studies and that the farmers using Bt cotton continued to use high levels of pesticides. Also, it is not clear if the suppression of the outbreaks of the CBW can be linked to the diffusion of Bt cotton as the control efforts against bollworm already started to decline prior to the uptake of Bt cotton varieties (Waibel et al., 2009).

While Bt cotton was subjected to extensive research by agricultural economists, FFS in China has rarely been the subject of rigorous studies. Although anecdotal description of its impacts can be frequently found in literature and in mess media (e.g. Chen, 2002; Huang et al., 2003b), a few existing studies were built on farm level survey data (Mangan et al., 1998; Yang et al., 2005a). Based on descriptive analysis, those studies unanimously report substantial gains for trained farmers from FFS, such as improved knowledge, better farming performances and more stable ecosystem management. However, without establishing a reliable causal relationship between the FFS intervention and impact indicators, no strong conclusion can be drawn and hence to a large extent the impacts of FFS in China remain opaque.

The dispute of the economic effects of Bt cotton and opacity of the impacts of FFS in China give strong impetus for further research. Since both Bt cotton and FFS can be considered as components of IPM, to explore the possible interaction between those two innovations is promising. Therefore, this study was designed to extend and apply econometric models to have a careful check of the impacts of Bt cotton and FFS at the same time.

The FFS sampled for this study were conducted under the framework of the FAO-EU IPM Program for Cotton in Asia. With an overall objective to develop a “Sustainable, profitable and environmentally sound production of cotton in the participating countries, through the development, promotion, and practice of IPM by farmers and extension staff” (PGMU, 2001), the program was implemented from 2000 to 2004 in six member countries, namely Bangladesh, China, India, Pakistan, the Philippines and Vietnam. In China, more than 1,000 FFS were conducted in five provinces in two main cotton production regions with Shandong and Henan provinces representing the Huanghe River Cotton Region (HRR)[2], and Anhui, Hubei and Sichuan representing the Changjiang River Cotton Region (CRR). Since Bt varieties were dominant in the project areas, the use of Bt cotton was included as an important component in the curriculum of FFS and hence a chance was given to concurrently study the impacts of Bt cotton and its interaction with the training approach.

Furthermore, taking into consideration the fact that the commercial release of genetically modified rice is considered by the Chinese government and that more FFS are planned with public funding (Jing et al., 2008; Qiu, 2008), it is expected that the findings by this study will have wider policy implications for China.

1.2 Objectives

The objective of this study is to assess the impacts of Bt cotton and improvement of knowledge and understanding of pest management in cotton through farmer training using the Farmer Field School (FFS) concept on insecticide use, cotton productivity and farmer income. Based on panel and cross-sectional data, a set of models were developed and applied. It is expected that the findings will generate a more comprehensive understanding of Bt cotton and FFS, and will also shed light on the merits and demerits of different methodologies of impact assessment of crop protection technologies in China and other developing countries.

The specific objectives of the study are:

- To assess the impacts of FFS on productivity and insecticide use within different temporal (immediate and medium terms) and spatial (pilot and upscale stages) scopes,
- To evaluate the impacts of Bt cotton on productivity and insecticide use to further unveil the role of Bt cotton adopted by small-scale farmers in China,

2 There are three major cotton producing regions in China, which produce more than 98% of the national total output (Niu, 2006). In addition to the Huanghe River Cotton Region (HRR) and Changjiang River Cotton Region (CRR) where this study was conducted, another major cotton producing region is the North-western Cotton Region (NWR) mainly covering Xinjiang Uyghur Autonomous Region and Gansu Province. A map of the major cotton producing regions is presented in Appendix 1.

- To explore the interaction between FFS as an extension approach and Bt cotton as the technology to be extended, and
- To contribute to the development of methodologies of impact assessment in crop protection by testing the classic “difference in difference” (DD) model and damage control function and comparing different methodologies.

1.3 Organization of the Thesis

Chapter 2 gives a comprehensive examination of the pest problems and pesticide use in some major field crops, and particularly cotton, in China. After a brief review of the pesticide sector, the trends of pest infestations and pesticide use in major field crops in the past two decades were portrayed. The focus was then narrowed down to the most pesticide intensive field crop – cotton, and the product mix, toxicity levels, pesticide use of different categories and insecticides used against specific pests in different areas were analyzed.

Chapter 3 applies a two-period DD model to the data collected from 168 farmers in Lingxian County, Shandong Province to check the impacts of FFS on cotton productivity, pesticide use and gross margins at the pilot stage and in the short term. The findings in this chapter serve as a comparison with the impacts of FFS at upscale stage and in medium term as well.

Chapter 4 concentrates on the construction of a three-period DD model and provides a detailed explanation of the strengths of the model for impact assessment. With the time span prolonged to medium term (four years after the FFS conduction), the sample was also expanded to cover 480 farmers in three counties in three provinces. Bt cotton was added to the dimension, and some interaction terms were included to provide an insight into the dynamics of the impacts of FFS with the passage of time and the relationship between the FFS training and Bt cotton.

Chapter 5 provides a review of the impact assessment of FFS world wide and then carries out a cross-sectional analysis of an amplified sample covering 1,119 farmers in nine counties in three provinces. After a careful check and control of the econometric problems such as selection bias and endogeneity, production functions including some with inbuilt damage control functions were run by two stage least squares to check the impacts of the FFS training and Bt cotton. With interaction between the FFS intervention and the years of FFS conduction, the cross-sectional analysis also allows to check the impact dynamics with time passage and program scale-up. Based on the results of the econometric analysis, the marginal value products of insecticides were calculated to evaluate the level of insecticide use with wide adoption of biotechnology.

Chapter 6 presents a summary of the results and comparison of different methodologies, and derives some conclusions from the findings in this thesis. At the end of this chapter, some recommendations were raised for policy making and further research.

2 Pest Problems and Pesticide Use in Cotton in China

This chapter presents an overview of the pest problems and pesticide use in cotton in China, serving to provide some background information for further studies in later chapters. The first section explains the data sources, followed by a comparative introduction to the study areas. In the second section, the pesticide sector in China is briefly reviewed and some outstanding problems are highlighted. The third section carries out an analysis of the overall trend of pest infestations and pesticide use in cotton in the past two decades based on the comparison with some other major field crops, namely rice, wheat and maize. The annual dynamics of pest infestations are also compared with the trajectory of Bt cotton adoption to help understand the relationship in-between. Section four turns to the analysis of empirical data on pest control in cotton collected in the study areas. Based on the analysis of the product mix, toxicity levels, pesticide use of different categories and insecticides used against specific insect pests, that section provides a deep insight into the current situation of pesticide use and the underlying pest pattern in cotton in China. This chapter is closed with some conclusions drawn from the abovementioned analysis.

2.1 Data

The data for this study were from several sources. First, the professional plant protection data collected by the National Agro-technical Extension and Service Center (NATESC) were used to examine the national trend of pest infestations and pest control efforts in some major field crops in the past two decades. NATESC collects data through the network of plant protection stations across the whole country every year which cover the areas infested by and treated against major pests in major crops, estimation of yield losses abated by pest control efforts and actual losses inflicted by different pests. Second, the cost data on crop production collected by the Department of Price under the National Development and Reform Commission (NDRC) were used to analyze the general trend of pest control expenditures. Secondary data from the National Pest Forecasting System were also used to explain the pesticide use in different areas.

The majority of the data were collected by season long monitoring of a sample of 1,577 farmers in 2005 in Lingxian, Linqing and Zhanhua counties in Shandong Province, Dongzhi, Wangjiang and Guichi counties in Anhui province and Yingcheng, Xiantao and Tianmen counties in Hubei province (see Appendix 1 for a map and Appendix 2 for the distribution of the respondents). The three counties in Shandong Province are located in the Huanghe River Cotton Region (HRR) while the other six are situated in the Changjiang River Cotton Region (CRR). As a result, the sample from those counties can reflect the pest problems and pest control practices in two major cotton regions in China.

Among those study areas, Counties 1, 2, 3, 5, 8 and 9 are among the top 100 cotton producing counties in China (NBSC, 2005), and the others also have importance in cotton production in respective provinces. As a result, they were incorporated into the FAO-EU IPM Program for Cotton in Asia at an early stage and granted most of the funds through out the years. The FAO-EU IPM Program totally sponsored 1,061 FFS in 31 counties, five provinces in China from 2000 to 2004 (Ooi et al., 2004), among which more than 70% were placed in the sample counties of this study. A number of 614 participants trained in the FFS conducted under the framework of the FAO-EU IPM Program were surveyed for this study. The sample also included 587 exposed and 376 control farmers.

The enumerators mainly consisted of local agricultural technicians. Some consultants from universities and research institutes and FFS participants were also involved in the survey. In order to follow a standard social scientific survey procedure, a workshop was held in every province in early 2005 to train the enumerators. The farmers sampled were invited to participate in a meeting at township level to confirm their willingness to join in the study and were trained to record their cotton production from the procurement of seeds to sale of outputs in standard form. In the whole season, the enumerators visited all the sampled farmer households once per month to guide and check the recording. The recording sheets and questionnaires covered 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.

In order to have an overview of the sample situation, some farmer and household (HH) characteristics are summarized in Table 2-1. The farmer households were typically small holders with considerable variation across different counties. On average, the households each had around four family members, 2.5 laborers[3] and a farm size[4] of around 0.5 hectare. The farmers involved in cotton production were above 40 years old with an educational level[5] of more than six years in school. They had been growing cotton for almost two decades and the cotton share[6] in most counties was over 60 percent, indicating the importance of cotton production in the study areas.

There were always significant differences of the farmer and household characteristics. Bt cotton was 100% percent adopted in the three counties in Shandong province, while the farmers in the other six counties still planted some conventional varieties. The per capita annual revenue in County 3 was strikingly higher than that in the other counties. County 3 is located in a coastal area and has abundant lands reclaimed from coast, and hence the farmers there run much bigger farms and earn substantially higher revenues.

3 Laborer refers to those family members who belonged in the age group between 16 and 60 when the survey was conducted. The students in school and those adults who were not involved in farm work were excluded.

4 Farm size was defined as the total area of the land cultivated by a household.

5 Educational level refers to the number of years the respondent spent in school for formal education.

6 Cotton share is the proportion of cotton area to the total area of the land cultivated by a household, i.e. farm size.

Table 2-1: Summary statistics of farmer and household (HH) characteristics (2005)[7]

	County								
	C1[8]	C2	C3	C4	C5	C6	C7	C8	C9
Age of respondents	42.93^{b} (8.84)	45.58^{cd} (8.96)	38.78^{a} (7.14)	47.69^{de} (9.11)	46.77^{de} (8.97)	47.90^{e} (7.55)	43.23^{b} (9.20)	44.45^{bc} (7.83)	51.13^{f} (8.78)
Educational level (years in school)	7.08^{bc} (2.04)	7.80^{d} (2.04)	6.32^{a} (2.32)	6.32^{ab} (2.32)	6.88^{abc} (2.34)	6.80^{abc} (2.17)	7.20^{c} (2.10)	6.73^{abc} (2.51)	6.65^{abc} (1.90)
HH size (No. of people)	3.77^{ab} (0.99)	3.93^{bc} (1.17)	3.56^{a} (0.69)	4.27^{d} (1.11)	3.60^{a} (1.09)	4.42^{d} (1.05)	4.14^{cd} (0.99)	4.21^{d} (0.90)	3.51^{a} (1.20)
HH laborers (No. of people)	2.35^{a} (0.74)	2.73^{bc} (0.92)	2.36^{a} (0.73)	2.51^{a} (0.78)	2.41^{a} (0.79)	2.92^{c} (0.77)	2.43^{a} (0.81)	2.83^{bc} (0.80)	2.70^{b} (0.93)
Farm size (ha)	0.50^{a} (0.14)	0.52^{a} (0.15)	2.64^{b} (1.74)	0.42^{a} (0.16)	0.41^{a} (0.19)	0.41^{a} (0.18)	0.51^{a} (0.26)	0.54^{a} (0.30)	0.42^{a} (0.11)
Cotton experience (years of cultivation)	18.54^{bc} (7.61)	20.08^{de} (9.37)	16.83^{ab} (5.69)	19.10^{cd} (5.35)	20.91^{e} (4.65)	17.41^{abc} (4.21)	18.38^{bc} (6.17)	16.54^{a} (6.34)	20.38^{de} (7.18)
Cotton share (% of total land)	42.55^{a} (15.39)	54.74^{b} (17.44)	79.66^{e} (31.16)	79.66^{e} (31.16)	65.41^{c} (28.17)	64.14^{c} (23.59)	73.89^{d} (19.39)	64.73^{c} (27.04)	61.11^{c} (13.06)
Annual revenue[1/] (US$ per capita)	508.42^{a} (146.04)	487.28^{a} (165.05)	1774.53^{b} (1111.57)	468.80^{a} (146.54)	424.20^{a} (147.04)	452.10^{a} (108.99)	499.30^{a} (175.08)	489.06^{a} (151.03)	476.75^{a} (107.22)
Bt adoption (% of total cotton area)	100.00^{e} (0.00)	100.00^{e} (0.00)	100.00^{e} (0.00)	94.11^{cd} (19.86)	90.50^{bc} (20.90)	96.37^{de} (12.39)	78.16^{a} (31.46)	93.15^{cd} (21.99)	86.72^{b} (28.03)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); [1/] both on farm and off farm income were included in annual revenue.

Source: Own survey

2.2 Pesticide Sector in China

As an important input in intensive agriculture, pesticide is always set as a priority in the development of chemical industry in China (Wang, 2000). In the past decades, the pesticide sector in China has greatly evolved. Some selected statistics of the pesticide sector in China from 1995 to 2006 are presented in Table 2-2, in which the increasing trend of production, consumption and export and the fluctuation of import are clearly demonstrated. The production of pesticides was more than tripled in that period. With a production of 1,040,000 metric tons, China became the world's largest producer for the first time in 2005 (Wang, 2006). It was also the world's largest pesticide consumer and

7 The monetary figures in the table were converted from the Chinese currency RMB Yuan at the rate US$1 = 8 Yuan and this exchange rate was consistently used throughout the thesis for the year 2005.

8 Throughout this thesis, the following county numbers were used for brevity: Lingxian (C1), Linqing (C2), Zhanhua (C3), Dongzhi (C4), Wangjiang (C5), Guichi (C6), Yingcheng (C7), Xiantao (C8) and Tianmen (C9).

the consumption for agricultural purpose reached 281,000 tons (ibid). The share of Chinese pesticides in world market has increased drastically in recent years. Although the import fluctuated at a low level less than 50,000 tons, the pesticide export soared from 71,000 tons in 1995 to 398,000 tons in 2006. A large number of products were registered every year and the total number of valid registrations accumulated to be above 22,000 in 2006[9].

Table 2-2: Selected statistics of the pesticide sector in China (1995-2006)

Year	No. of products registered in year	Amount of production (1,000 tons)[1/]	Amount of consumption (1,000 tons)[2/]	Amount of export (1,000 tons)	Amount of import (1,000 tons)
1995	563	417	238	71	34
1996	690	427	179	74	32
1997	1017	552	213	88	48
1998	1851	605	281	107	44
1999	2451	625	275	147	47
2000	2535	607	250	162	41
2001	2786	787	230	197	34
2002	2617	929	258	222	27
2003	2441	767	260	272	28
2004	2664	870	280	391	28
2005	3904	1040	281	428	37
2006	4013	1296	285	398	43

Note: [1/] Figures in column 3 to 6 were measured in active ingredient; [2/] only pesticides used for agricultural purpose were included, the pesticides used for the other purposes such as forestry and public health constituted a difference between the production and the sum of consumption and import/export balance.
Source: ICAMA (2007) & MOA (2007)

Despite the remarkable development of producing capacity, there are widely recognized structural drawbacks in the production and use of pesticides in China. In sharp contrast to the large pesticide industry, most of the pesticide plants in China operate on very small scale, and more than 2600 manufacturers are involved in pesticide production (Wang, 2009a). The wide spread of small plants renders the governmental control especially difficult. There are around 650 varieties of active ingredients registered, among which only a little more than 200 are regularly used in pesticide production (ICAMA, 2006). Therefore, many of the registered products are

9 Since some registrations of pesticide products were revoked or were not renewed every year, the number of the valid registrations was smaller than the sum of the registration numbers year by year.

actually the same active ingredient(s) with different concentrations and trade names. The prevalence of blend products with identical active ingredients and similar trade names poses harsh challenges for farmers to choose suitable pesticides for pest problems in their fields (Sui et al., 2007). Moreover, a considerable proportion of the pesticide products on market are not registered or properly labelled, and hence cannot be identified to active ingredients (Pemsl, 2006). As a result, farmers might risk buying and using a pesticide product without knowing what it is. For long time until the early years of this century, another typical drawback of the pesticide industry in China had been described as the problem of "three 70%" (Hu, et al., 2003). The amount of insecticides accounted for 70% of total pesticides, with organophosphates accounting for 70% of all the insecticides and highly toxic phosphates accounting for 70% of all the phosphates.

Addressing those problems, various measures are taken to improve the structure of pesticides. Up to date, 23 varieties (categories) of pesticides have been completely banned for use, and another 16 varieties have been restricted to only some crops owing to their chronic poisoning, persistent residue or high toxicity (MOA, 2002a; 2003). Meanwhile, the manufacturers are encouraged to produce less toxic products and new pesticide varieties. About 20 new products are granted registration annually in recent years, among which two thirds were innovated by Chinese companies or research institutes (Liu, 2006). The proportional relationship between the three major pesticide categories, namely insecticide, herbicide and fungicide, has also evolved considerably over time. As depicted in Figure 2-1, the proportion of insecticides declined from 79% in 1990 to 34% in 2007 while the share of herbicides increased from 7% to 33% in the same period. Even so, as compared to the world average ratio of 25:48:24 between the insecticide, herbicide and fungicide, the share of insecticide in China still remains very high (JSCN, 2007).

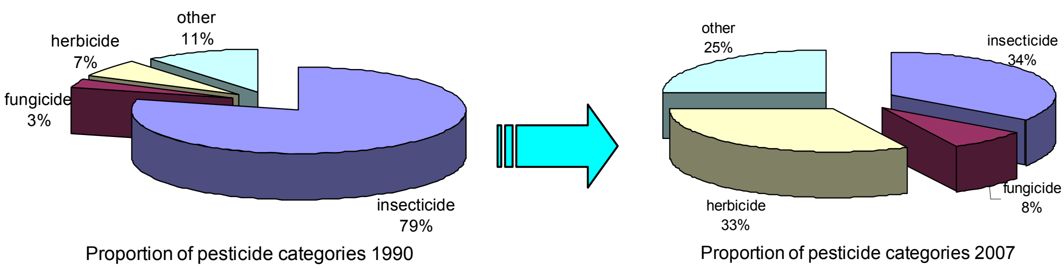

Figure 2-1: Evolution of the structure of pesticide products

Source: Gu (2009)

2.3 Evolution of Pest Problems in Cotton as Compared to Other Crops

Cotton is the crop at the center of the research interest, while a comparison of the pest problems between cotton and the other major field crops, namely rice, wheat and maize, can help understand the role and importance of pest control in cotton. The ratios between treated areas and total sown areas in China, i.e. the national average spraying frequencies, were used to indicate the extent and severity of pest problems. As revealed in Figure 2-2, with the exception of cotton, all the other three crops have succumbed to apparently increasing pest infestations. Rice, wheat and corn demanded two or less spays per season in 1980s, but in 2007 rice received more than six treatments and the figures for wheat and maize both increased to some extent as well. The global warming which benefits the pest overwintering and the change of cropping systems which provides more bridge hosts were raised as reasons for such an overall worsening of pest problems in recent years (MOA, 2008b; Wang et al., 2009). As compared to any of the other three major field crops, the pest problems with cotton are almost always more severe. The spraying frequencies in cotton increased dramatically before mid 1990s and peaked at 10 times per season in 1995. From then on the pest problems with cotton have shown a general trend to ease off, while there were appreciable rebounds in some years.

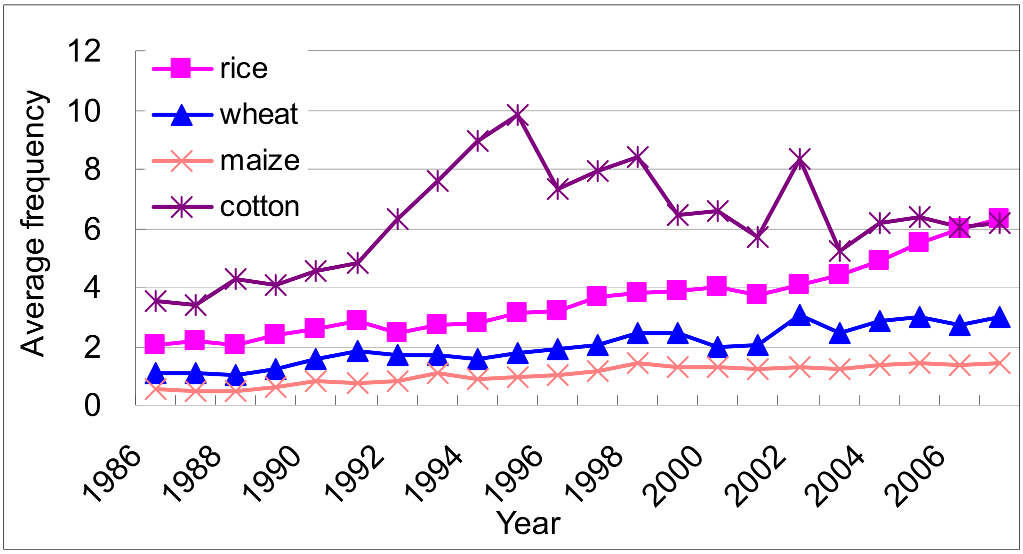

Figure 2-2: Average spray frequencies in major field crops

Source: NATESC (1987-2008)

Pest control measures are taken to abate the damage inflicted by pests. However, even with intensive control efforts there is still remaining damage which finally leads to the actual losses in the fields. The estimated yield losses abated by pest control efforts and actual yield losses for the above mentioned four crops are plotted in Figure 2-3. Generally speaking, those losses are fairly considerable for all the crops, especially cotton. The mounting resistance to pesticides and some other factors such as favorable climate and crop systems concurred to cause extremely severe occurrence of cotton bollworm (CBW) (*Helicoverpa armigera*) in early 1990s (Dai et al., 1993; Xia, 1993; Lu et al., 1998; Wu et al., 2005). In peak years from 1992 to 1994, the cotton yield losses abated by pesticide application were as high as around 35%. Such percentage declined to some degree later on, but in most years it was over 20%, which strikingly implies if cotton farmers in China had not sprayed any pesticide, the national cotton production would have fallen by 20 to 35 percent. The actual cotton yield loss inflicted by pests was found to have followed a similar trend. It peaked at 14% in 1992 and then declined to around 6% in recent years. The reduction of the losses abated and actual losses might reflect some amelioration of the underlying pest problems with cotton and the improvement of pest control measures in this crop. However among all the four major field crops, cotton still succumbs to the highest losses of both kinds in most of the recent years, which shows that the eased pest infestations are still an important restrictive factor of current cotton production in China. Another impressive finding is the sharp increase in the rice yield losses abated in recent years, which actually exceeded the abated level in cotton after 2005. The increasing infestations of rice pests in recent years, particularly the brown planthopper (*Nilaparvata lugens*) and rice leaf roller (*Cnaphalocrocis medinalis*), have called more control efforts (Zai et al., 2006).

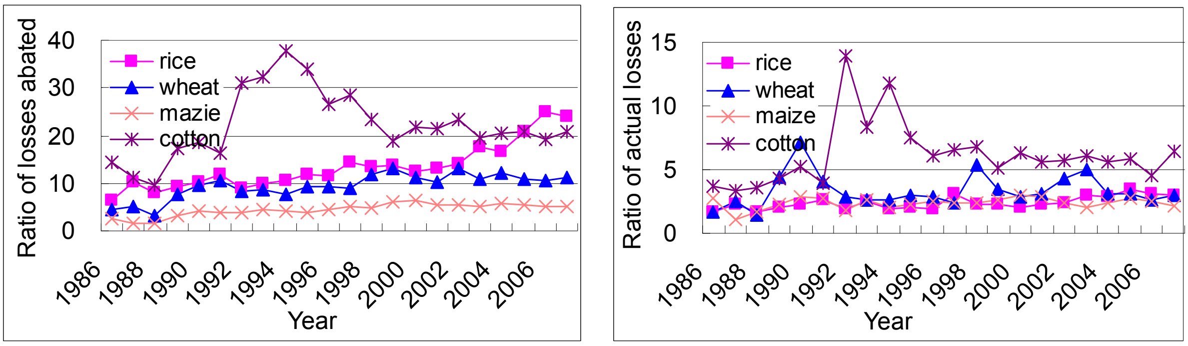

Figure 2-3: Ratios of losses abated and actual losses[10]

Source: NBSC (2008) and NATESC (1987-2008)

The observations derived from the NATESC data are substantiated by the surveys of the production costs organized by the National Development and Reform Commission (NDRC). As shown in Figure 2-4, rice, wheat and maize all experienced an appreciable increase in unit cost for pesticides and such an increase was especially apparent for rice. The unit cost for pesticides for rice jumped from 15.6 US$/ha to 75.7 US$/ha from 1985 to 2007 and the upward slope tended to be steeper with the passage of time. In the same period, the unit cost for pesticides increased from 3.1 US$/ha to 18.7 US$/ha for wheat and from 1.5 US$/ha to 16.1 US$/ha for maize. Given the most severe pest problems as illustrated before, the unit cost for pesticide use in cotton is always much higher than those in the other three crops. Cotton farmers spent 38.7 US$/ha on pesticides in 1985, but up to 1995 the expenditure had soared to 130.5 US$/ha. With some decline in the subsequent years it remained at a quite high level of 96.8 US$/ha in 2007.

Bt varieties were first officially approved as a remedy for pest and pesticide problems with cotton in China in 1997 and then rapidly expanded to many areas in short time. The adoption rates of Bt varieties were imposed on Figure 2-4 to detect possible relationship between Bt variety adoption and pesticide use on cotton. In the process of rapid Bt cotton expansion from 1997 to 2004, the pesticide costs of cotton production did follow a downward trend, which might imply that the increasing adoption of Bt

10 The ratios were calculated by dividing the estimated yield losses abated and actual yield losses with the realized gross cotton production.

varieties could have contributed to some reduction of pesticide use. However, it should be noted that the most abrupt decline already took place before the approval of Bt cotton for commercial use, and the pesticide cost was still quite high in 2007 when the adoption rate of Bt cotton was already 64%. As a result, care should be taken when explaining the merit of Bt cotton in reducing pesticide use.

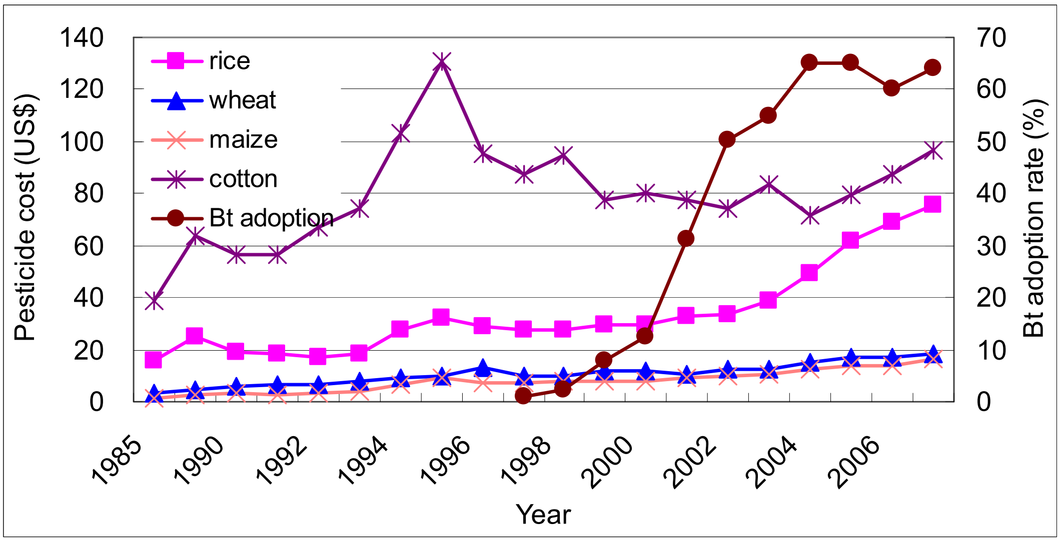

Figure 2-4: Pesticide costs in major field crops and adoption of Bt cotton

Note: Rural retail price index of pesticides was used to inflate the costs to 2007 value and the figures were converted from the Chinese currency RMB Yuan at the rate US$1 = 7.5 Yuan.
Source: NDRC (2008) and James (1997-2003, 2004-2007)

To further investigate the impact of Bt cotton adoption, the areas treated against different insect pests are presented in Figure 2-5. Obviously the CBW is the most important pest in cotton in China which always receives more pest control efforts as compared to any other insect species. The efforts to control CBW had continuously grown up before mid 1990s and then started to turn down. The intensity of CBW control declined most sharply in 1996, one year before Bt cotton was approved for commercial use in China. Another sharp decline took place in 1999, when the adoption rate of Bt cotton was less than 10% as shown in Figure 2-4. In later years, although Bt cotton expanded more rapidly, the efforts to control CBW only went down slightly and then remained relatively stable from 2003 on. Therefore, even if Bt cotton might have played a role, there must be some other reasons for the overall decline of CBW infestations. Another pertinent observation from Figure 2-5 is that, the control efforts against red spider mite (RSM) (*Tetranychus cinnabarinus*), aphids (*Aphis* spp. and *Acyrthosiphon gossypii*) and mirids (*Adelphocoris* spp. and *Lygus* spp.) have increased considerably in the period of Bt cotton expansion since late 1990s. For instance, the mirids which used to be a minor pest were targeted by a considerable proportion of pesticide sprays in 2007. This finding is consistent with some other studies reporting increasing occurrence of sucking pests in Bt cotton (Wang et al., 2002; Zhao et al., 2002), and tends to aggravate the worry that, the Bt cotton innovated to solve the pest problems caused by some lepidopterous insects might result in new problems caused by the other species. The category of others in Figure 2-5 includes tobacco cutworm (*Spodoptera litura*), thrips (*Frankliniella intonsa* and *Thrips* spp.) and some other insect pests, which also tended to cause bigger problems in recent years than before.

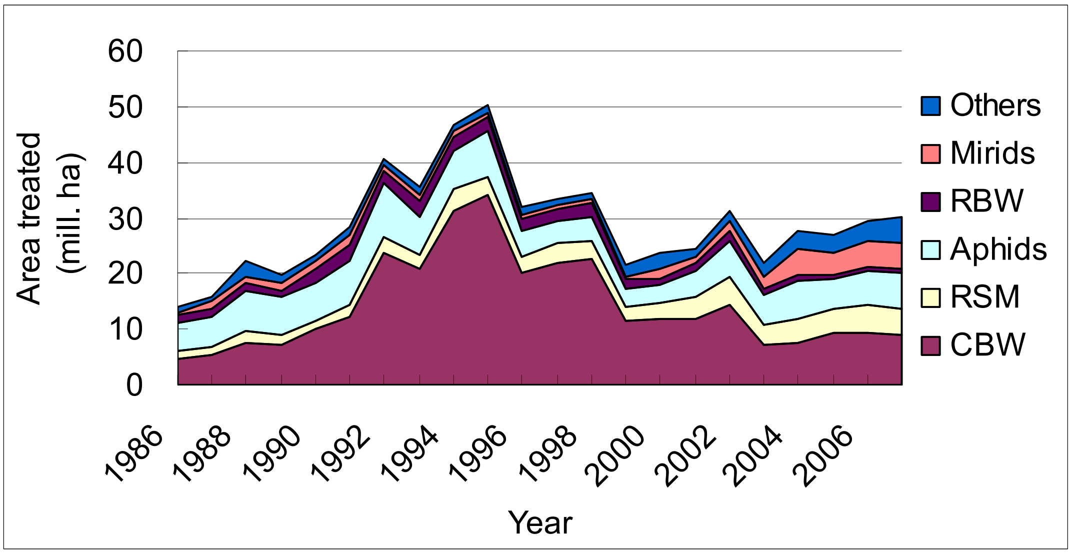

Figure 2-5: Area treated against specific insect pests in cotton

Source: NATESC (1987-2008)

2.4 Empirical Results of Pesticide Use in Cotton in Sample Counties

2.4.1 Analysis of Pesticide Compounds

The large number of confusing pesticide trade names is a major problem of the pesticide market in China. As presented in Table 2-3, large numbers of trade names, i.e. different products, were recorded by the farmers in the sample. In County 2 the figure was even greater than 400. Facing so many products among which a lot had similar trade names and claimed to be effective against the same target pests, farmers always felt helpless at choosing pesticide products. More seriously, the active ingredients of almost 40% of those products could not be identified. There was no indication on the label and the product could not be found in the registration data base of the Institute for the Control of Agrochemicals, Ministry of Agriculture (ICAMA, 2005). Since the dealers did not know the active ingredients either and the label specification often exaggerated the efficacy, the reliable information for those products could only be achieved based on farmers' own experience in the fields. Such experience is sometimes costly because the farmers have to risk poor efficacy or even phytotoxicity. Moreover, many of those products might appear with new trade names the second year and hence further aggravate the problem of asymmetric information. More than 80% of those products were insecticides, which strongly shows that the insect pests are a major constraint in cotton production. However on the other hand, it might also suggest a lack of attention given to disease and weed control in cotton in China.

Table 2-3: Division of pesticides by category

	County									
Number	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total
All pesticides	96	423	57	97	119	84	67	121	52	917
Unidentified	35	170	18	24	30	23	26	36	17	357
Insecticides	78	360	46	85	106	69	50	106	42	789
Fungicides	7	44	6	5	4	6	11	7	4	76
Herbicides	7	4	2	3	4	5	4	3	4	20
Plant hormones	4	15	3	4	5	4	2	5	2	32

Source: Own survey

Claiming efficacy on major pests in trade names is a common marketing strategy for pesticide manufacturers in China and the pests of severe occurrence are frequently included in the trade names of pesticide products. As a result, pesticide naming can to some extent mirror the pest problems in the fields. The insecticide products are divided by the target insects included in the trade names and the results are reported in Table 2-4. More than a half of the trade names contained at least one target insect. Consistent with the increasing infestations of sucking insects as shown in section 2.3, efficacy on RSM and aphids appears to be a big selling point in both the Huanghe River and Changjiang River Cotton Regions. The former minor pest mirids also drew a lot of attention in the Huanghe River Cotton Region, which indicates the increasing damage caused by that pest. In the Changjiang River Cotton Region, very few products included mirids in their trade names, suggesting that the infestations of those pests in that region were not so severe as in the Huanghe River Cotton Region in 2005.

The CBW was referred to in fewer trade names as compared to RSM and aphids, indicating a decrease in its relative importance in cotton production. Excepting the above mentioned four insects, the other insects were rarely used in pesticide naming. However as section 2.4.4 will show, some other pests, especially the tobacco cutworm and thrips in the Changjiang River Cotton Region, actually received a considerable proportion of pesticide sprays. Perhaps because the farmers were less familiar with those pests, pesticide manufacturers did not value them as good advertisements for pesticide products.

Table 2-4: Division of insecticides by target insects included in trade names

	County									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total
CBW	2	20	1	4	6	5	4	8	5	49
Aphids	15	54	3	5	5	4	8	12	7	96
RSM	22	75	3	23	30	17	19	19	15	183
Mirids	13	58	3	3	0	0	0	2	0	77
Other insects[1/]	1	15	1	4	3	5	3	7	0	29
No specific insects[2/]	29	161	36	57	67	42	24	67	21	407

Note: [1/] Other insects refer to those insect pests other than CBW, aphids, RSM and mirids which were indicated in the trade names of pesticide products, such as cotton whitefly and underground pests; [2/] "no specific insects" refers to the category of insecticide products which did not include any specific insect in their trade names.

Source: Own survey

2.4.2 Toxicity of Identified Pesticides

Since the unidentified pesticides were usually less frequently used by farmers, the volume share of unidentified pesticides was 12.7% in 2005, much lower than the proportion of unidentified products as described earlier. The 83.7% identifiable pesticides are grouped according to their toxicity levels and the results are reported in Figure 2-6. On average, around 30% of all the identifiable pesticides contained extremely or highly hazardous active ingredients listed as WHO class Ia and Ib. As compared to the share of 70% in the past, such a reduced percentage might signify a considerable progress in bringing down pesticide toxicity. However, the percentage was still very high and the actual proportion could be even higher, since the unidentified products were usually produced by small plants with less "social responsibility" and were more likely to contain extremely or highly hazardous compounds. There was also a considerable difference between different counties. In six out of the nine sampled counties, the extremely or highly hazardous products took up a share of around 20%, while the proportion was higher than 30% in Counties 2 and 9 with the highest of 54.5% in County 7. The most popular extremely hazardous pesticides used in cotton production in China were methamidophos, parathion and parathion methyl which pose high incidence of occupational poisonings world wide especially in the developing countries including China (FAO, 1997). The wide use of extremely hazardous pesticides and the resultant problems prompt the government to take strict measures on the control of pesticides. Since the turn of 2007, five extremely hazardous pesticides, i.e. the above mentioned three together with monocrotophos and phosphamidon, have been completely banned for use (MOA, 2003).

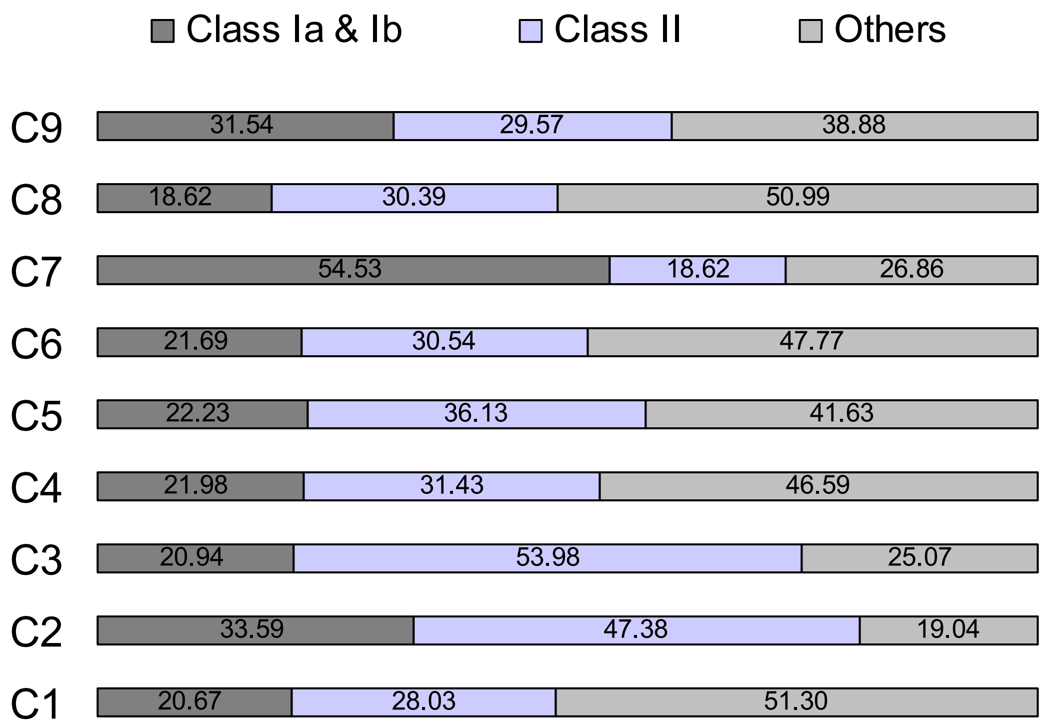

Figure 2-6: Proportion of pesticides by WHO toxicity classification in different counties

Note: Ia = extremely hazardous, Ib = highly hazardous, II = moderately hazardous.
Source: Own survey

2.4.3 Pesticide Use of Different Categories

Pesticide use of different categories is summarized in Table 2-5. Generally speaking, Chinese farmers use pesticides intensively in cotton production with a considerable variation between areas. The spraying frequency varied from around nine times per season in County 1 to more than 15 times in County 8. Some 20% of all the pesticides used in the sample contained two or more active ingredients, but field mixing was still very common in many counties. On average, farmers mixed pesticide products 3.3 times and in Counties 2 and 7 the figure was as high as 6.5. A broader variation existed with the pesticide volumes. In County 7, farmers applied more than 35 kg pesticides on one hectare cotton field, which was four times more than the unit volume used in County 1. In the same cotton region and hence similar ecosystem, the variation was also huge. For instance, the farmers in Counties 2 and 3 sprayed almost twice more pesticides as compared to those in County 1 in the same Huanghe River Cotton Region. However, as will be shown in chapter 5, the cotton yields in County 1 were the highest among all the nine counties. The divergence of the pesticide use and cotton yields raises critical doubt about the rationality of the high level of pesticide use in many counties.

The distribution of different pesticide categories is consistent with the overall national pattern. Insecticides accounted for most of the pesticides in all the nine counties and next came herbicides and fungicides. The average insecticide share was more than 75%, which underlines the importance of insect pest control in cotton production. Diseases are also an important restrictive factor in cotton production in China and some diseases such as *Verticillium* wilt and *Fusarium* wilt have reportedly increased their infestations in recent years (Yang, 2003; Chen, 2009). Nonetheless, the proportion of fungicide was just fractional in all the counties, implying a deficiency of disease control in crop production. Owing to the poor efficacy of chemical control of cotton diseases, resistant varieties remain as the principal countermeasure and the farmers are usually advised to increase plant vigour and hence disease resistance with balanced fertilization (Li et al., 2003; Yang, 2003). Accounting for 16.8% of all the pesticides, herbicides were commonly used by cotton farmers once or rarely twice one season. Plant hormones were also widely used in cotton production. However, they only accounted for a meagre proportion of all the pesticides used owning to a small dosage per application. Molloscicides were only used in the Changjiang River Cotton Region where the snail is a problem with cotton seedlings.

Table 2-5: Summary of pesticide use in cotton in sample households (HH)

	County									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total
No. of applications	9.11^{a} (3.13)	13.34^{bc} (3.10)	15.39^{g} (3.07)	13.09^{b} (2.77)	14.03^{cd} (3.26)	14.34^{de} (3.74)	14.41^{def} (3.52)	15.22^{fg} (4.15)	14.98^{efg} (2.00)	13.18 (3.80)
No. of field mixings	0.25^{a} (0.49)	6.56^{f} (3.39)	1.57^{c} (1.96)	3.18^{d} (1.85)	3.89^{e} (2.66)	1.55^{c} (2.08)	6.42^{f} (2.80)	0.91^{b} (1.33)	2.83^{d} (2.53)	3.35 (3.28)
All pesticides (kg ha^{-1})	6.71^{a} (2.97)	18.79^{b} (8.08)	18.34^{b} (8.32)	24.47^{c} (7.83)	27.68^{d} (8.65)	25.63^{cd} (11.75)	35.14^{e} (16.11)	27.07^{d} (13.35)	28.24^{d} (6.71)	22.54 (13.51)
Insecticides (%)	66.73^{a} (13.71)	84.88^{d} (9.72)	78.65^{c} (11.11)	85.89^{d} (11.59)	68.51^{a} (14.50)	68.00^{a} (14.39)	75.34^{b} (13.91)	68.65^{a} (16.94)	75.65^{bc} (11.74)	76.30 (14.87)
Fungicides (%)	2.68^{b} (5.27)	4.20^{c} (5.80)	2.35^{b} (3.91)	2.21^{b} (3.33)	0.91^{a} (1.61)	1.85^{ab} (4.43)	5.29^{c} (5.82)	5.25^{c} (3.55)	4.10^{c} (3.53)	3.36 (4.88)
Herbicides (%)	26.11^{e} (13.18)	9.56^{a} (7.38)	16.75^{c} (9.22)	10.06^{a} (11.08)	28.69^{e} (14.96)	28.12^{e} (13.68)	12.51^{ab} (12.11)	21.75^{d} (17.03)	15.24^{bc} (10.25)	16.80 (13.86)
Plant hormones (%)	4.48^{e} (2.63)	1.36^{c} (2.54)	2.25^{d} (2.07)	1.47^{c} (0.79)	0.81^{ab} (0.92)	1.13^{bc} (1.01)	0.88^{ab} (0.75)	1.25^{bc} (2.32)	0.52^{a} (0.24)	1.82 (2.19)
Molloscicides (%)	0.00^{a} (0.00)	0.00^{a} (0.00)	0.00^{a} (0.00)	0.38^{a} (1.61)	1.08^{a} (2.56)	0.90^{a} (2.61)	5.98^{d} (7.45)	3.11^{b} (7.48)	4.48^{c} (8.10)	1.71 (4.88)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05).

Source: Own survey

2.4.4 Insecticide Compounds and Target Pests

Since the insecticides accounted for an overwhelming proportion of all the pesticides, special attention was given to insecticide use. As revealed in Table 2-6, the frequency and volume of insecticide use also varied broadly between different counties, and the farmers in the Huanghe River Cotton Region tended to apply less insecticide than those in the Changjiang River Cotton Region. With an average of 17.61 kg/ha, the insecticide use appeared to be too high in the context of wide adoption of Bt varieties in the study areas. As a major target insect of Bt cotton, the CBW still took up a considerable share of insecticide use, and around 30% of insecticide use was claimed by the farmers to control that pest on national average. The CBW was actually found to have increased its infestations in some areas in recent years due to warmer climate, more bridge hosts and poor assurance of the quality of Bt cotton seeds (Lu et al., 2008).

The RSM and aphids are always among major cotton pests in China, but they have increased their damage owing to the reduced use of broad spectrum pesticides after the wide adoption of Bt varieties (Xu et al., 2004; Wang et al., 2001). Although the occurrence of those two pests was evaluated as normal by the plant protection stations in most of the study areas, the insecticides against RSM and aphids accounted for 18.18% and 13.42% of all the insecticides respectively in 2005. The mirids which used to be a secondary pest have become a key insect pest after the introduction of Bt cotton (Zhang et al., 2005). A proportion of 22.17% insecticides were sprayed to control the mirids on national average, and the percentage was even higher in the Huanghe River Cotton Region. Although such a proportion was relatively lower in the six counties in the Changjiang River Cotton Region, the infestations of mirids have increased greatly in most recent years in that region (Zhang et al., 2008a). The other insects include tobacco cutworm and thrips, etc. which severely broke up in the three counties in Anhui Province in 2005 and took up more than 1/3 of all the insecticide use.

Table 2-6: Summary of insecticide use according to target insects

	County									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total
No. of applications	7.10^{a} (2.94)	12.27^{de} (3.07)	12.71^{e} (2.91)	11.14^{b} (2.59)	11.43^{bc} (3.16)	11.70^{bcd} (3.53)	11.99^{cde} (3.36)	12.13^{cde} (3.82)	11.70^{bcd} (1.77)	10.98 (3.55)
All insecticides (kg ha^{-1})	4.62^{a} (2.68)	16.25^{bc} (7.96)	14.95^{b} (8.25)	20.99^{ef} (6.93)	18.75^{de} (7.04)	18.26^{cd} (11.19)	26.76^{g} (13.75)	19.29^{def} (11.95)	21.16^{f} (5.56)	17.61 (11.34)
CBW (%)	25.16^{ab} (22.61)	31.97^{c} (15.10)	22.72^{a} (13.54)	20.96^{a} (17.26)	27.71^{b} (12.02)	23.79^{ab} (21.10)	43.73^{e} (11.71)	35.40^{cd} (22.10)	37.26^{d} (15.52)	29.80 (19.13)
RSM (%)	19.64^{bcd} (16.49)	13.07^{a} (9.95)	16.03^{ab} (12.78)	18.96^{bc} (15.28)	17.29^{bc} (11.06)	22.82^{d} (17.32)	17.98^{bc} (10.24)	20.15^{cd} (12.33)	19.96^{cd} (11.08)	18.18 (13.68)
Aphids (%)	16.08^{de} (14.75)	17.35^{e} (10.10)	17.30^{e} (11.05)	11.39^{bc} (10.38)	6.00^{a} (7.21)	12.79^{bc} (10.66)	10.02^{b} (9.99)	13.58^{cd} (9.48)	14.09^{cd} (9.27)	13.42 (11.45)
Mirids (%)	37.98^{e} (23.73)	31.49^{d} (15.35)	39.58^{e} (16.55)	15.31^{c} (11.74)	12.63^{bc} (9.49)	8.43^{a} (13.19)	14.69^{c} (5.57)	10.38^{ab} (13.33)	10.70^{ab} (5.93)	22.17 (18.60)
Others (%)	1.14^{a} (6.13)	6.11^{b} (9.00)	4.37^{b} (7.52)	33.38^{ef} (19.17)	36.37^{f} (12.01)	32.18^{e} (22.32)	13.54^{c} (9.64)	19.85^{d} (15.80)	17.99^{d} (9.22)	16.37 (18.18)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05).
Source: Own survey

To examine the rationale of insecticide use, the monitoring data of CBW and the volumes of insecticides sprayed against that pest are plotted in Figure 2-7. Because most of the CBW larvae might be eliminated by Bt toxin, the cumulative numbers of CBW eggs of major damaging generations were used to indicate the severity of CBW infestations[11]. The results strikingly suggest that the insecticides could be overused against that pest in most areas. The farmers in Counties 2 and 3 sprayed much more insecticides against the CBW than those farmers in County 1 in the same cotton region, although the CBW infestations in County 1 were the highest in 2005. The majority of CBW eggs in those three counties were of the second generation. No farmer in County 1 sprayed against the second generation CBW because the Bt toxin produced by the early stage Bt cotton plants was believed to be adequate for keeping the CBW population in check. However, the spray against the second generation CBW was quite common in Counties 2 and 3. So stark a difference of pesticide use might partially resulted from different qualities of Bt seeds, since both Plant Protection Station (PPS) staff and the farmers in Counties 2 and 3 stated in the survey their concern about the decline of Bt resistance, and it was reported by a recent study in County 2 that the Bt toxin concentrations in Bt plants had declined significantly in 2005 as compared to those in 2002 (Pemsl et al., 2007b). However, the farmers' perception and handling of pest problems might be more important determinants for pesticide use, because the pesticide use in County 1 was found already much less than those in Counties 2 and 3 in 2001 (Pemsl, 2006).

The pesticides used to control CBW in the Changjiang River Cotton Region were substantially higher than those in the Huanghe River Cotton Region. The performance of Bt cotton in the Changjiang River Cotton Region is not so good as in the Huanghe River Cotton Region, because the expression of Bt gene declines at the later growing stage of cotton which concurs with the main damaging period of the CBW in the former region (Xue, 2002). Even so, considerable amount of pesticides applied in Counties 4 to 6 to control slight infestations of the CBW apparently indicates an irrational use and a volume of 12 kg/ha against CBW in County 7 was unlikely necessary.

11 The major damaging generations of CBW are the second and third in the Huanghe River Cotton Region, third and forth in the Changjiang River Cotton Region (Wang, 2003).

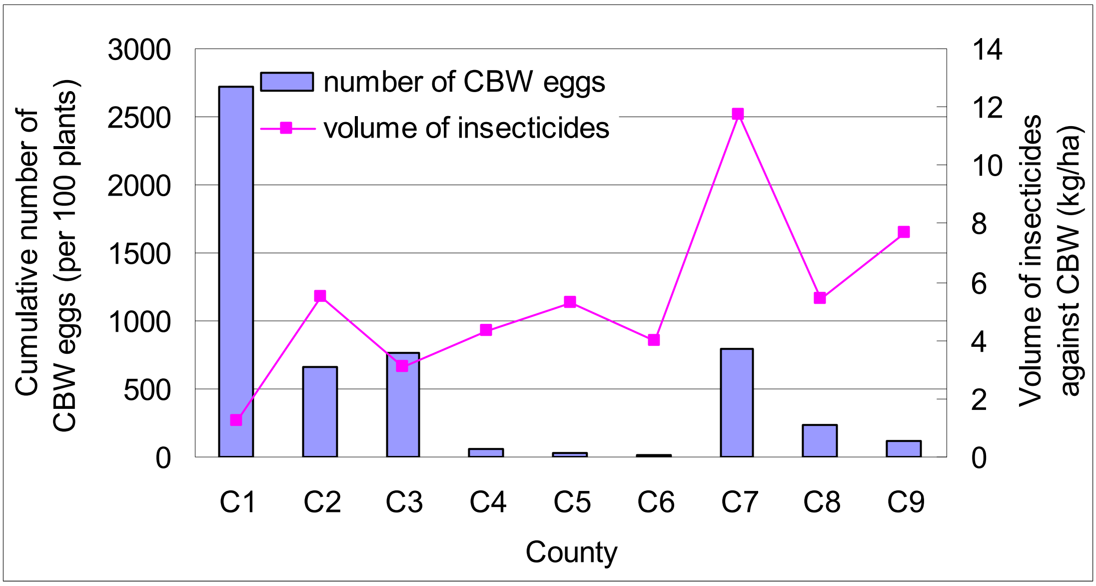

Figure 2-7: Insecticide use vs cumulative number of CBW eggs

Source: National Pest Forecasting Network & own survey

2.5 Summary and Conclusions

Although there are still perceived problems with the production and application of pesticides in China, the pesticide sector has evolved greatly in the country during the past decades. Most major field crops such as rice, wheat and maize encountered mounting pest problems in that period, but cotton has experienced an overall decline of pest infestations since mid 1990s. The pest pattern of cotton has also changed appreciably with the CBW generally reducing its infestations while RSM, aphids, mirids and some other pests increasing their damage. Although the decline of CBW infestations happened in parallel with the expansion of Bt cotton over some period, the most abrupt decline already took place before the commercialization of Bt cotton. With wide distribution of Bt varieties, cotton remains as the major field crop with most severe pest problems and receiving most intensive pesticide treatment nowadays.

Cotton farmers faced tremendous difficulties in selecting suitable pesticides from a huge number of products with similar and confusing trade names, among which a large proportion could not be identified to active ingredients. Extremely or highly hazardous products were prevalent in the study areas, constituting an unignorable threat to farmers' health. Before the background of wide distribution of Bt varieties, the farmers continued to use high levels of pesticides with a large proportion targeting the CBW. The RSM, aphids, mirids and some other pests all took up considerable shares of pesticide use, indicating their increasing importance in cotton production. There were a great variation of pesticide use between different counties and divergence between the pesticide use and pest infestations, implying a substantial overuse of pesticides in many areas.

The analysis of pesticide product mix mirrors a deficiency in the pesticide control in China. In order for an effective solution, mounting efforts have been undertaken to improve the pesticide management in recent years, especially after 2007 when six regulations were promulgated by MOA at the same time to tighten the pesticide registration and labelling (MOA, 2008a). Those measures work very well and the pesticide market situation has been improved measurably (Xiong et al., 2009). However, there are still serious challenges, such as illegal use of banned products and non-standard labelling. As a result, the crackdown on illegal production, sale and use of high toxic pesticides is still at the top of MOA’s agenda (Jiang, 2009). There are several factors rendering the pesticide management in China an onerous task. First of all, the liberalization of pesticide distribution system gave birth to hundreds of thousands of small pesticide dealers, half of whom are actually not qualified for dealing with pesticides (Zhao, 2007). Secondly, the farmers in China usually lack a sense of self protection and many of them do not have adequate knowledge to distinguish the good products from bad ones (Tang, 2008). Thirdly, the shortage of operation funds drives plant protection stations to get involved in pesticide business, which in turn diverts the limited human resources or even twists their attitude to pesticide use (Huang et al., 2002b; Zhao, 2007). From these points of view, the effective pesticide management is not only a mission for the government, but also a matter relevant to all the stakeholders in the game. A change of the ideology of pesticide management from controlling pesticides to managing the game players involved might be recommendable. If more efforts are undertaken to enhance the dealers’ qualification, increase the farmers’ awareness and improve the extension agents’ condition, the pesticide managing stipulations on paper could be better turned into actions in reality.

Bt cotton was introduced as a prescription against the excessive use of pesticides in cotton production. The general trend of the declining infestations of target pests CBW and RBW in the progress of Bt cotton adoption tends to evidence the effectiveness of biotechnology. However, the very high level of insecticide use and the rising infestations of some other non-target pests strongly show that Bt cotton is by no means a panacea.

Since there were significant changes of the pest pattern in cotton in the past decade and the effect of Bt cotton depends on the severity of target pest infestations, it might be better to analyze the impacts of Bt cotton in a time period rather than at a specific point in time. Further analysis with econometric models is conducted in the following chapters of this thesis. In addition to a cross-sectional data set covering more farmers, a panel data set spanning five years is analyzed for a more comprehensive understanding of the impacts of Bt cotton and FFS training in China.

3 FFS Impact Analysis: A Case Study of Cotton Production in Shandong Province in China[12]

This chapter carries out a case study in Lingxian County in Shandong province, where panel data were collected before and after the FFS was delivered to some of the sampled farmers. After a short introduction to the objectives of the study in section one, the way to collect data and the sample composition are explained in section two. Section three provides a brief description of the study area with focus on local cotton production. The role of "difference in difference" (DD) model in controlling for selection bias is discussed and the empirical functions for this case study are specified in section four. Section five comes up with the empirical results. Selected household (HH) characteristics and cotton production parameters are compared for the baseline year to check the homogeneity of the sample, followed by a comparison of major performance indicators before and after the program delivery for different farmer groups. The results of the multivariate analysis of the impacts of FFS training on cotton yields, pesticide costs and gross margins are then presented. At the end of this chapter, a summary and some conclusions are drawn, and the strengths and weaknesses of this case study are briefly analyzed.

3.1 Objective of the Study

The overall objective of this chapter is to investigate whether there are significant impacts of FFS on the performance of the participants and exposed farmers. The specific objectives are:

- To describe important socio-economic parameters of the participants, exposed farmers and control farmers, and
- To analyze the impacts of FFS on cotton yields, pesticide costs and gross margins using proper econometric modelling.

12 This chapter is an extended version of a paper published in the Pesticide Policy Project Publication Series Special Issue No. 9 "The Impact of the FAO-EU IPM Program for Cotton in Asia". The co-authors Associate Professor S. Praneetvatakul in Kasetsart University in Thailand, Prof. H. Waibel in Leibniz University of Hannover in Germany and Mrs. L. Wang in the Plant Protection Station of Lingxian County in China are sincerely acknowledged.

3.2 Data Collection

The data for this study were from the surveys organized by the National Agro-technical Extension and Service Center (NATESC) and the Plant Protection Station (PPS) of Shandong Province. Enumerators consisted of local agricultural technicians, consultants from research institutes and some FFS participants. In order to follow a standard social scientific survey procedure, a workshop was held before the survey to train the investigators. The questionnaires for the survey were jointly designed by experts from extension agencies and research institutes. A pilot survey was conducted to pre-test the questionnaires. Based on the test, the questionnaires were further improved and then formally used for the survey. The survey covered a considerable scope including economic, environmental, health, education and social dimensions. However, this study only focuses on economic facets.

The FFS sampled for this study were conducted during the cotton season of 2001 under the framework of the FAO-EU IPM Program for Cotton in Asia. A baseline survey was carried out at the beginning of that cotton season and retrospective data were collected for the cotton season of 2000. A repeat survey was launched in 2002 to collect the immediate impact data with the same questionnaires, enumerators and interviewees, which was essentially a season long monitoring. The farmers were asked to keep a detailed diary of their cotton producing activities in standard form, and the recording was regularly checked by the enumerators during their monthly visit to farmer households.

The data were collected from six villages within two townships named Mi and Dingzhuang (see Table 3-1). FFS were delivered in Mi Township in 2001, while no FFS has been conducted in Dingzhuang. Those two townships are located 50 kilometers apart without any FFS conducted in-between. Such a distance was purposively set to prevent any possible diffusion effect of FFS on the farmers in Dingzhuan. Three villages in each township were selected based on the consultancy from the Agricultural Bureau of the Lingxian County and the analysis of secondary data. Factors such as cotton production, distance from the county capital and infrastructure condition were compared to achieve necessary representativeness of the sample to the population as well as the similarity between the FFS villages and the control ones. As the next step, a group of 20 participant and 20 exposed farmer households were randomly selected from every sample village in Mi Township, and the same number of farmer households were randomly picked up as the control in every village in Dingzhuang Township. Owing to dropout and some missing data, a sample of 167 complete observations was finally available for this study, including 51 participant, 59 exposed and 58 control farmer households.

Table 3-1: Sample size and location for the case study in Shandong Province

Farmer group	Township	Village	Sample size	Total
Participants	Mi	Menghu	17	51
		Qianzhou	18	
		Houzhou	16	
Exposed farmers	Mi	Menghu	20	59
		Qianzhou	20	
		Houzhou	19	
Control farmers	Dingzhuang	Daliu	19	57
		Qianliu	20	
		Houliu	18	

Source: Own compilation

3.3 Description of the Study Areas

Lingxian County is located in north-western Shandong Province. The common cropping pattern in the county is the production of maize in summer and wheat during winter on the same plot or one harvest of cotton per year as the alternative. Ranked by sown area, wheat, maize and cotton are the three largest crops in the country (BSDC, 2008).

Cotton is the most important cash crop in Lingxian County, and the sale of cotton is the major source of cash income for local farmers. As shown in Figure 3-1, the cotton area in Lingxian County fluctuates between years with an annual average of around 20,000 ha. The cotton yields in Lingxian County are usually higher than the national average. However, the results of such comparison were reversed in early 1990s. There were severe occurrences of cotton bollworm (CBW) (*Helicoverpa armigera*) in that period which led to massive plummet of cotton production in China (Xia, 1993; Wu et al., 1995). The infestations by that pest were especially serious in the Huanghe River Cotton Region (Tong et al., 2004) where Lingxian County is located. The much steeper decline of cotton yields in the county as compared to the national average is an evidence for the striking influence of pest infestations on cotton production.

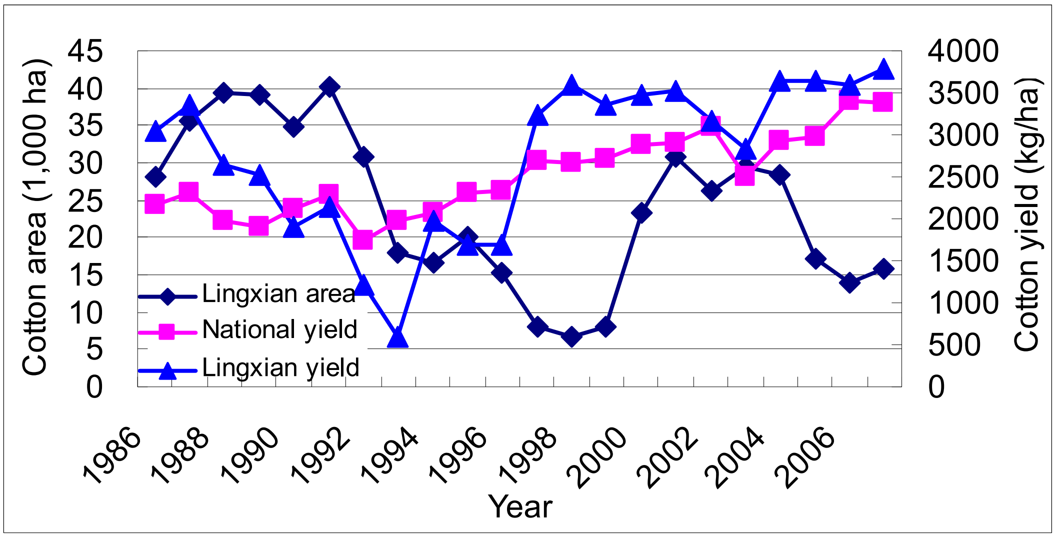

Figure 3-1: Trend of cotton production in Lingxian County and comparison of average yields between the county and China

Source: BSDC (2008) & NBSC (2008)

In response to the worsening pest problems with cotton, Bt cotton was approved for commercial use in 1997 in China (Huang et al., 2002c). However, with Bt seeds from neighboring Hebei Province where the Bt varieties were tested, some farmers in Lingxian Country already planted some Bt cotton in 1996 (Pemsl, 2006). As depicted in Figure 3-2, the Bt cotton spread rapidly after the official approval and it took only five years for the Bt varieties to be 100% adopted in the county. All the farmers in Lingxian planted only Bt varieties on their plots in 2001, while the national adoption rate of Bt cotton was just around 30% that year.

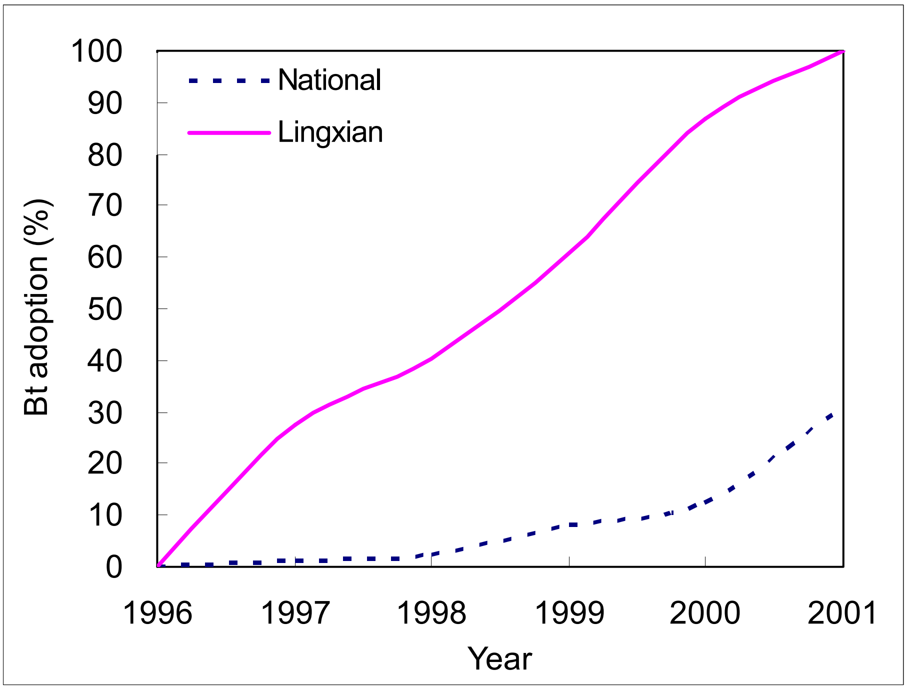

Figure 3-2: The adoption of Bt cotton in Lingxian County and China

Source: Bureau of Agriculture of Lingxian County (2007) & James (1997-2001)

As a traditional cotton growing area with its importance in national cotton cultivation[13], Lingxian County was incorporated into the FAO-EU IPM Program at its inception, and a total of 209 FFS has been conducted in the program period from 2000 to 2004. This study covers three FFS delivered in 2001.

3.4 Empirical Model Specification

The general design of this study is to compare the performance of participants, exposed farmers and control farmers with proper control for selection bias. With a two-period panel data set, a naive approach to measure the impacts is to just pool the two periods and use OLS to estimate the performance parameters on variables indicating a farmer's participation in or exposure to the FFS training and other relevant variables. For farmer i in village j at time period t, the model may be constructed as follows:

$$\ln(Y_{ijt}) = \alpha_0 + \alpha D_t + \beta D_{Nijt} + \mu D_{Gijt} + \gamma X_{ijt} + \delta Z_{jt} + \lambda_i + \eta_j + \varepsilon_{ijt} \qquad (1)$$

13 Lingxian County once ranked among the top 10 cotton producing counties in China in early 1990s. Although there has been a considerable decrease in cotton production, the county is still among the top 30.

In the specification, Y stands for farmer performance, D_t is the dummy variable for the second time period, D_G and D_N are dummy variables for participants and exposed farmers (with control farmers implicit). Variables X and Z represent the household and village characteristics that change over time, λ_i and η_j capture the unobserved, time-constant factors in household and village respectively, while ε_{ijt} is the idiosyncratic error representing the unobserved factors that change over time. For model (1) to yield unbiased estimates with OLS, λ_i and η_j must be assumed to be uncorrelated with all the explanatory variables. However, such assumptions are unlikely to hold because the participants and villages are usually nonrandomly selected in development programs. With non-random selection of participants, D_N and D_G might be correlated with λ_i, while nonrandom placement of the program across villages could lead to correlation between D_N, D_G and η_j. As a result, there is no guarantee for unbiased OLS estimates of μ and β with model (1) and no strong conclusion can be drawn about the causal effect of FFS on participants or exposed farmers.

A powerful way to eliminate the bias caused by the unobserved time constant variables is to differ the two periods of panel data, which is called “difference in difference” (DD) estimator (Wooldridge, 2003). In model (1), the performance is compared directly between different farmer groups (i.e. with and without), while the DD estimator is used to compare not only “with and without” but also “before and after”. With the first period subtracted from the second period, model (1) turns out to be:

$$\Delta \ln(Y_{ijt}) = \alpha + \beta D_{Nijt} + \mu D_{Gijt} + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt} \qquad (2)$$

In this specification, Δ denotes the differencing operator between the two periods. The strengths of the DD estimator are apparent in model (2). The variables λ_i and η_j have been differenced out owing to their time constancy, and hence the time invariant unobserved household or village characteristics do not bias the estimates any more. Moreover, the program impacts on participants and exposed farmers are estimated by comparing changes in their cotton production performance relative to the changes in the performance of control farmers, any variation in performance due to the factors that affect all farmers, such as systemic climate changes, current policy and price changes is also eliminated (Feder et al., 2004a). Since there is only one period left after differencing, the term of the period dummy is reduced to be the constant.

The DD estimator of model (2) is effectively an exponential growth model[14], and the individual coefficient in the model actually measures the contribution of appropriate explanatory variable to the growth rate of farmers' performance. Specifically in this study, α measures the pre-program growth rate in performance for all the farmer groups, β measures the difference of the post-program growth rate between the exposed farmers and control farmers, while μ denotes such a difference between the participants and control farmers.

Cotton yields, pesticide costs and gross margins were chosen as performance indicators (i.e. Y in the model) on the left hand side of the model. In addition to the participation dummy D_G and exposure dummy D_N, the costs of various inputs such as labor, fertilizer, irrigation and seed were included as the vector of household characteristics (i.e. X in the model) to control for the effect of the factors other than program intervention. No control for factors at village level was applied in this study. Because the village characteristics might roughly remain unchanged over a three-year period, their effects could be differenced out by the nature of the DD model.

Since knowledge gained in FFS may improve participants' agricultural practice and eventually lead to better performance, it is hypothesized that the participants experience a faster increase or slower decrease in yields and gross margins as compared to the control farmers. In model (2), those hypotheses can be verified with a t test of (μ>0). In the case of pesticide use, as the farmers were trained in FFS to adopt IPM instead of relying on chemical pesticides, it is hypothesized that the pesticide use among the participants increase slower or decrease faster in contrast to the control farmers, which is embodied in the t test of (μ<0) in model (2). Similarly, t tests of (β >0) or (β <0) can tell whether there is some indirect impacts of FFS on the performance of exposed farmers.

It might also be interesting to know whether there is any significant difference of the growth rates between the participants and the exposed farmers. However, the test of the difference between μ and β as indicated in equation (2) is laborious, because the

14 With some elemental manipulation and rearrangement, model (2) can be re-written as:

$Y_{ijt} = Y_{ij(t-1)} \times e^{(\alpha + \beta D_{Nijt} + \mu \Delta D_{Gijt} + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \varepsilon_{ijt})}$. Therefore, it is apparent that, the underlying conceptual framework for the DD model is essentially an exponential growth process.

standard error of (μ - β) is not provided by statistic software. Wooldridge (2003) proposes a simpler route to do a test like this, with some small modifications to model (2) as follows:

$$\Delta \ln(Y_{ijt}) = \mu + \alpha D_{Cijt} + \beta D_{Nijt} + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt} \quad (3)$$

The dummy variable for the control farmers D_{Cijt} is explicitly included in model (3), while the dummy variable for the participants is rendered implicit. With those modifications, the coefficient β itself measures the difference of the growth rates between the participants and exposed farmers, and hence the needed estimate and its standard error can be directly read from the outputs of statistic software. Excepting α, β, μ and their standard errors, none of the other coefficients or standard errors changes with the re-estimation. For this reason, only the statistics related to the constant term (participants), control farmers and exposed farmers are reported in the re-estimation results.

Heteroscedasticity may cause problem to the “difference in difference” models (Wooldridge, 2003). Tests detected significance of heteroscedasticity for the yield and gross margin functions. Therefore, the robust standard errors were used for their correction. No significant heteroscedasticity was identified with the pesticide function, and hence normal standard errors were used in pesticide regression. Since there was only one period left, serial correlation which is seriously treated in chapter 4 is not a problem in this chapter. The results of the heteroscedasticity tests are presented in appendix 3.

3.5 Results

3.5.1 Descriptive Analysis

Table 3-2 presents some descriptive statistics for the sample farmers in the baseline year of 2000. The household size and composition, educational level and most inputs including fertilizer, seed and labor were similar across all the farmer groups. There was no significant difference in gross margin[15] and cotton yields either. However, the

15 Gross margin is the difference between cotton revenue and total variable costs, including costs of pesticide, fertilizer, seed, labor and irrigation. Since gross margins were used as a dependent variable in this chapter to analyze the impact of FFS, both hired and family labor were included in the computation of gross margins in this chapter.

pesticide cost was significantly higher in the participant group than that in the control group with exposed group lying between. The priority of the FFS training was given to areas with more pesticide use, and hence such a difference is the natural result of the non-random program placement. Additional significant differences were identified with the farm size and cotton acreage. The FFS participants and exposed farmers cultivated more land and in turn grew more cotton. Under the household responsibility system in China, land is equally allotted to farmers on village base. The uneven distribution of lands always results in some difference of landholding. The identification of those significant differences indicates that the farmers in the sample were not strictly homogeneous owing to different natural endowment or non-random placement of the program. Therefore, it is important to apply proper approach like the DD estimator to purge the likely bias when assessing the program impacts.

Table 3-2: Descriptive statistics by farmer group in the baseline year of 2000[16]

	Farmer groups		
	Control farmers	Exposed farmers	Participants
HH size (No. of people)	4.12 (0.98)	4.19 (0.99)	4.39 (1.18)
Male (%)	49.88 (13.50)	53.50 (15.86)	51.00 (18.01)
Female (%)	50.12 (13.50)	46.50 (15.86)	49.00 (18.01)
Laborer (%)	69.12 (21.19)	63.25 (19.56)	58.68 (19.94)
Educational level (years in school)	6.95 (1.92)	6.49 (2.51)	7.20 (2.26)
Cotton yield (kg ha^{-1})	3498.22 (546.43)	3588.71 (514.66)	3627.32 (597.64)
Gross margin (US$ ha^{-1})	790.63 (373.57)	806.19 (370.03)	886.54 (405.99)
Pesticide cost (US$ ha^{-1})	13.77[a] (10.30)	17.51[ab] (15.57)	20.04[b] (14.98)
Fertilizer cost (US$ ha^{-1})	115.08 (45.22)	120.32 (56.77)	133.43 (92.93)
Seed cost (US$ ha^{-1})	47.16 (21.42)	48.26 (34.04)	54.32 (35.29)
Labor cost (US$ ha^{-1})[1/]	683.53 (237.85)	655.74 (235.46)	601.35 (323.74)

16 Monetary figures in the table were converted from the Chinese currency RMB Yuan at the rate US$1 = 8.26 Yuan and this exchange rate was consistently used throughout this thesis for the years 2000 and 2002.

	Farmer groups		
	Control farmers	Exposed farmers	Participants
Irrigation cost (US$ ha^{-1})	25.22 (9.61)	25.30 (9.46)	26.90 (10.74)
Farm size (ha)	0.46[a] (0.14)	0.58[b] (0.15)	0.53[b] (0.18)
Cotton acreage (ha)	0.13[a] (0.06)	0.19[b] (0.08)	0.18[b] (0.10)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); producer price index for farm products and price index of agricultural inputs were used to inflate 2000 prices of cotton and inputs to 2002 value; [1/] both family and hired labor were included and the opportunity cost of labor based on average hired labor wage was RMB 9 Yuan per personday in 2000 in China.
Source: Survey by NATESC and PPS of Shandong Province

Table 3-3 reports the results of before-and-after comparison of some indicators for different farmer groups. There was an overall increase in yields for all the farmers. Yields went up significantly for the participants and a shift of border significance could be identified for the exposed farmers. However, only a very non-significant increase in yields was observed in the control group. As for the pesticide costs, there was a significant shift in every group, while the ends were different. Pesticide cost was significantly reduced in the participant and exposed groups, while the control farmers substantially increased the use of pesticides. A significant rise in gross margins was identified in every group. It might be surprising to find the significant shift of gross margins with the control farmers, who did not have any significant increase in yields but experienced a remarkable increase in pesticide costs within the study period. The comparison of labor costs was specially included in the table to give some explanation to this "illogic" finding. Most farmers in Lingxian County sowed cotton seeds in nutrition pots and then transplanted the seedlings to the field in 2000. The preparation of nutrition pot was very time consuming and resulted in very high labor cost. Almost all the farmers shifted to sow seeds directly in the fields in 2002, which saved a lot of labor force and contributed considerably to higher gross margins.

Table 3-3: Comparison of performance indicators by farmer group

	Year		Absolute change	% Change
	2000	2002		
Yield (kg ha^{-1})				
Control farmers	3498.22 (546.43)	3552.73 (237.31)	54.51 (78.49)	1.6
Exposed farmers	3588.71 (514.66)	3734.98 (254.90)	146.27* (75.21)	4.1
Participants	3627.31 (597.64)	4214.57 (354.59)	587.26** (89.34)	16.2
Pesticide cost (US$ ha^{-1})				
Control farmers	13.77 (10.30)	21.38 (4.17)	7.61** (1.44)	55.4
Exposed farmers	17.51 (15.57)	11.84 (5.22)	-5.67* (2.16)	-32.4
Participants	20.04 (14.98)	11.46 (4.49)	-8.58** (2.13)	-42.8
Gross margin (US$ ha^{-1})				
Control farmers	790.63 (373.57)	974.30 (144.57)	183.67** (48.47)	23.2
Exposed farmers	806.19 (370.03)	1211.34 (166.23)	405.15** (50.97)	50.3
Participants	886.54 (406.46)	1411.60 (224.80)	525.06** (69.21)	59.2
Labor cost (US$ ha^{-1})				
Control farmers	683.53 (237.85)	449.70 (44.33)	-233.82** (29.95)	-34.2
Exposed farmers	655.75 (235.46)	402.92 (87.57)	-252.82** (27.63)	-38.6
Participants	601.35 (323.74)	418.71 (114.20)	-182.64** (51.63)	-30.4

Note: **, * denoted significance at 1% and 5% respectively; standard deviations reported for 2000 and 2002 observations, and standard error means reported for change between 2000 and 2002 in parentheses; producer price index for farm products and price index of agricultural inputs were used to inflate 2000 prices of cotton and inputs to 2002 value.

Source: Survey by NATESC and PPS of Shandong Province

3.5.2 Multivariate Analysis

The DD model constructed in section 3.4 was applied to fit the two-period data set following a stepwise regression procedure. In addition to the dummy variables indicating participation in and exposure to FFS training, only those independent variables, which had a significant effect on the dependent variables, were finally included in the regression.

Table 3-4 provides the estimates of the growth rates of cotton yields. The constant term is insignificant with relatively low probability; the negative sign ambiguously indicates that there would have been a decrease in cotton yields in the second time period (2002) without the contribution of the other factors. The highly significant coefficient to the dummy variable “participation” reveals that the FFS training contributed to a substantial improvement of the growth rate of cotton yields among the participants. The dummy variable “exposure” has a very insignificant coefficient, and hence no indirect impact of FFS training on cotton yields was concluded. Irrigation contributed to a significant increase in cotton yields. Since rainfall is not abundant in the study area, irrigation plays an important role in local cotton production.

Table 3-4: Estimated coefficients for yield function[17]

Dependent variable: yields N=167, R^2=0.14, F=8.79			
Variable	Coefficient	Robust std error	Robust prob.
Constant	-0.0447	0.0368	0.2253
Exposure	0.0178	0.0303	0.5571
Participation	**0.1420**	0.0339	0.0000
Irrigation costs	**0.0021**	0.0009	0.0197

Source: Survey by NATESC and PPS of Shandong Province

The estimates of the pesticide cost function are presented in Table 3-5. The highly significant positive constant reveals that the pesticide use in the control group increased substantially during the study period. The dummy variables “participation” and “exposure” both have a significant negative coefficient, indicating that the direct participation in or indirect exposure to FFS both led to substantial decrease in pesticide use. Additionally, more fertilizer use and higher seed cost both induced a significant increase in pesticide costs. Fertilizer especially nitrogen of high concentrations could increase pest incidence and hence demand more pesticide use (Hill, 1989). More expenditure on seeds might imply higher crop density and dense plant stand and hence increase pest incidence (Guo, 1998). Since Bt cotton was 100% adopted in the study area, the positive relationship between the seed and pesticide costs might also be a reflection of the problems with local seed market. If the marketing system did not

17 When reporting the results of econometric analysis, the variables participation, exposure and control were directly used instead of D_G, D_N or D_C used in the section of empirical model specification. The treatment in this way held throughout this thesis.

function well, higher seed costs might not mean better seed quality or higher Bt toxin concentrations. As a result, it would be less possible to expect a reduction of pesticide use resulting from higher seed costs.

Table 3-5: Estimated coefficients for pesticide function

Dependent variable: pesticide costs N=167, R^2=0.26, F=14.23			
Variable	Coefficient	Std error	Prob.
Constant	**0.6271**	0.1399	0.0001
Exposure	**-0.6795**	0.1693	0.0001
Participation	**-0.9207**	0.1744	0.0001
Fertilizer cost	0.0015	0.0009	0.1004
Seed cost	**0.0046**	0.0022	0.0360

Source: Survey by NATESC and PPS of Shandong Province

Table 3-6 reports the estimates of the growth rates of gross margins. The positive estimate of the constant provides some indication of a general increase in gross margins in the second period (although insignificant), which is consistent with the findings by previous descriptive analysis. The significant positive coefficient on the "participation" dummy shows that, the FFS training further improved the growth rate of gross margin significantly before the background of an overall increase. The "exposure" dummy has an insignificant coefficient and hence no conclusive inference about the improvement of gross margins was drawn for the exposed farmers. At a first glance it might be surprising to observe that, the yield-increasing inputs fertilizer and labor led to significant reduction of gross margins, while such findings are practically possible. Those inputs might contribute to some increase in yields and hence higher cotton revenue, but on the other hand they show up directly in the computation of gross margin as subtrahends.

Table 3-6: Estimated coefficients for gross margin function

Dependent variable: gross margins
N=167 R^2=0.43, F=30.69

Variable	Coefficient	Robust std error	Robust prob.
Constant	0.1029	0.0768	0.1823
Exposure	0.0973	0.1134	0.3920
Participation	**0.2103**	0.0945	0.0275
Fertilizer cost	**-0.0016**	0.0005	0.0013
Labor cost	**-0.0016**	0.0002	0.0000

Source: Survey by NATESC and PPS of Shandong Province

Table 3-7 presents the results from the re-estimation of the three regressions with the participants as the base group. For yields, the growth rate experienced by the exposed farmers was significantly lower than that by the participants, while no significant difference was found for the growth rates of pesticide costs and gross margins between those two groups. The relationship presented here between the control farmers and participants is exactly the same as that identified by the corresponding regressions in foregoing paragraphs.

Table 3-7: Re-estimated coefficients for yield, pesticide and gross margin functions with participants as the base group[18]

Dependent variable	Variable	Coefficient	(Robust) std error	(Robust) prob.
Yields R^2=0.14, F=8.79	Constant	**0.0973**	0.0323	0.0030
	Control	**-0.1420**	0.0339	0.0000
	Exposure	**-0.1242**	0.0344	0.0004
Pesticide costs R^2=0.26, F=14.23	Constant	**-0.2936**	0.1330	0.0287
	Control	**0.9207**	0.1744	0.0000
	Exposure	0.2412	0.1664	0.1493
Gross margins R^2=0.43, F=30.69	Constant	**0.3131**	0.0676	0.0000
	Control	**-0.2103**	0.0945	0.0275
	Exposure	-0.1130	0.1038	0.2782

Source: Survey by NATESC and PPS of Shandong Province

18 As explained in section 3.4, the robust standard errors were used to correct heteroscedasticity of yield and gross margin functions, while normal standard errors were used for pesticide regression.

3.6 Summary and Conclusions

The empirical results from the analysis above provide evidence of significant impacts of FFS on participants' performance, including a substantial increase in cotton yields, rise of gross margins and reduction of pesticide costs. Diffusion impact of FFS on the exposed farmer was also found with a considerable reduction of pesticide use, while no significant diffusion impacts on yields and gross margins were identified. Based on those findings, it can be concluded that, in the case of Lingxian County, FFS training is an effective way to introduce IPM knowledge to farmers who participated in the training. To some extent, it is also possible to have some influence on the participants' neighboring farmers who did not take the training courses. Therefore, FFS may be a more effective way to transfer pest management technology to the farmers in China than through traditional top-down extension approaches.

The diffusion impact on pesticide use identified by this study lends some support to the expectation that, FFS approach may rely on farmer to farmer diffusion to be more fiscally sustainable than other extension approaches. However, no significant diffusion impact on yield increase shows that, it might be difficult for the IPM knowledge to be effectively transmitted by informal conversation. There is also some doubt about the sustainability of the pesticide reduction observed in the group of "exposed" farmers (Walter-Echols et al., 2005a) because they may just copy the pest control activities of the participants without any deeper understanding or improved decision making skills. As a result, the question remains how long such an impact will last with the passage of time, and especially in view of a changing pest situation? It would be reasonable to assume that, the knowledge gained through participatory approach need to be disseminated in a similar way. Little time was spent to organize farmers into sustainable alumni groups under the FAO-EU IPM Program for Cotton in Asia (Walter-Echols et al., 2005b), and hence it might be difficult for the follow-up activities to develop. Without institutionalization of FFS within the communities, the neighbors of the FFS participants may not have a chance to really understand IPM, and the participants may not have an incentive to optimize their management practices. The importance to create an enabling environment for the follow-ups of FFS activities has been pinpointed by peer studies (Khan et al., 2005a, 2005b; Praneetvatakul et al., 2005), and it is also highlighted by the findings of this study.

A large number of studies have been conducted to evaluate the impacts of FFS, among which most have reported desirable outcomes of FFS training (van den Berg, 2004). As compared to most other studies in this area based on only descriptive analysis, this study may have stronger confidence in drawing conclusions because a causal relationship between the program intervention and the performance indicators was established by the econometric models and efforts have been taken to control for the possible selection bias resulting from time invariant unobserved factors. On the other hand, this case study has also some limitations:

- First, the participants included in this study were sampled from three FFS. The conclusions here might be true to the situation in the study area, but great caution should be taken to infer from this study about the impacts of the whole FFS training in China.

- Second, this study covers a period of only three years and hence provides an insight only into immediate impacts. There is no answer to another important question, whether the impacts in short term can be sustained with the passage of time.

- Third, the pesticide use was quantified in monetary value. There could be a broad variation of the toxicity of different chemical substances of the same monetary value. As a result, the cost analysis is inadequate to measure the true impact on pesticide reduction.

- Forth, this study concentrates on economic indicators. However, FFS training may generate an array of impacts transcending environment protection, capacity building and health improvement (Khan et al., 2005b; Mancini, 2005a; Walter-Echols et al., 2005a). A broader scope will contribute to a better understanding of the impacts of FFS training.

Some attempts to break those constraints were already made by Pananurak (2009) who conducted a comparative welfare analysis of FFS in China, India and Pakistan. And also, some of these limitations, such as small number of FFS sampled and short period covered, will be compensated in the following chapters of this thesis. However, further studies are still in need as China is now considering the expansion of the FFS training to wider areas and additional crops (Wang, 2009b). A comprehensive check of the impacts of FFS will benefit not only the decision making in the meeting rooms, but also the program implementation in the vast fields.

4 A Multi-period Analysis of the Medium Term Impact of FFS and its Interaction with the Diffusion of Bt Varieties in Cotton[19]

This chapter extends the "difference in difference" model presented in chapter 3 to assess the short and the medium term effects, including the direct and indirect (exposure) impacts of Farmer Field School on some major economic indicators, namely yields and insecticide costs. Efforts are also undertaken to analyze the interaction between the farmer training and Bt cotton. Section one specifies the objectives of the study. In section two, data collection procedure and study areas are illustrated, and some descriptive statistics are presented in order to demonstrate the production conditions in the study areas. Thereafter the models for this multi-period analysis are developed with detailed illustration of the econometric procedure applied, followed by a brief description of the variables used in modeling analysis. The empirical results are presented in section five, including a statistical testing procedure for group comparisons and in-depth interpretation of the results of the multivariate analysis. In the last section, the findings are summarized and some policy conclusions are drawn.

4.1 Objective of the Study

The overall objective of this chapter is to extend the "difference in difference" (DD) model to make unbiased and consistent assessment of dynamic impacts of FFS in a context of rapid diffusion of biotechnology. According to the existing literature, FFS might generate an array of impacts transcending socio-economic, environmental and health spheres (van den Berg et al., 2007). As a result, impact assessment of FFS 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., 2007). Recognizing the fact that the yields and pesticide use are primary indicators, on which many other social, environmental and health impacts largely depend, this study concentrates on those two aspects. Because insecticides accounted for around 95% of total pesticide use in the study areas, and most high toxic compounds were insecticides, this study is further

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19 This paper was presented at "Tropentag 2007" held from 9th to 11th October, 2007 in Göttingen, Germany. The co-authers Dr. D. Pemsl in World Fish Center, Penang, Malaysisa and Prof. H. Waibel in Leibniz University of Hannover are sincerely acknowledged.

narrowed to focus on insecticide use. Based on those considerations, the specific objectives are set as follows:

- To measure the short term and medium term impact of FFS on yields and insecticide use within different farmer groups,
- To discover the dynamic change of the impacts of FFS on yields and insecticide use within a medium time span, and
- To explore the interaction between FFS training and biotechnology, particularly Bt cotton, adoption.

4.2 Data Collection and Study Areas

This Multi-period study was conducted in Lingxian County in Shandong Province, Dongzhi County in Anhui Province and Yingcheng County in Hubei Province. All those counties have a long history of cotton cultivation. Given their importance in local cotton production, they were incorporated into the FAO-EU IPM Program for Cotton in Asia at its inception in 2000 and prioritized in later project placement. By 2004 when the program came to its end, a sub-total of 209, 132 and 94 FFS had been conducted in Lingxian, Dongzhi and Yingcheng respectively.

In 2001, a self evaluation was launched by the Program Management Unit of FAO-EU IPM Program for Cotton in Asia to measure changes, intended or unintended, brought about by the FFS and to understand the reasons for such changes (or no changes). For that purpose, a baseline survey and an immediate impact survey were organized in the three counties by NATESC and the Plant Protection Stations (PPS) of respective provinces. The data collected during those surveys constituted the major part of the dataset for this study. In order to catch the medium term impact, a third survey was organized specifically for this study in 2005, when the same methodology and questionnaire were used by the same enumerators to survey the same farmer households (HH).

Six villages including three FFS villages and three control villages were selected in every 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 county capital and village infrastructure were compared to achieve necessary representativeness of the sample to the population and similarity between the FFS villages and control ones. In all the FFS villages, an FFS was delivered 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. However, with the expansion of the IPM program, some FFS were opened in-between and the minimum distance from the control villages to the nearest FFS village was reduced to 20 kilometers. A group of 20 FFS participants and 20 exposed farmers were randomly selected in every FFS village, and 20 farmer households were randomly sampled in every control village for the survey. Owing to dropout and some missing data, a sample of 480 complete observations was finally available for this study, including 155 participants, 158 exposed and 167 control farmers. The sample composition is given in Table 4-1.

Table 4-1: Sample distribution for the multi-period case study

County	No. of participants	No. of exposed farmers	No. of control farmers	Total
Lingxian	46	50	57	153
Dongzhi	55	51	58	164
Yingcheng	54	57	52	163
Total	155	158	167	480

Source: Own compilation

The enumerators consisted of local agricultural technicians, consultants from universities and research institutes and some FFS participants. In order to follow a standard social scientific survey procedure, workshops were held prior to the survey to train the enumerator team. Questionnaires for the survey were elaborately designed and pre-tested by a pilot survey. The baseline survey was carried out at the beginning of the cotton season in 2001 to collect retrospective data for the year of 2000. Since most farmers in the study areas keep records of their major agricultural activities, the recall survey mainly drew on farmer recording to get detailed information on inputs and outputs. The two impact surveys were actually season long monitoring 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. In addition to detailed account of inputs and outputs, the questionnaire also covered household and village attributes and farmer knowledge on pest control.

In order for an overview of the study areas, some background information about those three counties is given in Table 4-2. Generally speaking, those three counties were typical agricultural areas with most residents living in rural areas and a large proportion of GDP from agricultural sector. More than 1/3 of the total arable land in Lingxian County was allotted for cotton cultivation. Such a proportion was around 1/4 and 1/10 in Dongzhi and Yingcheng respectively, indicating a more diversified cropping system in the Changjiang River Cotton Region. Bt cotton was first introduced into Lingxian in 1996 (one year before the official approval for commercial use of Bt varieties), and then spread to Dongzhi in 1998 and Yingcheng in 1999. Bt varieties were 100 percent adopted in Lingxian in 2001. However, there are still some farmers in the other two counties growing non-transgenic cotton nowadays.

Table 4-2: Background information about the study areas

County	Total population (1000)[1/]	Rural population (1000)[1/]	Agri-share in GDP (%)[1/]	Total arable land (1000 ha)[1/]	Cotton acreage (1000ha)[1/]	Cotton production (1000ton)[1/,2/]	First year Bt cotton
Lingxian	545	465	40.8	63.0	23.3	80.9	1996
Dongzhi	531	475	57.4	33.0	7.9	25.4	1998
Yingcheng	644	586	33.3	38.5	3.8	12.0	1999

Note: [1/] Data for the baseline year of 2000, extracted from Shandong Provincial Yearbook, Anhui Statistical Yearbook and Hubei Statistical Yearbook; [2/] in order for cotton yields to be consistent throughout this thesis, the lint yields in Yearbooks were divided by standard lint percentage 0.38 to convert to seed cotton yields.

Descriptive statistics of selected household and farmer characteristics as well as cotton production parameters in Table 4-3 show that, there was considerable variation between different counties. The household size was similar across the counties, while the farm size in Dongzhi was markedly smaller than those in Lingxian and Yingcheng. Interesting is that, with the smallest farm sizes, farmers in Dongzhi earned the highest incomes. Small farms appeared to have driven more farmers to find temporary jobs in cities. The off-farm income for farmers in Dongzhi made up 35% of their total revenue in 2000, which was much higher than in the other two counties. As for cotton cultivation, the farmers in Lingxian were the best growers who realized the highest yields with lowest variable costs. Total variable costs were strikingly lower in Lingxian as compared to those in the other two counties. Since reduction of insecticide use is a major goal of FFS training, insecticide cost was specially included in the table and it was also impressively lower in Lingxian County. According to Pemsl (2006), the underlying reason for the relatively lower variable costs in Lingxian could be generally lower wealth level and cash constraint that limited the purchase of production inputs. The comparison of labor use presents another picture with the average labor input in Lingxian significantly higher than those in the other two counties. The wide variation between different areas entails careful efforts to control for locality specific differences. However on the other hand, a homogenous sample has little chance to well represent the diversity of the vast cotton growing areas in China.

Table 4-3: Descriptive statistics by county in the baseline year of 2000

	Counties		
	Lingxian	Dongzhi	Yingcheng
HH and farmer characteristics			
HH size (No. of people)	4.26 (1.02)	4.51 (1.26)	4.37 (1.38)
Male (%)	51.97 (14.83)	52.53 (14.87)	53.81 (15.51)
HH laborers (No. of people)	2.65[b] (1.01)	2.25[a] (0.79)	2.25[a] (1.10)
Educational level (years in school)	6.89[b] (2.25)	6.25[a] (2.57)	7.19[b] (2.20)
Farm size (ha)	0.52[b] (0.16)	0.37[a] (0.17)	0.53[b] (0.28)
Total household revenue (US$)[1/]	979.77[a] (337.93)	1131.01[b] (490.18)	1038.12[ab] (481.93)
Cotton production			
Acreage (ha)	0.17[a] (0.08)	0.27[b] (0.09)	0.42[c] (0.23)
Yield (kg ha^{-1})	3536.78[b] (511.40)	3052.09[a] (443.27)	3084.92[a] (639.87)
Gross margin (US$ ha^{-1})[2/]	1570.71[c] (328.13)	1279.30[b] (298.46)	1025.94[a] (411.50)
Total variable costs (US$ ha^{-1})[3/]	388.08[a] (98.58)	645.19[b] (77.85)	769.37[c] (86.52)
Insecticide cost (US$ ha^{-1})	17.48[a] (14.52)	180.09[c] (33.57)	165.91[b] (49.77)
Labor input (personday ha^{-1})	560.42[c] (215.78)	432.37[b] (53.65)	357.06[a] (145.29)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); [1/] total household revenue included both on farm and off farm income; [2/] cost of family labor was not included in computation; [3/] total variable costs included costs of pesticide, fertilizer, seed, irrigation and hired labor.

Source: Survey by NATESC and PPS of Shandong, Anhui and Hubei Provinces

Since one objective of this thesis is to look at the impact of FFS training by comparing participants, exposed farmers and control farmers, it is more important to know whether all the farmers had similar starting points. According to the descriptive statistics presented in Table 4-4, most of the household and farmer characteristics and cotton production parameters were similar across the groups. However, the participants had the highest educational levels but the smallest farms, both of which were significantly different from those farmers in the control group. The principle of the program placement also led to some differences. Above the village level, the priority of the IPM program was given to areas where more pesticides were used in the past. As the result, the participants and their exposed neighbors applied some more pesticides than the control farmers. Insecticides, as the lion's share of pesticides, followed a similar distribution among different farmer groups. Within the villages, the participant enrollment was based on voluntary applications. If the applications were more than FFS capacity, priority was given to poorer farmers. This kind of selection criterion explains the lowest household income for the participants' households. It is difficult to say a priori the consequence of those selection principles on the impact of the program. However, careful efforts and reliable methodology should be used to handle the nonrandom selection of the FFS villages and participants, to avoid possible overestimation or underestimation of the impacts.

Table 4-4: Descriptive statistics by farmer group in the baseline year of 2000

	Farmer groups		
	Participants	Exposed farmers	Control farmers
HH and farmers characteristics			
HH size (No. of people)	4.39 (1.23)	4.42 (1.34)	4.35 (1.14)
Male (%)	52.25 (14.73)	52.57 (16.10)	53.48 (14.41)
HH laborers (No. of people)	2.41 (1.03)	2.30 (0.92)	2.43 (1.01)
Educational level (years in school)	7.18[b] (2.16)	6.75[ab] (2.34)	6.42[a] (2.56)
Farm size (ha.)	0.40[a] (0.18)	0.42[a] (0.19)	0.58[b] (0.25)
Total household revenue (US$)[1/]	984.23[a] (376.34)	1023.37[a] (457.03)	1139.87[b] (486.53)
Cotton production			
Acreage (ha)	0.26[a] (0.11)	0.26[a] (0.10)	0.34[b] (0.26)
Yield (kg ha^{-1})	3262.92 (657.87)	3195.70 (560.71)	3196.64 (518.23)
Gross margin (US$ ha^{-1})[2/]	1333.32 (445.52)	1250.08 (412.96)	1276.50 (379.00)
Pesticide cost (US$ ha^{-1}), incl.	136.62 (81.56)	134.81 (84.58)	122.53 (90.56)
Insecticide cost (US$ ha^{-1})	128.92 (76.79)	128.11 (80.66)	113.96 (85.12)

	Farmer groups		
	Participants	Exposed farmers	Control farmers
Fungicide cost (US$ ha^{-1})	4.20[b] (4.30)	3.31[a] (4.38)	2.94[a] (3.58)
Herbicide cost (US$ ha^{-1})	3.50[a] (5.80)	3.39[a] (5.45)	5.63[b] (7.22)
Seed cost (US$ ha^{-1})	36.41 (31.30)	36.93 (30.62)	39.76 (25.73)
Fertilizer cost (US$ ha^{-1})	229.38 (92.29)	229.48 (93.87)	227.72 (96.65)
Irrigation cost (US$ ha^{-1})	9.03 (15.42)	8.83 (14.35)	9.52 (14.64)
Labor input (personday ha^{-1})	428.80 (163.67)	449.48 (157.61)	463.30 (192.73)
Bt adoption (% of total cotton area)	46.80 (47.59)	46.01 (49.26)	41.80 (49.09)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); [1/] total household revenue included both on farm and off farm income; [2/] the cost of family labor was not included in computation.

Source: Survey by NATESC and PPS of Shandong, Anhui and Hubei Provinces

4.3 Empirical Model Specification

One of the problems in impact assessment is that the control and treatment groups are not randomly assigned (Wooldridge, 2003). Hence standard multiple regression models using cross sectional data, may lead to wrong conclusions due to selection or self selection bias (ibid). Such problem can be readily illustrated with a commonly used specification in applied work which has the dependent variable appearing in logarithmic form, with one or more program intervention dummies appearing as independent variables. In the case of FFS, for farmer i in village j such model can be specified as:

$$\ln(Y_{ij}) = \alpha + \beta D_{Nij} + \mu D_{Gij} + \gamma X_{ij} + \delta Z_j + \lambda_i + \eta_j + \varepsilon_{ij} \quad (1)$$

where Y stands for farmer performance (viz yields and insecticide costs in this chapter), D_G and D_N are dummy variables for FFS participants and exposed farmers (with control farmers implicit). X and Z denote vectors of household and village observable characteristics, while λ_i and η_j are time constant unobservable effects resulting from household and village features respectively. ε_{ij} is idiosyncratic error or time varying error which represents all the unobserved factors that change over time and affect Y_{ij}. The terms λ_i, η_j and ε_{ij} constitute the so called composite error. An important requirement for equation (1) to yield consistent estimates with OLS is that, the composite error is uncorrelated with all the explanatory variables. However, since nonrandom participant selection leads to correlation between D_N, D_G and λ_i, nonrandom program placement results in correlation between D_N, D_G and η_j, the orthogonality assumption of OLS is violated. As a result, there is no guarantee for unbiased OLS estimates of μ and β (Wooldridge, 2003; Feder et al., 2004a). This problem can be much alleviated, if not completely solved when panel data are available. For illustration, some modifications are made to equation (1) to introduce time periods. Specifically to the study in this chapter, the panel dataset includes three time periods.

$$\ln(Y_{ijt}) = \alpha + \alpha_2 D_{2t} + \alpha_3 D_{3t} + \beta D_{Nijt} + \mu D_{Gijt} + \gamma X_{ijt} + \delta Z_{jt} + \lambda_i + \eta_j + \varepsilon_{ijt} \qquad (2)$$

In equation (2), “t” is added to appropriate subscripts to denote time periods. Since λ_i and η_j do not change over time, “t” does not show up in their subscripts. Two additional dummies D_{2t} and D_{3t} are added for time period two and three respectively to account for secular changes that are not being modeled. With period one as the base, it is straightforward to derive $\alpha+\alpha_2$ as intercept for time period two and $\alpha+\alpha_3$ for time period three. Equation (2) simply pools three time periods together and the sample size of this equation is triple that of the original cross sectional equation. However with λ_i and η_j staying in the equation, the econometric problems between the composite error and explanatory variables remain unsolved. In order to eliminate λ_i and η_j, the model can be improved by subtracting time period one from time period two and time period two from time period three:

$$\Delta \ln(Y_{ijt}) = \alpha_2 \Delta D_{2t} + \alpha_3 \Delta D_{3t} + \beta \Delta D_{Nijt} + \mu \Delta D_{Gijt} + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt} \qquad (3)$$

Equation (3) is effectively an exponential growth model. With some elemental manipulation and rearrangement, equation (3) can be re-written as:

$$Y_{ijt} = Y_{ij(t-1)} \times e^{(\alpha_2 \Delta D_{2t} + \alpha_3 \Delta D_{3t} + \beta \Delta D_{Nijt} + \mu \Delta D_{Gijt} + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt})} \qquad (4)$$

It is more apparent now, that the underlying conceptual framework for the DD model is the exponential growth process. As pointed by Feder et al. (2004a), modeling performance as a dynamic process is compatible with sociologists and economists' perception of innovation uptake. And from this underlying model specification, it is straightforward to understand that, the individual coefficient in the model actually measures the contribution of appropriate explanatory variable to the growth rate of farmers' performance.

Back to the empirical model specification, one time period is lost because there is nothing to subtract from the t = 1 equation when taking first difference. Equation (3) represents two time periods for every farmer in the sample. The merit of first differencing is that, owing to their time constancy, λ_i and η_j are differenced out in equation (3). Therefore the problems arising from the correlation between D_N, D_G and λ_i, η_j are now solved. Under a much relaxed assumption $\Delta\varepsilon_{ijt}$ is not correlated with any explanatory variable, equation (3) will produce unbiased and consistent estimates. Equation (3) does not contain an intercept, which is inconvenient in several ways, including the computation of R squared. For convenience, the dummy for time period two is dropped and only one dummy is kept for time period three (Wooldridge, 2003).

$$\Delta \ln(Y_{ijt}) = \alpha_2 + \alpha_3 D_{3t} + \beta \Delta D_{Nijt} + \mu \Delta D_{Gijt} + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt} \qquad (5)$$

Generally, all the variables including dummy variables indicating program intervention should be differenced as in equation (3) (Wooldridge, 2003). However in this study, after all the FFS were held in 2001, it is important to allow the program effect to persist during the later two impact surveys. In this sense, the dummies indicating farmers' participation and exposure in the third time period are maintained and equation (5) is rearranged to be[20]:

$$\Delta \ln(Y_{ijt}) = \alpha_2 + \alpha_3 D_{3t} + \beta D_{Nijt} + \mu D_{Gijt} + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt} \qquad (6)$$

Equation (6) places a restrictive assumption on the impacts of FFS on the performance of the participants and exposed farmers. With this modeling specification, the impacts do not change over time, neither develop nor diminish. Given the dynamic nature of human perception, this restriction is most probably unrealistic and better to be relaxed. For this purpose, time period dummy is interacted with program intervention dummies. On the other hand, the adoption of Bt cotton, indicated by the proportion of Bt cotton area to total cotton area in a household, is also at the center of the interest. Since FFS is largely a tool to disseminate IPM knowledge and Bt cotton is a component of IPM

20 Wooldridge (2002) suggests adding a lagged dummy indicating the program intervention to allow the persistent effect. Since the program intervention was interacted with other factors in this chapter, such a solution did not fit in this case. However, the empirical specification in this chapter was compared with Wooldridge's solution and both yielded the identical results for FFS participation and exposure.

strategies, and the proper handling of Bt varieties is also included in FFS curriculum, it is expected that the participation in FFS and possibly the exposure to FFS training can improve the performance of Bt cotton and hence generate supplementary interaction between the technology and extension. Based on those considerations, three additional terms related to Bt are explicitly specified in the equation and the model turns out to be:

$$\Delta \ln(Y_{ijt}) = \alpha_2 + \alpha_3 D_{3t} + \beta D_{Nijt} + \beta_1 (D_{Nijt} * D_{3t}) + \mu D_{Gijt} + \mu_1 (D_{Gijt} * D_{3t}) + \gamma_1 \Delta Bt + \gamma_{1N} (\Delta Bt * D_{Nijt}) + \gamma_{1G} (\Delta Bt * D_{Gijt}) + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt} \quad (7)$$

In equation (7), α_2 indicates the "natural" growth rate caused by secular changes for control farmers in the second time period, while α_3 represents the difference of such growth rates between periods 2 and 3. μ measures the short term difference of the growth rate between the participants and their control counterparts, while $\mu + \mu_1$ estimates the medium term impact of FFS participation on the growth rates of farmers' performance. For the exposed farmers, β and $\beta + \beta_1$ denote their short term and medium term gains (more appropriately reduction for insecticide costs) resulting from exposure to FFS as compared to the control farmers.

Since FFS and Bt cotton are expected to increase yields but reduce insecticide use, the hypotheses for those two performance indicators need to be made reverse to each other. For simplicity, yields are taken as an example to illustrate. To verify the short term impact of FFS participation and exposure on yields, the one side tests of ($\mu>0$) and ($\beta>0$) need to be performed. For the medium term impact, the tests are a little laborious. A common approach is to estimate the restricted and unrestricted models and then use Wald test to check whether ($\mu + \mu_1>0$) or ($\beta + \beta_1>0$). An easier approach is available when minor changes are made to model (7) as follows:

$$\Delta \ln(Y_{ijt}) = \alpha_2 + \alpha_3 D_{3t} + \beta [D_{Nijt} - (D_{Nijt} * D_{3t})] + \beta_1 (D_{Nijt} * D_{3t}) + \mu [D_{Gijt} - (D_{Gijt} * D_{3t})] + \mu_1 (D_{Gijt} * D_{3t}) + \gamma_1 \Delta Bt + \gamma_{1N} (\Delta Bt * D_{Nijt}) + \gamma_{1G} (\Delta Bt * D_{Gijt}) + \gamma \Delta X_{ijt} + \delta \Delta Z_{jt} + \Delta \varepsilon_{ijt} \quad (8)$$

With those modifications, the short term impacts are still measured by μ and β. However, changes occur to the measurement of medium term impacts. In equation (8), the medium term impact of FFS participation on yields is measured by the sum of three parameters, μ before D_{Nijt}, -μ before $D_{Gijt}*D_{3t}$ and μ1 before $D_{Gijt}*D_{3t}$. Obviously, the measurement is μ_1 which can be easily tested with a t test. The same story happens to the medium term impact of FFS exposure.

For the hypothesis that Bt cotton contributes to higher yields, a one side test of (γ>0) can be performed. Since Bt cotton and FFS are supposed to work in the same direction for higher yields, a positive interaction between them is expected and the hypotheses can be verified with the tests of (γ_{1G}>0) and (γ_{1N}>0). The foregoing discussion about the tests holds for the insecticide function with reversed signs. Furthermore, for the convenient tests of the relative magnitude of direct impacts on participants and indirect impacts on exposed farmers, equation (8) can be rerun for both yields and insecticide costs with participants implicit. As explained in chapter 3, the results of those tests are then easily read from the t tests for coefficients before the "exposure" dummy and its interaction term with "period" dummy.

During the period of this study, no substantial change occurred in village characteristics such as irrigation facility, input kiosk, road quality and distance to market, etc. Therefore, those variables were dropped and the model only relies on the household characteristics, including ability to recognize pests and beneficial organisms, cotton share, farm size, and various input costs, to control for individual differences. County dummies are also introduced to control for the district differences. A brief description of those variables used in multivariate analysis is presented in next section.

4.4 Description of Variables Used in Econometric Models

In the previous section, the model used to estimate the impacts of FFS training and Bt cotton on yields and insecticide costs was outlined. For convenience of model specification, the variables indicating participation in and exposure to FFS training as well as Bt cotton adoption were also explained with respective hypotheses. In this section, a brief description of the other variables is presented.

In the yield function, the dependent variable is the difference of logged seed cotton yields measured in kg per hectare. As explained earlier, such a difference is in effect the growth rate of cotton yields and hence the DD model provides an insight into the dynamic process of cotton production between years.

Since the first period is differenced out when taking first difference, only periods 2 and 3 are left with the estimation and a dummy variable period was assigned to period 3. Any secular change in period 3, such as change of climate and evolution of pest resistance to pesticides, which might have effect on the performance indicator for all the farmers but not controlled by the observed variables in the model, are embodied in the period dummy. As shown in Table 4-3, there were significant differences of cotton production between different counties, and hence it is meaningful to include two county dummies county1 and county2 to control for the county specific unobserved factors.

Insecticide, fungicide and herbicide are respective categories of pesticides applied in cotton in one season and measured in US$ per hectare. As those inputs are used to abate pest (including weed) damage, they are expected to contribute to higher yields with reduced losses. Irrigation, fertilizer and labor are direct inputs and expected to directly increase cotton yields, among which the former two were measured in US$ per hectare, while labor was defined as the number of persondays that are used to produce cotton on unit hectare of land. Cotton share is the proportion of the land sown to cotton to total land cultivated by a household. Ability to recognize pests and beneficial organisms is a proxy of pest control knowledge and measured by the number of pest and natural enemy species recognized by individual interviewees. It is expected that, with better knowledge on pest control, the farmers may apply pest control measures more timely and properly and hence realize higher yields.

The common variables in the insecticide function were defined in the same way as in the yield function. The period, county1 and county2 dummies were explained in the same way as in the yield function. Herbicide is used to get rid of weeds which might harbor both harmful and beneficial insects and hence affects the insecticide use. As for fertilizer, it has been shown that the intensive use of fertilizer especially nitrogen fertilizer might trigger more severe pest problems and hence increase pesticide use (Hill, 1989). As the proxy of knowledge on pest control, it is reasonable to expect that better ability to recognize pests and beneficial organisms leads to less insecticide costs. The new variables in the insecticide function are the insecticide price and farm size. Insecticide price was defined as the weighted average price of all the insecticides sprayed in cotton in individual farmer households and measures by US$ per kg. Farm size was measured in hectare, representing the total area of land cultivated by a farmer household in a specific survey year. If the price of insecticides can reflect the quality of the products, higher price might result in lower costs. Farm size might have diluting effect on the intensity of farming activities and hence lead to less input use on unit area.

4.5 Empirical Results

4.5.1 Descriptive Analysis

Descriptive analysis was first conducted to identify significant linear shift of major performance indicators for different farmer groups. Table 4-5 reports the longitudinal and latitudinal comparison of some key indicators of interest by farmer group. Apparently, some secular factors applied their influences and caused remarkable overall differences between years. Owing to favorable climate and increasing producing intensity motivated by higher cotton price there was an overall increase in cotton yields in 2002 as compared to 2000 (MOA, 2002b). In 2005, the trend was reversed mainly due to unfavorable weather such as drought in early cotton season and too much rain at late stage (APMA, 2005). In this process, the FFS participants established and maintained some advantage over the others. According to the latitudinal comparison of yields in 2000, there was no significant difference between farmer groups. However, substantial disparity in favor of the participants emerged in 2002 and the gap remained in 2005. With bigger gains in 2002 and smaller losses in 2005, the FFS participants had significantly higher yields in both years. As compared to those in the control group, the cotton yields in the exposed group increased more in the second time period and then declined more in the third time period. Even so, the exposed farmers had significantly higher yields in contrast to the control farmers in 2005. The latitudinal comparison of the gross margins between the farmer groups tells a similar story. From almost the same starting points in 2000, the participants greatly outmatched the control farmers in 2005 with exposed farmers lying in between. On longitudinal axis, the gross margins increased continuously in both time periods even though there was an overall yield drop in 2005. The soaring up of net profit in 2002 mainly resulted from higher yields. However, the modest increase in 2005 should be attributed to substantially higher cotton price which climbed by 16.7% as compared to that in 2002.

The pesticide use presents a different picture. A general dramatic reduction in pesticide use took place in 2002, but an overall increase happened in 2005. Behind the scene, rapid diffusion of Bt varieties and variation of pest pressure could be raised as explanation. Within the study period, the adoption rate of Bt cotton increased from 12% in 2000 to 64% in 2005 in China. The rapid diffusion of Bt cotton might have contributed to some reduction in pesticide costs. However, with Bt cotton widely grown, some earlier worries seems to gradually come true. Non-lepidopterous pests especially sucking aphids (*Aphis* spp. and *Acyrthosiphon gossypii*), mirids (*Adelphocoris* spp. and *Lygus* spp.) and red spider mite (RSM) (*Tetranychus cinnabarinus*) increase their infestations seriously, which have triggered the rebound of pesticide use in recent years (Qin, 2005; Wang et al., 2006). Those factors do have a bearing on the pesticide use. Nonetheless, they can not explain the latitudinal difference between farmer groups. Starting from a little higher level of pesticide use, the FFS participants experienced the most drastic drop in pesticide use in 2002, which rendered their pesticide expenditure significantly lower than that in the other farm groups from then on. The exposed farmers also improved their performance in pest control to some extent as compared to the control farmers. The insecticides followed a similar shifting pattern to the pesticides, significant differences in favor of the participants and the exposed farmers also emerged in 2002 and were sustained to 2005. What was the reason for the recently emerged difference of yields, pesticide and insecticide costs between farmers groups? With this question this study proceeds to multivariate analysis.

Table 4-5: Comparison of performance indicators and Bt cotton adoption by farmer group

	2000	Difference 2002/2000	2002	Difference 2005/2002	2005
Yield (kg ha^{-1})					
Participants	3262.92	657.80**	3920.71c	-79.31**	3841.40^{c}
	(657.86)	(48.99)	(274.24)	(27.64)	(319.85)
Exposed farmers	3195.70	447.36**	3643.07^{b}	-138.43**	3504.64^{b}
	(560.71)	(49.40)	(271.62)	(27.04)	(328.17)
Control farmers	3196.64	300.05**	3496.69^{a}	-105.10**	3391.59^{a}
	(518.23)	(43.48)	(234.81)	(22.94)	(299.30)
Gross margin ($\text{US\$ ha}^{-1}$)[1/]					
Participants	1333.32	549.38**	1882.70^{c}	128.30**	2011.00^{c}
	(445.52)	(31.90)	(181.07)	(18.69)	(218.55)
Exposed farmers	1250.08	408.61**	1658.69^{b}	122.62**	1781.31^{b}
	(412.96)	(33.59)	(285.02)	(17.56)	(270.86)
Control farmers	1276.51	234.51**	1511.02^{a}	162.80**	1673.82^{a}
	(379.00)	(30.31)	(276.65)	(18.30)	(246.55)
Pesticide cost ($\text{US\$ ha}^{-1}$)					
Participants	136.62	-83.20**	53.43^{c}	11.32**	64.74^{a}
	(81.56)	(5.72)	(42.04)	(2.23)	(44.63)
Exposed farmers	134.81	-66.56**	68.24^{b}	13.98**	82.23^{b}
	(84.58)	(5.27)	(53.48)	(3.42)	(64.18)
Control farmers	122.53	-38.02**	84.50^{a}	14.50**	99.00^{c}
	(90.56)	(5.15)	(50.60)	(2.75)	(59.17)
Insecticide cost ($\text{US\$ ha}^{-1}$)					
Participants	128.92	-78.70**	50.22^{c}	7.16**	57.39^{a}
	(76.79)	(5.19)	(40.81)	(2.21)	(41.52)
Exposed farmers	128.11	-63.94**	64.17^{b}	10.59**	74.76^{b}
	(80.66)	(4.88)	(52.41)	(3.31)	(60.43)
Control farmers	113.96	-35.35**	78.61^{a}	10.93**	89.54^{c}
	(85.12)	(4.73)	(49.84)	(2.62)	(57.11)
Bt cotton adoption (%)					
Participants	46.80	33.34**	80.14	6.83*	86.97
	(47.59)	(3.95)	(38.52)	(3.12)	(26.75)
Exposed farmers	46.01	28.53**	74.54	12.24**	86.78
	(49.26)	(3.80)	(41.94)	(3.25)	(29.33)
Control farmers	41.80	33.85**	75.65	16.53**	92.18
	(49.09)	(3.85)	(41.87)	(2.89)	(21.97)

Note: **, * denoted significance at 1% and 5% respectively; superscript letters denoted the results of Duncan's test (0.05); standard deviations reported for 2000, 2002 and 2005 observations, and standard error means reported for change between years in parentheses; producer price index for farm products and price index of agricultural inputs were used to inflate 2000 and 2002 prices of cotton and inputs to 2005 value; [1/] the cost of family labor was not included in computation.

Source: Own survey and survey by NATESC and PPS of Shandong, Anhui and Hubei Provinces

4.5.2 Multivariate Analysis

In this section, the results of two multi-period panel models, namely the yield and the insecticide cost model, are presented.

The results of the yield model are summarized in Table 4-6. The high F value and reasonable R squared value for a three period panel data demonstrate the overall robustness of the model specification. The significant positive constant indicates a general yield increase in the second time period (2002), while the negative parameter to the "period" variable reveals a yield loss in the third time period (2005). The control for the district differences was well warranted by the significant coefficient to one county dummy. Results also indicate that the insecticides, fungicides and herbicides all contributed somewhat to higher yields, but none of those three coefficients is significant. Even so, some meaningful implications can still be drawn from those results. The very small coefficient for insecticide use suggests an overuse of this input. By calculation with the average yields and cotton price in 2005, it was found that the economic return to 1 more US$ insecticide use was only 0.16 US$ (see Box 1). The figures for fungicides and herbicides were 3.41 and 0.96 respectively. Those findings are consistent with previous studies reporting an overuse of insecticide in Bt and Non-Bt cotton in China (Huang et al., 2002b; Pemsl, 2006). However, the high return to fungicides might indicate a deficiency in disease control.

Box 1: Derivation of MVP from DD model

By approximation, the marginal product (MP) of a certain factor of interest can be readily derived from equation (4). For simplicity, the subscripts except t are dropped and then the equation is condensed to $Y_{t+1} = Y_t * e^{[\alpha+\gamma_F*(F_{t+1}-F_t)+\gamma*(V_{t+1}-V_t)]}$, where F denotes the variable of interest, a is the constant and V indicates the vector for all the other variables. Use approximation $e^x \approx x+1$, it can be achieved that: $Y_{t+1} \approx Y_t * [\alpha + \gamma_F * (F_{t+1} - F_t) + \gamma * (V_{t+1} - V_t) + 1]$. Take partial derivative of Y with respect to F and then the MP can be expressed as: $\partial(Y_{t+1}) / \partial F_{t+1} = \gamma_F * Y_t$. Substitute the average yield $\overline{Y}$ to Y_t and multiply MP with the average price of cotton $\overline{P}$, the MVP of factor F is approximately equal to $\gamma_F * \overline{Y} * \overline{P}$.

As for the other inputs, the fertilizer and labor contributed significantly to yield increase. The irrigation also conduced somehow to higher yields, but non-significantly. A reasonable explanation lies with the climatic difference between the study areas. The agriculture heavily relies on irrigation in Lingxian County, while in the other two counties there is usually abundant rainfall for crop development. As a proxy for pest control knowledge, the variable "ability to recognize pests and beneficial organisms" has a non-significant positive coefficient, which implies that, if a farmer better recognizes harmful and beneficial organisms, he can have somehow higher cotton productivity in his field. The negative parameter for cotton share is a little surprising at a first glance. However, on a second thought it is reasonable in this case because the DD model measures the effect of the change of cotton share rather than cotton share per se on cotton yields. The land allotted to cotton cultivation is relatively stable for those households who are more professional cotton growers. The less specialized families are more responsive to external influence such as a change of the price of cotton and its competing crops.

The high level of significance of the coefficient to the variable "participation" strongly indicates that the participation in FFS contributed to higher cotton yields. With other factors held constant, FFS participants achieved 8.4% higher yields as compared to the control farmers (see Box 2). In addition, the parameter for the interaction term between "participation" and "period" dummies has a positive sign. The very high probability of this parameter dampens any argument for a stronger FFS impact in the medium term. However on the other hand, it provides a solid confirmation of the retention of the impact gained by the participants in the short period. For the exposed farmers, a barely non-significant coefficient to the "exposure" dummy suggests a tendency of improvement in yields in the short term. Such an improvement seems to be evanescent. The negative coefficient to the interaction term between "exposure" and "period" dummies denotes, even if the exposure to FFS contributed to somewhat higher yields in the short term, it was difficult for the impact to be sustained over time.

Box 2: Derivation of the percentage interpretation of the coefficients to dummy variables in DD model

The dummy variables in DD model can be interpreted in terms of difference in change rate and absolute value as well. Suppose there are two farmers, the only difference between them is indicated by a household feature dummy D (*e.g.* 1 for FFS participation and 0 otherwise). As in Box 1, equation (8) can be condensed to $\Delta \ln(Y_t) = \alpha + \mu D + \gamma \Delta V_t$. Holding all the other factors constant, the change rate from time period t to t+1 for FFS participants is

$\ln(Y_{t+1}^p / Y_t^p) = \ln\left[(Y_{t+1}^p - Y_t^p + Y_t^p)/Y_t^p\right] = \alpha + \mu + \gamma * (V_{t+1} - V_t)$, and for the control farmer $\ln(Y_{t+1}^c / Y_t^c) = \ln\left[(Y_{t+1}^c - Y_t^c + Y_t^c)/Y_t^c\right] = \alpha + \gamma * (V_{t+1} - V_t)$. Further manipulations yield: $(Y_{t+1}^p - Y_t^p)/Y_t^p = e^{[\alpha+\mu+\gamma*(V_{t+1}-V_t)]} - 1$ and $(Y_{t+1}^c - Y_t^c)/Y_t^c = e^{[\alpha+\gamma*(V_{t+1}-V_t)]} - 1$. Use approximation $e^x \approx x + 1$, it can be derived that: $(Y_{t+1}^p - Y_t^p)/Y_t^p = \alpha + \mu + \gamma * (V_{t+1} - V_t)$ and $(Y_{t+1}^c - Y_t^c)/Y_t^c = \alpha + \gamma * (V_{t+1} - V_t)$. Subtraction of the growth rate for the control farmers from the participants produces: $(Y_{t+1}^p - Y_t^p)/Y_t^p - (Y_{t+1}^c - Y_t^c)/Y_t^c = \mu = (100 * \mu)\%$. Therefore the coefficient to the dummy in DD model can be approximately interpreted as $100 * \mu$ percentage points difference between the change rates of the two farmer groups. On the other hand, since most existing work in this field measures the impact in absolute value rather than growth rate, it is helpful to interpret the result of DD model in this way as well. For this purpose one more assumption is needed that the control farmers and FFS participants have the same original yield: $Y_t^p = Y_t^c = Y_t$. This assumption should not hurt the effort for derivation because from an econometric point of view it is already assumed that all the other factors than the "participation" dummy are held constant when interpreting the coefficient to the dummy. In the time period t+1, the equations for the FFS participants and control farmers are: $\ln(Y_{t+1}^p) - \ln(Y_t) = \alpha + \mu + \gamma * (V_{t+1} - V_t)$ and $\ln(Y_{t+1}^c) - \ln(Y_t) = \alpha + \gamma * (V_{t+1} - V_t)$. Subtraction of the control equation from the participant equation produces: $\ln(Y_{t+1}^p) - \ln(Y_{t+1}^c) = \mu$. With further manipulations, it turns out to be: $\ln(Y_{t+1}^p / Y_{t+q}^c) = \mu$, $\left[(Y_{t+1}^p - Y_{t+q}^c) + Y_{t+q}^c\right]/Y_{t+q}^c = e^\mu$ and then $(Y_{t+1}^p - Y_{t+q}^c)/Y_{t+q}^c = e^\mu - 1$. It is clear that the coefficient to a dummy variable in DD model can be interpreted as the contribution to the performance by a percentage of $100 \times (e^\mu - 1)$ as compared to the base group.

Given the non-significant coefficient of the variable "Bt", it is hard to say the adoption of Bt cotton could independently increase cotton yields. However, the coefficient to the interaction term between Bt and participation is barely not significant at 10%, and the Wald test of Bt and its two interaction terms with FFS participation and exposure gives an F value of 2.73, which rejects the joint null hypotheses of no impact at 5% level. So a plausible extrapolation can be made as such, success of biotechnology is not a simple matter of adoption or non-adoption. Only adopters with adequate knowledge can take full advantage of the technical advancement. In this case, it was the FFS training that trained FFS participants to handle Bt varieties properly and hence might promise higher yields. Less likely, some exposure impact could be expected for the exposed farmer in this regard, since the coefficient to the interaction term between Bt and exposure also bears a positive sign, implying some improvement in the "right" direction.

Table 4-6: Estimated coefficients for yield function

Dependent variable: yields N=960, R^2=0.36, F=30.45			
Variable	Coefficient	Robust std error[21]	Robust prob.
Constant	**0.1105**	0.0174	0.0000
Period	**-0.1559**	0.0176	0.0000
County1	0.0084	0.0121	0.4899
County2	**-0.0326**	0.0127	0.0105
Exposure[1/]	0.0337	0.0225	0.1344
Exposure * period	-0.0125	0.0103	0.2252
participation	**0.0809**	0.0250	0.0013
Participation * period	0.0009	0.0093	0.9271
Insecticide	0.0001	0.0001	0.5884
Fungicide	0.0014	0.0011	0.2309
Herbicide	0.0004	0.0010	0.7109
Fertilizer	**0.0002**	0.0001	0.0001
Irrigation	0.0001	0.0002	0.5643
Labor	**0.0001**	0.0000	0.0005
Cotton share	-0.0415	0.0282	0.1418
Ability to recognize pests and beneficial organisms	0.0008	0.0014	0.5667
Bt	0.0040	0.0187	0.8320
Bt * exposure	0.0282	0.0263	0.2839
Bt * participation	0.0415	0.0269	0.1236

Note: [1/] As illustrated in the section of empirical model specification, the actual variable used in the regression was "exposure - exposure* period" for the exposed farmers and "participation - participation * period" for the participants. This note held for all the tables reporting multivariate results in this chapter.

Source: Own survey and survey by NATESC and PPS of Shandong, Anhui and Hubei Provinces

Table 4-7 reports the estimates of insecticide function. The very high F value and R squared value indicate strong overall significance of the model and high level of goodness-of-fit. All the coefficients conform to prior expectations. As in the yield

21 Most "difference in difference" papers ignore the bias in the estimated standard errors that serial correlation induces (Bertrand, 2004). Heteroscedasticity might also cause a problem to "difference in difference" models (Wooldridge, 2003). Tests following Wooldridge (2003) detected significance of serial correlation and heteroscedasticity in this case. Therefore, robust standard errors were used for correction. The results of the tests of serial correlation and heteroscedasticity are presented in Appendices 4 and 5 respectively.

function, there is an apparent merit in controlling for the district difference. The significant negative constant and positive parameter to the “period” dummy are consistent with overall decrease in insecticide use in the second period and rebound in the third period. Farmers spent less money on insecticide if they purchased products of higher price and hence probably higher quality. More intensive fertilizer use triggered more insecticide application. This is in line with natural scientific studies that uncover the relationship between fertilizing timing and fertilizer composition to pest incidence (Jahn, 2005; Zhu et al., 2004). Plots with more labor input received more insecticides. As suggested by Pemsl (2006), this could be due to higher general production intensity or lower economic threshold resulting from higher potential yields in more labor intensive plots. Consistent with some other studies (e.g. Huang et al., 2002a), it was revealed that the increasing farm size resulted in decreasing insecticide use, implying that the input intensity was diluted if farmers needed to take care of more lands. Pest control knowledge, proxied by the ability to recognize pests and beneficial organisms also significantly contributed to insecticide reduction.

As in the yield function, the impact of FFS training was also highlighted in the insecticide regression. The “participation” dummy has a substantial coefficient of -0.6183, which means FFS training resulted into a 46% reduction in insecticide costs. This strong impact generated in the short term was sustained at least up to the medium term. The non-significant negative parameter for the interaction term between the “participation” and “period” dummies suggests that FFS participants well maintained their gains from reduced insecticide use four years after the training. For the exposed farmers, they also benefited considerably from the spill-over effect of FFS in the short run. According to the results, exposure to FFS led to a 40% decline in insecticide costs. However, no matter how strong the diffusion impact was, it diminished substantially with the passage of time. In the medium term, the insecticide costs in the exposed group rebounded fiercely at a rate 14.4 percentage points over that in the control group[22]. Bt cotton significantly reduced insecticide costs by 10%, which however was much smaller than those reported by some previous studies (e.g. Huang et al., 2002a; 2002b). The effect of Bt was greatly reinforced by interaction with FFS participation. Bt varieties planted by FFS participants further contributed to a 15.5% reduction in insecticide costs as compared to those grown by the control farmers. With a

22 See Box 2

non-significant parameter, exposure to FFS ambiguously improved the performance of Bt cotton by 8.3%.

Table 4-7: Estimated coefficients for insecticide function

Dependent variable: insecticide costs
N=960, R^2=0.57, F=78.99

Variable	Coefficient	Robust std error	Robust prob.
Constant	-0.2654	0.0580	0.0000
Period	**0.1992**	0.0736	0.0070
County1	**-0.0769**	0.0396	0.0527
County2	**0.4861**	0.0508	0.0000
Exposed	**-0.5181**	0.0820	0.0000
Exposure*period	**0.1445**	0.0545	0.0081
Participation	**-0.6183**	0.0925	0.0000
Participation*period	-0.0050	0.0516	0.9226
Insecticide price	**-0.0256**	0.0126	0.0426
Herbicide	-0.0008	0.0038	0.8321
Fertilizer	**0.0020**	0.0002	0.0000
Labor	**0.0007**	0.0002	0.0000
Farm size	**-0.4037**	0.1259	0.0014
Ability to recognize pests and beneficial organisms	**-0.0170**	0.0075	0.0242
Bt	**-0.1070**	0.0631	0.0904
Bt * exposure	-0.0867	0.0877	0.3232
Bt * participation	**-0.1679**	0.0919	0.0682

Source: Own survey and survey by NATESC and PPS of Shandong, Anhui and Hubei Provinces

Table 4-8 provides the results from the re-estimation of the yield function with the participants as the base group. Most of the estimates are not presented here since they are identical to those produced by the original model specification and already presented in Table 4-6. The statistic comparison between the direct and indirect impact of FFS on yields can be readily read from the table. A significant negative parameter to the “exposure” dummy indicates the growth rate for the exposed farmers was 4.7 percentage points lower than that for the FFS participants in the short term. In the medium term, the gap between those two groups is further broadened by 1.3 points although it is barely non-significant. The significant positive coefficient to “Bt” variable indicates that, if the adopter was an FFS participant the adoption of Bt cotton significantly increased yields by 4.6%. The gains from Bt cotton adoption attenuated with exposed farmers and especially with the control farmers. The relationship between the participants and the control farmers is synonymous as the one shown in Table 4-6 and no more explanation is added here for brevity.

Table 4-8: Re-estimated coefficients for yield function with participants as the base group

Dependent variable: yields N=960, R^2=0.36, F=30.45			
Variable	Coefficient	Robust std error	Robust prob.
Constant	**0.1913**	0.0240	0.0000
Period	**-0.2360**	0.0212	0.0000
Control	**-0.0809**	0.0250	0.0013
Control * period	-0.0009	0.0093	0.9271
Exposure	**-0.0472**	0.0239	0.0486
Exposure * period	-0.0134	0.0093	0.1488
Bt	**0.0455**	0.0207	0.0283
Bt * control	-0.0415	0.0269	0.1236
Bt * exposure	-0.0133	0.0275	0.6288

Source: Own survey and survey by NATESC and PPS of Shandong, Anhui and Hubei Provinces

Table 4-9 presents the results from the re-estimation of the insecticide function. In the short term, the decreasing rate of insecticide costs in the exposed group was 10 points lower than that for the participants. Such a difference is not statistically significant, indicating a strong diffusion impact of FFS on insecticide use. On the other hand the difference in the insecticide growth rate was significantly enlarged in the medium term when insecticide costs of the exposed farmers significantly increased further by 14.9 points over the participants. As for Bt cotton, adoption by FFS participants resulted in a significant decline in insecticide costs by 24%. Such an effect diminished with the exposed farmers and weakened markedly in the fields of control farmers.

Table 4-9: Re-estimated coefficients for insecticide function with participants as the base group

Dependent variable: insecticide costs

N=960, R^2=0.57, F=78.99

Variable	Coefficient	Robust std error	Robust prob.
Constant	**-0.8836**	0.0822	0.0000
Period	**0.8124**	0.0849	0.0000
Control	**0.6183**	0.0925	0.0000
Control * period	0.0050	0.0516	0.9226
Exposure	0.1001	0.0978	0.3060
Exposure * period	**0.1495**	0.0582	0.0104
Bt	**-0.2749**	0.0728	0.0002
Bt * control	**0.1679**	0.0919	0.0682
Bt * exposure	0.0812	0.0948	0.3919

Source: Own survey and survey by NATESC and PPS of Shandong, Anhui and Hubei Provinces

4.6 Summary and Conclusions

The results of this chapter demonstrate the significant impacts of FFS on both yield increase and insecticide reduction for FFS participants. Those impacts developed shortly after the training took place and were sustained also in the medium term. In the short term, substantial diffusion impact on insecticide use was also identified. Although of considerable magnitude, such an impact diminished apparently after some time. No significant spill over effect on yields was concluded in this case. There was some indication of accelerated yield growth in the exposed group in the short run, but it was counteracted by a reversed tendency in the medium term. Another informative finding here is the favorable interaction between the FFS training and adoption of biotechnology. As an alternative to chemical pesticides, the adoption of Bt cotton was found to contribute to a modest reduction in insecticide use. When the FFS was added to Bt cotton cultivation, the insecticide reduction effect of Bt varieties was augmented. Furthermore, significant productivity gains could be achieved in the Bt cotton plots managed by those farmers who ever participated in FFS training.

The findings about the FFS impacts comply with the majority of previous studies. However, there are some discrepancies deserving more discussion. Yield increase resulting from FFS training was documented as very difficult in intensive cropping systems in rice (Praneetvatakul et al., 2008). This chapter pinpoints significant impact of FFS on yields in cotton production. Among others, three factors may be crucial to this success: the crop, the personnel and the FFS curricula. Cotton is a crop subject to severe damage inflicted by various pests. Even with high levels of pesticide use, the actual cotton yield loss caused by pest damage in China is estimated to be 6% on average, and up to 14% in years of unusual pest infestation (NATESC, 1987-2008). As a result, the improved pest control practices resulting from FFS training had a fair chance to more effectively abate yield loss and hence contributed to higher productivity. As regards the personnel, the trainers and trainees concurred to foster a smooth knowledge flow. In the case of China, most of the facilitators were from the extension system. The professional background and experience in extension of those facilitators might contribute to a smoother facilitation. At the same time the improved farmer educational level after decades of development promised a more effective intake of the knowledge imparted in FFS. As for the curricula, appropriate scope and content may have strengthened the impact of FFS on yields. The curricula were developed based on the concept of “grow a healthy crop”, and a series of operational outcomes of scientific research were disseminated in FFS, including the removal of early buds, light cultivation, rational plant density and balanced fertilizing. The extension of those practices had encountered difficulties in the past because they were somehow contrary to common sense or farmers’ accustomed practices. The participatory and discovery nature of FFS prevailed in telling farmers not only “what” but also “why” and hence convinced the participants to start and try.

The severe pest problems and the resulting economic losses are also a natural motivation for exposed farmers to seek to reduce pesticide use. This interior pursuit and exterior influence combined to generate a significant diffusion effect on pesticide reduction. In the project areas, advocacy campaigns were launched by local governments to promote the concept of IPM. Local mass media including TV, broadcast and newspaper were required to provide free coverage of FFS activities and IPM knowledge. The institutional support created a favorable environment for IPM knowledge diffusion. Actually many farmers in the control villages did hear of IPM. When asked why they did not conduct IPM, those farmers usually responded with “we want but we can’t” because of “without knowing details” or “lack in confidence”. In the FFS villages, there was a different picture. Those farmers outside of FFS were occasionally invited to attend FFS field days. Some of the FFS participants established interest groups and proclaimed their willingness to share IPM knowledge with the others. As a result, it should not be surprising that better crop stands with less pesticide applications in the fields of the participants allured exposed farmers to look, ask and then replicate the work in their own plots. However, the durability of the diffusion effect is questionable. Pest control by replication rather than own decision might be adequate for ordinary pest infestation. When new pest problems emerged, for instance the resurgence of mirids and RSM, difficulty in adapting the control measures started to drive the exposed farmers back to their habitual solo pesticide solution. From this perspective, this study is not only an empirical validation of the diffusion effect but also an admonitory reminder of its diminution. The sustainability of the FFS approach depends to a great extent on the strength and scope of the diffusion effect. Therefore, even though FFS training can bring about significant impacts on participants, follow-up activities are still in need and more farmers should be involved. Knowledge gained through participatory and discovery approach needs to be diffused in a similar manner. Only when the exposed farmers can replicate critical thinking and better decision making rather than some concrete IPM practices, can the durable diffusion effect then be expected.

This chapter reveals that, Bt cotton per se contributed to a statistically significant reduction of insecticide costs by 10%, which is much less than those found in previous studies by Huang et al. (e.g. 2002a; 2002b; 2002c). There might be three possible reasons for such a divergence. First, this chapter applies the “difference in difference” model to panel data and hence may have eliminated some unobservable determinants which were not properly controlled for by previous studies. Second, two third of the farmers in the sample were drawn from the Changjiang Rive Cotton Region where Bt cotton has been demonstrated to be less effective (Huang et al., 2004). Third, some fundamental problems with the introduction of the Bt cotton varieties in China, such as unreliable quality of Bt seeds, default of necessary institutions and inability for farmers to make informed decisions (Pemsl et al., 2005), remained there and could be even more apparent nowadays. Indeed, as well as some earlier studies (Yang et al., 2005a; 2005b), this chapter demonstrates a strong impact of empowering farmers through FFS training on the performance of Bt varieties. The commercialization of Bt cotton brought the small-scale cotton farmers in China one more option for the control of some lepidopterous pests but many new challenges for cotton cultivation. They had to adapt agronomic practices because of phenotypic differences of Bt varieties from conventional ones, to choose whether to complementarily apply pesticide to control

CBW without properly understanding the seed quality and Bt resistance dynamics, and to tackle new problems resulting from resurgence of some former minor pests.

Ideally, relevant training should be synchronized with biotechnology diffusion to assist farmers to overcome those challenges. Unfortunately the popular belief was that Bt cotton offers pest control solution in seeds. This has led to the negligence of enabling farmers to make informed decisions (Pemsl et al., 2005). As a result, resource poor farmers have paid the price for more expensive Bt seeds and still excessive use of pesticides. Also, inappropriate handling of Bt varieties enhances the risk for CBW to build up resistance to Bt toxin, undermines Chinese government' efforts to develop agricultural biotechnology to help improve the nation's food security, increase farmers' incomes and foster sustainable agriculture (SSTC, 1990). From this point of view, there is a valuable contribution by this study to highlight the problems and suggest a solution: giving FFS a role to play in the explosive diffusion of biotechnology will benefit all the major players in the game, the farmers, the seed companies and the government as well.

5 Lessons Learned of Scaling up Farmer Field Schools in Cotton in China

Based on careful check and control of important econometric problems including selection bias and input endogeneity, this chapter applies both conventional and damage control frameworks to analyze the impacts of FFS training on insecticide use and cotton yields in the context of program scale-up. In the first section of this chapter, a literature review of agricultural extension in developing countries is presented in order to set the scene for an assessment of scaling up the Farmer Field School concept under the conditions of the agriculture in China. Thereafter, the objective for the study is specified in section two. After a brief explanation of the data collection procedure in section three, a description of the study areas and farmer groups is presented in section four with comparisons of farmer and household (HH) characteristics and cotton production parameters. Section five presents a concise introduction of the theoretical background for damage control framework, and then based on this framework the empirical models are constructed and a series of tests of econometric problems are carried out to choose the proper procedure for model estimation. The results of descriptive and multivariate analysis are presented in section six with focus on the interpretation of the outputs regarding FFS training, insecticide use and Bt cotton. Section seven closes the chapter with a summary of the study and some conclusions drawn from the findings.

5.1 Agricultural Extension and Farmer Field School in Developing Countries

5.1.1 Evolution of Agricultural Extension Systems

It is widely recognized that the knowledge and related information, skills, technologies, and attitudes are key to sustainable agriculture and rural development (Alex et al., 2002). For knowledge to be effective there must be an efficient mechanism whereby it can reach farmers as the end users. The process of bridging the gap between laboratories and farmer fields is the function of extension (Asiabaka, 2002). Owing to the significant public good attributes of agricultural knowledge diffusion, government funding is often provided to work with farmers in explaining and testing new technologies (Farrington, 2002). In the past decades agricultural extension has grown to what may be the largest institutional development effort the world has ever known

(Jones et al., 1997). Many countries especially developing countries invested heavily in agricultural extension. Between 1959 and 1980, spending in real terms for extension grew more than six fold in Latin America, tripled in Asia and more than doubled in Africa (WorldBank, 1990). And by late 1990s, the agricultural extension worldwide had already employed at least 800,000 extension workers, and about 80 percent of the world's extension services were publicly funded and delivered by civil servants (Feder et al., 2001).

Past investments in extension have yielded high economic rates of return and are seen as one reason for good global performance in food production (Alex et al., 2002). However on the other hand, agricultural extension has some generic problems such as the difficulty of fiscal sustainability, weak accountability to clientele, poor interaction with knowledge generation and dependence on wider policy environment (Feder et al., 2001). Those problems tended to render extension failing, moribund, barely functioning or in disarray (Rivera et al., 2001). As a result, many past extension paradigms including the ever widely used training and visiting system (T&V) were first promoted with good intentions but finally abandoned facing hard realities (Anderson et al., 2004).

The T&V system was developed in early 1970s and then expanded to more than 70 developing countries in more than two decades (Umali et al., 1994). Even from a contemporary point of view, some positive elements were already incorporated into this approach (Nagel, 1997). The reorientation from desk bound bureaucracy to a field-based, professionally motivated cadre of agents could improve the interaction with farmers; the tight supervision and the strict time table of contact farmer group visits might enhance the accountability; seasonal meetings with research personnel and possible feedback of farmers' problem might strengthen the links with technology generation (Piccioto et al., 1997; Anderson et al., 2006). However, there were apparent deficiencies. The attempt to cover many farmers, the demand for larger field level cardre and a multi-level hierarchy for midlevel management and technical support exacerbated the problem of fiscal sustainability (Anderson et al., 2006). The standardized message flow driven by supply rather than by demand was often of little relevance to local conditions and the implementation in a top-down manner left little possibility for farmer participation and initiative (Nagel, 1997). Those weaknesses and the resulting lack of convincing evidence of major gains finally induced the fall of T&V.

Agricultural extension was once again at a crossroads (Piccioto et al., 1997). The lessons from T&V and other extension modalities in history, however, have thrown light on ensuing efforts to search for more appropriate alternatives. Powerful global trends developed toward incorporating into the extension system the elements of “demand driven”, “participatory” and “farmer orientation”, which are believed as indispensable for an effective, efficient and sustainable extension modality (Qamar, 2002). Among those innovations, the Farmer Field School (FFS) is the one gaining prominence.

5.1.2 Farmer Field School and Agricultural Extension

The FFS was piloted in Indonesia to introduce knowledge on integrated pest management (IPM) to irrigated rice farmers in 1989 (Pontius et al., 2001). Prior to its advent, there were disastrous outbreaks of brown planthopper (Nilaparvata lugens) in South-east Asia and national initiatives were taken to transfer packaged IPM technology to farmers with the T&V approach in many countries such as the Philippines, Indonesia, Sri Lanka and India, etc. (Kenmore, 1997; Röling et al., 1994). However, the inertia, indifference and many conflicting responsibilities of the extension agents precluded high quality field training effort and farmers’ pest management practices did not change appreciably (Matteson, 2000). It was the failure of IPM technology transfer by T&V extension that gave impetus to the innovation of the new modality of FFS (ibid). Fundamentally distinguished from prior farmer training models in regard to the roles of players, the way to organize, the content to be instilled and the goal to be achieved, the innovation of FFS is renowned by many as a paradigm shift in extension work (Ooi, 2000; Röling et al., 1994; Xia, 2006). In FFS, the farmers are equal partners rather than passive recipients while the trainers are facilitators but not instructors (Matteson, 2000). Contrasted to conventional technology transfer featured by the brief, instructional, classroom-training mode, FFS follows interactive, participatory, field-based and experiential learning processes to instill a regenerative ecological concept and to “help farmers develop their analytical skills, critical thinking and creativity and help them learn to make better decisions” (van de Fliert, 2003; Kenmore, 2002). Empowerment of farmers has been the essential feature of FFS from the very beginning (Bartlett, 2005). After participating in FFS, the farmers master a process of learning (Dilts, 2001) and by applying the learning process continuously, they can then have great opportunities to become “confident pest experts, self-teaching experimenters, and effective trainers of other farmers” (Wiebers, 1993).

Sustainability, from both technical and fiscal points of view is among the major concerns of all the extension endeavors. In addition to the belief that the skills learnt in FFS allow farmers to continue and sustain IPM activities, the FFS approach further tackles those issues through follow-up activities and institutionalization of IPM in farmer communities. Successful FFS often serve as platforms for follow-up activities (van de Fliert et al., 2002). No matter what forms those activities might take, farmer association, IPM club or follow-up farmer field studies, they contribute to the retention of knowledge, acquisition of skills and generation of insights into new pest problems (Dilts, 2001; Ooi, 2000). Farmer to farmer training is an important follow-up activity with special meaning for the economic sustainability of the FFS approach. FFS facilitation does not require a high level of lecturing and hence opens the door for many Field School participants to become facilitators themselves (Gallagher, 2002). When FFS are carried out by farmer facilitators who are selected participants from FFS and given additional training, the running costs are much lower (Gallagher, 2003). The FFS also sets in motion a long term process to institutionalize IPM at community level. Taking into consideration that sustainable implementation of IPM requires an enabling environment at the community and even higher levels, Community IPM has been established as the conceptual framework for national IPM programs in the member countries of the FAO Regional Program (Pontius et al., 2001). Through years, diverse farmer institutions on IPM have emerged, evolved, prospered and sometimes disappeared as well (Dilts, 2001). It is the expectation of the promoters of Field Schools that, FFS participants manage their own IPM programs, empower themselves, influence others and improve their “bargaining” status when they come to face external opportunities and challenges such as economic liberalization and globalization (Gallagher, 2002; Dilts, 2001).

After FFS was first introduced in Indonesia at the end of 1980s, it expanded rapidly to other countries in Asia, many parts of Africa, Latin America and Eastern/Central Europe with millions of farmers in at least 78 countries undergoing the training (Braun et al., 2006). From its initial focus on IPM in rice, FFS has been introduced to many other crops such as cotton, fruits and vegetables, forestry, livestock, water conservation, soil fertility management, food security and nutrition and even social and health issues. With its expansion in crops, topics and geographic distribution, FFS, usually with some adaptation of the content of curricula or methodology to organize, is nowadays a widely recognized model for farmer training in many developing countries (ibid). The large-scale implementation and substantial investment call for a rigorous evaluation of the impacts. However, the methodological obstacles, the difficulty in defining impact, the different perspectives of stakeholders and the default of an agreed conceptual framework render the impact evaluation of FFS a difficult task (van den Berg, 2004). And as shown in later paragraphs in this subsection, the cost-effectiveness of FFS is still an issue of energetic debate. Especially, very little is known about the costs, benefits and organizational implications of scaling up FFS.

The most direct gains from FFS are acquisition of knowledge and skills should there be any impact. All the study efforts in this area unanimously demonstrate an increase in participants' knowledge about pest and crop management and in some cases changes in farmer behavior suggesting improved skills (van den Berg et al., 2007). As immediate and easy-to-measured indicators, pesticide use and yields are the impacts under most thorough scrutiny. All the studies with the one by Feder at al. (2004a) as the only exception report remarkable reductions in pesticide use usually accompanied by considerable yield gains (Braun et al., 2006). Those findings were first mainly derived from FFS in rice in Asia but have later been vindicated by studies of FFS in other crops and other regions (van den Berg et al., 2007). The environment, human and social impacts, and impact trajectory in the medium and long term are important for a holistic understanding of the role of FFS. They were rarely rigorously touched in the past mainly because of the difficulty in defining and measuring appropriate indicators. However, some recent studies have taken a step forward and their results tend to reinforce the mainstream positive reports. The environmental impact quotient (EIQ), a widely recognized method to quantify the environmental and health impacts of pesticides, has most recently been introduced to explore the environmental impact of FFS. A study in India and Pakistan attributes a significant reduction of EIQ to FFS training (Walter-Echols et al., 2005a). Two linked studies using a self-monitoring method in India manifest that the FFS in cotton greatly increased farmers' awareness of pesticide risks, and at the same time contributed to a change in pesticide use practices (Mancini 2005b; 2007). Following the sustainable livelihood approach, the study in India also demonstrates significantly higher impacts on sustainable livelihoods for FFS participants as regards gains to human capital, higher economic resilience and improved individual and social well being (Mancini, 2007). Additionally, two studies conducted respectively with internal and external efforts in Sri Lanka both show the durability of the impact: farmers trained five years ago only used one third of insecticides in rice as compared to the control farmers (van den Berg et al., 2002; Tripp et al., 2005).

Nonetheless, there is controversy about the impact of the FFS approach. Concern about the fiscal sustainability of the FFS approach was first raised eight years ago (Quizon et al., 2001). Rallied by a questioning of the diffusion impact on knowledge (Rola et al., 2002), the debate was fuelled in 2004 by two papers reporting no effect of the FFS on pesticide use, rice yields for trained farmers and no knowledge diffusion between trained and non-trained farmers eight years after the delivery of FFS training in Indonesia - the cradle of FFS (Feder et al., 2004a; 2004b). Lying at the center of the debate are the fiscal sustainability of the FFS approach and another close related issue: the feasibility to disseminate knowledge acquired in FFS from trained to non-trained farmers through farmer to farmer training and informal diffusion.

The concern about fiscal sustainability is derived from the high upfront and recurrent costs of scaling up FFS to reach a meaningful proportion of farmers. If the mechanisms developed for FFS to spread with reasonable costs failed, as perceived by those FFS skeptics, it would be a real challenge for FFS' future. However, as illustrated by Fleischer et al. (2002), it is insufficient to rely on simple measures of costs per farmer trained to assess the impact of agricultural extension and there is a need to include the prospective cost-benefits into the analytical framework. Another study by van den Berg et al. (2007) shows that, the costs and benefits of FFS are not easy to define and vary with program settings, content and stage as well. The costs calculated by Quizon et al. (2001) are much higher than other estimations at a later stage in Indonesia and also higher than the costs for FFS in most other countries (Braun et al., 2006). Farmer to farmer training, as mentioned before, is regarded crucial to augment FFS coverage in a more cost effective way. Quizon et al. (2001) conclude that the FFS run by farmer facilitators were quantitatively a minor factor in the national FFS initiatives in Indonesia and in the Philippines. But according to some other studies, farmer to farmer training was actually very active in many countries, and in 2001 nearly 50 percent of all the FFS were organized and run by farmer facilitators (Dilts, 2001). As for the diffusion impact, the picture is especially obscure. The studies by Feder et al. (2004a; 2004b) negate any diffusion impact on knowledge acquisition, yield increase and pesticide reduction. Other studies show that, the trained farmers had a strong intention to share knowledge with others and provide some evidences of knowledge diffusion (Nathaniels, 2005;

Simpson et al., 2002). The FAO-EU IPM Program for cotton in Asia reports as a general trend among six countries that, following the trained farmers, the neighboring non-trained farmers also reduced pesticide use to some extent as compared to the control farmers, but the gains in yields were found not to spread (Braun et al., 2006). This diffusion impact on pesticide use is substantiated by a study on rice in the Philippines which reports a remarkable reduction of pesticide use for the non-trained farmers in the FFS villages (Palis et al., 2002). Chapters 3 and 4 in this thesis also conclude some diffusion impact on pesticide reduction by applying the “difference in difference” model to the China case. There are evidences from those studies that the so called diffusion is more possible for simple ideas or tangible practices to spread by imitation or duplication, but the ecological concept and analytical skills are unlikely to be transferred by informal diffusion. As a result, the sustainability of the diffusion impacts remains as a matter of concern and the findings in chapter 4 have effectively shown a diminishing trajectory of the diffusion impact.

Despite of the ongoing debate, most studies on both sides have one thing in common: some drawbacks in research design or methodology. As a result of nonrandom program placement and participant selection, there is possible selection bias between the trained and the other farmers and only a few previous studies have properly checked and controlled for this issue (Godtland et al., 2004). Some other studies, for instance those by Feder et al. (2004a; 2004b), on the other hand, were criticized because of the improper use of the counterfactual. Independent observations found that three out of four control villages in their sample were only one km away from some FFS villages (Braun et al., 2006). Most likely some “contamination” of the control already took place during a time period of eight years between the baseline and impact surveys. Taking into consideration the divergent results and common drawbacks in previous studies, it is pressing to strive for a clearer picture of the impacts of FFS with sounder methodologies. Some significant attempts have recently been taken to address the methodological issues in the field of impact assessment of FFS. By applying a multi-period “difference in difference” (DD) model which is effective to control for the selection bias as shown in chapter 3, Praneetvatakul et. al. (2008) show that the farmers trained in FFS, in both short and medium term, significantly reduced pesticide use and generated positive environmental effects indicated by a much lower EIQ in Thailand. Another study by Pananurak (2009) applied multiple methodologies including cost-benefit analysis and econometric analysis built on DD model and fixed effect model to study the impacts of FFS training in cotton in China, India and Pakistan. Those methodologies complemented one another very well with consistent results, and concurred to conclude that the investment in FFS was likely to pay off in a crop like cotton. As another effort to strive for a better understanding of the impacts of FFS, this chapter carries out an econometric analysis of a large cross sectional data set based on a careful check of the selection bias. The difference between this chapter and the previous two is thus very evident.

This chapter covers more than 90 FFS which were conducted in China in the process of scaling up the FAO-EU IPM Program for Cotton. As noted by many studies, scale-up of a program is not a simple duplication of some work already done, the success of program scale-up depends on some prerequisites and many internal and external factors (Menter et al., 2004; World Bank, 2003). The previous chapters reveal that the direct effects of FFS training on pesticide reduction and yield gains as well as the diffusion impact on pesticide reduction among exposed farmers. In this chapter, the analysis is extended to answer the question whether and to what extent there is a loss of effectiveness in the FFS approach once the program is being scaled up?

5.2 Objective of the Study

The overall objective of this chapter is to make an unbiased and consistent assessment of the impacts of FFS and especially to answer the question whether the impacts of FFS can be maintained during the program scale-up. As presented later in this chapter, Bt cotton as an alternative to chemical pesticides has been widely adopted in China and accounted for 94% of total cotton cultivation in the sample. Therefore, this chapter also serves to explore the performance of FFS before the background of wide adoption of biotechnology.

Since FFS in principle can generate an array of impacts including those in the socio-economic, environmental and health spheres, it is recognized that impact assessment of FFS requires a mixture of approaches and disciplines (Waibel et al., 1999). However, in order to be as rigorous as possible and also apply a certain level of comprehensiveness, this study chooses to concentrate on two primary indicators, namely pesticide costs and yields. Furthermore, since the insecticides account for absolutely most of total pesticide use, and most of the high toxic compounds are insecticides, the focus of this study is further narrowed to insecticide costs.

5.3 Data Collection

This study was carried out in nine counties, namely Lingxian, Linqing and Zhanhua in Shandong Province, Dongzhi, Guichi and Wangjiang in Anhui Province and Yingcheng, Tianmen and Xiantao in Hubei Province, with the first three representing the Huanghe River Cotton Region (HRR) and the latter six representing the Changjiang River Cotton Region (CRR). All those counties have a long history of cotton cultivation and cotton plays a vital role in the local economy. Among those counties, Counties 1, 2, 3, 5, 8 and 9 are among the top 100 cotton producing counties in China, the others also have importance in cotton production in the respective provinces. As a result, they were incorporated into the FAO-EU IPM Program at an early stage and granted overwhelmingly most funds through years. The FAO-EU IPM Program totally sponsored 1,061 FFS in 31 counties, five provinces in China from 2000 to 2004, among which more than 70% were placed in the sample counties.

The data were collected by a season long monitoring in 2005. Since only a few FFS were conducted in the first and last years (2000 & 2004) of the FAO-EU IPM Program, this study focuses on the majority of the FFS opened during the period from 2001 to 2003. The complete lists of FFS and participants were obtained from the three Provincial Plant Protection Stations which were the program implementing units in the respective provinces. The lists of FFS conducted from 2001 to 2003 in the three counties in the same province were pooled together and 27 FFS were randomly selected from every province. After choosing the FFS and hence FFS villages, the control villages where no FFS had ever been conducted were then selected based on the consultancy from the County Agricultural Bureaus and secondary information. The selection of control villages were based on two considerations: first a comparison between the control and FFS villages with respect to cotton production, social and natural environment and infrastructure to achieve similarity and second a distance usually greater than 10 kilometers between the control and nearest FFS village to prevent the diffusion of FFS impacts to the control farmers. In this way, three control villages were chosen in most counties and one more were selected in Counties 1, 4 and 7 respectively because more FFS were sampled in those counties. With full lists of households in every FFS and control village provided by village leaders, five participant and exposed farmer households respectively were randomly selected from every FFS village, with five control farmer households randomly picked up in every control village. Additionally, nine FFS villages and the same number of control villages sampled by the program self evaluation in 2001 (NATESC, 2003a; 2003b; 2003c) and three FFS and two control villages selected by Pemsl (2006) in 2002 for Bt cotton study were also included in this survey. With 16 farmer households dropping out during the survey, the sample finally covered 93 FFS villages, 41 control villages and 1119 farmer households. The sample composition is presented in Table 5-1.

Table 5-1: Sample composition

	County								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
No. of FFS villages (2001)[1/]	5	2	2	6	0	1	6	1	2
No. of FFS villages (2002)	4	4	3	7	2	3	4	5	3
No. of FFS villages (2003)	5	3	5	3	3	5	3	3	3
No. of participants	70	44	50	80	25	45	65	39	40
No. of exposed farmers	70	40	50	79	25	45	65	44	38
No. of control villages	7	5	3	7	3	3	7	3	3
No. of control farmers	35	25	15	35	15	15	35	15	15

Note: [1/] Figures in parenthesis refer to the year when FFS were conducted in the villages.
Source: Own compilation

Excepting some enumerators in Counties 1, 4 and 7 who had conducted the self evaluation surveys organized by the FAO-EU IPM Program in 2001 and 2002, most of the enumerators were enrolled at the end of 2004. Those enumerators mainly consisted of local agricultural technicians. In some counties consultants from universities and research institutes and FFS participants were also involved in the survey. In order to follow a standard social scientific survey procedure, a workshop was held in every province early in 2005 to train the enumerators. The farmers sampled were invited to participate in a meeting at township level to confirm their willingness to join in the study and trained to record their cotton production in a standard form from the procurement of seeds to the sale of outputs. In the whole season the enumerators visited every sampled farmer household once a month to guide and check the recording. The recording sheet and questionnaires were adapted from the program self evaluation surveys which covered 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 (see Appendices 9 and 10). Furthermore, secondary data such as local cotton production, village infrastructure and information on pest occurrence were also collected through focus group meetings or contact with responsible agencies, for instance the national pest monitoring and forecasting system.

5.4 Description of the Study Areas and Farmer Groups

In the following paragraphs, some household and farmer characteristics are presented to illustrate the conditions in the study areas and the status of different farmer groups. Table 5-2 shows that, the farmers on average had been growing cotton for almost two decades and more than 60% of land holdings were allotted to cotton cultivation, indicating the importance of cotton production in the study areas. The average age of farmers involved in cotton production was around 45 and their level of schooling was almost 7 years. The farmer households were typically small holders with around four family members and 0.5 ha land, and the per capita annual revenues were similar in all but one county. County 3 is located in a coastal area and has abundant coastal lands. Farm size in County 3 was comparatively large. Consequently the farm revenues were also higher in that county. There was also significant difference of cotton share. Majority of the farmers in most counties allotted around two thirds or even more of their landholdings to cotton cultivation with the highest percentage of 79.66% in County 3, while the farmers in Counties 1 and 2 had lower shares of cotton in their farming systems.

Table 5-2: Summary statistics of farmer and household (HH) characteristics by county

	County								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
Age of respondents	41.66^{b} (7.52)	44.43^{c} (9.29)	38.78^{a} (7.14)	47.44^{d} (8.49)	46.77^{d} (8.97)	47.90^{d} (7.55)	43.50^{bc} (8.35)	44.45^{c} (7.83)	51.13^{e} (8.78)
Educational level (years in school)	7.10^{bc} (2.08)	7.53^{c} (2.10)	6.32^{a} (2.32)	6.68^{ab} (2.56)	6.88^{ab} (2.34)	6.80^{ab} (2.17)	7.16^{c} (1.97)	6.73^{ab} (2.51)	6.65^{ab} (1.90)
HH size (No. of people)	3.68^{a} (0.89)	3.94^{b} (1.22)	3.56^{a} (0.69)	4.06^{b} (0.92)	3.60^{a} (1.09)	4.42^{c} (1.05)	4.07^{b} (0.91)	4.21^{bc} (0.90)	3.51^{a} (1.20)
HH Laborers (No. of people)	2.26^{a} (0.65)	2.58^{bc} (0.98)	2.36^{ab} (0.73)	2.51^{bc} (0.78)	2.49^{bc} (0.79)	2.92^{d} (0.77)	2.42^{ab} (0.70)	2.83^{de} (0.80)	2.70^{cd} (0.93)
Farm size (ha)	0.48^{a} (0.13)	0.52^{a} (0.16)	2.64^{b} (1.74)	0.43^{a} (0.16)	0.41^{a} (0.19)	0.41^{a} (0.18)	0.54^{a} (0.22)	0.54^{a} (0.30)	0.42^{a} (0.11)
Cotton experience (years of cultivation)	17.66^{ab} (6.40)	18.84^{bc} (7.26)	16.83^{a} (5.69)	19.69^{cd} (5.74)	20.91^{d} (4.65)	17.41^{ab} (4.21)	18.90^{bc} (5.94)	16.54^{a} (6.34)	20.38^{cd} (7.18)
Cotton share (% of total land)	43.86^{a} (15.10)	56.14^{b} (19.65)	79.66^{d} (31.16)	78.15^{d} (23.07)	65.41^{c} (28.17)	64.14^{c} (23.59)	67.03^{c} (19.18)	64.73^{c} (27.04)	61.11^{bc} (13.06)
Annual revenue[1/] (US$ per capita)	496.49^{a} (120.33)	471.92^{a} (155.89)	1774.53^{b} (1111.57)	473.00^{a} (143.60)	424.20^{a} (147.04)	452.10^{a} (108.99)	502.03^{a} (170.13)	489.06^{a} (151.03)	476.75^{a} (107.22)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); [1/] annual revenue included both on farm and off farm income.

Source: Own survey

Table 5-3 presents the comparison of cotton production across counties, which is essentially a complicated picture with appreciable disparity. The various differences can largely be subscribed to two categories, first systematic differences between the cotton regions and second county specific variations. Hybrid cotton varieties were commonly adopted in Counties 4 to 9 in the Changjiang River Cotton Region but seldom used in the Counties 1 to 3 in the Huanghe River Cotton Region. Owing to the very laborious seed producing process and the higher yield potential of hybrid cotton varieties, the price of hybrid cotton seeds is usually eight or even more times higher than that of conventional ones. Although direct sowing in the Huanghe River Cotton Region consumed somewhat five times of seeds per hectare as much as the common practice "sowing seeds in bed and then transplanting" in the Changjiang River Cotton Region, the seed expenditures in Counties 1 to 3 were significantly lower than those in the other counties. Less precipitation in the Huanghe River Cotton Region necessitates regular irrigation. Generally speaking, the expenditures on irrigation in Counties 1 to 3 were significantly higher than those in the other counties. Machinery and mulching expenditures as included in other costs were also significantly higher in

Counties 1 to 3. The lands in Counties 1 to 3 were ploughed by machine; the direct sowing there was usually protected by mulching. In the other six counties, no-till farming in cotton cultivation had increasingly gained popularity and only little mulching film was needed for the seedling bed. The common investment in machines for cotton farmers in those counties was just a pesticide sprayer.

The statistics in Table 5-3 also show that, the cotton farmers in the Changjiang River Cotton Region applied more pesticides than those in the Huanghe River Cotton Region. However, the actual pesticide use depends on the pest prevalence on one hand and farmers' habit of pesticide application on the other hand. According to a discussion with local plant protection staff, the pest severity in Counties 2 and 3 was similar to that in County 1, while the pesticide costs in the former two counties were much higher than those in County 1. The polarization of pesticide use in the same ecological zone, in the opinion of plant protection experts, was a strong signal of irrational use of this input (personal communication with Mr. Liu Hongcun and Mrs. Mu Xiangming in the Plant Protection Stations of Linqing County and Zhanhua County, 2005). In addition to pesticide use, there were more county specific variations. Since about 15% of the seeds used in County 9 were home saved or of second generation (F_2), the seed costs in that county were significantly lower than those in the other counties in the same region. As compared to some previous studies (e.g. Huang et al., 2002a), there had been a universal tendency of labor cut in cotton production. Advancement of technology such as no-till farming and reduced plant density for improved cotton varieties contributed to the save of labor (Zhu, 2007). Meanwhile, since more and more farmers started to find temporary jobs in cities, the increasing opportunity costs for rural labor gave farmers a strong motivation to reduce their work time on farm (NBSC, 2006).

Among all the counties, County 3 was quite different in cotton production. Cotton yields in County 3 were significantly lower than those in the other counties, which in turn resulted in much lower gross margins. Endowed with abundant coastal lands, the farmers in County 3 grew much more cotton than the farmers elsewhere. Owing to the relatively bigger farm size, the demand of cotton cultivation for labor outstripped the household capacity and hence hired labor was popularly used in County 3 with an average cost of 167.34 US$ per hectare. Even so, the labor input in cotton production was only 187 persondays per hectare in the county, a figure much lower than that in the other counties, which implies that the dilution of labor input resulting from larger farm size could be a reason for the lower yields. Along with less labor use, another reason for the significantly lower cotton yields in County 3 could be the poor soil quality. Because County 3 is close to coast, the lands there are less fertile and actually somehow saline and alkaline.

In general, the statistics have shown broad differences of cotton production between the study areas. Therefore, it is important to apply proper control of the locality characteristics in the study, which will be elaborated in more detail in section five.

Table 5-3: Summary statistics of cotton production by county

	County								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
Cotton acreage (ha)	0.21^{a} (0.09)	0.29^{a} (0.14)	2.28^{b} (1.71)	0.33^{a} (0.15)	0.27^{a} (0.19)	0.25^{a} (0.10)	0.36^{a} (0.19)	0.32^{a} (0.19)	0.25^{a} (0.08)
Yield (Kg ha^{-1})	3670.51^{d} (307.38)	3363.08^{b} (334.01)	2848.82^{a} (356.65)	3498.79^{c} (416.92)	3517.05^{c} (546.11)	3418.86^{bc} (449.97)	3524.93^{c} (368.47)	3477.15^{c} (591.71)	3526.63^{c} (317.03)
Gross margin[1/] (US$ ha^{-1})	1997.82^{d} (201.32)	1899.01^{c} (220.75)	1273.88^{a} (238.09)	1886.43^{c} (266.23)	1960.74^{cd} (322.62)	1903.36^{c} (284.38)	1650.59^{b} (253.09)	1710.66^{b} (335.33)	1887.31^{c} (210.56)
Total variable costs (US$ ha^{-1})	519.11^{a} (124.66)	644.22^{bc} (178.52)	839.90^{e} (222.07)	667.69^{c} (105.66)	623.66^{bc} (157.66)	542.37^{a} (117.47)	743.57^{d} (202.47)	618.94^{b} (209.81)	609.89^{b} (161.82)
Pesticide cost (US$ ha^{-1})	28.46^{a} (9.90)	90.57^{b} (35.87)	114.25^{c} (34.55)	88.74^{b} (23.86)	104.85^{c} (33.09)	84.49^{b} (31.22)	127.07^{d} (50.93)	106.74^{c} (54.51)	112.42^{c} (24.99)
Seed cost (US$ ha^{-1})	48.95^{a} (18.87)	46.47^{a} (20.51)	66.80^{b} (22.35)	90.92^{d} (9.39)	87.51^{d} (20.86)	92.73^{de} (14.20)	97.22^{e} (30.84)	93.19^{de} (18.45)	76.96^{c} (19.58)
Fertilizer cost (US$ ha^{-1})	297.53^{a} (102.62)	399.54^{de} (149.34)	354.55^{bc} (147.06)	466.17^{f} (93.32)	395.87^{de} (124.24)	329.82^{ab} (82.42)	431.32^{e} (136.11)	368.57^{cd} (145.03)	399.56^{de} (145.07)
Irrigation cost (US$ ha^{-1})	52.96^{e} (23.51)	32.56^{d} (17.29)	30.13^{d} (18.48)	5.59^{a} (14.01)	12.69^{b} (16.24)	6.51^{a} (8.71)	23.84^{c} (17.32)	7.54^{a} (15.49)	5.44^{a} (10.54)
Hired labor cost[2/] (US$ ha^{-1})	12.87^{ab} (36.21)	4.76^{a} (29.54)	167.34^{d} (132.11)	3.22^{a} (30.94)	5.28^{a} (24.35)	16.20^{ab} (47.91)	44.91^{c} (79.14)	28.37^{b} (69.72)	1.10^{a} (10.65)
Other costs[3/] (US$ ha^{-1})	78.34^{d} (27.69)	70.32^{c} (28.69)	106.83^{e} (37.76)	13.05^{a} (3.32)	17.46^{ab} (13.85)	12.62^{a} (2.95)	19.21^{b} (14.24)	14.53^{ab} (5.80)	14.41^{ab} (7.86)
Labor input (personday ha^{-1})	331.23^{bc} (69.95)	391.75^{d} (93.15)	187.12^{a} (31.95)	385.96^{d} (51.50)	389.39^{d} (58.29)	328.95^{b} (49.30)	346.12^{c} (58.79)	321.00^{b} (46.45)	324.88^{b} (22.39)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); [1/] the cost of family labor was not included in computation; [2/] the wage for hired labor was RMB 25 Yuan per personday in 2005 in China; [3/] other costs included the costs of machinery and mulching film.

Source: Own survey

Since the purpose of the study is to assess the impacts of FFS over a larger scale by the comparison of the performance of the participants, exposed farmers and control farmers, it is meaningful to have a look at the situation of different farmer groups. According to the statistics in Table 5-4, most indicators including the age of the respondents, educational level, farm size, cotton experience and annual revenue were similar across the three farmer groups. Although there were some indications in favor of the participants such as better education, longer experience and higher annual revenue, those differences were not statistically significant. For the other indicators, significant differences existed between the participants and the other farmers. Since the importance of cotton production in the local economy was a major criterion for program placement, the cotton shares of the farmers in the FFS villages were generally higher than those in the control villages, and significant difference on this aspect was identified between the participants and control farmers. The participants had statistically bigger household sizes and more family laborers as compared to the exposed farmers with control farmers lying in-between, which implies that the affordability of laborers to take the training could be a major determinant for farmers' decision to join in the program. The relationship between farmer and household characteristics and program participation will be treated in more detail with probit models later in this chapter.

Table 5-4: Summary statistics of farmer and household (HH) characteristics by farmer group

	Farmer groups		
	Participants	Exposed farmers	Control farmers
Age of respondents	44.90 (8.91)	44.48 (8.92)	45.41 (8.39)
Educational level (years in school)	7.02 (2.17)	6.75 (2.07)	6.89 (2.74)
HH size (No. of people)	4.02[b] (1.05)	3.85[a] (0.97)	3.82[a] (1.00)
HH laborers (No. of people)	2.64[b] (0.88)	2.41[a] (0.72)	2.53[ab] (0.76)
Farm size (ha)	0.71 (0.88)	0.70 (0.97)	0.65 (0.65)
Cotton experience (years of cultivation)	18.87 (6.46)	18.21 (5.99)	18.41 (5.84)
Cotton share (% of total land)	65.87[b] (25.55)	64.47[ab] (26.32)	61.57[a] (19.95)
Annual revenue[1/] (US$ per capita)	619.96 (553.62)	615.48 (604.67)	583.92 (369.12)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); [1/] annual revenue included both on farm and off farm income.

Source: Own survey

5.5 Methodology

5.5.1 Theoretical Background

Although the central interest of this study is to assess the impacts of FFS training with econometric analysis, the confidence of such assessment depends on the trust in the estimation of the effect of other variables in the modeling. A challenge in this regard lies with the treatment of pesticides in the yield function. Early studies treated pesticides as conventional inputs, just like land and labor. The marginal products of pesticides derived from those studies were usually far greater than the factor price and hence a significant underuse was often concluded (e.g. Headly, 1968; Campbell, 1976), which constituted a blunt contrast to the growing evidence of pesticide overuse in many countries, especially in the developing world (Carrasco-Tauber et al., 1992). The reason for those puzzling findings was first systematically explored by Lichtenberg and Zilberman (1986) when they highlighted the concept of damage control. They showed that the pesticides are damage abating factors and hence do not increase potential output. Instead, the contribution of pesticides to output lies in the abatement of the damage inflicted by various pests to potential yields, and the inclusion of pesticides in a standard production function leads to an overestimation of their marginal productivity but underestimation of the marginal productivity of the other factors.

According to the study by Lichtenberg and Zilberman (1986), the actual yields are the combination of potential output and damage abated. With Y denoting the outputs, Z the vector of standard inputs and X the vector of damage abating factors, a basic functional form following the concept of damage control is usually specified as:

$$Y = F(Z)G(X) \qquad (1)$$

In equation (1), F(Z) measures the potential yields given the levels of direct inputs Z, while G(X) indicates the proportion of the damage eliminated by the application of a level of damage control agents X. The damage control function G(X) possesses the properties of a cumulative probability distribution, monotonously increases in X and is generally defined on the interval of [0, 1]. When G(X) takes on the value of 1, the destructive capacity of damaging agents is completely eliminated and the output attains its maximum. In the other extreme, G(X) = 0 denotes zero elimination of the damage and the output falls to the level consistent with maximum destructive capacity. Different functional forms of cumulative probability distribution have been used for the damage control function, among which Exponential and Weibull are popularly used because of their abilities to capture the biological response of damage to pesticide applications (Shankar et al., 2005):

$$Exponential: \quad G(X) = 1 - \exp(-mX) \qquad (2)$$

$$Weibull: \quad G(X) = 1 - \exp(-X^c) \qquad (3)$$

With different specifications of the damage control functions, the estimates of the coefficients in one function can differ from those in another (Carrasco-Tauber et al., 1992), and hence there has been debate on suitable function forms and such an issue has not been definitely resolved (Pemsl, 2006). However, the general concept of damage control is now widely accepted as a standard procedure in agricultural production economics (ibid). Therefore, it is also used as a basic framework in this chapter.

5.5.2 Model Specification

The previous subsection presents some theoretical background for the damage control function. This subsection proceeds to construct the models with the empirical application of the damage control concept. To assess the impact of FFS on yields, dummy variables for program participation and exposure need to be added to the production function. With D_G indicating participation and D_N indicating exposure, function (1) can be expanded as:

$$Y = F(D_G, D_N, Z)G(X) \tag{4}$$

Given the fact that the FFS were conducted in the period from 2001 to 2003, four interaction terms between program intervention and the conduction years of respective FFS are added to the yield function. With year2 and year3 indicating that FFS were conducted in 2002 or 2003 respectively, equation (4) turns out to be:

$$Y = F(D_G, D_G * year2, D_G * year3, D_N, D_N * year2, D_N * year3, Z)G(X) \tag{5}$$

Different damage control functions (2) and (3) are then substituted into equation (5) as G(X) to test their applicability in this case and to allow for a comparison of different specifications. Since the insect pests constitute the major source of pest damage in cotton production, insecticides and the alternative option to control insect pests, namely Bt trait, are incorporated as damage abating factors. With those modifications, equation (5) turns out to be:

$$Y = F(D_G, D_G * year2, D_G * year3, D_N, D_N * year2, D_N * year3, Z)[1 - \exp(-m_1 pesticide - m_2 Bt)] \tag{6}$$

$$Y = F(D_G, D_G * year2, D_G * year3, D_N, D_N * year2, D_N * year3, Z)[1 - \exp(-Pesticide^{c_1} - Bt^{c_2})] \tag{7}$$

Since FFS training may affect cotton production through direct improvement of cultivation practices and indirect enhancement of the damage abating efficiency, equation (6) is further modified with an interaction term between FFS participation and insecticide use[23]. To facilitate the estimation, the interaction terms between program intervention and conduction years of FFS are left out in this equation:

$$Y = F(D_G, D_N, Z)[1 - \exp(-m_1 pesticide - m_2 Bt - m_3 pesticide * D_G)] \quad (8)$$

As for the assessment of the impact of FFS training on insecticide use, the construction of the functions is relatively straightforward. The cost of insecticides in cotton production denoted by P can be expressed as:

$$P = F(D_G, D_G * year2, D_G * year3, D_N, D_N * year2, D_N * year3, Z, Bt, K) \quad (9)$$

where K represents a vector of other determining factors of insecticide use, such as the pest pressure, insecticide price and farm size, all the other denotations have the same meaning as in the yield functions. To explain the insecticide use, both a linear and a Cobb-Douglas type functions were estimated and the results from those specifications were compared with the results of some previous studies (e.g. Pemsl, 2006; Huang et al., 2001).

5.5.3 Description of the Variables Used in Econometric Models

In the previous subsection, the models used to estimate the impacts of FFS training and Bt cotton on yields and insecticide use are outlined. In this subsection, a brief description and relevant hypothesis of the variables used in the models are presented.

In the yield function, the dependent variable is the seed cotton yield in kg that was harvested per hectare. Since the knowledge gained by the farmers directly or indirectly from FFS training might help improve farmer's practice in cotton cultivation, it is expected that the participation in or exposure to FFS indicated by dummy variables D_G and D_N in the yield functions might contribute to higher yields.

It is difficult to hypothesize the estimates of the interaction terms between the participation and exposure dummies and the conduction years of FFS, namely D_G*year2, D_G*year3, D_N*year2 and D_N*year3, apriori. In the period when the FFS included in this study were conducted, the FAO-EU IPM Program for cotton was scaled

23 As presented later, the coefficient to Bt variable is not significant and hence no interaction term between FFS participation and Bt was included in the empirical model.

up from 120 FFS in 2001 to more than 400 FFS in 2003 in China. The scaling-up might incur a decrease of the quality of program implementation and hence lead to a diminution of the training effect in later years. On the other hand, the impacts of FFS training might diminish to some extent over time, and hence the impacts on the farmers who were trained in or exposed to FFS in later years might be stronger than those on the farmers directly or indirectly involved in the training in earlier years.

Addressing the broad difference between the study areas demonstrated in section four, township dummies were introduced to control for locality specific characteristics. Excepting that three control villages were sampled from two FFS townships in County 6 where FFS had been delivered to all the major cotton producing townships when the survey was conducted in 2005, all the other townships only had either FFS or control villages. As a result, the township dummies are expected to properly control for the locality-specific differences between FFS and control villages. If the soil quality, infrastructure or other factors which might have an effect on the performance indicators in some townships were better than those in the other townships, such effect can be well absorbed by the township dummies.

Insecticide was measured in US$ per hectare while Bt was defined as the proportion of the area sown to Bt varieties to the total cotton area in an individual household, both of which are expected to contribute to higher yields with the abatement of losses inflicted by insect pests. Various inputs, including irrigation, fertilizer, seed, herbicide and labor are also expected to increase cotton yields, among which the former four were measured in US$ per hectare, while labor was defined as the number of persondays that were used to produce cotton on unit hectare of land[24]. The other inputs, machinery and mulching film, were included in the variable other costs[25] defined in US$ per hectare and are also expected to contribute to some increase in cotton yields.

24 In table 5-3, the hired labor was converted into unit cost per hectare to calculate the gross margin of cotton production, but it was measured by personday and included in econometric modeling in the same way as family labor.

25 Since data on machinery and mulching were not collected in the retrospective survey for the cotton season in 2000 and the monitoring survey for the cotton season in 2002, the variable “other costs” was not used in the DD modeling analysis in chapters 3 and 4.

Experience[26] was defined as a dummy variable taking the value of 1 if the respondent has been cultivating cotton for over 18 years (the average of the whole sample) and 0 otherwise. It is assumed that the cotton farmers may become more efficient through trial and error in field practices, and hence the longer involvement in cotton production might lead to some improvement of the performance. Education[27] was defined as the years an individual respondent spent in school for formal education. Stronger educational background may result in better ability to make informed decision in cotton production and hence lead to higher yields. Cotton share is the proportion of the land sown to cotton to total land cultivated by a household. Ability to recognize pests and beneficial organisms is a proxy of pest control knowledge and measured by the number of pest and natural enemy species recognized by individual respondents. It is expected that, with better knowledge on pest control, the farmers may apply pest control measures more timely and properly and hence achieve higher yields.

The common variables in the insecticide function were defined in the same way as in the yield functions. The participation in and exposure to FFS are expected to lead to some reduction of insecticide use because of the knowledge on pest control received directly or indirectly by the farmers from FFS training. The interaction terms D_G*year2, D_G*year3, D_N*year2 and D_N*year3 are explained in the same way as in the yield functions. Bt trait was designed as a substitute for insecticides against major insect pests in cotton and hence might contribute to some reduction of insecticide use. Herbicide was used to get rid of weeds which might harbor both harmful and beneficial insects and hence affect pesticide use. As for fertilizer, it has been shown that the intensive use of fertilizer especially nitrogen fertilizer might trigger more severe pest problems and hence increase pesticide use (Hill, 1989). As the proxies of knowledge or ability to better implement pest control measures, it is expected that stronger education, longer experience and better ability to recognize pests and beneficial organisms could lead to less pesticide use.

Another three variables were included in the insecticide functions, namely the insecticide price, farm size and pest pressure. Insecticide price was defined as the

26 Since the experience changed by the same value for all the respondents in the period of the panel survey, no difference of experience existed between farmer groups after first differencing, and hence that variable was not used in the panel study in chapters 3 and 4.

27 The education level usually remains unchanged for cotton farmers in China after they graduated from schools, and hence it was also excluded from the panel study using DD models.

weighted average price of all the insecticides sprayed in cotton in individual farmer households and measured by US$ per kg. Theoretically, higher insecticide price means better quality of the insecticide products and could hence reduce insecticide use. However, if the market system does not function well in the study areas, which is usually the case in developing countries, the relationship between the price and quality might be twisted and higher price could incur higher insecticide costs. Farm size measured in hectare is the total area of land cultivated by a farmer household in the survey year. Larger farm size might dilute farming intensity and hence lead to less input use on unit area. Pest pressure was defined as a dummy variable indicating farmers' perception of the severity of pest problems in their cotton fields (1 indicating higher than usual and 0 otherwise). If a farmer perceives the pest problem more serious than usual, he/she might respond with more sprays.

5.5.4 Model Testing

After the introduction of D_G and D_N, the functions used in this study fall to the broad category of treatment effects (Winship et al., 1992) and hence demand careful control of selection bias because the treatment is usually not randomly assigned between different respondent groups (Angrist, 2006). For those equations to yield unbiased and consistent estimates with OLS, D_G and D_N should be exogenous or in other words should not be correlated with the error term. If some important variables which are correlated with both the dependent variables Y and P and independent variables D_G, D_N are omitted, the orthogonality assumption is violated and the OLS estimates with equations constructed in subsection 5.5.2 are biased and generally inconsistent (Wooldridge, 2003).

In the case of FFS, such bias could be introduced at two levels, the nonrandom assignment of the FFS training to villages and farmers. The decision by program organizer to place FFS in some villages but not the others is usually made according to some criteria such as perceived convenience in program management, importance of target crop production in villages and village infrastructure. This selection is determined by village characteristics and might render the control villages in the sample an improper counterfactual to the FFS ones. After the FFS villages have been chosen, farmer self selection or in some cases nonrandom selection of farmers by facilitators and village leaders come into play[28]. This process is based on farmer and household characteristics and might lead to systematic differences between the FFS participants and exposed farmers. If those differences also affect the performance indicators and the selectivity is not properly controlled, their effects would be at least partially attributed to the program intervention, and hence lead to overestimation or underestimation of the program impacts.

A practical solution to this problem is to follow the concept of “ignorability of treatment” or “selection on observables” and include more relevant village, household and farmer characteristics in the regression (Heckman et al., 1985; Rosenbaum et al., 1983). For this purpose and as described in subsection 5.5.3, farmer and household characteristics such as educational level, cotton experience, cotton share and the “ability to recognize pests and beneficial organisms” were added to the independent variable list. At the same time, township dummies were introduced to control for the locality-specific characteristics between different townships, especially between the FFS and non-FFS townships. Even with all those controlling measures, the Heckman procedure (Heckman, 1976; 1979) was performed to check whether the inclusion of controlling variables was adequate to solve the problem of selection bias. Given the two possible sources of biases, a test was first conducted between the farmers in FFS villages and those in the control villages, and then a second test was carried out between the participants and exposed farmers within the FFS villages.

For simplicity, the pure Cobb-Douglas specifications for both insecticide and yield functions were used for the tests. Two probit models were estimated first to compute the inverse Mills ratios (IMR). The first probit model was designed to test the difference between the FFS and control villages. In that model, a binary dependent variable was used to indicate whether an individual farmer was from an FFS or a control village, with value 1 assigned to the farmers in the FFS villages while 0 assigned to those in the control villages. Three village characteristics, namely distance from the village to county capital, with or without a primary school and with or without an input kiosk, were used as explanatory variables which might influence the placement of the program and

28 In the context of FAO-EU IPM Program in China, all the farmers joined in the program on their own initiative. In some cases when the farmer applicants in some villages were beyond the capacity of the FFS, the FFS facilitators and village leaders selected the participants from the applicant lists. Under this circumstance, farmer and household characteristics such as gender, literacy, wealth and cotton share were taken into consideration.

hence affect the opportunity for the farmers to get involved in the FFS training. Since cotton experience, farm size and cotton share to some extent reflect village features and might have affected the program placement, those three variables were also included in the regression. The second probit model was designed to test the difference between the FFS participants and exposed farmers, with the value 1 assigned to the participants while 0 to their non-trained neighbors. Since the participants and exposed farmers lived in the same villages, common factors at village level did not affect the selection of farmers into training. Therefore, the three variables indicating village characteristics used in the first probit model were left out. Meanwhile, more farmer and household characteristics including age, gender, education, household size and the number of household laborers were added, since they might have some influence on self selection or selection of farmers into the training program.

The results of the probit models are reported in Table 5-5. If a village was farther away from the county capital, it had less chance to be incorporated into the program. Since most facilitators were from county technical extension services, distance and transportation were really the matters of importance. With the aim to enhance local cotton production, it is also reasonable to find that the villages with higher cotton shares were more likely to receive the program. As for farmer selection, affordability of time appears to be a major factor, and the members from the households with more laborers were more likely involved in the training. Attendances at the season long FFS training are time consuming and farmers are found to carefully weigh the benefits and costs of participating in the field school (Fleischer et al., 2002; Praneetvatakul et al., 2001). The results also reveal that, the farmers with higher education and longer cotton growing experience were more motivated to join in the training.

Table 5-5: Estimated coefficients for probit models (1st stage of Heckman procedure)

Variable	**Between FFS and control villages**		**Within FFS villages**	
	Coefficient	Standard error	Coefficient	Standard error
Distance	-0.0276***	0.0061		
School	-0.0362	0.1374		
Kiosk	0.1338	0.1314		
Age			-0.0082	0.0069
Gender			-0.0412	0.1094
Education			0.0350*	0.0201
HH size			0.0162	0.0522
No. HH laborers			0.2143***	0.0669
Cotton experience	0.0012	0.0073	0.0170*	0.0092
Farm size	0.0432	0.0556	-0.0021	0.0482
Cotton share	0.3169*	0.1875	0.0711	0.1706
LR chi^2	29.42***		25.18***	

Note: ***, **, * denoted significance at 1%, 5% and 10% respectively; the estimated coefficients for 53 township dummies and intercepts were not reported for brevity.
Source: Own survey

The inverse Mills ratios computed from the first stage probit models were then included as additional variables in appropriate regressions of insecticide costs and yields separately by farmer group. According to the results reported in Table 5-6, none of the coefficients to any IMR is significant, which shows that the selectivity bias was not a critical issue after the farmer, household characteristics and township dummies were introduced to control for the selectivity. Therefore the rest of the analysis can proceed by treating FFS participation and exposure as exogenous.

Table 5-6: Estimated coefficients for insecticide and yield functions (2nd stage of Heckman procedure)

Variable	**Between FFS and Control Villages**				**Within FFS Villages**			
	Insecticide costs		Yields		Insecticide costs		Yields	
	FFS	Control	FFS	Control	Participant	Exposed	Participant	Exposed
IMR	-1.9915 (1.9833)	-0.3075 (0.2671)	0.0627 (0.1517)	0.0178 (0.0829)	-0.0629 (0.1204)	0.1762 (0.1394)	-0.0330 (0.0325)	0.0254 (0.0403)

Source: Own survey

Another long standing problem with the direct estimation of the production function is the questionable treatment of the inputs as exogenous (Shankar et al., 2005). Although the inputs should ideally be applied in response to field needs, the widely reported misuse and overuse of some inputs substantively indicate that in many circumstances the application of inputs is endogenously decided by farmers. For the same reason as illustrated in the foregoing paragraphs, endogenous input uses will render the OLS estimators of Equations (6), (7) and (8) biased and inconsistent. Theoretically, the endogeneity might occur to all inputs, but pesticide use is more liable to this problem because of the sequential and usually numerous applications in one crop season (ibdi). In the case of cotton production in China, insecticides account for most of pesticide use and farmers spray insecticides up to 10 more times in one season. As a result, many previous studies treated insecticide use as endogenous and two stage or three stage least squares (2SLS, 3SLS) estimators were applied to correct for the endogeneity bias (e.g. Pemsl, 2006; Huang et al., 2002a, 2002b). Those instrumental estimators can yield unbiased and consistent estimates when there is a significant endogeneity problem. However on the other hand, those approaches are not so efficient as ordinary least square estimator if endogeneity is not a critical issue (Wooldridge, 2003). It is advisable to perform an endogeneity test and then choose a proper econometric estimator.

Hausman test was conducted to check the possible endogeneity of insecticide use (Hausman, 1978). The insecticide costs were regressed on all the dependent variables except insecticide itself in the production function, and three more instrumental variables, namely insecticide price, farm size and farmers' perception of the severity of pest problems in their fields termed as pest pressure. It is assumed that those variables are among the determinants of insecticide use but do not have direct impact on yields[29]. In fact, they are commonly used in productivity estimation in cotton (e.g. Huang et al., 2002a; 2002b). The residuals from the insecticide regression were then included as an additional explanatory variable to the production function. The t test of the coefficient to the "residuals" variable reveals whether endogeneity was likely to exist. The Hausman test presents a coefficient of -0.0995 (standard error = 0.0489) to the "residuals" variable, which is significant at 5% level. And hence, the instrumental estimation was called for and this study will proceed with the two stage least squares (2SLS) to treat insecticide use as endogenous.

29 Insecticide price and farm size can only indirectly influence yields through their direct effect on the input levels. The pest pressure used in this study is the farmers' subjective estimation of pest infestation in the field. The same level of infestation could be estimated as either high or low by different farmers and farmers responded accordingly with different pest control measures. Therefore it is assumed that the effect of so called pest pressure on yields is indirect.

Collinearity and heteroscedasticity were also checked for a reliable and efficient estimation (Pindyck et al., 1998). Separate estimation of the correlation between any pair of the explanatory variables in insecticide and yield functions was performed. If the correlation coefficient in absolute value between any pair of explanatory variables is greater than 0.9, the strong linear relationship could cause bias to the estimates (Hill et al., 2001). According to the results, the highest correlation in absolute value is 0.68 between labor and farm size. Therefore, collinearity was probably at an acceptable level in this study. Heteroscedasticity was tested with the White (1980) and Breusch-Pagan (1979) tests. Both the insecticide and yield functions suffered from heteroscedasticity according to the White test while the Breusch-Pagan test reports no such problem (see Appendices 6 and 7). Since heteroscedasticity leads to inefficient parameter estimates and causes bias to the estimated variance of the estimated parameters, the non-linear Generalized Method of Moments (GMM) procedure (Greene, 2003) was applied for correction for assurance.

5.6 Empirical Results

5.6.1 Descriptive Analysis

Descriptive analysis was first conducted to identify significant differences of major performance indicators between different farmer groups. Table 5-7 reports the results of the descriptive analysis of cotton production and some relevant indicators. Most entries on the input side were similar across farmer groups except the seed, pesticide and hired labor costs. Exposed farmers used more home saved seeds and hence spent significantly less on this input as compared to the FFS participants and control farmers. As the approach employed primarily to transfer IPM knowledge, FFS training seems to have a strong impact on pesticide use. FFS participants spent around 30% less on pesticides than the control farmers with the exposed farmers lying in-between. The smaller while statistically significant gap between the exposed and control groups implies some diffusion effect on this regard. A closer look at different categories of pesticides readily identified insecticide as the source of the significant difference of pesticide costs. The fungicides, herbicides and other pesticides including plant hormones and molluscicides, however, only accounted for a minor part of total pesticide use and remained similar for all the farmers. The participants and exposed farmers used significantly more hired labor as compared to the control farmers. The comparisons of the ability to recognize pests and beneficial organisms and pest pressure provide some explanation for the difference in pesticide use. The participants were able to identify substantially more harmful and beneficial organisms than the exposed and control farmers. At the same time the pest pressure estimated by the participants was significantly lower than those by the other farmers, which indicates that the FFS participants took advantage of their pest control knowledge and had more confidence in dealing with pest problems. There was some trace of diffusion impact on pest knowledge but the estimation of pest pressure was almost the same for the exposed and control farmers. On the output side, there was also a significant difference between the FFS participants and the other farmers. The participants harvested significantly more cotton on unit area and hence enjoyed markedly higher gross margins in contrast to the other farmers. No significant difference was detected between the exposed and control farmers on this regard, although the yields and gross margins were both slightly higher for the exposed farmers. One more thing of relevance is the very high adoption rate of Bt cotton varieties for all the farmers. Among the three provinces, Shandong had 100% adopted Bt cotton for years, although there were still some farmers in the other two provinces retaining conventional cotton varieties. The overall adoption rate of Bt cotton in the study areas was as high as 94% and similar across the farmer groups. However, as shown by some previous studies (e.g. Pemsl et al., 2005, 2007a; Pemsl, 2006), there was the problem with adulteration of Bt seeds. Therefore, this figure might be higher than the true adoption rate of real Bt varieties and the Bt adoption rate could indeed have different meanings than a trustable measurement of the application of the biotechnology.

Table 5-7: Summary statistics of cotton production by farmer group

	Farmer groups		
	Participants	Exposed farmers	Control farmers
Cotton acreage (ha)	0.52 (0.91)	0.49 (0.84)	0.43 (0.55)
Cotton Yield (kg ha^{-1})	3556.89[b] (471.86)	3384.79[a] (445.08)	3320.56[a] (401.94)
Gross margin (US$ ha^{-1})[1/]	1894.20[b] (323.88)	1741.24[a] (332.84)	1708.96[a] (283.78)
Pesticide cost (US$ ha^{-1}), incl.	78.85[a] (37.93)	96.56[b] (48.58)	110.41[c] (49.75)
Insecticide cost (US$ ha^{-1})	67.40[a] (34.92)	85.76[b] (45.61)	99.13[c] (47.71)
Fungicide cost (US$ ha^{-1})	3.09 (3.93)	2.82 (3.78)	2.97 (3.82)
Herbicide cost (US$ ha^{-1})	5.81 (3.42)	5.49 (3.38)	5.76 (3.33)
Cost of other pesticides (US$ ha^{-1})	2.55 (3.33)	2.49 (3.49)	2.55 (3.52)
Seed cost (US$ ha^{-1})	80.71[b] (26.90)	73.91[a] (28.12)	78.25[b] (28.72)
Fertilizer cost (US$ ha^{-1})	381.51 (137.73)	389.88 (133.12)	385.97 (136.88)
Irrigation cost (US$ ha^{-1})	22.68 (25.15)	20.58 (22.24)	20.88 (23.67)
Hired labor cost (US$ ha^{-1})[2/]	32.68[b] (79.32)	34.74[b] (84.04)	20.33[a] (61.19)
Other costs (US$ ha^{-1})[3/]	38.95 (40.74)	39.92 (39.13)	41.67 (38.71)
Labor input (personday ha^{-1})	332.26 (84.34)	338.31 (80.78)	337.82 (73.34)
No. of pests and beneficial organisms recognized	12.26[c] (2.76)	9.25[b] (2.50)	8.19[a] (2.44)
Pest pressure (% of farmers perceiving pest problems more severe than usual)	28.82[a] (45.34)	36.84[b] (48.29)	38.05[b] (48.67)
Bt adoption (% of total cotton area)	94.60 (18.06)	92.95 (20.87)	93.95 (19.50)

Note: Standard deviations reported in parentheses; superscript letters denoted the results of Duncan's test (0.05); [1/] cost of family labor was not included for computation; [2/] the wage for hired labor was RMB 25 Yuan per personday in 2005 in China; [3/] other costs included the costs of machinery and mulching film.

Source: Own survey

5.6.2 Multivariate Analysis

Table 5-8 reports the OLS estimates of the insecticide functions. Most coefficients show the expected signs and the similar outcomes from the linear and Cobb-Douglas functions indicate that the results are robust. Weeds harbor both harmful and beneficial insects and hence weeding might have a positive or negative impact on insect pest control depending on the field conditions (Tindall, 2004; Altieri et al., 1980). The barely non-significant coefficient to herbicide implies that the clearance of the weeds in the fields contributed to less insecticide use. More fertilizer application triggered more insecticide use, which is in line with natural scientific studies that uncover the relationship between timing of fertilizer applications and fertilizer composition to pest incidence (Jahn, 2005; Zhu et al., 2004). The more labor intensive production was also accompanied by more insecticide use, a finding consistent with some previous studies and might be due to a higher general production intensity or a lower economic threshold resulting from higher potential yields in more labor intensive plots (Pemsl, 2005). More experienced farmers applied less insecticides. Pest control knowledge, proxied by the variable “ability to recognize pests and beneficial organisms”, too, significantly reduced the insecticide use. The negative sign to the “Bt” variable suggests that the Bt trait was a contributory factor to insecticide reduction but the non-significance of the coefficient indicates that such a role was much limited in this case.

As for the three instrument variables, increasing farm size resulted in significantly decreasing insecticide use, which means that the input intensity was diluted when farmers needed to take care of more lands. If the farmers perceived the pest problem in their fields more severe they would respond with more insecticide applications. The insecticide price bears a significant positive sign, which implies that those farmers who chose to use more expansive and presumably higher quality insecticides actually spent more on insect pest control. The highly significant coefficients of those variables demonstrate that they are appropriate instruments subject to the assumption that they do not have direct effect on yields. As pinpointed by Wooldridge (2003), an important precondition for an instrumental estimator like two stage least squares to effectively solve the problem of endogeneity is that, the instrument variables need to or at least one instrument variable needs to be significant in the first stage estimation.

As regards the direct impact of FFS training on insecticide use, both specifications show considerable reduction of insecticide use. As compared to the control farmers, the participants saved insecticide costs by up to 26.3% according to the linear model and 36.5% according to the Cobb-Douglas specification[30]. Neither of the interaction terms between the participation and the conduction years of FFS is significant. It means that, on one hand the impact of the FFS conducted in earlier years was sustained with the passage of time and on the other hand the scale-up of the program in the later years did not compromise the quality of the training. For the indirect impact, the significant negative coefficients to the "exposure" dummy in both specifications demonstrate that the exposure to FFS did help the exposed farmers reduce insecticide costs. However, there was some inconsistency with the estimates of the interaction terms on this respect. Neither of the interaction terms in the Cobb-Douglas specification is significant, but the interaction term between the exposure and the year 2003 has a barely significant coefficient with negative sign in the linear specification, which indicates that the more recently the farmers were exposed to FFS the stronger the exposure impact could be and once again casts some doubt on the sustainability of the exposure impact on insecticide use.

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30 For the Linear model the percentage contribution was computed by dividing the coefficient of participation with the average insecticide cost. For the Cobb-Douglas specification, usually the contribution of a dummy explanatory variable to the percentage change of dependent variable is calculated with 100*[exp(c)-1] in which c is the estimated coefficient to the dummy. Kennedy (1981) pointed out that the precedent formula results in a biased estimator since c is not identical to the true coefficient. Kennedy proposed another formula 100*[exp(c-V(c)/2)-1] where V(c) is the OLS estimate variance of c. This formula was later verified as approximate unbiased by van Garderen et al. (2002) and hence used in this study for relevant computation.

Table 5-8: Estimated coefficients for insecticide functions with different model specifications

Variable	Linear	Cobb-Douglas
Exposure	-10.003 (5.7101)*	-0.2270 (0.0627)***
Exposure * 2002	-5.6190 (4.2378)	-0.0390 (0.0460)
Exposure * 2003	-7.9544 (4.7544)*	-0.0213 (0.0498)
Participation	-26.1321 (5.6012)***	-0.4186 (0.0707)***
Participation * 2002	-2.0796 (3.6582)	-0.0208 (0.0492)
Participation * 2003	0.0980 (4.0705)	0.0528 (0.0538)
Herbicide	-0.3800 (0.2565)	-0.0200 (0.0133)
Fertilizer	0.0678 (0.0086)***	0.2513 (0.0345)***
Labor	0.1339 (0.0197)***	0.6381 (0.0762)***
Experience	-6.5576 (1.7486)***	-0.0765 (0.0204)***
Education	-0.4504 (0.3479)	-0.0331 (0.0224)
Ability to recognize pests and beneficial organisms	-1.1179 (0.4355)**	-0.0983 (0.0492)**
Bt	-7.9260 (5.8779)	-0.0610 (0.0700)
Insecticide price	1.5110 (0.5901)**	0.1502 (0.0425)***
Farm size	-4.4408 (1.7602)**	-0.0903 (0.0298)***
Pest pressure	12.6854 (1.8117)***	0.1417 (0.0198)***
R^2 / adj. R^2	0.6867/0.6661	0.8227/0.8110

Note: ***, **, * denoted significance at 1%, 5% and 10% respectively; the estimated coefficients for 53 township dummies and intercepts were not reported for brevity.
Source: Own survey

The results of the simultaneous estimation of the insecticide and yield functions using two stage least squares (2SLS) are summarized in Table 5-9. The Cobb-Douglas specification of the pesticide function was chosen here because it returned a better goodness of fit. In order to capture the difference of treating insecticide as a standard input and damage abating factor, a pure Cobb-Douglas production function was first estimated and then the functions (6), (7) and (8) following the damage control concept with exponential and Weibull distributions were integrated. Excepting the increased significance of herbicide, the outputs of the first stage insecticide function are basically the same as those from the preceding OLS estimation, which further underscores the robustness of the results.

The different yield function specifications generated highly consistent estimates for most variables. Fertilizer as the major component of material inputs has a highly significant parameter but the small magnitude implies that the elasticity and marginal contribution of this input to cotton production was very low. Labor also contributed significantly to higher yields, which departs from the findings by some previous studies reporting no significant contribution of labor to cotton yields (e.g. Huang et al., 2002b). As mentioned earlier, the labor input has generally declined in crop production in China in recent years, the reduced input level is likely to help achieve the increased significance. However, an average of 330 person days per hectare was still very high and rendered the elasticity of labor very low. Herbicide reduced the competition of weeds for light, water and nutrients and hence contributed to a significant yield increase (Zimdahl, 2004). Seed has a significant positive coefficient in most of the specifications, which suggests that in addition to the engineered Bt gene, cotton varieties had other yield increasing traits such as hybrid vigor. This finding is consistent with the public opinion that F1 hybrid seeds have a higher yield potential while home saved seeds are inferior in productivity (Zhou, 2006). Farmers with higher cotton shares might be more specialized in cotton cultivation and therefore realized higher yields. Education was another significant contributory factor. Better educated farmer might be more capable to catch and understand new technology and hence have a better performance in the fields. Irrigation bears a positive sign, suggesting it also contributed somewhat to higher yields. However, since irrigation is indispensable for cotton production in Shandong province but rarely used in the other two, the coefficient is highly insignificant.

The important findings here are the unanimous affirmation of the direct FFS impact on cotton yields. Other factors being equal, FFS training contributed to yield gains ranging from 5.7% with pure Cobb-Douglas to 6.9% with equation (6). None of the interaction terms between the participation and conduction years of FFS is significant and hence there was sustainability of such impact with the passage of time and maintenance of the effect during the program scale-up. For the exposed farmers, unlike in the insecticide functions, no significant impact on yields was identified with any specification. According to the results from equation (8), the interaction term between FFS participation and insecticide has a positive sign and hence suggests some tendency by the FFS training to improve the damage abating efficiency. However, the high insignificance of the coefficient shows that, as compared to the direct impact embodied in the highly significant coefficient on the "participation" dummy, this interaction might not make any meaningful difference in practical production.

Table 5-9: Estimated coefficients from simultaneous estimation of insecticide function and yield functions (CD and different damage control function specifications) using two stage least squares

Variable	Insecticide function	**Production function**			
		Pure Cobb-Douglas	Damage control specification		
			Equation (6)	Equation (7)	Equation (8)
Exposure	-0.2128 (0.0693)***	0.0165 (0.0283)	0.0207 (0.0290)	0.0179 (0.0286)	0.0263 (0.0289)
Exposure*2002	-0.0432 (0.0426)	0.0121 (0.0133)	0.0114 (0.0133)	0.0114 (0.0133)	
Exposure * 2003	-0.0301 (0.0422)	0.0060 (0.0126)	0.0022 (0.0129)	0.0051 (0.0125)	
Participation	-0.4101 (0.0718)***	0.0711 (0.0311)**	0.0822 (0.0317)***	0.0727 (0.0316)**	0.0731** (0.0320)
Participation*2002	-0.0237 (0.0409)	0.0063 (0.0115)	0.0022 (0.0120)	0.0057 (0.0115)	
Participation*2003	0.0295 (0.0423)	0.0016 (0.0104)	-0.0067 (0.0118)	0.0006 (0.0107)	
Herbicide	-0.0221 (0.0126)*	0.0103 (0.0037)***	0.0122 (0.0044)***	0.0103 (0.0038)***	0.0117 (0.0040)***
Fertilizer	0.2529 (0.0319)***	0.1171 (0.0117)***	0.1161 (0.0116)***	0.1166 (0.0117)***	0.1176 (0.0107)***
Seed		0.0138 (0.0080)*	0.0141 (0.0083)*	0.0137 (0.0080)*	0.0134 (0.0081)
Irrigation		0.0005 (0.0030)	0.0016 (0.0031)	0.0005 (0.0030)	0.0017 (0.0032)
Other costs		0.0309 (0.0100)***	0.0288 (0.0097)***	0.0307 (0.0100)***	0.0297 (0.0093)***
Labor	0.6352 (0.0710)***	0.1690 (0.0288)***	0.1525 (0.0364)***	0.1689 (0.0299)***	0.1597 (0.0327)***
Cotton share		0.0320 (0.0089)***	0.0282 (0.0101)***	0.0316 (0.0091)***	0.0303 (0.0094)***
Experience	-0.0754 (0.0187)***	0.0084 (0.0060)	0.0081 (0.0061)	0.0082 (0.0060)	0.0080 (0.0059)

Variable	Insecticide function	Production function			
		Pure Cobb-Douglas	Damage control specification		
			Equation (6)	Equation (7)	Equation (8)
Education	-0.0307 (0.0209)	0.0395 (0.0067)***	0.0398 (0.0069)***	0.0394 (0.0067)***	0.0396 (0.0066)***
Ability to recognize pests and beneficial organisms	-0.0851 (0.0429)**	0.0119 (0.0118)	0.0104 (0.0127)	0.0122 (0.0119)	0.0083 (0.0115)
Insecticide price	0.1565 (0.0405)***				
Farm size	-0.0738 (0.0285)***				
Pest pressure	0.1366 (0.0191)***				
Insecticide		0.0119 (0.0334)			
Bt	-0.0612 (0.0634)	0.0210 (0.0141)			
Damage control function					
Insecticide			0.0540 (0.0234)**	0.0973 (0.3403)	0.0446 (0.0301)
Participation*insecticide					0.0211 (0.0753)
Bt			1.6000 (1.6137)	0.0744 (0.2114)	1.9199 (1.7090)
R^2 / adj. R^2	0.8218/0.8101	0.6413/0.6170	0.6148/0.5887	0.6408/0.6164	0.6245/0.6001

Note: ***, **, * denoted significance at 1%, 5% and 10% respectively; the estimated coefficients for 53 township dummies and intercepts were not reported for brevity.
Source: Own survey

The estimates to Bt trait are also similar across the specifications, all positive but none significant. Therefore it is consistently shown that, no matter Bt trait was treated as yield increasing input or damage abating factor, it only played a minor role in achieving higher yields in the context of this study. As for the insecticides, all specifications returned positive signs, but only equation (6) came up with a significant coefficient. The difficulty in getting significant estimates for insecticide was frequently encountered by similar studies in China and believed to be a reflection of the overuse of pesticides by Chinese farmers (e.g. Pemsl, 2006; Huang et al., 2002a, 2002b). To see the trend of marginal contribution of insecticides to cotton yields, the estimated coefficients, the average level of all non-insecticide variables and average cotton price were used to compute the marginal value products (MVPs) for insecticides at different levels of insecticide use. There were only some slight shifts between the curves for different farmer groups with the same model specification, and the influence of FFS training on the damage abating efficiency was only of negligible importance as illustrated earlier. As a result, only the pure Cobb-Douglas, equation (6) following exponential distribution and equation (7) following Weibull distribution were used for this computation, and only the MVP curves for the FFS participants were plotted for clarity of the figure.

As presented in Figure 5-1, the marginal value products decreased as the levels of insecticide use increased, showing the usual pattern of diminishing marginal return. Over a wide range of the x axis there is considerable distance between the exponential curve and the other two. The MVPs derived from the pure Cobb-Douglas functional form is consistently smaller than those from the Weibull specification, while at the left end of the x axis the MVPs from the pure Cobb-Douglas specification are greater than those from the exponential specification. As pointed out by many other studies (e.g. Pemsl, 2006; Hall et al., 2002), this graph apparently shows that the results of the damage control functions are sensitive to functional forms and the pure Cobb-Douglas function could either overestimate or underestimate the marginal productivity of damage abating agents depending on the functional form of the damage control functions and the levels of input use.

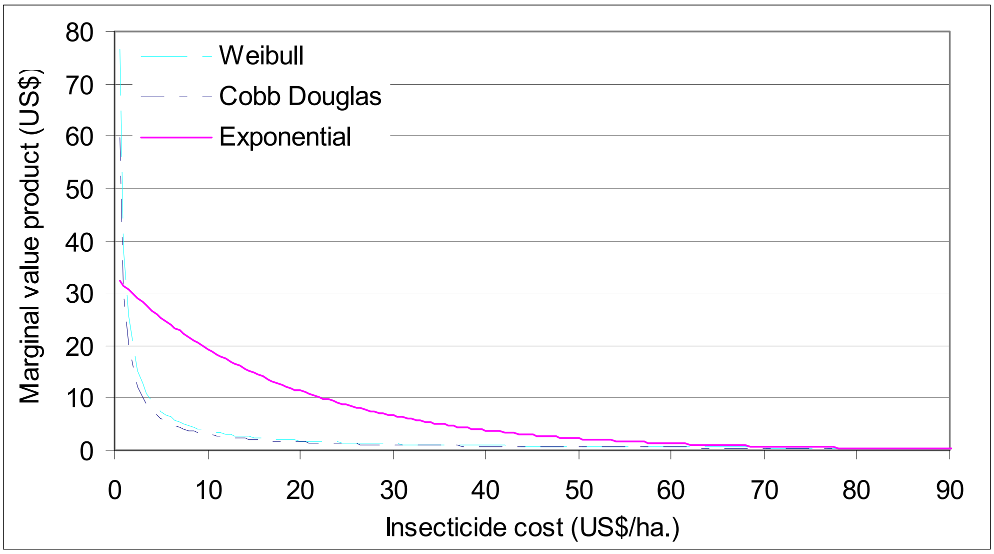

Figure 5-1: Marginal value products of insecticides with different model specifications

Source: Own survey

Since the insecticides were measured in monetary value, the intersections of the unity marginal value product and the various marginal value product curves represent the economically optimal input levels[31]. The optimal insecticide use ranged from 31 US$/ha derived from the pure Cobb-Douglas production function, to 35 US$/ha from the Weibull specification and to 65 US$/ha from the exponential functional form. A comparison of those optimal use levels with the actual insecticide costs presented in Table 5-7 strongly concurs with previous studies reporting overuse of pesticide in China (Pemsl, 2006; Huang et al., 2002a, 2002b). Excepting the combination of FFS participants and the exponential specification, considerable gaps existed between the optimal levels and the actual costs for all the farmers, especially in the case of the control farmers. If compared to the results from pure Cobb-Douglas or Weibull specifications, the actual insecticide applied by the control farmers was twice more than the optimum. Even if the exponential function is the pertinent one, there was still a gap of 50% for the control farmers. Such a gap for the FFS participants was much narrowed and some improvement was also identified with the exposed farmers. However, the remaining difference between the actual and optimal levels of insecticide use for the exposed farmers and participants as well suggests that it is really an onerous task to help the farmers off the pesticide treadmill.

5.7 Summary and Conclusions

This chapter applies a damage control framework to assess the impacts of FFS training on insecticide use and cotton yields in the context of program scale-up. Results show that on a larger scale with a total of over 1,000 FFS conducted under one program in China, the trained farmers were able to reduce insecticide use significantly with a substantial increase in cotton yields. The second result is that no difference in terms of impact was found between the FFS conducted at the start of the program as compared to those FFS implemented in later years. This suggests that the quality of FFS implementation was maintained as the program was scaled up. The third finding is that there was only a partial diffusion effect of the training. Exposed farmers, also reduced insecticide in the short term but the sustainability of this effect was ambiguous. Also there was no evidence of yield gains for the exposed farmers. The fourth result is that the models do not suggest that on the large scale Bt cotton had made any significant contribution to either productivity increase or insecticide

31 Since the curve of unity marginal value product is very close to the x axis, it was not included in the figure.

reduction. However, the results strongly indicate that even with a wide adoption of Bt cotton, FFS still has an important role to play in cotton production.

According to the descriptive analysis, there were some significant differences between the participants and the others, for instance family labor and cotton share. Educational level was also found to be somewhat higher for the participants in this chapter and chapter 4. Although efforts were undertaken during the sampling process to achieve a better similarity between the FFS and control villages, it seems that there were still some important locality specific differences. The Heckman Procedure was also run between the FFS and control villages with the county dummies rather than the township dummies. The inverse Mills ratio in the insecticide function for farmers in the FFS villages has a highly significant parameter (see Appendix 8), which means that there was a substantial difference between the FFS and control villages and those differences did have an influence on the performance indicator of interest. This finding provides strong justification for the inclusion of township dummies in this study and more generally accentuates the importance of proper control for selection bias in the empirical assessment of the impacts of development programs including FFS.

The most important finding of this chapter is the maintenance of the training effect during the program scale-up. The number of FFS conducted under the framework of the FAO-EU IPM Program expanded from 120 in 2001 to more than 400 in 2003, reaching a total of 1,061 in 2004, and the effect was proven to be well maintained. A likely contributor is the emphasis on quality issue at the program level. Maintenance of the quality was always held as a major concern of the FAO-EU IPM Program. Impact assessment was incorporated as an integral component during program design, the training of facilitators (TOF) was preferably funded prior to the scale-up of FFS implementation, the monitoring and reporting system was improved for quality control and activities such as farmer alumni groups, and district facilitator meetings were advocated as “quality circles” to self-assess and improve project activities (Ooi et al., 2004).

As for the case of China, the support from the government could be a factor of importance. To meet the requirement of the scale-up for various resources, the local governments in key program areas increased the running funds for program implementing units, cut the traditional extension assignments and even reduced the labor duties in FFS communities (NATESC, 2002). Additionally, the existing extension system provided abundant personnel resources for the up-scaled facilitation. As illustrated by an FFS facilitator in Wangjiang County in Anhui province, the combination of his “old” expertise and new training approach gave him an “ace in hole” to catch the farmers’ interest (personal communication Mr. Wang Kaitang in the Plant Protection Station of Wangjiang County on 23 June, 2005).

Although significant impact of FFS training has been identified with FFS participants in China, a caveat must be made regarding the cost effectiveness of the FAO-EU IPM Program. Agricultural production in China is typical of small scale. In the case of cotton production, one household usually cultivates less than 0.3 hectare cotton land. The small scale essentially imposes an upper bound to the profit which can be realized by the FFS participants. Although individual trained farmers might enjoy a considerable increase in cotton yields and decrease in input costs on their small plots, the aggregate gains at the program level could still fail to recover the program costs. A recent study by Pananurak (2009) shows that, without the diffusion impacts on the performance of the non-trained farmers and the sustainability of the impacts on the trained farmers, the FAO-EU IPM Program in China was actually cost ineffective. Therefore, it could be more important for implementing agencies in China to take effective measures to sustain the impacts of FFS on participants and to make the impacts also accessible to non-trained farmers.

In chapter 4 based on panel data, a significant diminution of the exposed impact on insecticide use was identified but mixed results were reported here. Since exposed farmers might only imitate the pest management practices of the trained farmers, they could certainly fail to adapt to changing pest problems. The panel data analysis reveals that this was most likely the case. In the past years non-lepidopterous pests, especially the sucking aphids (*Aphis* spp. and *Acyrthosiphon gossypii*), mirids (*Adelphocoris* spp. and *Lygus* spp.) and red spider mite (RSM) (*Tetranychus cinnabarinus*) increased their infestation seriously in cotton in China. If the improvement of pest control in the exposed group was largely limited to replication, it should not be surprising that the difficulty in adapting the control measures drove the exposed farmers back to their habitual solo pesticide solution and resulted in a significant diminution in later years. Therefore, informal daily communication seems to be inadequate, relatively formal follow up activities should be strengthened to help the exposed farmers not only know but also understand the IPM knowledge.

This study does not find any significant impact of Bt cotton on yields and insecticide use, which constitutes a sharp contrast to some previous studies in China (e.g. Huang et al., 2002a; 2002b; 2002c; 2003a). Since the performance of Bt cotton depends on a series of factors such as the type and severity of pest shock and seed quality, it should not be surprising for a cross sectional study to come up with such a result. One limitation of this study is that, the vast majority of cotton fields were planted with Bt varieties which made the sample rather biased and hence might have blurred the difference between Bt varieties and the conventional ones. However on the other hand, it might imply that the merits of Bt cotton are not so apparent as claimed by the proponents of the technology. Although some studies have attempted to show that Bt cotton might have greatly suppressed the population of CBW and other target pests during the period of its fast expansion (Carriere et al., 2003; Wu et al., 2008), the findings with aggregate data in chapter 2 in this thesis clearly reveal that the infestations of CBW had already declined abruptly before the approval of Bt cotton for commercial use. As a result, great caution should be taken not to simply affirm or negate the impacts of Bt cotton. It might be better to leave the role of Bt cotton as an open question and consider seriously how to improve the performance of the biotechnology. Many studies show that the insecticide use is still very high even though Bt cotton has been widely adopted in China (Pemsl et al., 2005, 2007a, 2007b; Yang et al., 2005a, 2005b, 2005c; Wang et al., 2006). And hence, it is perhaps more urgent to train the farmers to deal with Bt varieties properly than to draw a hasty conclusion about the role of Bt varieties in cotton production.

6 Summary, Conclusions and Recommendations

6.1 Summary

Modern technologies including biotechnology and improved extension services are among the policies implemented by China to deal with the constraints of natural resources and to achieve the productivity increase in agriculture. FFS as a participatory approach to extend IPM knowledge is now conducted in hundreds annually throughout China, and the area planted with Bt cotton as the only large-scale commercial application of biotechnology to control insect pests in the country accounts for two thirds more of its total cotton area. Wide adoption of the FFS and Bt cotton calls for thorough understanding of their roles in the development of agriculture. However, owing to the lack of rigorous study the impacts of FFS remain opaque in China, and the role of Bt cotton is still a matter of dispute resulting from different studies with different findings.

This study carries out an economic analysis of the roles of FFS and Bt cotton in agriculture in China with the main objective to assess their impacts on productivity and insecticide use. By using several primary data sets for rigorous econometric analysis, this study contributes to the development of the methodology for impact assessment as well. The specific objectives are: 1) To assess the impacts of FFS on productivity and insecticide use within different temporal (immediate and median terms) and spatial (pilot and upscale stages) scopes; 2) To evaluate the impacts of Bt cotton on productivity and insecticide use to further unveil the role of Bt cotton adopted by small-scale farmers in China; 3) To explore the interaction between FFS as an extension approach and Bt cotton as the technology to be extended; and 4) To contribute to the development of methodologies of impact assessment in crop protection by testing the classic “difference in difference” (DD) model and damage control function and comparing different methodologies. To achieve the aforementioned objectives, different analytical frameworks were developed and applied to both panel and cross-sectional data sets with careful check and control of econometric problems such as selection bias and input endogeneity.

The data for this study were collected in nine counties, namely Lingxian, Linqing and Zhanhua in Shandong Province, Dongzhi, Guichi and Wangjiang in Anhui Province and Yingcheng, Tianmen and Xiantao in Hubei Province, covering a total of 1,577 farmers. Most data were collected by season long monitoring except that the first period of a three-period panel data set covering 540 farmers was collected by a recall survey. The recall survey was carried out at the beginning of 2001 to collect data for the baseline year of 2000 and largely drew on farmer recording to get detailed information on inputs and outputs. For the season long monitoring, farmers were asked to keep a detailed diary of their cotton production activities in standard form, and the recording was checked by enumerators during their monthly visits to farmer households. In addition to the detailed account of input and output information, the household and village attributes and farmer knowledge on pest control were also collected in the surveys.

The farmers were categorized into three groups according to the access to FFS intervention, viz FFS participants, exposed farmers and control farmers. The participants are those farmers who had ever participated in the FFS training before the surveys were conducted. Exposed Farmers refer to the farmers who had not participated in FFS but lived in the same villages as participants, and hence might indirectly benefit from the training. Control Farmers are those farmers who lived in the villages where no farmer had received FFS training. From 2000 to 2004, a total of 1,061 FFS were conducted in China under the framework of the FAO-EU IPM Program for Cotton in Asia, among which 93 were involved in this study. The Bt cotton was overwhelmingly adopted in the study areas with an overall adoption rate of around 94% in the sample in 2005, but there were still some farmers who partially or less likely solely planted conventional cotton.

Chapter 2 presents an overview of the pest problems and pesticide use in cotton in China. In contrast to other major field crops such as rice, wheat and maize which succumbed to increasing pest infestations over the past two decades, cotton experienced an overall decline of pest infestations since mid 1990s, and in the same period the pest pattern of cotton has changed appreciably with CBW and RBW generally reducing their infestations while RSM, aphids, mirids and some other pests increasing their damage. The declining largely coincided with the rapid expansion of Bt cotton in China. However, the sharpest decline of pest infestations already took place before the approval of Bt cotton for commercial use in 1997, and nowadays cotton is still the major field crop receiving most intensive pest control effort. The national average cost for pesticides in cotton was 96.8 US$ per hectare, which was 21.1, 78.1 and 80.6 US$ higher than that in rice, wheat and maize in 2007. The empirical results from the data collected from the sampled farmers in 2005 reveal some problems with the pest use in cotton. A total of 917 kinds of pesticide products were used by the sampled farmers, among which 357 kinds could not be identified to active ingredients, indicating the tremendous difficulty in farmers' selection of suitable products. Farmers' health is at risk by the prevalence of extremely or highly hazardous pesticides. On average, around 30% of all the pesticides applied contained extremely or highly hazardous active ingredients listed as WHO class Ia and Ib. Great variation of pesticide use between areas in the same ecosystem and divergence between pesticide uses and pest infestations were also identified by this study, implying substantial overuse of pesticides in some areas.

To evaluate the immediate impacts of FFS conducted at the pilot stage of the program, chapter 3 applies a DD model to a two-period panel data set collected in Lingxian County in Shandong Province. It was shown that the participants enjoyed a significant increase in cotton yields and gross margins, but no remarkable improvement of those indicators was identified with the exposed farmers. The modelling of pesticide use presents a different picture with the pesticide use also reduced significantly in the exposed group, although such reduction was much smaller in magnitude as compared to that for the participants.

In chapter 4, an expanded version of the DD model was applied to three-period panel data collected in Lingxian County in Shandong Province, Dongzhi County in Anhui Province and Yingcheng County in Hubei Province. In the yield function, the direct inputs, labor and fertilizer, both contributed significantly to higher yields, while no significant output gains could be attributed to irrigation. The coefficient for cotton share is non-significant and actually bears a negative sign. Different categories of pesticides all have non-significant positive coefficients which correspond to a marginal return of 0.16, 0.96 and 3.41 US$ for insecticides, herbicides and fungicides respectively, indicating an overuse of insecticide and a deficiency in disease control. The participation in FFS contributed to a significant yield increase by 8.4%, and such gains were shown to be well sustained in the medium term. No significant impact on yields was concluded for the exposed farmers. Bt per se did not have a significant impact on yield increase. However, the Wald test of Bt and its interaction terms with FFS participation and exposure is significant, revealing that the combination of Bt with FFS training could contribute to higher yields.

According to the results of the insecticide function, more intensive use of fertilizer and labor led to an increase in insecticide costs, while larger farm size and better knowledge on pest control proxied by the ability to recognize pests and beneficial organisms contributed to a reduction in insecticide use. Participation in FFS contributed to a significant decrease in insecticide use by 46%, and the non-significant negative coefficient to the interaction term between FFS participation and period dummies reveals the maintenance of such impact up to the medium term. Exposure to FFS also led to a reduction of insecticide use by 40%, but the immediate impact diminished substantially in the medium term as shown by the significant positive coefficient to the interaction term between the exposure and period dummies. Bt cotton alone contributed to a 10% decrease in insecticide costs, and a further reduction of insecticide use by 15.5% was achieved when the Bt cotton adoption went together with FFS participation.

In chapter 5, the large cross-sectional data set collected in the nine counties was fit to assess the impacts of FFS in the upscale stage. The impacts on yields were analyzed by a pure Cobb-Douglas function and Cobb-Douglas functions with different inbuilt damage control functions. All those functions generated highly consistent estimates for most variables, and the findings were generally in line with the outputs of the preceding DD models. Labor, fertilizer, seed and herbicide all significantly increased yields, while the contribution of irrigation was insignificant. Farmers with better education and higher cotton share were shown to achieve appreciably higher yields. Participation in FFS contributed to a significant increase in yields ranging from 5.7% to 6.9% with different model specifications. None of the interaction terms between participation and the conduction years of FFS is significant, implying the maintenance of the impacts in the process of scaling-up and their sustainability over time. The “exposure” dummy always has a non-significant positive coefficient, and hence no conclusive yield gains can be claimed for the exposed farmers. The “Bt” variable in all the specifications consistently has a non-significant positive coefficient, showing that no matter whether the Bt trait was treated as yield increasing or damage abating factor, it only played a trivial role in achieving higher yields. In the case of insecticides, all the model specifications produce positive coefficients, but only one in the exponential form of damage control function is significant. The calculation of the marginal value products of insecticide presented economically optimal use levels ranging from 31 US$ to 65 US$ with different model specifications, revealing apparent overuse for all the cotton growers, especially the control and exposed farmers.

Both a linear and Cobb-Douglas form functions were estimated to explain the insecticide use. In either function, herbicide had an impact of border significance on the reduction of insecticide costs, while fertilizer and labor both significantly increased insecticide use. Longer experience, more knowledge on pest control, less severe perception of pest problems and larger farm size all significantly reduced insecticide use, while higher insecticide price led to more insecticide costs. The negative sign to the “Bt” variable suggests that the Bt trait was a contributory factor to insecticide reduction but the non-significance of the coefficient indicates that such a role was much limited in this case. The participation in FFS contributed to a reduction of insecticide use by 26.3% with the linear specification and 36.5% with Cobb-Douglas specification, the insignificance of the coefficients for the interaction terms between participation and conduction year dummies confirmed the maintenance of the impacts during program scale-up and their durability with the passage of time. The exposure to FFS also contributed significantly to insecticide reduction, while the interaction term between the exposure and 2003 conduction year dummies in the linear specification has a significant negative coefficient, implying that the most recently the FFS was delivered, the stronger the diffusion impact could be. In other words, the exposure impact on insecticide reduction had diminished for those farmers who were exposed to FFS in earlier years.

6.2 Conclusions

Sound use of FFS and Bt cotton as developing tools for agriculture demands further scrutiny of their roles. Based on both panel and cross-sectional data, different methodologies were applied to investigate the impacts of FFS from different perspectives, viz direct and indirect effects of the intervention, short and medium terms after the FFS delivery, pilot and upscale stages of the program implementation. Meanwhile, equal attention was paid to Bt cotton and its interaction with FFS. With all those efforts, it is expected that the informative findings by this study could contribute to a better understanding of the performance of FFS and Bt cotton on the small-scale cotton farms in China.

Different methodologies unanimously report significant direct impacts of FFS on yields and pesticide use. Such impacts took place immediately after the FFS was delivered and were well sustained up to the medium term. It was also demonstrated that the impacts of FFS were not compromised in the process of program scale-up and the participants in earlier and later stages all benefited substantially from an increase in yields and a decrease in pesticide use. It is actually difficult to achieve significant yield gains through FFS training in intensive cropping systems in rice (Praneetvatakul et al., 2008). However, in this case the heavy yield loss inflicted on cotton every year by pests provided considerable room for damage abatement, and the concept of "grow a healthy crop" included in the curricula promised better cultivating practices. As a result, the improved pest management and cotton cultivation by FFS participants might concur to culminate in discernable yield gains. In this sense, the impacts of FFS depend heavily on the target crop and the training organization, and hence caution should be taken to extrapolate the findings of one assessment to other crops and programs.

As regards the indirect impacts of FFS training, this study presents a somehow pessimistic scene. The exposed farmers reduced pesticide use significantly immediately after their exposure to FFS, but no significant increase in yields was identified in this farmer group. Moreover, the durability of such diffusion impacts was seriously questioned by the finding that the reduced pesticide use rebounded markedly in the medium term. FFS is a costly undertaking, and the knowledge diffusion between farmers has a vital implication to its fiscal sustainability. However, the studies by Rola et al. (2002) and Feder et al. (2004b) have seriously questioned the role of informal communication in disseminating the complex IPM knowledge from the trained to non-trained farmers. Another study by Witt et al. (2008) reveals that the extent and effectiveness of farmer to farmer diffusion depends on a "clustering" FFS program placement strategy to create a critical mass of trained farmers within individual farmer communities. According to the findings in this thesis, it seems that the reduction of pesticide use in the exposed group in the short term was just an imitation of the pest control practices in their neighbouring participants' plots. Without having acquired the complex knowledge such as decision-making processes and ecosystem concepts, the exposed farmers could not achieve higher yields through systematic improvement of field management in the beginning, and had to go back to rely heavily on chemical control facing the changed pest pattern in the end.

No conclusive evidence of the impact of Bt cotton on yields was provided by this study. No matter in the cross-sectional or panel analyses, the contribution of Bt trait per se to higher yield was always affirmed in the right direction (positive sign) but denied by the negligible coefficient magnitude. Mixed results were presented as regards the impact on insecticide use. When checked by the three-period DD model, Bt trait led to a significant reduction of insecticide costs. However, the substitution of the pesticide by Bt was relegated to be insignificant in the cross-sectional analysis. From 2000 to 2005 which was covered by the three-period panel data, the Bt cotton adoption rate in the study areas increased from around 45% to 94%. During the years of its rapid diffusion and wide adoption, Bt cotton might have contributed to some suppression of the natural population of CBW and other target pests (Carriere et al., 2003; Wu et al., 2008). As a result, the possible difference of the pesticide use between the Bt and non-Bt plots in early years could have been blurred with the expansion of the biotechnology and the impacts of Bt cotton should better be appraised in a historical time period.

Informative conclusion can be drawn from the study of the interaction between Bt and FFS training. Although Bt per se did not contribute significantly to yield increase, the joint contribution of Bt and its interaction terms with FFS participation and exposure were demonstrated to be significant, indicating a substantial improvement of the Bt performance by FFS training. As for insecticide use, a reduction by more than 10% was caused by Bt solely, and the interaction between Bt and FFS training led to a further decrease by 15.5%. Proper handling of Bt varieties was included as an important ingredient of the FFS curricula in the FAO-EU IPM Program for Cotton implemented in China. The complementary effect between Bt and FFS training pinpointed by this study and some others (e.g. Yang et al., 2005a) not only attests to the importance of tailoring the FFS curricula to local conditions, but also offers a promise to ameliorate the tendency of increasing pesticide use in Bt cotton reported by some recent studies (Pemsl et al., 2005; Wang et al., 2006).

Both panel and cross sectional data were fitted with different methodologies. Substantial efforts were undertaken to check and control selection bias, input endogeneity, error heteroscedasticity, etc. It was revealed that the estimates produced in either way can be generally consistent. The careful treatment of econometric issues in this study may hold a reference for similar studies in the future. A pure Cobb-Douglas function and Cobb-Douglas functions with different inbuilt damage control functions were used to study the impacts on yield. The different specifications present similar results for the direct yield increasing production factors, such as labor, fertilizer and variables like experience and education. However, the coefficient for insecticide use is significant in only one exponential specification and substantial difference exists between the economically optimal levels of insecticide use calculated from different specifications. The results here concur with another study in the conclusion that the results of the assessment are influenced by the specification of the econometric models (Pemsl, 2006), and at the same time highlight the importance to include different model specifications in a study for a more comprehensive assessment of the role of indirect production factors such as Bt trait and insecticides.

6.3 Recommendations

The results and conclusions found in this study allow to derive a number of policy recommendations.

The first suggestion addressed to policy makers is to synchronize the expansion of biotechnology with the extension of proper knowledge. It is recognized that the diffusion of technology can be facilitated when the technology is materialized in certain input (Dong et al., 2000). However the popular belief that the solution to pest problems with cotton lies in Bt seeds has led to new problems (Pemsl et al., 2005). It is important to synchronize the input expansion with technology extension. As shown by this study, significant complementary effect can be generated by such synchronization. This recommendation is of special implication for China where Bt rice is under evaluation for commercial release (Huang et al., 2005; Qiu, 2008). Even for the case of Bt cotton, there is still a perceivable need to make up the missed lessons in technology dissemination. In some of the study areas in the Huanghe River Cotton Region (HRR), many farmers always spray against CBW of second generation. However, according to the studies by plant protection experts, this spray is actually unnecessary in normal years because the Bt toxin concentration is adequate for the control of CBW in early growing period of cotton plants (Qu et al., 2001; Li, 2007).

The second recommendation is to foster the follow-up activities of FFS. The admonitory finding by this study is the somehow pessimistic picture about the exposure impacts of FFS. The FFS approach relies on the farmer to farmer diffusion to be fiscally sustained, but the complex knowledge such as agro-ecosystem concepts and decision making principles is difficult to be effectively transmitted in casual and informal conversations (Feder et al., 2004a). The follow-up activities are required for the trained farmers to relay the knowledge they learned in FFS to non-trained farmers in a similar way. However, in small-scale agricultural systems that are facing increasing opportunity cost of labor, the follow-up activities are not likely to take place spontaneously without external motivation. The program implementing agencies need to continue their efforts after the program is closed. With regular visits by extension agents, occasional organization of farmers' day, frequent media propaganda and other enabling interventions, the FFS training may stand a better chance to benefit more farmers in addition to its participants.

The third recommendation, once more addressed to policy makers in China is to create a more favourable institutional framework. The extent of the success of a technology and the realization of it benefits is considerably determined by institutional conditions (Pemsl et al., 2005). Although Bt cotton has been overwhelmingly adopted in China, the striking overuse of insecticides in cotton production is still uncovered by this study and many others (e.g. Huang et al., 2002b; Pemsl, 2005; Yang et al., 2005a). The insufficient quality control of Bt seeds and pesticides on the market is a major factor to be held to account. Facing the uncertainty of the input quality, the farmers could likely be driven to spray more pesticides rather than risk pest-inflicted damage (Pemsl, 2006). Serial initiatives have been launched by the Chinese government to rectify the market (Wang, 2008; Chen, 2009b), but more are needed to build up the farmers' trust in agricultural material. Only in this way can the farmers be convinced to keep to the right track of rational use of various inputs. Another case of pertinence is the agricultural extension. The overuse of pesticide is also blamed on the extension system because of its involvement in pesticide dealings (Huang et al., 2002b). Although more support has been directed to the system, it is still popular for extension agencies, especially those at township and county levels, to rely on income generated from sales of inputs. If and only if the government separates the public service activities and staff of the extension system from the input sale activities and staff, the extension service can then be relied on as a driving force towards sound use of modern technologies.

The last recommendation addresses the need for further studies. Firstly, since the sample for the panel studies in chapters 3 and 4 was selected at the inception of the FAO-EU IPM Program for Cotton in Asia when only a small number of FFS were available, there was a limited coverage of FFS. If more FFS can be included in future studies, a better representativeness of the sample to the population will be achieved. Secondly, this thesis focuses on economic indicators of yields, insecticide use and gross margins. Nonetheless, the FFS training has a much broader scope and may generate an array of impacts. It is worthwhile for future studies to include more impact indicators, such as those on environment and health improvements. Thirdly, the data for this study were not collected on plot basis. As a result, the Bt trait was measured by household adoption rate of Bt varieties, which might have blurred the demarcation between Bt and non-Bt plants. The collection of plot specific data can certainly benefit future studies with a more precise measurement of the inputs and outputs of cotton production using Bt varieties.

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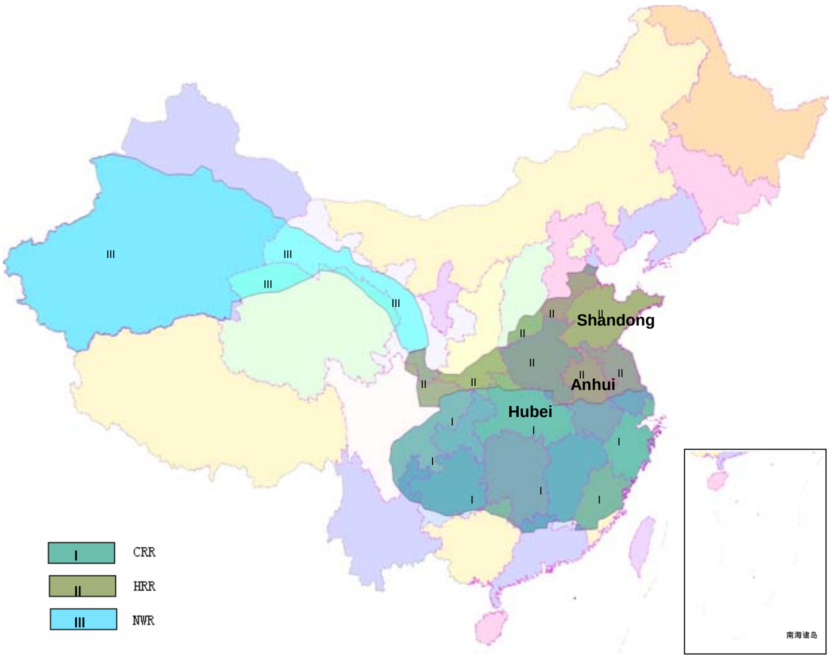
Appendix

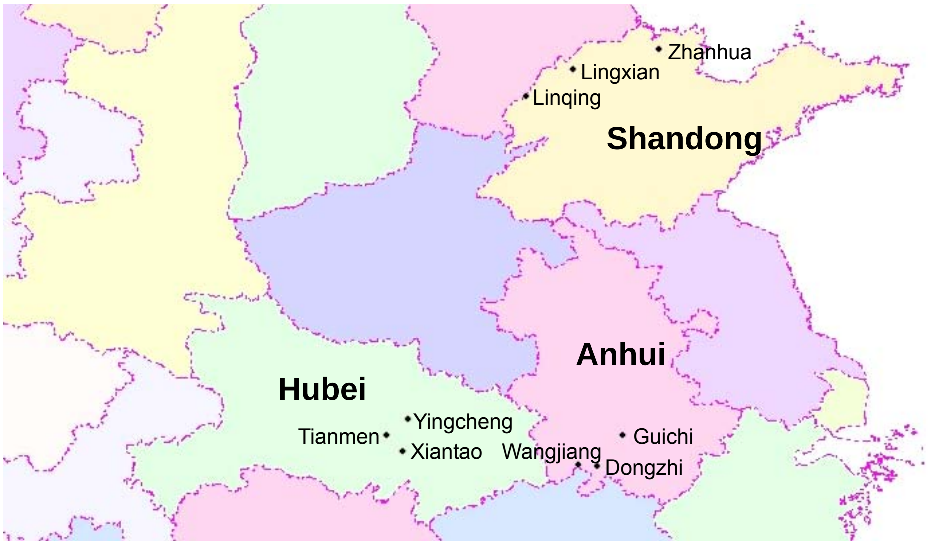
A- 1: Map of China (with Major Cotton Regions) and Location of the Study Areas

(a) Map of China (with major cotton regions) and Shandong, Anhui and Hubei Provinces



Note: CRR = Changjiang River Cotton Region, HRR = Huanghe River Cotton Region, NWR = North Western Cotton Region.

(b) Map of the nine Counties in Shandong, Anhui and Hubei Provinces



A- 2: Distribution of the Farmers Sampled for this Study

Province	County	Township	Village	No.of respondents	Note
Shandong	Lingxian	Bianlin	Houtong, Qiantong	20	FFS
		Mi	Dongjie, Luanwang, Menghu, Qianzhou, Zhoujia	116	FFS
		Shentou	Qiaojia, Zaohuyang	20	FFS
		Yuji	Mengjia, Suntun	20	FFS
		Zi	Liuyazhuang, Zhanglong, Zhaotun	30	FFS
		Dingzhuang	Daliu, Houliu, Qianliu, Sunjiaji	62	CK
		Songjia	Fangjia, Xinzhuang	10	CK
		Zhengjiazhai	Houqin	5	CK
	Linqing	Daxinzhuang	Jiangzhuang	9	FFS
		Liugaizi	Liaozhuang, Liugaizi, Kongji, Kongzhuang, Yinzhuang, Zhangzhuang	99	FFS
		Zhaozhuang	Tiangongmiao, Wugudao	40	FFS
		Bachalu	Houyangfen	29	CK
		Jinhaozhuang	Xinji	30	CK
		Panzhuang	Qianwangdi, Wangyan	10	CK
		Weiwan	Tianzhuang	5	CK
	Zhanhua	Binhai	Hebei, Shizihe	20	FFS
		Fengjia	Beizhao, Daliu, Lijia, Liyazhuang, Sunwang	50	FFS
		Potou	Fengwang, Xuwangliang	20	FFS
		Xiawa	Qianlu	10	FFS
		Liguo	Chewangzhuang, Mayingliu, Qicun	15	CK

Distribution of the Farmers Sampled for this Study (continued)

Province	County	Township	Village	No.of respondents	Note
Anhui	Dongzhi	Dadukou	Datong, Guanghui, Guangrong, Huzhang, Lianxu, Xinfeng, Xinqiao, Xinting, Yongqing	175	FFS
		Qingshan	Pushu	10	FFS
		Shengli	Fangcun, Qingyun, Yu	30	FFS
		Zhaotan	Qiaozhu, Wanglong	20	FFS
		Hongfang	Huayuan, Wangqiao	10	CK
		Jianxin	Weixingchang, Xiaoanli	10	CK
		Xiangyu	Laohugang, Maolin, Xianjin	58	CK
	Wangjiang	Leiyang	Songfan	10	FFS
		Yanglin	Boyue, Shilinsan	30	FFS
		Yangwan	Jiguan	10	FFS
		Yatan	Maiyuan, Yatan, Zhujiawu	15	CK
	Guichi	Gaojiling	Gangxi, Sanlian	20	FFS
		Muzha	Honghu	10	FFS
		Yantang	Hongzhuang	10	FFS
		Ruanqiao	Lianshan, Ruanqiao, Tianran, Tongxin	30	FFS,CK
		Wusha	Ciyun, Hongyang, Wangxing, Zhujia	35	FFS,CK
Hubei	Yingcheng	Huangtan	Feiyue, Liuyuan, Longwang, Lumiao, Sanba, Yujia, Shanghe, Yanglin, Ganhe	171	FFS
		Yihe	Dingzui, Erwan, Yihe, Xinliu	40	FFS

Distribution of the Farmers Sampled for this Study (continued)

Province	County	Township	Village	No. of respondents	Note
Hubei	Yingcheng	Nanyuan	Erfenchang, Yifenchang, Meigang	52	CK
		Tiandian	Xiaohuang, Yepeng	10	CK
		Yangling	Miantian, Mingguang	10	CK
	Xiantao	Changtangkou	Dafu, Huhua, Sanfu	30	FFS
		Huchang	Sihao	9	FFS
		Yanglinwei	Youhao	10	FFS
		Zhanggou	Liantan, Santong, Xinsheng	26	FFS
		Zhengchang	Huayuan	8	FFS
		Dafu	Chenjiadaqiao	5	CK
		Dunhou	Chenjialaotai, Zengjiatai	10	CK
	Tianmen	Baimaohu	Changdi, Huahu	20	FFS
		Shihe	Lizui	5	CK
		Wangchang	Bietai, Yangqiao	18	FFS
		Yuekou	Jiankang	10	FFS
		Duobao	Bianwan, Shuangqiao	10	CK
		Kaifaqu	Guihua, Qunlilin, Kuaihuolin	30	FFS

A- 3: Test of Heteroscedasticity for Two-period DD Models

(a) Yield function

```
The SAS System                              13:12 Tuesday, December 8, 2009   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                      Adj
Equation       Model   Error        SSE        MSE   R-Square      R-Sq
dlyd               4     163     4.6035     0.0282     0.1392    0.1234
                       Nonlinear OLS Parameter Estimates

                            Approx                Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a1             -0.04473     0.0360     -1.24      0.2153   constant
a2              0.01784     0.0313      0.57      0.5689   exposed
a3             0.142004     0.0325      4.37      <.0001   participant
a4             0.002136   0.000861      2.48      0.0142   irrigation
Number of Observations     Statistics for System
Used               167    Objective        0.0276
Missing              0    Objective*N      4.6035
                            Heteroscedasticity Test
Equation      Test             Statistic   DF  Pr > ChiSq  Variables
dlyd          White's Test          7.72    6      0.2596  Cross of all vars

              Breusch-Pagan         7.03    1      0.0080  1, dlyd
```

(b) Pesticide function

```
The SAS System                              13:12 Tuesday, December 8, 2009   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                      Adj
Equation       Model   Error        SSE        MSE   R-Square      R-Sq
dlpce              5     162      122.4     0.7557     0.2600    0.2417
                       Nonlinear OLS Parameter Estimates

                            Approx                Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a1             0.627116     0.1399      4.48      <.0001   constant
a2             -0.67953     0.1693     -4.01      <.0001   exposed
a3              -0.9207     0.1744     -5.28      <.0001   participant
a4             0.001484   0.000898      1.65      0.1004   fertilizer
a5             0.004638    0.00219      2.11      0.0360   seed
Number of Observations     Statistics for System
Used               167    Objective        0.7330
Missing              0    Objective*N    122.4175
                            Heteroscedasticity Test
Equation      Test             Statistic   DF  Pr > ChiSq  Variables
dlpce         White's Test          7.69   11      0.7410  Cross of all vars

              Breusch-Pagan         0.04    1      0.8354  1, dlpce
```

(c) Gross margin function

```
The SAS System                              13:12 Tuesday, December 8, 2009   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                      Adj
```

```
Equation       Model   Error        SSE        MSE   R-Square      R-Sq
dlgme              5     162    49.5079     0.3056     0.4311    0.4171
                       Nonlinear OLS Parameter Estimates

                            Approx                Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a1             0.102846     0.0897      1.15      0.2534   constant
a2             0.097335     0.1077      0.90      0.3672   exposed
a3             0.210283     0.1112      1.89      0.0603   participant
a4             -0.00163   0.000523     -3.11      0.0022   fertilizer
a5             -0.00164   0.000158    -10.36      <.0001   labour
Number of Observations     Statistics for System
Used              167    Objective        0.2965
Missing             0    Objective*N     49.5079
                            Heteroscedasticity Test
Equation      Test             Statistic   DF  Pr > ChiSq  Variables
dlgme         White's Test         27.05   11      0.0045  Cross of all vars
              Breusch-Pagan        68.56    1      <.0001  1, dlgme
```

A- 4: Test of Serial Correlation for Three-period DD Models

(a) Yield function

```
The SAS System                          14:38 Friday, February 9, 2007   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                        Adj
Equation       Model   Error        SSE        MSE   R-Square      R-Sq

dlncyld           17     463     1.3699    0.00296     0.6545    0.6425

                       Nonlinear OLS Parameter Estimates
                            Approx                Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a1             -0.04255    0.00956     -4.45      <.0001   constant
a2              -0.0615    0.00843     -7.30      <.0001   county1
a3             -0.04579    0.00915     -5.01      <.0001   county2
a4             -0.00586    0.00698     -0.84      0.4018   exposed
a5             0.015168    0.00687      2.21      0.0278   participant
a6             0.000982   0.000095     10.36      <.0001   insecticide
a7             0.001731   0.000708      2.44      0.0149   fungicide
a8             0.006363   0.000710      8.96      <.0001   herbicide
a9             0.000166   0.000029      5.80      <.0001   fertilizer
a10            -0.00005   0.000118     -0.38      0.7029   irrigation
a11             0.00023   0.000035      6.55      <.0001   labor
a12            -0.01564     0.0155     -1.01      0.3127   cotton share
a13            0.000665   0.000861      0.77      0.4401   ability to recognize pests
                                                           and beneficial organisms
a14            -0.00196     0.0123     -0.16      0.8736   Bt
a15            0.005878     0.0160      0.37      0.7142   exposed*Bt
a16            -0.00306     0.0166     -0.18      0.8542   participant*Bt
a17            -0.01996     0.0143     -1.39      0.1642   residue

Number of Observations     Statistics for System
Used                480    Objective       0.002854
Missing               0    Objective*N       1.3699
```

(b) Insecticide function

```
The SAS System                          14:38 Friday, February 9, 2007   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                        Adj
Equation       Model   Error        SSE        MSE   R-Square      R-Sq
dlncincid         15     465    64.9737     0.1397     0.6315    0.6204
                       Nonlinear OLS Parameter Estimates

                            Approx                Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a1             -0.11884     0.0689     -1.73      0.0852   constant
a2             0.097232     0.0515      1.89      0.0598   county1
a3             0.617321     0.0466     13.24      <.0001   county2
a4              0.10114     0.0482      2.10      0.0364   exposed
a5             -0.03765     0.0472     -0.80      0.4255   participant
a6             -0.02265     0.0142     -1.60      0.1104   insecticide price
a7             -0.03917    0.00487     -8.05      <.0001   herbicide
a8              0.00223   0.000174     12.82      <.0001   fertilizer
```

a9	0.001464	0.000237	6.17	<.0001	labor
a10	-0.16838	0.0993	-1.70	0.0906	farm size
a11	0.006243	0.00595	1.05	0.2943	ability to recognize pests and beneficial organisms
a12	-0.00111	0.0843	-0.01	0.9895	Bt
a13	-0.07816	0.1088	-0.72	0.4730	exposed*Bt
a14	0.01069	0.1144	0.09	0.9256	participant*Bt
a15	-0.19648	0.0291	-6.75	<.0001	residue

Number of Observations		Statistics for System	
Used	480	Objective	0.1354
Missing	0	Objective*N	64.9737

A- 5: Test of Heteroscedasticity for Multi-period DD Models

(a) Yield function

```
The SAS System                               16:42 Friday, February 9, 2007   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                      Adj
Equation       Model   Error        SSE        MSE   R-Square      R-Sq
dlncyld           19     941    17.7865     0.0189     0.3681    0.3560
                       Nonlinear OLS Parameter Estimates
                            Approx              Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a1             0.110446     0.0155      7.12      <.0001   constant
a2             -0.15594     0.0178     -8.78      <.0001   period
a3             0.008362     0.0130      0.64      0.5194   county1
a4             -0.03261     0.0125     -2.60      0.0094   county2
a5             0.033694     0.0176      1.91      0.0559   exposed
a6             -0.01252     0.0163     -0.77      0.4419   exposed*period
a7             0.080862     0.0203      3.99      <.0001   participant
a8             0.000852     0.0160      0.05      0.9576   participant*period
a9             0.000063   0.000114      0.55      0.5797   insecticide
a10            0.001366    0.00120      1.14      0.2543   fungicide
a11            0.000385    0.00103      0.37      0.7078   herbicide
a12            0.000182   0.000047      3.85      0.0001   fertilizer
a13            0.000103   0.000207      0.50      0.6194   irrigation
a14            0.000136   0.000034      3.96      <.0001   labor
a15            -0.04147     0.0285     -1.46      0.1457   cotton share
a16            0.000781    0.00173      0.45      0.6514   ability to recognize pests
                                                           and beneficial organisms
a17            0.003959     0.0183      0.22      0.8285   Bt
a18            0.028225     0.0247      1.14      0.2533   exposed*Bt
a19            0.041528     0.0254      1.64      0.1020   participant*Bt
Number of Observations     Statistics for System
Used               960    Objective        0.0185
Missing              0    Objective*N     17.7865
                            Heteroscedasticity Test
Equation      Test              Statistic   DF  Pr > ChiSq  Variables
dlncyld       White's Test          332.8  154      <.0001  Cross of all vars

              Breusch-Pagan          8.06    1      0.0045  1, dlncyld
```

(b) Insecticide function

```
The SAS System                               16:42 Friday, February 9, 2007   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                      Adj
Equation       Model   Error        SSE        MSE   R-Square      R-Sq
dlncincid         17     943      280.3     0.2972     0.5727    0.5654
                       Nonlinear OLS Parameter Estimates
                            Approx              Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a1             -0.26538     0.0577     -4.60      <.0001   constant
a2              0.19915     0.0757      2.63      0.0087   period
a3             -0.07687     0.0486     -1.58      0.1142   county1
a4             0.486047     0.0469     10.36      <.0001   county2
a5             -0.51812     0.0686     -7.55      <.0001   exposed
```

a6	0.144473	0.0646	2.24	0.0255	exposed*period
a7	-0.61826	0.0786	-7.87	<.0001	participant
a8	-0.00501	0.0635	-0.08	0.9370	participant*period
a9	-0.02561	0.00975	-2.63	0.0088	insecticide price
a10	-0.00081	0.00403	-0.20	0.8411	herbicide
a11	0.002033	0.000179	11.36	<.0001	fertilizer
a12	0.000671	0.000138	4.86	<.0001	labor
a13	-0.40365	0.1069	-3.78	0.0002	farm size
a14	-0.017	0.00679	-2.50	0.0125	ability to recognize pests and beneficial organisms
a15	-0.10703	0.0719	-1.49	0.1369	Bt
a16	-0.08668	0.0976	-0.89	0.3749	exposed*Bt
a17	-0.16785	0.1003	-1.67	0.0945	participant*Bt

Number of Observations		Statistics for System	
Used	960	Objective	0.2919
Missing	0	Objective*N	280.2588

Heteroscedasticity Test

Equation	Test	Statistic	DF	Pr > ChiSq	Variables
dlncincid	White's Test	244.1	118	<.0001	Cross of all vars
	Breusch-Pagan	0.60	1	0.4386	1, dlncincid

A- 6: Test of Heteroscedasticity for Cross-sectional Yield Functions[32]

(a) Pure Cobb-Douglas

```
2sls results                          15:04 Thursday, May 17, 2007   3
The MODEL Procedure
                Nonlinear 2SLS Summary of Residual Errors
                DF      DF                                          Adj
Equation       Model   Error        SSE        MSE   R-Square      R-Sq
lncincd           70    1049    94.7760     0.0903     0.8227    0.8110
lncyld            72    1047     7.4612    0.00713     0.6427    0.6185
                      Nonlinear 2SLS Parameter Estimates
                            Approx                Approx
Parameter      Estimate    Std Err   t Value     Pr > |t|   Label
a              -1.85732     0.3710     -5.01       <.0001   constant
k1             -0.22698     0.0975     -2.33       0.0201   exposed
k2             -0.03901     0.0452     -0.86       0.3885   exposed*year2
k3              -0.0213     0.0443     -0.48       0.6309   exposed*year3
x1             -0.41857     0.0981     -4.26       <.0001   participant
x2             -0.02076     0.0439     -0.47       0.6365   participant*year2
x3             0.052842     0.0437      1.21       0.2273   participant*year3
b3             0.150195     0.0371      4.05       <.0001   insecticide price
b4             -0.01997     0.0130     -1.53       0.1252   herbicide
b5             0.251276     0.0302      8.31       <.0001   fertilizer
b6              0.63811     0.0633     10.09       <.0001   labor
b7              -0.0903     0.0261     -3.46       0.0006   farm size
b8             -0.07654     0.0193     -3.98       <.0001   experience
b9             0.141694     0.0200      7.07       <.0001   pest pressure
b10            -0.09832     0.0413     -2.38       0.0176   ability to recognize pests
                                                            and beneficial organisms
b11            -0.06098     0.0515     -1.18       0.2370   Bt
b12            -0.03308     0.0234     -1.41       0.1575   education
c              6.133529     0.1235     49.67       <.0001   constant
k4             0.017597     0.0285      0.62       0.5371   exposed
k5             0.014852     0.0131      1.14       0.2564   exposed*year2
k6             0.007881     0.0126      0.62       0.5331   exposed*year3
x4             0.074143     0.0313      2.37       0.0179   participant
x5              0.00571     0.0127      0.45       0.6534   participant*year2
x6             0.002982     0.0124      0.24       0.8095   participant*year3
d3              0.00956    0.00373      2.56       0.0106   herbicide
d4              0.11522     0.0111     10.34       <.0001   fertilizer
d5             0.015781    0.00857      1.84       0.0659   seed
d6             0.170581     0.0287      5.93       <.0001   labor
d7             0.001383    0.00270      0.51       0.6083   irrigation
d8             0.030233    0.00997      3.03       0.0025   other costs
d9             0.032954    0.00862      3.82       0.0001   cotton share
d10            0.007058    0.00609      1.16       0.2465   experience
d11            0.014523     0.0121      1.20       0.2300   ability to recognize pests
                                                            and beneficial organisms
d12            0.038359    0.00672      5.71       <.0001   education
l1             0.016988     0.0345      0.49       0.6224   insecticide
l2              0.01987     0.0148      1.34       0.1805   Bt
Number of Observations     Statistics for System
Used              1119    Objective       0.003643
Missing              0    Objective*N       4.0761
                            Heteroscedasticity Test
```

32 The estimates of township dummies are deleted for brevity.

Equation	Test	Statistic	DF	Pr > ChiSq	Variables
lncincd	White's Test	834.7	697	0.0002	Cross of all vars
	Breusch-Pagan	0.37	1	0.5437	1, lncyld
lncyld	White's Test	932.7	786	0.0002	Cross of all vars
	Breusch-Pagan	1.64	1	0.2007	1, lncyld

(b) Equation (6)

2sls results 15:04 Thursday, May 17, 2007 4

The MODEL Procedure

Nonlinear 2SLS Summary of Residual Errors

Equation	DF Model	DF Error	SSE	MSE	R-Square	Adj R-Sq
lncincd	70	1049	94.7760	0.0903	0.8227	0.8110
lncyld	72	1047	8.0996	0.00774	0.6121	0.5858

Nonlinear 2SLS Parameter Estimates

Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
a	-1.85732	0.3710	-5.01	<.0001	constant
k1	-0.22698	0.0975	-2.33	0.0201	exposed
k2	-0.03901	0.0452	-0.86	0.3885	exposed*year2
k3	-0.0213	0.0443	-0.48	0.6309	exposed*year3
x1	-0.41857	0.0981	-4.26	<.0001	participant
x2	-0.02076	0.0439	-0.47	0.6365	participant*year2
x3	0.052842	0.0437	1.21	0.2273	participant*year3
b3	0.150195	0.0371	4.05	<.0001	insecticde price
b4	-0.01997	0.0130	-1.53	0.1252	herbicide
b5	0.251276	0.0302	8.31	<.0001	fertilizer
b6	0.63811	0.0633	10.09	<.0001	labor
b7	-0.0903	0.0261	-3.46	0.0006	farm size
b8	-0.07654	0.0193	-3.98	<.0001	experience
b9	0.141694	0.0200	7.07	<.0001	pest pressure
b10	-0.09832	0.0413	-2.38	0.0176	ability to recognize pests and beneficial organisms
b11	-0.06098	0.0515	-1.18	0.2370	Bt
b12	-0.03308	0.0234	-1.41	0.1575	education
c	6.387156	0.3334	19.16	<.0001	costant
k4	0.02179	0.0304	0.72	0.4733	exposed
k5	0.014047	0.0134	1.05	0.2955	exposed*year2
k6	0.00348	0.0134	0.26	0.7950	exposed*year3
x4	0.085011	0.0332	2.56	0.0106	participant
x5	0.002021	0.0136	0.15	0.8818	participant*year2
x6	-0.00565	0.0136	-0.41	0.6786	participant*year3
d3	0.011832	0.00436	2.71	0.0067	herbicide
d4	0.114702	0.0110	10.47	<.0001	fertilizer
d5	0.015665	0.00899	1.74	0.0816	seed
d6	0.151648	0.0379	4.01	<.0001	labor
d7	0.002448	0.00285	0.86	0.3906	irrigation
d8	0.028607	0.00983	2.91	0.0037	other costs
d9	0.028266	0.0103	2.74	0.0062	cotton share
d10	0.006788	0.00624	1.09	0.2771	experience
d11	0.012604	0.0128	0.98	0.3253	ability to recognize pests and beneficial organisms
d12	0.038886	0.00695	5.60	<.0001	education
l1	0.054255	0.0190	2.86	0.0044	insecticide
l2	1.4	1.2717	1.10	0.2712	Bt

Number of Observations		Statistics for System	
Used	1119	Objective	0.003636
Missing	0	Objective*N	4.0692

Heteroscedasticity Test

Equation	Test	Statistic	DF	Pr > ChiSq	Variables
lncincd	White's Test	834.7	697	0.0002	Cross of all vars

	Breusch-Pagan	0.37	1	0.5437	1, lncyld
lncyld	White's Test	1031	799	<.0001	Cross of all vars
	Breusch-Pagan	0.03	1	0.8544	1, lncyld

(c) Equation (7)

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The MODEL Procedure

Nonlinear OLS Summary of Residual Errors

Equation	DF Model	DF Error	SSE	MSE	R-Square	Adj R-Sq
lncincd	70	1049	94.7760	0.0903	0.8227	0.8110
lncyld	72	1047	7.4817	0.00715	0.6417	0.6174

Nonlinear OLS Parameter Estimates

Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
a	-1.85732	0.3710	-5.01	<.0001	constant
k1	-0.22698	0.0975	-2.33	0.0201	exposed
k2	-0.03901	0.0452	-0.86	0.3885	exposed*year2
k3	-0.0213	0.0443	-0.48	0.6309	exposed*year3
x1	-0.41857	0.0981	-4.26	<.0001	participant
x2	-0.02076	0.0439	-0.47	0.6365	participant*year2
x3	0.052842	0.0437	1.21	0.2273	participant*year3
b3	0.150195	0.0371	4.05	<.0001	insecticde price
b4	-0.01997	0.0130	-1.53	0.1252	herbicide
b5	0.251276	0.0302	8.31	<.0001	fertilizer
b6	0.63811	0.0633	10.09	<.0001	labor
b7	-0.0903	0.0261	-3.46	0.0006	farm size
b8	-0.07654	0.0193	-3.98	<.0001	experience
b9	0.141694	0.0200	7.07	<.0001	pest pressure
b10	-0.09832	0.0413	-2.38	0.0176	ability to recognize pests and beneficial organisms
b11	-0.06098	0.0515	-1.18	0.2370	bt
b12	-0.03308	0.0234	-1.41	0.1575	education
c	6.282368	0.1040	60.39	<.0001	costant
k4	0.01809	0.0275	0.66	0.5108	exposed
k5	0.013931	0.0129	1.08	0.2791	exposed*year2
k6	0.006704	0.0126	0.53	0.5935	exposed*year3
x4	0.074012	0.0279	2.66	0.0080	participant
x5	0.005117	0.0125	0.41	0.6830	participant*year2
x6	0.002559	0.0123	0.21	0.8356	participant*year3
d3	0.009764	0.00367	2.66	0.0080	herbicide
d4	0.115734	0.00883	13.11	<.0001	fertilizer
d5	0.015843	0.00858	1.85	0.0650	seed
d6	0.172116	0.0182	9.47	<.0001	labor
d7	0.001522	0.00270	0.56	0.5733	irrigation
d8	0.030947	0.00829	3.73	0.0002	other costs
d9	0.033066	0.00754	4.38	<.0001	cotton share
d10	0.006651	0.00545	1.22	0.2225	experience
d11	0.014441	0.0117	1.24	0.2164	ability to recognize pests and beneficial organisms
d12	0.038306	0.00658	5.82	<.0001	education
l1	0.117	0.1008	1.16	0.2458	insecticide
l2	0.042357	0.0653	0.65	0.5165	Bt

Number of Observations		Statistics for System	
Used	1119	Objective	0.0914
Missing	0	Objective*N	102.2577

Heteroscedasticity Test

Equation	Test	Statistic	DF	Pr > ChiSq	Variables
lncincd	White's Test	834.7	697	0.0002	Cross of all vars
	Breusch-Pagan	0.37	1	0.5437	1, lncyld

lncyld	White's Test	940.1	799	0.0004	Cross of all vars
	Breusch-Pagan	1.65	1	0.1987	1, lncyld

(d) Equation (8)

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The MODEL Procedure

Nonlinear 2SLS Summary of Residual Errors

Equation	DF Model	DF Error	SSE	MSE	R-Square	Adj R-Sq
lncincd	70	1049	94.7760	0.0903	0.8227	0.8110
lncyld	69	1050	7.9735	0.00759	0.6182	0.5934

Nonlinear 2SLS Parameter Estimates

Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
a	-1.85732	0.3710	-5.01	<.0001	constant
k1	-0.22698	0.0975	-2.33	0.0201	exposed
k2	-0.03901	0.0452	-0.86	0.3885	exposed*year2
k3	-0.0213	0.0443	-0.48	0.6309	exposed*year3
x1	-0.41857	0.0981	-4.26	<.0001	participant
x2	-0.02076	0.0439	-0.47	0.6365	participant*year
x3	0.052842	0.0437	1.21	0.2273	participant*year
b3	0.150195	0.0371	4.05	<.0001	insecticde price
b4	-0.01997	0.0130	-1.53	0.1252	herbicide
b5	0.251276	0.0302	8.31	<.0001	fertilizer
b6	0.63811	0.0633	10.09	<.0001	labor
b7	-0.0903	0.0261	-3.46	0.0006	farm size
b8	-0.07654	0.0193	-3.98	<.0001	experience
b9	0.141694	0.0200	7.07	<.0001	pest pressure
b10	-0.09832	0.0413	-2.38	0.0176	ability to recognize pests and beneficial organisms
b11	-0.06098	0.0515	-1.18	0.2370	Bt
b12	-0.03308	0.0234	-1.41	0.1575	education
c	6.383946	0.2478	25.76	<.0001	costant
k4	0.04361	0.0315	1.39	0.1659	exposed
x4	0.05833	0.0298	1.96	0.0508	participant
d3	0.011667	0.00422	2.76	0.0058	herbicide
d4	0.112368	0.0102	11.06	<.0001	fertilizer
d5	0.013066	0.0100	1.30	0.1931	seed
d6	0.165789	0.0249	6.66	<.0001	labor
d7	0.001721	0.00275	0.63	0.5319	irrigation
d8	0.028522	0.00946	3.02	0.0026	other costs
d9	0.033749	0.00919	3.67	0.0003	cotton share
d10	0.008667	0.00593	1.46	0.1442	experience
d11	0.007982	0.0129	0.62	0.5363	ability to recognize pests and beneficial organisms
d12	0.038295	0.00719	5.33	<.0001	education
l1	0.035616	0.0113	3.16	0.0016	insecticide
l2	1.387849	0.7550	1.84	0.0663	Bt
l3	0.259605	1.2274	0.21	0.8325	ginteraction

Number of Observations		Statistics for System	
Used	1119	Objective	0.003642
Missing	0	Objective*N	4.0751

Heteroscedasticity Test

Equation	Test	Statistic	DF	Pr > ChiSq	Variables
lncincd	White's Test	834.7	697	0.0002	Cross of all vars
	Breusch-Pagan	0.37	1	0.5437	1, lncyld
lncyld	White's Test	931.2	749	<.0001	Cross of all vars
	Breusch-Pagan	0.22	1	0.6386	1, lncyld

A- 7: Test of Heteroscedasticity for Cross-sectional Insecticide Functions[33]

(a) Linear

```
2sls results                          11:34 Saturday, May 19, 2007   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                      Adj
Equation       Model   Error       SSE       MSE   R-Square      R-Sq
cincd             70    1049    667419     636.2     0.6867    0.6661
                       Nonlinear OLS Parameter Estimates
                            Approx               Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label
a              -23.2489     9.7513     -2.38      0.0173   constant
k1              -10.003     8.1682     -1.22      0.2210   exposed
k2             -5.61898     3.7906     -1.48      0.1386   exposed*year2
k3             -7.95441     3.7239     -2.14      0.0329   exposed*year3
x1             -26.1321     8.2461     -3.17      0.0016   participant
x2              -2.0796     3.6924     -0.56      0.5734   participant*year2
x3             0.097969     3.6770      0.03      0.9787   participant*year3
b3              1.51102     0.5056      2.99      0.0029   insecticde price
b4             -0.38003     0.2422     -1.57      0.1170   herbicide
b5             0.067794    0.00712      9.52      <.0001   fertilizer
b6             0.133871     0.0153      8.76      <.0001   labor
b7             -4.44076     1.4889     -2.98      0.0029   farm size
b8             -6.55764     1.6167     -4.06      <.0001   experience
b9             12.68539     1.6769      7.56      <.0001   pest pressure
b10            -1.11786     0.3668     -3.05      0.0024   ability to recognize pests
                                                           and beneficial organisms
b11            -7.92604     4.3191     -1.84      0.0668   bt
b12            -0.45043     0.3543     -1.27      0.2038   education
Number of Observations     Statistics for System
Used             1119    Objective       596.4419
Missing             0    Objective*N       667419
                            Heteroscedasticity Test
Equation      Test             Statistic   DF  Pr > ChiSq  Variables
cincd         White's Test         884.2  697      <.0001  Cross of all vars
              Breusch-Pagan        149.3    1      <.0001  1, cincd
```

(b) Cobb-Douglas

```
2sls results                          11:34 Saturday, May 19, 2007   3
The MODEL Procedure
                Nonlinear OLS Summary of Residual Errors
                  DF      DF                                      Adj
Equation       Model   Error       SSE       MSE   R-Square      R-Sq
lncincd           70    1049   94.7760    0.0903     0.8227    0.8110
                       Nonlinear OLS Parameter Estimates
                            Approx               Approx
Parameter      Estimate    Std Err   t Value    Pr > |t|   Label

a              -1.85732     0.3710     -5.01      <.0001   constant
k1             -0.22698     0.0975     -2.33      0.0201   exposed
k2             -0.03901     0.0452     -0.86      0.3885   exposed*year2
k3              -0.0213     0.0443     -0.48      0.6309   exposed*year3
x1             -0.41857     0.0981     -4.26      <.0001   participant
```

33 The estimates of township dummies are deleted for brevity.

x2	-0.02076	0.0439	-0.47	0.6365	participant*year2
x3	0.052842	0.0437	1.21	0.2273	participant*year3
b3	0.150195	0.0371	4.05	<.0001	insecticde price
b4	-0.01997	0.0130	-1.53	0.1252	herbicide
b5	0.251276	0.0302	8.31	<.0001	fertilizer
b6	0.63811	0.0633	10.09	<.0001	labor
b7	-0.0903	0.0261	-3.46	0.0006	farm size
b8	-0.07654	0.0193	-3.98	<.0001	experience
b9	0.141694	0.0200	7.07	<.0001	pest pressure
b10	-0.09832	0.0413	-2.38	0.0176	ability to recognize pests and beneficial organisms
b11	-0.06098	0.0515	-1.18	0.2370	Bt
b12	-0.03308	0.0234	-1.41	0.1575	education

Number of Observations		Statistics for System	
Used	1119	Objective	0.0847
Missing	0	Objective*N	94.7760

Heteroscedasticity Test

Equation	Test	Statistic	DF	Pr > ChiSq	Variables
lncincd	White's Test	834.7	697	0.0002	Cross of all vars
	Breusch-Pagan	14.80	1	0.0001	1, lncincd

A- 8: Test of Selection Bias with County Dummies[34]

Insecticide (FFS participants vs control farmers)

```
Heckman selection model -- two-step estimates   Number of obs      =      1119
(regression model with sample selection)        Censored obs       =       205
                                                Uncensored obs     =       914

                                                Wald chi2(18)      =    866.51
                                                Prob > chi2        =    0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lncincd						
county1	-1.499432	.0771433	-19.44	0.000	-1.65063	-1.348234
county2	-.4030214	.0744709	-5.41	0.000	-.5489817	-.257061
county3	.5074351	.1010457	5.02	0.000	.3093892	.705481
county4	-.2647746	.0648026	-4.09	0.000	-.3917853	-.1377639
county5	-.2358448	.0853001	-2.76	0.006	-.40303	-.0686596
county6	-.2824132	.073161	-3.86	0.000	-.4258061	-.1390203
county8	-.124468	.0719174	-1.73	0.084	-.2654236	.0164875
county9	.0221224	.0736415	0.30	0.764	-.1222124	.1664571
lnipric	.146046	.0594614	2.46	0.014	.0295037	.2625883
lnchcdt	-.0230498	.0218592	-1.05	0.292	-.065893	.0197934
lncalfrt	.2764256	.0493662	5.60	0.000	.1796696	.3731817
lnralab	.68676	.0987826	6.95	0.000	.4931496	.8803704
lnfsize	-.0828192	.0421925	-1.96	0.050	-.165515	-.0001234
dexp	-.0912128	.0363576	-2.51	0.012	-.1624725	-.0199532
dpress	.1529806	.034147	4.48	0.000	.0860537	.2199075
lnreg	-.2173889	.0550055	-3.95	0.000	-.3251977	-.1095801
bt	-.1037911	.0884848	-1.17	0.241	-.277218	.0696358
lneducat	-.0271934	.0443539	-0.61	0.540	-.1141255	.0597386
_cons	-.5476312	.5996909	-0.91	0.361	-1.723004	.6277415
ffs						
dist	-.0276475	.0061029	-4.53	0.000	-.039609	-.0156859
schl	-.0361758	.1374162	-0.26	0.792	-.3055066	.2331551
kiosk	.1338334	.1314218	1.02	0.309	-.1237486	.3914154
cshar	.3168904	.1875306	1.69	0.091	-.0506628	.6844436
fsize	.0431752	.0555776	0.78	0.437	-.065755	.1521053
exp	.0012122	.0072926	0.17	0.868	-.0130809	.0155054
_cons	1.081594	.2683155	4.03	0.000	.5557049	1.607482
mills						
lambda	-.5970005	.2632782	-2.27	0.023	-1.113016	-.0809846
rho	-1.00000					
sigma	.59700048					
lambda	-.59700048	.2632782				

34 Tests were also conducted for insecticide (Control farmers vs FFS participants) and for yields between FFS participants and control farmers. The only one test presenting significant estimate for inverse Mills ratio is presented in appendix 8.

A- 9: Season Long Survey Form for Impact Assessment

Name of Province:______________Name of County_____________________
Name of Township:______________Name of Village______________________
Name of enumerator_____________Name of Householder:_________________
Name of Respondent_______Gender_____Educational level______Age________

1. Land preparation and sowing

Plot	Area (667m^2)	Method of land preparation	Method of sowing (Direct or nutrition pot)	Total Labor input (personday)*	
				Home	Hired
1					
2					
3					
4					
5					
6					
7					
8					

Note: * 1 personday = 8 hours

2. Cotton varieties and seed input

Plot	Area (667m^2)	Variety	Seed source	Seed amount (500 g)	Seed cost (¥/500g)
1					
2					
3					
4					
5					
6					
7					
8					

3. Fertilizer used in cotton field

Date	Fertilizer kind (Incl. manure)	Area applied to (667m^2)	Labor input (personday)		Fertilizer amount (500g/500ml)	Fertilizer cost (¥/500g)
			Home	Hired		

4. Pesticide used to control pest

Date	Trade name of pesticide	Target pest	Area sprayed ($667m^2$)	Labor input (personday)		Pesticide amount (500g/500ml)	Pesticide cost (¥/500g)
				Home	Hired		

Note: 1 personday = 8 hours

5. Irrigation

Date	Cost (incl. cost of fuel, water fee, excl. labor) (¥)	Labor (personday)	
		Home	Hired

Note: 1 personday = 8 hours

6. De-topping, harvest and other field managing activities

Date	Activity	Labor (personday*)	
		Home	Hired

Note: 1 personday = 8 hours

7. Cost for machinery

Kind of machine	Self owned		Co-shared with other households		Rent if rented (¥)
	Duration	Cost (¥)	Duration	Cost (¥)	
Knapsack sprayer					
Motor sprayer					
Transportation					
Land preparation					
Irrigation					
Others					

8. Pesticide poisoning during agricultural activities

Name of victim	Date	Symptoms	Loss of working time (personday)	Cost for healing (¥)

9. Participation in farmer training (farmer field school, on-spot meeting, night school, green certificate)

Kind of training	Sponsor organization	Date	Impact on pest control strategy	Voluntary or not

10. Cotton yields and incomes

Date	Amount of seed cotton harvested (500g)	Cotton sales	
		Amount of seed cotton sold (500g)	Selling price for seed cotton (¥/500g)

A- 10: Questionnaires on Pest Control Knowledge

1) How long has your family grown cotton?___________Years.

2) What do you think of the pest pressure on cotton this year?

□More serious than usual ( ) □lighter then usual ( )

□the same as usual ( )

3) What is the first consideration when choosing cotton variety?

□high yield ( ) □good quality ( ) □pest resistant ( ) □early maturity ( )

□moderate maturity ( ) □late maturity ( )

4) What kinds of pests do you recognize? (if you recognize more, please add more numbering and specify the pests)

□ □ □ □ □

□ □ □ □ □

5) What kinds of natural enemies that you recognize? (if you recognize more, please add more numbering and specify the natural enemies)

□ □ □ □ □

□ □ □ □ □

6) According to what do you make your decision on pest control?

□own perception ( ) □neighbors ( ) □control index ( ) □following government notice ( ) □regular application of pesticide for certainty ( ) □following agro-technician ( ) □field survey ( ) □following mass media ( ) □others ( )

7) What measure will you take when aphid is found in your cotton field?

□immediate application of pesticide □to count aphides through field survey

□to count aphides and natural enemies in the field □ no action to be taken

8) What is the principal source of the information on pest?

□TV ( ) □broadcast ( ) □poster ( ) □handout ( ) □ neighbor or relative ( )

□village meeting held by agro-technical station after forecasting ( ) □house visit by agro-technician ( ) □newspaper ( ) □others ( )

9) Do you conduct survey of pest occurrence in the field before applying pesticide?
□to have a look on the ridge ( ) □to conduct survey in field ( ) □ask other to have a look ( ) □no survey at all ( )

10) Is it possible to control pest without pesticide?
□Yes ( ) □No ( ) □I don't know ( )

11) What measure do you take besides the application of pesticide to control pests?
□ □ □ □ □

12) Do you think there will be yield loss without pest control :
□much loss ( ) □some loss but not a big problem ( ) □no loss ( )
□I don't know ( )

13) What measures do you take to control weeds?
□by hand ( ) □herbicide ( ) □by hand and herbicide ( ) □no weeding ( )

14) According to what do you select pesticides?
□recommended by agro-technicians ( ) □recommended by cooperative ( ) □self perception ( ) □recommended by neighbor or relative ( ) □try using after having a look at the label ( ) □following book, journal, newspaper, TV, radio and broadcast ( ) □ commercial advertisement ( ) □others ( )

15) How many surveys do you conduct in the field in one cotton season?
□no survey ( ) □regular survey ( ) □non-regular survey ( ) □others ( )

16) When is the first application of pesticide in cotton field?
□before May 1 □before June 1 □before July 1