Technologies Adoption in Vegetable Production in Northern Thailand

Der Wirtschaftswissenschaftlichen Fakultät nader

Gottfried Wilhelm Leibniz Universität Hannover

zur Erlangung des akademischen Grades

Doktorin der Wirtschaftswissenschaften

– Doctor rerum politicarum –

genehmigte Dissertation

von

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2008

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Tag der Promotion: 19.09.2008

Dedication

This thesis is dedicated to my family and my boyfriend, Sombat, Nuanta, Nantaya and Somnuek for their absolute love.

Acknowledgements

First of all, I would like to express my great appreciation to the German Academic Exchange Service (DAAD) for the PhD scholarship and to the German Research Foundation (DFG) for funding support of part of the data collection. Without these two institutions, this dissertation would not have been possible.

My most grateful thanks go to my supervisor, Prof. Dr. Hermann Waibel, for untiring support in the PhD programme, for stimulating and constructive comments, and for his valuable time in listening and teaching me in many different ways. His helpfulness extended not only to the study but also to everything I have confronted during my life's journey in Germany. Special appreciation and thanks go to Prof. Dr. Ulrike Grote, my second supervisor at the Institute for Environmental Economics and World Trade for her valuable comments and advice. My thanks also go to Prof. Dr. Erich Schmidt for his recommendation letter, and to Assist. Prof. Dr. Suwanna Praneetvatakul for her introduction and encouragement that led me to study in Germany.

Without the collaboration and general support from the Royal Project Foundation (RPF) and numerous vegetable producers living in the area of RPF, this dissertation could not have been completed. My great appreciation is extended to the Thai vegetable experts of Thai government agencies (DOA and DOAE), NGOs and private agencies. I am grateful to the enumerators, the students from Chiang Mai University and Maejoe University in Thailand, for data collection. I am indebted to my employer, Khon Kaen University, for permission to study for a PhD and for assistance and institutional support during the field survey. Special thanks also go to Kasetsart University for its close collaboration in the research project.

A note of thanks is expressed to my colleagues at the Institute of Development and Agricultural Economics for their valuable comments. I also thank my German best friend, Dr. H. Garming, Mr. Erwid Perez Valdivia and their little daughter Eva Perez Valdivia for sharing the best and worst moments of my life in Germany. I am very grateful to Ms. Piyatat Pananurak, Mrs. Palida Rauf, Mr. Kidsadakorn Pringproa, Ms. Somporn Techangamsuwann, the Boonyadireckul family, Ms. Yaowarat Sriwaranan, Ms. Anja Christina Fasse, and the Hardeweg family, who always kindly support me. Deep appreciation goes to Ms. Songporne Tongruksawattana, who never

failed to give me some comments on my dissertation and shared all events in my life.
Special thanks and deep appreciation go to Assist. Prof. Dr. Penporn Janekarnkit, my former lecturer, for her continuous support and valuable suggestions. Without her love and teachings on how to live, I could not have become strong enough to reach this goal.

Last but not least, deep appreciation goes to my family for the unconditional love that always supports me and helps me to overcome all possible adverse situations. I also want to thank my boyfriend, Somnuek Athipanyakul, for his patience and assistance in my PhD journey. He always shares the best and worst moments with me. Without his support I could have never completed this journey.

Thanaporn Krasuaythong

Hannover, September 2008

Zusammenfassung

Die vorliegende Arbeit zielt darauf ab, den Effekt der Teilnahme an Programmen zur Verbesserung des Wissens und der Adoption sicherer Gemüseproduktionspraktiken in Nordthailand zu analysieren. Die gegenwärtige Situation der landwirtschaftlichen Produktionstechnologien, besonders die des Gemüseanbaus, schädigt nicht nur die menschliche Gesundheit sondern auch die Umwelt. Folglich besteht die Herausforderung darin, dass die Produzenten ihre vorhandenen Anbaupraktiken durch die Adoption sicherer und umweltfreundlicherer Praktiken ändern müssen. Die Zielstellung der vorliegenden Arbeit ist folgende: (i) die Identifikation der Faktoren, welche die Gemüseproduzenten veranlasst, an Programmen zu sichereren Anbauverfahren teilzunehmen; (ii) den Effekt der Programmteilnahme in Bezug auf Wissensverbesserung zu überprüfen; (iii) die Rolle des Wissens in der Adoption von sichereren Anbaupraktiken zu spezifizieren; und (iv) diese Gemüseanbauverfahren im Hinblick auf Standards, die durch Experten in Thailand formuliert wurden, zu bewerten. Die Daten, welche für die Schätzung der Modelle verwendet wurden, stammen hauptsächlich aus zwei Quellen: (i) eine Befragung von 300 Gemüseproduzenten in der Provinz Chiang Mai in Nordthailand und (ii) aus Expertengesprächen im Rahmen eines Workshops und weiteren Befragungen von insgesamt 23 Experten in Bezug auf den Gemüsebau in Thailand. Es wird die Hypothese aufgestellt, dass die Teilnahme der Gemüseproduzenten an solchen Programmen deren Wissen verbessert und diese dadurch veranlasst werden, sicherere Anbaupraktiken zu übernehmen.

Der methodische Rahmen der vorliegenden Arbeit liefert eine Konzeption der Rolle der Beratungssysteme als Übermittler von wissensintensiven Technologien. Dabei wurde in mehreren Schritten vorgegangen. Zuerst wurde eine *Probit-Regression* geschätzt, die mögliche Cluster-Effekte innerhalb der Daten durch die Berechnung des robusten Standardfehlers einbezog, um die Determinanten einer Programmteilnahme zu identifizieren. Anschließend wurde ein so genanntes *Treatment-Effekt-Model* angewendet, um Probleme bezüglich der Verzerrung der Stichprobenauswahl und der Endogenität zu berücksichtigen. Ziel war es, den Effekt der Teilnahme auf die Verbesserung des Wissens zu identifizieren. Zum Schluss wurde ein *zweistufiges simultanes Schätzverfahren* angewendet, um die Verbindung zwischen der Teilnahme an Beratungsprogrammen, der Verbesserung des Wissens und der Adoption sicherer Anbauverfahren zu identifizieren. Diesbezüglich wurden

zwei Modelle miteinander verglichen: (i) das *gewichtete Practice-Score-Modell*, in dem die Schlüssel-Praktiken, welche durch die Expertengespräche identifiziert wurden, in einem Mittelwert anhand einer gewichteten aggregierten Adoptionsskala zusammengefasst wurden; (ii) das *ungewichtete Practice-Score-Modell,* in dem die derselben Praktiken als Proxy der Adoption genutzt wurde. Dieser Vergleich erlaubt die Bewertung der Standards aus Sicht der Experten mit der Situation in den Gemüsebaubetrieben.

Die Ergebnisse der *Probit-Regression* zeigten, dass die Entscheidung der Gemüseproduzenten, an Programmen zu sichereren Anbauverfahren teilzunehmen davon abhängt, ob der Gemüseanbau eine Haupteinnahmequelle darstellt oder nicht. Als weiterer Faktor wurde der Einfluss des Marktes identifiziert, d.h. wenn der Käufer eine Überprüfung der Pestizidrückstände am Produkt verlangt.

Im zweiten Modell erfolgte die Abschätzung der Wirkung einer Programmteilnahme auf das Wissen der Teilnehmer. Dabei wurde die Robustheit des Modells durch die Anwendung verschiedener Tests bestätigt, welche die nicht-zufällige Stichprobenauswahl berücksichtigten. Die Ergebnisse des Modells bestätigen die statistischen Vergleiche zwischen den Programmteilnehmern und den Nicht-Teilnehmern. Es zeigt sich ein Unterschied im Wissen zwischen den beiden Gruppen, besonders in Bezug auf das Wissen über komplexere Praktiken wie den Gebrauch von organischen Pestiziden und dem Einsatz von Nützlingen. Weitere signifikante Variable waren das Bildungsniveau, die Erfahrung im Anbau von Gemüse sowie die Weitergabe von Informationen unter den Landwirten selbst.

Das abschließende Modell eines *zwei-stufigen simultanen Schätzverfahrens zeigte, dass* im Vergleich von zwei Modellen dieselben Faktoren die Adoption erklären, lediglich das Ausmaß der Effekte ist unterschiedlich. Die Teilnahme an Beratungsprogrammen stellt einen signifikanten Faktor dar, wodurch nicht nur das Wissen erweitert, sondern auch die Adoption sicherer Praktiken stimuliert wird. Daraus kann geschlossen werden, dass die Verbesserung des Wissens eine Vorbedingung der Adoption von wissensintensiven Technologien darstellt. Die Ergebnisse zeigen auch, dass sich die Adoption auf komplexere Praktiken konzentriert, was durch die höheren Koeffizienten im gewichteten Modell nachgewiesen werden konnte. Weiterhin konnte gezeigt werden, dass solche wissensintensive Anbauverfahren arbeitsintensiver sind.

Die Ergebnisse des *stufenweisen Verfahrens* erlauben es, einige Schlussfolgerungen zu ziehen: (i) Bei einer Förderung verbesserter landwirtschaftlicher Anbautechnologien, besonders im Gemüseanbau, sind Bildung und Erfahrung wichtig bezüglich der Entscheidung, eine bestimmte Anbaumethode zu adoptieren (ii) die Rolle der Marktakteure, welche kaum in der Adoptionsliteratur erwähnt wird, z.B. die Forderungen der Käufer, das jeweilige Produkt auf Pestizidrückstände zu überprüfen, hat einen Einfluss auf die Nachfrage bezüglich der Wissenserweiterung für sicherere Verfahren. Folglich sollte sich die Entwicklung eines Trainingsprogramms für Gemüseproduzenten nicht nur auf Kulturpflanzen- und Pflanzenschutzaspekte konzentrieren sondern auch Aspekte der Vermarktung einzubeziehen.

Die Ergebnisse der vorliegenden Arbeit erlauben es auch, Empfehlungen in Bezug auf die Forschung zu geben. Erstens, die Adoption komplexerer und sicherer Anbautechnologien im Gemüsebau ist ein arbeitsintensiver Vorgang. Deshalb sollten beispielsweise Feldbeobachtungstechniken die von Wissenschaftlen entwickelt werden, einen guten Kompromiss zwischen Zeitaufwand und der Genauigkeit der zu erhebenden Beobachtungen anstreben. Zweitens bedarf es besserer Konzepte um die Entwicklung lokaler Märkte für biologische Schädlingskontrolle zu fördern.

Abschließend wird darauf hingewiesen, dass zukünftige Ansätze zur Adoptionsforschung in der Landwirtschaft in Entwicklungsländern dynamische Prozesse einbeziehen und durch neuere Erkenntnisse aus der Verhaltenstheorie erweitert werden sollten.

Schlagwörter: Gemüsebau, Adoption, Umweltverträglichkeit, Treatment-Effekt-Model, Thailand

Abstract

This study aims to analyse the effect of extension programme participation on knowledge improvement and adoption of safer vegetable production practices by farmers in Northern Thailand. Current agricultural production technologies, especially in vegetables, are damaging both human health and the environment. The challenge therefore is to encourage producers to change their existing practices by adopting safer and more environmentally benign methods. The objectives of the study were: (i) to identify factors affecting vegetable producers' decision-making on whether to participate in extension programmes that promote the use of safer vegetable production practices; (ii) to examine the effect of programme participation on the improvement of knowledge in vegetable producers; (iii) to specify the role of knowledge in the adoption of safer practices; and (iv) to evaluate vegetable producers' practices in the light of standards formulated by experts from research and extension in Thailand. The data used for the estimation of the models came mainly from two sources: (i) a survey of some 300 vegetable producers in the province of Chieng Mai and (ii) consultations with experts via a workshop and a questionnaire administered among some 23 vegetable experts from Thailand. It was hypothesised that programme participation would improve vegetable producers' knowledge and change their methods from conventional practices to safer ones.

The methodological framework applied in this study provides a conceptualization of the role of extension systems in the delivery of knowledge-intensive technologies and how knowledge relates to the adoption of safer vegetable production technologies. First, a probit regression model was developed that took account of the possible clustering effects in the data by calculating the robust standard error, and was used to identify the determinants for programme participation by vegetable producers. Thereafter, the treatment effect model that accounts for the problems of selection biases and endogeneity was applied determine the effect of programme participation on knowledge improvement. Finally, a simultaneous equation procedure was used to establish the link between programme participation, change in knowledge and the adoption of safer practices. At this point, two models were compared: (i) the weighted practice score model where key practices identified by expert consultations were summarized by means of a weighted aggregate adoption scale; (ii) the un-weighted practice score model where the same practices were measured using total count as a proxy for adoption. These comparisons allowed the assessment in the light of expert standards in comparison to the field situation.

Results of the probit model showed that decision of vegetable producers to participate or not in safer practice programme depends on whether vegetable production is the major occupation. Another factor was the influence of the market, namely whether the vegetable buyer requires testing for pesticide residues. If so, that was found to be a motivation for programme participation.

In the second model, the robustness of the models was confirmed by applying different variants that accounted for the non-random nature of the sample. Results from the second model confirmed the statistical comparisons between programme participants and non-participants that reported the difference in knowledge between these groups, especially the knowledge of some complex practices such as the use of bio-pesticides and bio–control agents. Other significant variables were the level of education and experience in vegetable growing. In addition, information dissemination from farmer-to-farmer was also significant.

Finally, the results of the simultaneous equation approach showed that the factors explaining adoption choices are the same in both models, but the magnitude of the effect differs. Programme participation is a significant factor that not only enhances knowledge but also stimulates adoption of safer practices. Therefore, it can be concluded that knowledge improvement is a precursor to the adoption of knowledge-intensive technologies. The results also indicated that adoption was concentrated on the more complex practices, as illustrated by the higher magnitude of the coefficients in the weighted model. Furthermore, it found that use of safer practices require more labour, i.e. they are labour intensive. The occupation and marketing conditions were also found to be barriers to the adoption of safer practices.

The results of this stepwise approach allow some conclusions to be drawn as follows: (i) in a promotion of safer agricultural production technologies, particularly in vegetables, education and experience are important factors that influence producers' adoption decisions; (ii) the role of market agents (that was hardly mentioned in the literature of adoption) is another important factor. For example, the requirement of buyers to test the product for pesticide residues enhances the demand for extension information and knowledge of safer practices. Therefore, development of training programmes for vegetable producers should concentrate on the crop and pest management aspects not only but also take into account the market challenges.

Furthermore, the results of this study suggest some recommendations for research. First, safer practices tend to be more complex and labour intensive, which can be a factor inhibiting their adoption. Hence, technologies developed by scientists should take into account the time limitations faced by farmers in the field situation and ensure that the procedures are an optimal compromise between practical and ideal. A second point is the lack of understanding about the development of optimal market outlets for biological control agents in such a way that these can be readily accessed by vegetable producers. Hence, this aspect should be investigated. Finally, additional adoption research should emphasise a dynamic approach, since the adoption processes is continuous. Also the theory of behavioural economics and decision theories such as cognitive dissonance or prospect theory could be integrated into the adoption model in order to allow more discussion of the adoption process.

Keywords: Vegetable production, adoption, environmental safety, treatment effect model, Thailand.

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List of abbreviations

AAN	Alternative Agricultural Network
AIC	Akaike Information Criterion
AIT	Asian Institute of Technology
ATE	Average Treatment Effect
ATET	Average Treatment Effect on the Treated
AVRDC	Asian Vegetable Research and Development Centre
BIC	Bayesian Information Criterion
CMU	Chiang Mai University
CPD	Co-operative Promotion Department
CP	Charoen Phokaphand Group
DANCED	Danish Cooperation for Environment and Development
DFG	Deutsche Forschung Gemeinschaft
DOA	Department of Agriculture
DOAE	Department of Agricultural Extension
DMSc	Department of Medicine Sciences
DOEP	Department of Export Promotion
DNFE	Department of Non-formal Education
ENF	Green/Earth Net Foundation
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FTL	Farmer Training and Learning Programme
FIML	Full Information Maximum Likelihood
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HYV	High Yield Varieties
KU	Kasetsart University
KKU	Khon Kaen University

IBAFFS	Institute for Biological Agriculture and Farmer Field Schools
IFOAM	International Federation of Organic Agriculture Movement
IMR	Inverse Mill Ratio
IPM	Integrated Pest Management
IPCS	International Programme on Chemical Safety
LDD	Land Development Department
LIML	Limited Information Maximum Likelihood
LR	Likelihood Ratio
LUH	Leibniz University of Hannover
IV	Instrument Variable
MHRP	Mae Hae Royal Project Development Center
MOAC	Ministry of Agriculture and Co-operatives
MOC	Ministry of Commerce
MOE	Ministry of Education
MOPH	Ministry of Public Health
MONRE	Ministry of Resources and Environment
MRL	Maximum Residue Limits
NEBT	National Environment Board of Thailand
NESDP	National Economic and Social Development Plan
NHRP	Nhong Hoi Royal Project Development Center
NGOs	Non-government Organizations
NP	Non-participation
ONFEC	Non-formal Education Commission
ONRE	Office of Natural Resources and Environmental Policy
P	Participation
PSU	Prince of Songkhla University
PS	Propensity Scores
PPCP	Planning and Pollution Control Department
RPF	Royal Project Foundation
ROC	Receiver Operating Characteristic
RU	Ramkhamhaeng University
SAT	Sustainable Agriculture Foundation Thailand

SE	Standard Error
TEF	Thai Education Foundation
2SLS	Two-stage Least Square Approach
WTO	World Trade Organization
WHO	World Health Organization
T&V	Training and Visit System

Chapter 1

Introduction

1.1 Background

In the course of rapid economic development, agriculture in Thailand has changed significantly in the past decades. Following the path of other emerging market economies, the share of agriculture in the Gross Domestic Product (GDP) has decreased from 20% in 1980 to just over 10% in 2005 (Figure1.1). However, the agricultural sector remains an important part of the economy: it helps to assure the country's food supply, it is a source of employment, it makes a significant contribution to the country's export earnings and it plays a stabilizing role in cases of economic crisis.

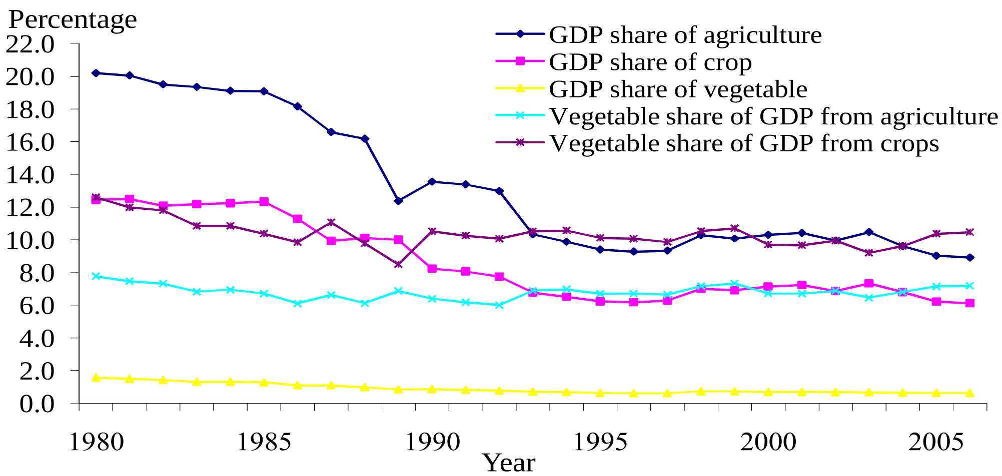

Figure 1.1: Thailand's GDP, GDP share of agriculture and vegetable component in constant 1988 price

Source: (NESDB 2002; NESDB 2006)

The agricultural sector is mainly classified into four sub-sectors; namely crops, livestock, forestry and fisheries. The crop sub-sector has the biggest share of GDP (see also figure1.1). Within the agricultural sector, crops contribute on average over 50% to agriculture GDP. Among all crops, rice still plays a dominant role and occupies almost half of the arable land.

Recently diversification towards other commodities has taken place. In particular, fruits and vegetables have grown rapidly in terms of crop value and have become a major source of cash income for small-scale farmers (ISAVILANONDA 1992; NATH *et al.* 1999). Despite Thai Government support for fruit and vegetable production being given high priority, their share of GDP in agriculture has increased only slightly, especially in the case of vegetables. Since 1980 vegetable share of GDP in agriculture has stayed at 6-8%.

Fruits and vegetables are mostly grown under intensive production conditions, often marked by high levels of chemical inputs such as mineral fertilizer and pesticides. These practices have led to concerns about environmental degradation and food safety. Evidence of such effects has been provided, for example, by a survey carried out by the National Environment Board of Thailand (NEBT). The study found residues of many harmful pesticides used in agricultural production systems in the soil and in the main rivers of the country (THAPINTA and HUDAK 2000). Another study carried out by the Division of Toxic Substances and the Occupational Health Department in 1995 demonstrated the negative effects of chemical pesticides on human health. Results showed that about 37% of vegetable samples were contaminated with insecticide residues, and blood sample taken from growers showed that 18% had unsafe levels of pesticide contamination in their blood. Environmental and human health effects lead to significant costs to the society. In an economic study of pesticide use in Thailand, JUNGBLUTH (1996) estimated that the annual external costs associated with pesticides could reach up to 5.4 billion Baht (over 120 million Euro). A major share of these costs was attributed to residues from vegetables and fruits.

Driven by changing consumer preferences and a higher priority given to environmental issues by the government in the course of Thailand’s path towards becoming a newly industrialized country (NIC), quality and safety issues are becoming more important. In fact the Thai government has recently been promoting its food sector to become what has been labelled as the “*Kitchen of the World*”. The aim is to improve food safety and quality and thereby increase competitiveness in the international food markets, as a selling point for the large tourist industry and also to satisfy the needs of domestic consumers and thus to improve health status of the national population. In this context, vegetables, which comprise a large variety of crops, are of particular interest as food raw materials with a high nutritional value.

Currently, vegetable producers still aim at high levels of productivity, while reducing production risks, such as from pests and diseases. However, the question of quality, safety and negative externalities has not played a major role. The main constraint towards safer, i.e. environmentally more benign, resource conserving, healthier and more sustainable vegetable production is the lack of appropriate technology or their lack of adoption by growers. Generally, the green revolution philosophy has dominated agricultural research and extension systems for a long time and therefore emphasis was given on increasing output and productivity. However, the impressive productivity growth in agriculture during the seventies and the eighties as demonstrated for example in the study of MUNDLAK (2005), has been at the expense of natural resources, wihch have been degraded (DOUTHWAITE *et al.* 2004). This phenomenon has also been confirmed for Thailand where KAOSA-ARD and RERKASEM (2000) shows that the growth in rice productivity has levelled off and may even be declining.

The government of Thailand has recognised the challenge to develop technologies that enable producers to adopt safer production practices and facilitate the production of higher quality, safer and healthier food raw materials and food products. Hence, the Thai government has incorporated natural resource conservation issues into the National Economic and Social Development Plan since 1997(PANYAKUL 2001). Furthermore, programmes have been implemented with the aim of prooting safer technologies and improved practices, primarily through a public participatory extension programme. One major constraint on the large scale adoption of such technologies is that they are knowledge-intensive, i.e. they required a producer’s ability to conduct informed crop management decisions based on a good understanding of the crop ecosystem. For example, in vegetables, good soil fertility management requires information on the nutrient balance of the soil and of the effects of alternative fertility management measures. Similarly, in the management of pests (a major constraint to vegetable production), the producer has to understand the life cycle of pests in order to make judicious control interventions that are effective and at the same time safe for the environment and human health. The role of knowledge as a major component of human capital in agricultural development and productivity growth has long been recognized (SCHULTZ 1975). In recent years, programmes to enhance producer knowledge have followed the principles of participation. Studies to assess the impact of such programmes are methodologically challenging and demand good empirical data as demonstrated in the studies of, for example, PRANEETVATAKUL et al. (2007), DALTON et al. (2005; 2007) and GODTLAND et al. (2003). Also, the efficacy of public investments in such programmes has sometimes been questionable as shown in the research conducted by FEDER et al., (2003; 2004).

A major issue in all impact assessment studies is the question of technology adoption. Generally, good adoption models are needed to understand the factors that drive and limit adoption and diffusion of knowledge-intensive technologies. This is particularly complex in the case vegetables because of the high production rate and land use intensity, with often several crops per year. Thus technology adoption and retention is situation-specific and conditional on the state of the environment. In other words, a technology may be useful in one year but may be the wrong choice if the external conditions change. Therefore, one often finds that producers have knowledge of new technologies but may decline to adopt them or perhaps abandon them.

This research takes up the challenge and aims to provide a methodology that links change in knowledge to change in behaviour and thus changing practices in vegetable production in Thailand. The results of this study could be a guide for policy makers in the development of strategies suitable for achieving a more rapid and more efficient introduction of safer vegetable production technologies. The results may also be relevant for other agricultural systems, with implications for natural resource management.

1.2 Objectives and research questions

The overall objective of this study is to provide an in-depth understanding of vegetable producers' motivation to substitute their conventional, often harmful, production technologies by more environmentally benign and safer practices if the relevant information is offered to them. To achieve this goal it is necessary to find an answer to at least four particular research questions:

1. What are the determinants that encourage producers to participate in extension programmes that promote the use of safer and more environmentally benign production practices?
2. What is the effect of such extension programmes on vegetable producers' knowledge of new practices?
3. Is improved knowledge a significant factor in causing vegetable producers to adopt safer and more environmentally benign practices?

4. To what extent do vegetable producers who adopt safer and more environmentally benign practices deviate from the recommendations and standards formulated by scientific experts?

The methodological approach used to provide an answer to these questions is multi-faceted. First, there is a need to provide a good description of the status quo of currently used production technologies in vegetables in Thailand.

Second, a definition of safer practices[1] is necessary, using a set of indicators related to environment and health. In order to reduce complexity, this study has concentrated on one vegetable commodity only, i.e. cabbage, which is the major vegetable crop for which safer vegetable production practices were firstly introduced.

Third, in order to investigate the relationship between the participation in information and training programmes and the effect on change in behaviour of using safer practices a good model of adoption is required. In this regard the classic diffusion model developed by ROGERS (1971) and applied in numerous adoption studies around the world in agriculture and other sectors serves as a point of departure. However, while the "Rogers model" recognized that the adoption decision is subject to a range of characteristics of the technology, for example, its relative profitability or its suitability to try the new technology on a small scale before full adoption, the model lacks an implicit microeconomic-based behavioural framework. Therefore, this study followed the line of thinking of more recent adoption models that recognize heterogeneity and explicitly incorporated microeconomic theory (SUNDING and ZILBERMAN 2001).

Hence, in this study adoption is treated as a multi-stage process that starts with the acquisition of new knowledge through participation in extension programmes, and that includes testing and adaptation of these technologies recognizing the specific socioeconomic conditions of the decision-maker. To adequately describe the adoption process, several econometric models are applied that are in principle based on the classic treatment effects model. The model also takes into account endogeneity and self-selection biases that limit the application of a simpler linear model of adoption.

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[1] The term "safer practices" is used to encompass both safer for humans and environmentally more benign, i.e. safer for the environment.

1.3 Organization of the thesis

The thesis is organized in seven chapters. In chapter 2 some background information and development trends of vegetable production in Thailand are presented. This descriptive chapter includes several sections. Firstly, relevant secondary data from the official statistics on area and production of vegetables in Thailand is presented. These data illustrate the constraints on the adoption of safer vegetable production technologies. Secondly, the currently used conventional vegetable production technologies and alternative safer practices are specified. The latter are based on the results of an expert workshop that was conducted at the beginning of the research.

In chapter 3, the theoretical framework and the conceptual model applied to achieve the research objective are presented. In the first part of the chapter, the theory of adoption is reviewed, while in the second part the econometric specifications of the models applied in the study are specified.

Chapter 4 gives an outline of the research design, and particularly the procedure of primary data collection from some 300 vegetable producers in the province of Chiang Mai in Northern Thailand. In addition, the procedure for conducting a survey among 23 vegetable experts from Thailand is presented.

Chapter 5 deals with the question of participation of vegetable producers in extension efforts of the Royal Project Foundation and related programmes in Thailand. These programmes provide information on safer practices to vegetable producers in the study area. Details of the content and of the implementation process of these programmes are provided. A statistical analysis to compare participants with non-participants is carried out as a prior step to model ling the decision of vegetable producers to participate in extension programmes. The model applies a probit regression to identify factors affecting participation of vegetable producers in the extension programs offered by the Royal Project Foundation and related agencies.

Chapter 6 analyses the level of knowledge of vegetable growers and their attitude towards safer production practices. A comparison between producers who participated in extension programmes and those who did not is carried out following the approach taken in chapter 5, i.e. an application of descriptive statistics is conducted. Then a model is developed to estimate the average treatment effect of participation on knowledge. Here several specifications of the classic treatment effects model were applied.

In chapter 7 the final adoption model is presented as a two-stage process. A simultaneous examination of the effect of programme implementation on knowledge and the adoption in selected key vegetable production practices is undertaken. Different models that accounted for endogeneity were developed. In addition, results of the analysis of the observed gaps between adoption of safer practices and the defined expert standards are presented and discussed.

In the final chapter the results of this research are summarized. Furthermore, some conclusions are drawn based on the results of this research. These conclusions form the basis on which to develop some recommendations for policy makers and technical experts in order to facilitate a wider diffusion of safer vegetable production practices in a more efficient way.

Chapter 2

Technical and institutional conditions of vegetable production in Thailand

This chapter commences with a description of the role of vegetables in the course of agricultural development. Following this is a presentation of the technical and institutional factors that are important in an analysis of the development trends of vegetable production in Thailand. Included is a description of the main production locations and the trends in total output and productivity. In addition, the development of input use, as well as available information on potential negative externalities, is presented. The analysis presented in this chapter uses secondary data from accessible statistical sources, which due to the multitude of vegetable types, makes the availability of such data very limited. Furthermore, the higher priority given by policy makers to food safety, human health and the environment has resulted in changes in the vegetable production and marketing chain. To describe these changes, information on respective research and development efforts and data on new production technologies provided through extension programmes is required. This information is presented in the last section of the chapter.

2.1. Global trends in vegetable production and their role in agricultural development

Vegetables are an important source of vitamins and micronutrients. As per capita income grows people consume more vegetables. The demand for vegetables is generally income elastic. In the developing world, vegetable production and consumption have increased continuously during the past four decades. However, this trend has been very uneven. While Sub-Saharan Africa has seen virtually no increase in vegetable production over the past 40 years, significant increases took place in Latin America and Asia. China has been at the forefront of this development. To date, China produces nearly half (47%) of the world's and over 60 % of Asia's vegetable supply followed by India and Japan (SAHU 2004). In spite of the growth in production, supply has been falling behind the growing demand. Higher incomes and changing demand patterns have therefore led to an increase in the real price of vegetables.

The situation in Thailand is similar to that in other Asian countries (NATH *et al.* 1999). Although vegetable production has increased, per capita consumption is still far below dietary intakes recommended by nutritionists (DEVARREWAERE 1995). Medical research has shown that an insufficient level of vegetable consumption in the diet has detrimental effects on human health. While no data are available from Thailand, it is recognised that on a global scale insufficient fruit and vegetable intake causes some 2.7 million deaths each year, making it one of the top ten risk factors contributing to mortality (EZZATI *et al.* 2002). Whereas demand continues to rise, the annual growth rate of vegetable per capita supply remains stagnant at less than 60 kg per year during the period 1980 to 2000(ALI *et al.* 2001). It has been argued that the green revolution has not yet paid sufficient attention to horticultural crops (WEINBERGER and LUMPKIN 2005). Despite investments in developing improved germplasm for breeding new vegetable varieties from international organisations such as the Asian Vegetable Research and Development Centre (AVRDC) and from national research systems as well as from the private sector, productivity growth in vegetables has been much lower than in cereals crops. In the future, in countries where land is scarce relative to labour and where agriculture is diversifying in the course of market expansion, the contribution of vegetables to farm income can be expected to increase.

Vegetables are also an important factor for household food security as they can be produced year-round on small pieces of land, including home gardens. Particularly in times of economic crisis when household members who have migrated to town lose their jobs (NATH *et al.* 1999), they tend to engage in vegetable production rather than in other crops since the returns per ha are higher than for rice and fibre crops (ISAVILANONDA 1992).

2. 2 The situation of vegetable production in Thailand

In the following section, the situation of vegetable production in Thailand is analysed in terms of the trend in area, production and productivity for the past thirty years. This analysis includes a description of the recent dynamics in vegetable production locations, as well as a brief on the available evidence of externalities of the vegetable production process.

2.2.1 Trends in area, production and productivity

Location theory suggests that the production of vegetables takes place near consumption centres. Traditionally this has also been the case in Thailand with the popular ditch and dike vegetable gardens in the vicinity of the capital Bangkok. However, that scenario has been changing recently. Vegetable production locations are moving from the Central Plains of Thailand to other regions where vegetables have a comparative advantage as determined by lower land prices, the availability of irrigation and marketing infrastructure (SOOTSUKHON *et al.* 2000). During the past three decades, the total area devoted to vegetables has more than doubled (Table 2.1). On a regional scale, a significant positive trend in vegetable areas has been calculated for the period of 1989 – 2000 for provinces in the northern and north-eastern regions, especially the provinces of Nakhon Ratchasima and Chaiyaphum. The area in the provinces of Chiang Mai and Chiang Rai remained unchanged in that period, but area expansion did take place before 1989. On the other hand, the share of vegetable production area in Bangkok and its outskirts has decreased (HARDEWEG and WAIBEL 2002). By and large, changes in the spatial arrangements of vegetable locations had little if no effect on overall vegetable productivity as production technologies largely remained the same (ISAVILANONDA 1992).

There has been about a threefold increase in vegetable production and a corresponding increase in productivity in Thailand, although the latter has been rather uneven. Until the mid-eighties, the average annual yield was about 6 metric tons per ha. (SOOTSUKHON *et al.* 2000). Thereafter yields have increased considerably, with a peak of over 10 metric tons from the mid-nineties until 2000. However, productivity seems to have levelled off thereafter (Table 2.1). It has been argued by ISAVILANONDA (1996) that the increase in productivity is largely due to improvements in infrastructure and marketing facilities and less from biological-technical progress. Also, environmental conditions and natural resource endowments play a crucial role in determining the level of vegetable productivity.

The multi-purpose role of vegetables has prompted the government in Thailand to undertake infrastructure investments, especially in irrigation and marketing facilities in remote rural areas suitable for vegetable production. At the same time high priority was given to research and development for new vegetable production technologies. Good potential exists through more efforts in the development of productivity improvement using hybrid seeds and more advanced methods of production and post-harvest-operations.

Table 2.1: Harvested area, yield and production of vegetables, crop year 1993 – 2008 total production and yield per ha of vegetables in Thailand

Year[1/]	Harvested area/year (1000 ha.)	Production/year (Metric ton)	Average/year/ha (Metric ton)
1992/93	165	2043	12.3
1993/94	359	4140	11.5
1994/95	427	4548	10.7
1995/96	415	4540	10.9
1996/97	472	5239	11.1
1997/98	540	5842	10.8
1998/99	550	5740	10.4
1999/00	495	5036	10.2
2000/01	442	4551	10.3
2001/02	511	5562	10.9
2002/03	461	4925	10.7
2003/04	440	4482	10.2
2004/05	495	5285	10.7
2005/06	200	1821	9.1
2006/07	262	2800	10.7
2007/08	287	3569	12.4

Note: [1/]Crop year from May to April.

Source: DEPARTMENT OF AGRICULTURAL EXTENSION (2008)

2.2.2 Externalities of vegetable production

Economic factors such as the rise in labour costs and the introduction of agro-chemical inputs[2] for farming led to the development of intensive vegetable production systems in Thailand. These are marked by mono-cropping and the use of plant and pest management

[2] Agro-chemicals used in the study include fertilizers, hormone, herbicides, insecticides, fungicides and other chemicals employed in the production systems.

technology that relies on a heavy use of agro-chemicals, especially mineral fertilizers and pesticides (WAIBEL and SETBOONSARNG 1993). The widespread use of these inputs has led to environmental and human health problems. In this regard, evidence on the existence of external costs of agriculture in Thailand is provided by the study of JUNGBLUTH (1996). She pointed out that overuse and misuse of pesticides was especially high in vegetables and fruits. About one fourth of pesticides used in Thailand is applied to fruits and vegetables, which account for almost 24% of the total cropping area (THAPINTA and HUDAK 2000).

The excessive use of pesticides with unawareness in its effects has exposed farmers to high risk from occupational health hazards. As shown in PANYAKUL (2001), vegetable producers overuse pesticides, with dosages above official recommendations. Half of the pesticide applicators do not wear facemasks for protection during spraying. Also, results of a survey conducted by the Department of Agriculture during 2003-2004 (DEPARTMENT OF AGRICULTURE 2004) showed that the use of highly toxic pesticides, including banned pesticides, is widespread. Consequently, pesticide poisonings are common due to the fact that little effort is made by operators to protect themselves from hazardous pesticides. These occurrences are supported by the statistics of poisoning cases during 1992-2002 from the Food Control Division, Ministry of Public Health, as shown in Table 2.2. The percentage of observed farmers found to have acetyl cholinesterase levels beyond acceptable daily intake in their blood ranged from 13% to 29%, indicating that farmers have high-risk exposure to pesticides[3].

[3] Acetyl cholinesterase is an indicator showing the toxicity of carbamate and organophosphate compounds, which results in the accumulation of acetylcholine at the nerve synapses, causing over stimulation and paralysis of neural transmission (SOLOMON *et al.* 2000).

Table 2.2: Pesticide poisoning among farmers in Thailand

Year	Farmers having high risk of pesticide poisoning		
	Cases	Above acceptable daily intake	Percentage of cases above acceptable daily intake
1992	42,471	8,669	20.4
1993	242,820	48,500	20.0
1994	411,998	72,590	17.6
1995	460,521	78,481	17.0
1996	156,315	40,520	25.9
1997	563,354	89,926	16.0
1998	369,573	77,789	21.1
1999	360,411	48,217	13.4
2000	278,612	52,604	18.9
2001	89,945	21,758	24.2
2002	115,105	33,858	29.4

Source: FOOD CONTROL DIVISION (2007)

Heavy use of pesticides has negative effects not only on farmers' health but also on consumers' health and the environment. As shown in a survey by the National Environment Board (NEB) in 1988 cited in JUNGBLUTH (1996), over 96% of soil samples and about 50% of water samples had a high level of pesticide residues. Similar results were reported in the study of THAPINTA and HUDAK (2000). At the same time, higher dosages of pesticides and more frequent pesticide applications significantly increase pest resistance to pesticides and pest resurgence[4]. The study of WAIBEL and SETBOONSARNG (1993) concluded that vegetable producers became path-dependent on chemical pesticides due to resistance and resurgence. WOOD (2005) also reported evidence of resistance in the diamondback moth (*Plutella maculipennis*) in vegetable production systems in Thailand.

[4] Resurgence is the phenomenon in which pest population levels increase in spite of heavy pesticide use. This effect is caused, among others, by excessive destruction of natural control factors such as beneficial insects.

With regard to product quality, data from the International Programme on Chemical Safety (IPCS) in 2003 show that more than 60% of vegetables sampled over the whole Kingdom of Thailand was contaminated with pesticides and about 10 -18% of these samples have pesticide residues above Maximum Residue Limits (MRL) (see Figure 2.1). The top five vegetables in which pesticide residue levels above MRL were found are Chinese kale, Chinese mustard, Chinese cabbage, yard long bean and cabbage, respectively.

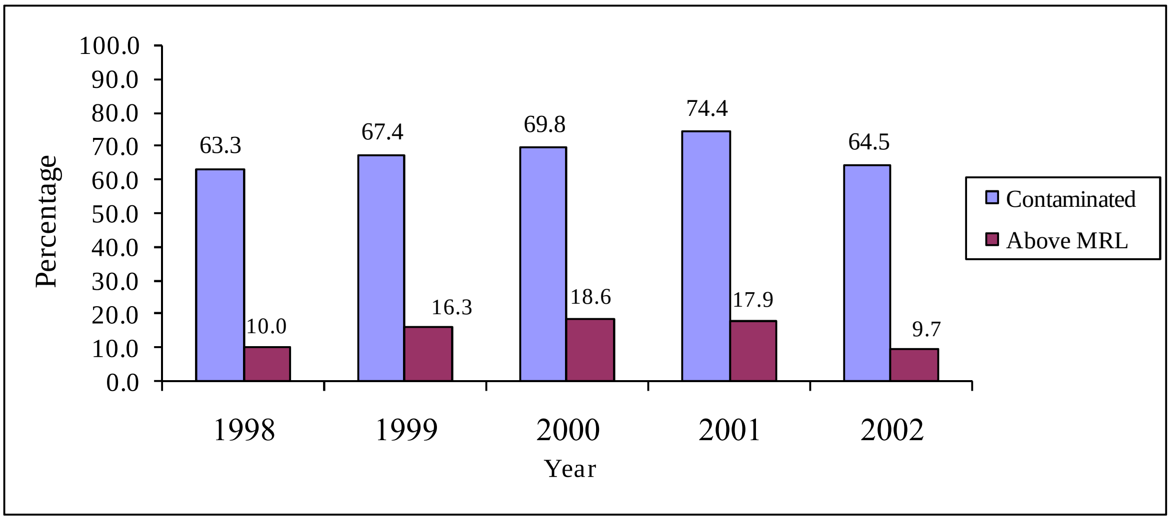

Figure 2.1: Vegetables contaminated with pesticide and those above MRL
Source: INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY (2003a)

Table 2.2 and Figure 2.1 suggest that pesticides use is likely to contribute on environmental degradation and that there are negative effects on human health. This also suggests that private and social costs of pesticides could be increasing. Considering variable costs, data from a field study conducted in Chinese cabbage production in Thailand by HARDEWEG and WAIBEL (2002) reported that over 50% of the variable cost is spent on plant protection. PHADUNGCHOM (1999), who analysed costs and returns of vegetable production in Central Thailand, notes that pesticides have the highest proportion of variable costs. If external costs of pesticide use are incorporated in addition, the social costs of vegetable production may be high, which may warrant government intervention. Although no recent comprehensive study for external costs of vegetable production has been conducted, the study of JUNGBLUTH (1996) referred to above provided a conservative estimate that puts the level of external costs at 5.5 billion Baht per year. About 40% of this amount was attributed to loss of produce due to pesticide residue levels above MRL. On the aggregate it was pointed out that for every Baht spent on pesticides, an additional Baht can be attributed to externalities (PINCUS *et al.* 1991). One explanation for the existence of high external costs is the use of inappropriate practices due to the limited information on their availability and use and a lack of knowledge about the effects of pesticides. Also, farmers may value the use of pesticides and mineral fertilizers in vegetable crops on productivity more highly than the negative effect on their health, some of which is chronic and thus unobserved. Hence information on safer methods of vegetable production is crucial for vegetable producers' decision-making. Public extension programmes have to counter the sometimes-biased information from pesticides companies, pesticide retailers and other farmers. Other constraints are conflicting government policy, with subsidies for pesticides, and the high fluctuation of vegetable prices. So, vegetable producers often harvest vegetables in disregard of the legally required waiting period after pesticide application if current prices in the market are high (HARDEWEG and WAIBEL 2002). RUHS *et al.* (1997b) indicated three major policies that foster overuse of pesticides: (i) an import tax structure related to pesticides being identified for agricultural inputs helps to keep pesticide prices lower than those of other agricultural inputs; (ii) the lack of regular enforcement regarding outdated and illegal pesticides; and (iii) the promotion of pesticide use via farmer extension services as risk-reducing technologies to prevent yield losses.

As shown by this review of the literature on externalities of vegetable production in Thailand, there is a need for policy information that can foster the introduction of more environmentally benign and safer production technologies.

2.3 Institutions and organizations to promote safer vegetable production

Responding to the challenge to reduce externalities of pesticides in agriculture, the Government of Thailand has implemented several programmes aimed at a reduction in pesticide use and improvement of the environment and the health of its population. In the following sections a description of the relevant regulations and the key organisations entrusted with the implementation of these programmes in the field of vegetables is provided.

2.3.1 Regulations for pesticide reduction

The Seventh National Economic and Social Development Plan (NESDP) covering the period 1992-1996, recognized for the first time that pesticides are an environmental concern and promoted measures for the reduction of their use in Thai agriculture. Under this framework, in 1992 the Government approved a new Hazardous Substance Act following the FAO

"Guidelines for the Registration and Control of Pesticides", [5]which provide an international standard for the importation, production and marketing of pesticides (FAO 2006). Under this Act the Government banned and restricted a number of outdated pesticides, mostly belonging to WHO toxicity class I and II[6] (WHO 2005). In addition, MRL were established for pesticide residues in food and agricultural products following the International CODEX ALIMENTARIUS standard for pesticide residues. While from a legal point of view Thailand has improved its standard in the regulation of potentially harmful substances e.g. chemical pesticides, the problem has been its lack of rigorous implementation. Inspections and monitoring, as well as serious follow-ups of violations of the law, have been notoriously ineffective, often hampered by insufficient resources and a dysfunctional judicial system. For example, as pointed out by RUHS *et al.* (1997a), farmers have easy access to banned or restricted pesticide products in many pesticide shops across the country.

2.3.2 Research

Vegetable research in Thailand is primarily undertaken by agricultural universities such as Kasetsart University (KU), Khon Kaen Unviersity (KKU), Chiang Mai University (CMU), Prince of Songkhla University (PSU) and Ramkhamhaeng University (RU). Further research is carried out and supported by government organisations under the Ministry of Agriculture and Cooperatives (MOAC), namely the Department of Agriculture (DOA) and the Department of Agricultural Extension (DOAE). Private sector companies also take part in agro-chemical research and development, mainly those involved in breeding and seed production such as Charoen Phokaphand Group (CP).

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[5] FAO first published its "Guidelines for the registration and control of pesticides" in 1985. The guidelines have the objective of assisting countries in setting up or strengthening a pesticide registration and control scheme. The guidelines were developed and updated in 1988. A modified version was published 1991 (FAO 2005).

[6] The World Health Organization (WHO) classifies pesticides by hazard based on their composition and their formulations. The levels of hazard are between one to four classes. The pesticides in the first class (Ia) represent "extremely hazardous", i.e. substantially toxic. Other classes are Ib, II, III, representing "highly hazardous", "moderately hazardous", and "slightly hazardous" (WHO 2005).

Some research coordination takes place among these organizations through the Asian Vegetable Research and Development Centre (AVRDC), which is a non-profit institution for vegetable research and development. The Centre develops vegetable varieties and other technologies that increase vegetable production and consumption in developing countries. The research priorities focus on five themes as follows (AVRDC 2007):

- Evaluation and screening of vegetable germplasm for yield, quality, resistance to pests and diseases and environmental stresses.
- Genetic enhancement and varietal development of vegetables
- Varietal improvement through breeding and selection
- Post-harvest management and market opportunities
- Food security, diet diversification, and human health by improving cultural practices to enhance productivity, control of pests and diseases through application of appropriate technologies e.g. biological control, culturing methods, and minimizing the use of insecticides and fungicides

In addition to national efforts on vegetable research, a project named “Protected Cultivation—an Approach to Sustainable Vegetable Production in the Humid Tropics” is carried out by Leibniz University of Hannover. This project has been implemented in collaboration with the Asian Institute of Technology (AIT) and Kasetsart University (KU) to develop production technologies for high quality tomatoes under conditions of protected cultivation with minimal inputs of chemical pesticides (DFG-RESEARCH GROUP FOR 431 2007).

2.3.3 Extension and monitoring by government agencies

The responsibility of overseeing regulations with regard to pesticide use is in the hands of five ministries, namely the Ministry of Agriculture and Co-operatives (MOAC), the Ministry of Public Health (MOPH), the Ministry of Resources and Environment (MONRE), the Ministry of Education (MOE) and the Ministry of Commerce (MOC). MOAC is responsible for regulations concerning the importation, production and distribution of pesticides as well as for advising farmers on the proper use of pesticides and for implementing emergency pest control operations in case of pest outbreaks. Under the structure of the MOAC, four main departments are entrusted with different functions with regard to the implementation of pesticide reduction programmes: (i) Department of Agriculture (DOA) is the agency responsible for research and the development of technologies; (ii) the role of the Department of Agricultural Extension (DOAE) is to test and to promote technologies that were developed by DOA with farmers; (iii) Co-operative Promotion Department (CPD) facilitates collective actions among farmers on village level and (iv) the Land Development Department (LDD) is responsible for the development of soil improvement and conservation practices, including other technologies that are related to pesticide reduction.

The Ministry of Public Health (MOPH) is responsible for monitoring pesticide residues in agricultural products and the health status of the population. There are two agencies under the auspices of this Ministry that assume specific functions, namely the Food and Drug Administration (FDA) and the Department of Medicine Sciences (DMSC). The former is responsible for food quality control and performs residue analysis in agricultural raw materials and processed products, while the latter monitors pesticide poisoning cases and reviews the safety status of pesticide compounds (CHAROENPONG 2003).

Under the Ministry of Natural Resources and Environment (MONRE) there are two agencies, the Office of Natural Resources and Environmental Policy (ONRE) and the Planning and Pollution Control Department (PPCP). The first is responsible for development of an environmental quality plan and measures to prevent, control and mitigate environmental pollution. The latter is responsible for the development of appropriate technologies to manage hazardous substances and to improve environmental quality. In addition, the Ministry of Education via the Department of Non-Formal Education (DNFE) in cooperation with the DOAE began conducting various training courses for their staff and field schools for both farmers and students of Non-Formal Education schools.

Last but not least, the Department of Export Promotion (DOEP) under the Ministry of Commerce (MOC) basically plays a role in organic production. DOEP cooperates with the DOA, DOAE and NGOs to develop organic production practices, standards and certification for organic products in Thailand. In addition, it provides information services about standards and requirements of importers for traders and exporters.

2.3.4 Activities of non-governmental organisations

Non-governmental organisations have also been playing a role in the development of alternatives to chemical pesticides and other environmentally friendly crop management practices. These NGOs include the Thai Education Foundation (TEF), the Sustainable Agriculture Foundation of Thailand (SAT), the Green/Earth Net Foundation (ENF), the Alternative Agricultural Network (AAN) and most importantly, the Royal Project Foundation (RPF). The TEF cooperates with the DOA to pioneer the use of ecological practices for plan protection with children in primary school. The SAT is the major factor in the establishment of the farmers' network, i.e. the AAN. The network has developed a strong relationship between farmers for supporting one another by sharing knowledge on safer vegetable production practices within the same eco-systems and on market issues. It also encourages farmers to participate in policy development at local and national levels by collaborating with the officers of the DOA and the DOAE. The ENF plays a major role in organic vegetable production and marketing.

The RPF was established by the King of Thailand in 1969. The major objectives of the Foundation are to improve the living standard of rural people in Thailand, to replace the cultivation of poppy seeds used for opium production with other crops, and to conserve natural resources in the highland areas of Northern Thailand. To reach these objectives, the Foundation has established three major divisions: research, development and extension, and marketing. The research division is responsible for developing alternative cash crops, including temperate fruits and vegetables, and for identifying technologies in plant protections that are more environmentally benign. Approximately 42% of the total budget goes to research, 54% to development and extension, and the remainder to marketing (CHIANG MAI UNIVERSITY 2004).

At present, there are four research stations, namely Inthanon Royal Project Research Station, Ang Khang Royal Project Research Station, Pang Da Royal Project Research Station, and Mae Lod Royal Project Research Station. The main stream of the research of Inthanon, Pang Da and Ang Khang Royal Project Research Stations is devoted to temperate vegetables and fruits, whereas Mae Lod provides research into coffee varieties. The production and marketing technologies on vegetables and fruits derived from the research significantly emphasize quality and safety standards in all links of the supply chain, i.e. Good and Agricultural Practices (GAP). The organizations involved in the researches are three public universities in Thailand, including Kasetsart University, Chiang Mai University, and Mae Joe University. In addition, the Ministry of Agriculture and Cooperatives and the Ministry of Science and Technology also facilitate researches for the RPF (ROYAL PROJECT FOUNDATION 2008).

The development and extension division is given the task of introducing technologies developed and identified by the above-mentioned research divisions to farmers in the areas. In implementing its programme for producing vegetables with minimal use of pesticides, the RPF relies on technologies developed by itself as well as by the Thai government agencies described above. For example, the officers of the DOAE conduct farmer training on behalf of the RPF. In the extension, the RPF has extension stations in different areas located in the North of Thailand, comprising 37 Royal Project Development Centres. Each centre has extension workers who are responsible for the education of farmers in its areas. The RPF supplies seeds and some inputs on a credit basis to project members, to be paid back when the produce is harvested. Vegetable production is carried out according to the standards set by the RPF. Technical supervision and monitoring are carried out using manpower from the DOA. The most important standard is that the products must be “safe” in terms of pesticide contamination, i.e. pesticides residues must be below the MRL. In the development, the RPF with financial assistance from the Government of Taiwan and the United State of America provides infrastructure to the respective project areas. This also includes conservation and improvement of natural resources. The major government agencies that are responsible for the provision of the basic infrastructure are the Ministry of Interior, the Ministry of Agriculture and the Ministry of Public Health.

In its marketing division, the RPF develops the technologies for its marketing, such as transportations and packaging. Grading and packaging is implemented in the station located in Chiang Mai province in Northern Thailand. All products purchased from the farmers in its areas are marketed under the own brand name of “Doi Kham”. Most of the products, especially fruits and vegetables, are placed in contracted supermarkets, green shops and export markets (ISAVILANONDA *et al.* 2006).

2.3.5 Projects

There are two types of projects aiming at the introduction of safer practices in vegetable production. The first type promotes the concept of Integrated Pest Management (IPM) and the second type promotes organic farming practices. IPM is a concept that does not exclude the use of chemical pesticides but attempts to minimize their use as a strategy to reduce health and environmental hazards. IPM is based on four general principles of sustainable crop management: (i) growing a healthy crop by giving priority to non-chemical inputs and using chemical pesticides only as a last resort (ii) educating and training farmers to understand the role of beneficial insects; (iii) encouraging farmers to observe their fields regularly and (iv) enabling farmers to base their decision-making regarding production inputs on observation and analysis of the field situation (MENAKANIT 2001b). In vegetable production systems, the project was first promoted by the so-called "Hygienic and Pesticide Free Vegetable Pilot Project" programme (see Table 2.3), which emerged from an earlier project, namely the "Pest Surveillance Project in Rice" which was initiated in 1983[7] (FAO 2005; M. RUMAKOM *et al.* 1992). Subsequently, in 1993 the project was transferred to DOAE and changed its name to "Pesticide Free Vegetable". These two projects basically have similar objectives, i.e. to reduce the pesticides used in vegetable production systems. In addition, the projects aim at setting up small groups and networks of small-scale farmers to starting a community learning and training process. The farmers who participate in these projects are registered with the local office of the DOAE. The projects also developed a logo under the name of "Hygienic Fresh Fruits and Vegetables Production Pilot Project" [8]. Also, production inputs such as seeds and nylon nets were provided to the registered farmers free of charge (PANYAKUL 2001) As a requirement, the products sold under this logo must be safe for consumption, i.e. the pesticide residues must be below the MRL. To ensure the production standard, random field inspection is carried out at least once a year.

[7] During 1982-1989, the Thai government established a programme of pest surveillance supported by the Government of Germany through a technical cooperation project with a total budget of about 450 million Thai Baht or about 9 million Euro (PRANEETVATAKUL *et al.* 2007) .

[8] In practice, there are many logos for pesticide-residues-safe vegetables sold in the market. For further information see the study of VANIT-ANUNCHAI(2006)

Table 2.3: Projects to introduce safer vegetable production practices in Thailand

Project title	Agency	Implemented year	Extension Methodology
Hygienic and Pesticide-free Vegetable Pilot Project[1/,2/]	DOA	1983-1992	• Farm registration • Use of IPM concept • Field inspection at least once during application and certification
Pesticide Free Vegetable Project[1/]	DOAE	1993-1996	• Farm registration • Use of IPM concept • Field visiting and certification
Vegetable FAO-IPM Programme[2/]	DOAE, DOA, FAO	1998-2007	• Farm registration • Promotion of IPM through Farmer Field School (FFS) programme • Supply of botanical/bio pesticides and bio agent controls • Inspection based on good agricultural practices (GAP) • Certification
Strengthening Vegetable Producers' IPM in Pesticide-Intensive Areas Programme[2/]	DANCE, DOA, DOAE, RPF, NGOs	2001-2006	
Good Agricultural Practices (GAP)[2/]	DOA DOAE, RPF, NGOs	2004-present	

Source: [1/] PANYAKUL (2001) and personal communication with Director of Vegetable, Flower, Ornamental Plant and Herbal Plant Production Promotion Division (Oct 3, 2006)

[2/] FAO (2005; 2007)

However, the introductions of these two projects did not lead to a significant reduction of pesticide residues in vegetable products because of the limited coverage. During 1999-2002, data published by the INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY (2003b) showed that the number of samples with pesticide residues above MRL did not decrease (see also

Figure 2.1). Also in 2003, the study of the DOA pointed out that more than 80% of all vegetable samples were contaminated with pesticide residues. The large number of projects that tried to reduce pesticide use in vegetables has led to lack of understanding and even confusion on the consumer side. In particular, the terms "pesticide-free vegetables", "pesticide-safe vegetables", and "hygienic vegetables"[9] are somewhat misleading and unclear to most consumers, since in practice all vegetables, even those produced under organic production regimes, contain pesticide residues ((VANIT-ANUNCHAI 2006). Recently, the responsible agencies under the MOPH and MOAC have agreed to no longer certify any vegetables as "pesticide-free" but use the term "pesticide-safe vegetables" instead.

Several explanations for the overuse of pesticides have been provided by government officials of the agencies responsible for the projects (LIANJUMROON 1997). On the regulatory level the Hazardous Substance Act stipulated in 1992 did not include any regulations for pesticide usage at the farm level. Farmers in Thailand can buy virtually any kind of pesticides, including those registered or banned (RUHS *et al.* 1997b). In addition, research and development (R&D) in plant protection and the encouragement of farmers and other organizations to adopt safer practices have been impeded by conflicting policies at the national level. It has become clear that regulatory policies alone, as proposed by the seventh National Economic and Social Development Plan (NESDP), are insufficient. Although the more recent NESDP has not explicitly mentioned the concept of IPM, it has been promoted as a concept that develops location-specific solutions to these problems. For example, it is used as one of the major practices in the GAP programme (see also table 2.3). At the heart of the IPM initiative is an aim to increase producers' knowledge and to change their perception in controlling pests, with more consideration given to the ecology. A nationwide pesticide reduction programme that relied on IPM as a core component was accompanied by institutional change. For example, the Institute for Biological Agriculture and Farmer Field Schools (IBAFFS) under the DOAE was established by the Royal Initiative of the King of Thailand with the aim of empowering farmers in pest management decision-making and thus encourage adoption of IPM (PRANEETVATAKUL *et al.* 2007). IBAFFS has implemented a farmer training and learning (FTL) programme by utilizing a participatory learning

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[9] In Thailand, the term "pesticide-free vegetable" means vegetables produced without the use of any herbicides or pesticides. All pesticides are allowed in the production systems of those marked as "pesticide-safe vegetables" and "hygienic vegetables". The requirement of the last two terms is that vegetable products must contain pesticide residues below the MRL (DEPARTMENT OF AGRICULTURE 2006).

approach[10] with financial support from the Thai government and technical assistance from FAO under the Programme for Community IPM in Asia and the Inter-Country Programme for Vegetable Growing in South and South-East Asia. The project cooperates with three other projects: “Vegetable-FAO IPM Project”, “Strengthening Vegetable producers IPM in Pesticide-Intensive Areas Project” and “GAP Project”. The first was implemented under the responsibility of the IBAFFS with technical assistance from the FAO Programme for Community IPM in Asia and the Inter-Country Programme for the Development and Application of Integrated Pest Management in Vegetable Growing in South and South-East Asia (MENAKANIT 2001a). The second was funded by the Danish Co-operation for Environment and Development (DANCED) and the third by the Thai government as a response to increasing demand from private food retailers and supermarkets in Europe.

For vegetables, IPM was first implemented in cabbage. Government agencies such as DOAE, DOA and NGOs have implemented their own projects and at the same time have become the main suppliers of RPF in highland vegetables. Vegetable producers participating in this programme have been registered and facilitated with financial credit and inputs such as nylon nets and bio-pesticides. They have been trained and educated based on the four basic principles of IPM through the farmer training and learning programme. In addition, the producers were required to undergo an inspection and a certification process. The organization responsible for these activities is the DOA.

The organic agriculture movement has also gained some momentum in Thailand and has contributed to the goal of reducing agro-chemical usage and conservation of the environment. Organic agriculture is stricter in terms of production standards than IPM. Most importantly the use of agro-chemicals is prohibited. Furthermore, inspection and certification of the standards are required. A specific minimum criterion for the organic farming is based on the International Federal of Organic Agricultural Movement (IFAOM). Based on this standard, organic agriculture is put into a wider context and includes social aspects (IFOAM 2006).

[10] A farmer training and learning programme is a procedure of adult non-formal education developed from the approach of participatory research programmes. It was first implemented in rice farming systems in Indonesia (PONTIUS *et al.* 2002).

The first official project related to organic agriculture was the Pilot Project on the Export of Organic Farm Products implemented during 1999-2002. The main purpose was to promote the organic production and export of rice, fruits and vegetables. The project was initiated and financed by the Department of Export Promotion. To operate this programme, local NGOs, the AAN (including the TEF, the SAT, and the ENT), the DOA, the DOAE and private companies are in close collaboration. The DOAE has conducted the training and learning programme on behalf of NGOs. The largest organisations acting as NGOs-supported are Green Net or Earth Net Foundations, Alternative Agricultural Network (AAN). There are about three major companies engaged in organic vegetable products, namely Plook Rak Farm, Rangsit Farm and Exotic Farm Produce Co., Ltd (ELLIS *et al.* 2006).

On the consumer side, during 1982-1985 the MOPH established the “Clean Food-Good Taste” project to improve food standards in restaurants and food stalls. However, the programme concentrated only on bacteria and other biological contaminants in food, and not of pesticide contaminations. Subsequent to this period, the “Inspection of Pesticide-Free Vegetable” project was conducted alongside the “Pesticide Free Vegetable Project”. The strategy of this project was to inspect pesticide contaminations of vegetables in the market. The projects were operated by the Food and Drug Administration (FDA) and the Department of Medical Sciences (DMS). More recently, other complementary programmes were launched by the MOPH, namely the “Food Safety Surveillance and Food Control Programme” and “the National Food Safety Programme” (SRITHAMMA *et al.* 2005). These two projects are responsible by the FDA and the DMS that are issued by the MOPH. The main objective of these two programmes is to assure that food safety standards in Thailand comply with international standards. They are the complementary to the last three programmes shown in table 2.3. However, the framework of these two programmes includes the market food importation and processing levels as well as the farm level.

Table 2.4: Projects to increase safety in vegetable consumption

Project type	Agency	Implemented year	Methodology
Clean Food-Good Taste	DMSc	1982-1985	• Inspection of bacteria and other biological contaminants in food
Inspection of Pesticide-Free Vegetable Project	FDA, DMSc	1986-1996	• Inspection of pesticide contaminants in vegetable products
Food safety Surveillance and Food Control Programme	FDA, DMSc	1999-2003	• Inspection of pesticide contaminants in vegetable products and control of food quality
National Food Safety Programme[3/]	DOAE, DOA, FDA, DMSc	2004-present	• Food production control throughout the entail food chain • Inspection and legal enforcement in food importation, fresh food product in the market, and production process

Source: [1/] PANYAKUL (2001) and personal contact with director of Vegetable, Flower, Ornamental Plant and Herbal Plant Production Promotion Division (Oct 3, 2006).
[2/] FAO (2005)
[3/] SRITHAMMA *et al.* (2005)

2.3.6 Adoption of safer vegetable production technologies

It is likely that the area in which safer production practices have been adopted has increased during the period of the Eighth National Economic and Social Development Plan (1997-2001) (VANIT-ANUNCHAI 2006). However, no official statistics are available at present, although indications are given in project reports about organic vegetable production and other documents of the DOAE. For example, the data show that the production area of safer vegetable increased from 835.3 hectares in

1997 to 5,318.9 hectares in 2002, which is an increment from 0.23% to 0.27% of the total vegetable production areas. It is important to note that these statistics exclude organic vegetable production.

The ENF indicates that the area of organic production increased during 2000-2006, but the area decreased to only 19,162 ha in 2007 (Figure 2.2). This figure also shows a gradual growth of organic vegetable and fruit production areas. The proportion of organic vegetable and fruit products to the total organic products was only 0.3% in 2003 and decreased further to 0.14% in 2006. PANYAKUL (2008) argues that the area of organic production decreased since the overall policy targets of organic vegetable production at the national level lack continuous enforcement. That is, the policies in each National Economic and Social Development Plan differ from one another. Furthermore, reasons behind the low level of adoption of safer practices might be the conflicts between policies of different government agencies and the overlapping tasks among them. This is confirmed by the studies of RUHS et al. (1997) and MENAKANIT (2001)

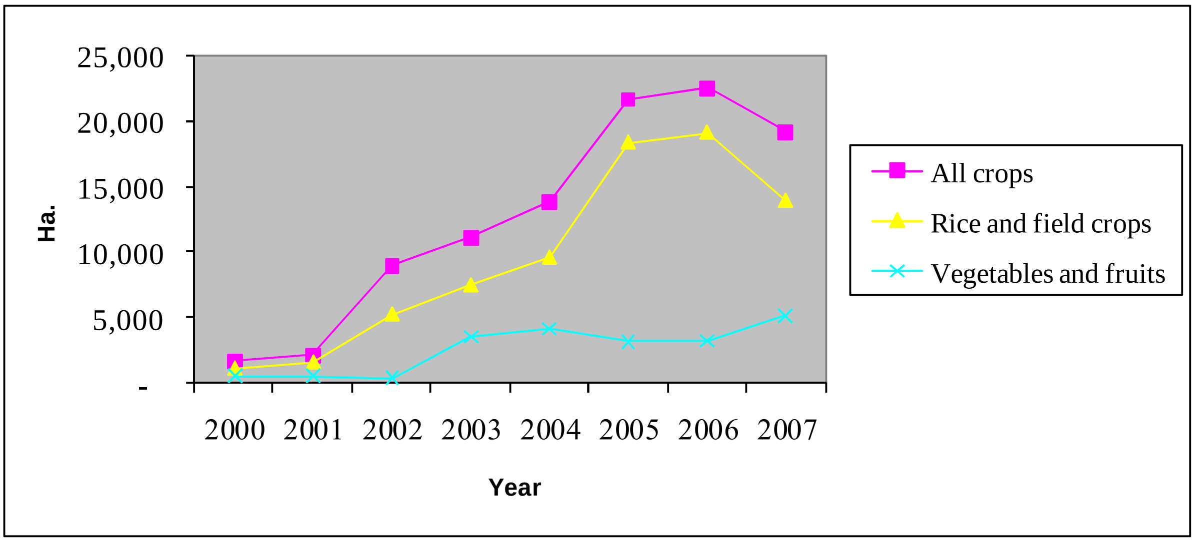

Figure 2.2: Organic vegetable and fruit production areas from 2000-2007
Source: EARTH NET FOUNDATION (2008)

2.4 Summary

Many reports and studies suggest that the vegetable products in Thailand put consumers at risk due to pesticides residues often above the Maximum Residues Levels (MRL). Producers are also subject to health hazards from the improper use of highly toxic pesticides. In addition, the overuse of pesticides degrades natural resources and environment. Thailand, as a member of the World Trade Organization and a major food and agricultural products exporter, recognizes the need to upgrade its agricultural production to meet international standards, i.e. the production of high quality, safe and healthy food raw materials and food products is indispensable. To respond to the challenge, the Thai government has strived to achieve this goal through an explicit food safety policy, especially through the implementation of GAP and the National Food Safety Programmes. The objectives of these two programmes aim to reduce food hazards and food-borne diseases along the production and marketing sides, respectively.

In this chapter, the institutional conditions for achieving these goals were described. It was shown that a large number of government agencies are given the responsibility of contributing to this goal, e.g. the Ministry of Agriculture and Cooperative, the Ministry of Public Health, and the Ministry of Natural Resources and Environment. They conduct research and development, including extension programmes at both production and marketing levels. In addition, NGOs and the private sector also play a major role in the extension of those safer vegetable production practices. Most importantly, the Royal Project Foundation (RPF) is playing a pivotal role, especially in the environmentally sensitive areas in the Northern highlands.

However, the adoption of safer vegetable production practices is very low. This may reflect the fact that the implementation of safer practices has not always been effective due to overlapping tasks and imprecisely defined roles of involving institutions. Discontinuity and inconsistency of the policy at national level might also be a major cause of low adoption. Theory suggests that adoption of innovation is determined by many factors. In this context, knowledge is hypothesised as the factor affecting adoption of safer practices. To examine this, an analytical framework and conceptual model are required. The next chapter describes the theoretical background and conceptualisation of the study, as well as the modelling of adoption.

Chapter 3

Methodology

This chapter is divided into two parts. The first part provides a definition of knowledge-intensive technologies and a conceptualization of the adoption decision-making process in the acquisition of knowledge through extension programmes. This also includes a literature review on the evolution of extension systems and their role in the delivery of knowledge-intensive technologies. The second part of the chapter provides an analytical framework for the analysis of the process of knowledge acquisition through participation in extension programmes, and the transformation of this knowledge to promote the use of safer technologies in vegetable production. The methodology concentrates on three major econometric models: (1) a probit regression model for the estimation of factors affecting the decision of vegetable producers to participate in an extension programme, (2) an average treatment effect model for the examination of the effects of the programme on vegetable producers' knowledge, and (3) a system of equations for the simultaneous examination of the participation-knowledge-practice change process. The chapter concludes with a summary of the models used in this research.

3.1 Definition of knowledge-intensive technologies

The classic studies on adoption processes (e.g. ROGERS (1971)) revealed that there is a gap in time between the introduction of a technology and when its adoption begins. Hence the classic diffusion model assumed that adoption is gradual and continuous, generally following an S-shaped function with time as the independent variable. Therefore, the early adoption studies (e.g. GRILICHES (1975); MANSFIELD (1963)) modelled technology diffusion as a process of imitation, assuming a costless communication among homogenous units of adopters. These adoption models essentially are imitation models that lacked an explicit economic decision framework for individual units. In reality, the homogeneity assumption is hardly merited. One way to deal with the problem of heterogeneity is to divide potential adopters into different groups with different features and likelihood of adoption. Statistical tools such as logit and probit models allow the analysis of discrete choices by adopters. A more advanced model of adoption is the threshold model (DAVID 1969). The threshold model has an explicit economic micro-level decision-making mechanism, recognizes heterogeneity among economic agents and incorporates dynamic processes that drive the diffusion process forward over time. This model is very flexible and allows the introduction of market-clearing mechanisms as well as policies into the analysis, and assesses their impacts on technological change. Hence it is demanding in terms of data requirements, which are often difficult to meet under the conditions of developing countries. SUNDING and ZILBERMAN (2001) in their survey of adoption point out that introduction of new technologies is associated with the introduction of various types of risks, which can be reduced by informational efforts provided by extension or effective marketing services. For example, the substitution of chemical pesticides by biological control may cause productivity losses if farmers do not know how to adjust the use of pesticides for the control of pests where the biological control agent is not effective. Hence, adoption of knowledge-intensive technologies depends on the knowledge and skills capacity of the potential adopters. SCHULTZ (1975) emphasizes the importance of the capacity to quantify and evaluate alternative technologies, which provides a case for combining the introduction of technologies with educational efforts that provide basic analytical skills.

Following the classic categorization of technologies, those that are knowledge-intensive are disembodied, as they are usually not tied to any physical tool but by their very nature are designs, concepts and decision-rules and are thus dependent on human capital accumulation through information acquisition and learning (SCHULTZ 1975; WOZNIACK 1984; WOZNIACK 1987). Agricultural technologies in this group are often confronted with problems of public acceptance and frequently deal with environmental issues (SUNDING and ZILBERMAN 2001). A good example is Integrated Pest Management (IPM) technology or, as in this study, the introduction of safer vegetable production practices, which apply some of the principles of IPM[11]. Introducing knowledge-intensive technologies does not only require information but also an in-depth understanding of the mechanisms that drive the effectiveness of the technology under variable environmental conditions. It is important in this context to understand the role of extension organisations in the delivery of agricultural technologies. Hence, the next section provides a literature review of the evolution of extension systems in agricultural development.

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[11] Integrated Pest Management is a concept developed by entomologists which aims the minimal use of chemical pesticides by promoting mechanical, physical and cultural methods of pest control and bases the decision to use pesticides on regular field monitoring.

3.1.1 The role of extension systems in the delivery of knowledge-intensive technologies

Producers can obtain knowledge about new technology from various sources. These include research organizations that normally provide information with a higher level of complexity, and extension organizations that are expected to simplify the information provided by research organizations. Information can also be acquired from other producers who provide their perceptions and experiences with the use of the technology. FEDER *et al.* (1985; 2004) were among the first to analyse the role of public extension systems in the transfer of agricultural technology. DORAN (1980) stressed the importance of effectiveness of extension systems; i.e. extensions personnel and producers must have strong links in order to satisfy information needs. Perhaps the first worldwide effort to introduce efficient extension systems in agriculture in developing countries in the mid eighties was the Training and Visit system (T&V) designed by BENOR and HARRISON (1977). It was adopted as a major tool for knowledge transformation and first implemented in India in 1977. This extension concept rested on several pillars (FEDER *et al.* 1987; FEDER and SLADE 1986; HUSSAIN *et al.* 1993): (i) a top-down hierarchical organizational structure with a fixed schedule of extension to farmer contacts; (ii) a large number of ground-level extension staff, linked with specialists to ensure the relevance of extension messages provided to contact farmers; (iii) selected villages with contact farmers who receive pre-formulated extension messages from extension workers. The contact farmers in turn are expected to disseminate knowledge to other farmers of their constituency; and (iv) a fixed schedule of bi-weekly visits for delivery of extension messages focussed only on the most important agricultural practices for the major crop of that area. Extension workers were expected to concentrate solely on extension messages and not become involved in other activities such as the collection of statistics.

The problems with the T&V system soon became apparent, although early studies suggested a high rate of return (ORIVEL 1983). Some disadvantages were reported in the literature (HUSSAIN *et al.* 1993). The major weakness of the T&V system was its costs due to the requirement of a large number of extension agents (FEDER and SLADE 1986). Hence, the system suffered from a lack of fiscal sustainability (QUIZON *et al.* 2000). Another limitation was the degree of technical competence and quality of extension staffs, which often could not be assured (ANTHOLT and ZOJP 1995). Moreover, the fixed extension messages ignored indigenous knowledge and the information was often not relevant for the solution of local problems. Finally, it was observed that the system became biased toward wealthier producers since the selection of contact farmers was often based on wealth, literacy and willingness to cooperate (ROLING and PRETTY 1997). A good example of an impact study of the T&V system is the work of HUSSAIN *et al.* (1993). They evaluated the impact of T&V on farmers' knowledge and the adoption of agricultural technology in Pakistan. The authors indicated that seven years after T&V adoption the programme did not live up to its expectations. Unfortunately, as pointed out by (QUIZON *et al.* 2000), there were only a few rigorous economic impact studies of the T&V system. Most evaluation studies focussed on the number of visits by extension agents but failed to provide evidence of the change in producers' practices, aside from effects on income.

The lessons learned from the T&V extension system led to a discussion of the role and design of public extension programmes. Thus, a participatory approach has been developed in which farmers are treated as partners of extension workers and are not simply the recipients of information. Also, participatory systems are organized in multiple command lines in order to overcome the hierarchical structure of the T&V system. The organization of participatory systems facilitates several options for the governing structure, including devolution of control to local units, sharing of costs between personnel extension agents and producers, contracting of services among researchers, NGOs, cooperatives and producers' organizations (ANTHOLT and ZOJP 1995). In recent years, several agencies, including the World Bank, promoted this approach as an effective way to transfer new technology, particularly for those of the knowledge-intensive kind (FEDER *et al.* 2003). An example of costs and prospective benefits of a participatory extension system was provided by a study in Egypt (FLEISCHER *et al.* 2002)

The participatory approach has been especially applied in the field of Integrated Pest Management (IPM). The first and most comprehensive effort was undertaken in rice and subsequently in vegetable production systems in Asia. In participatory extension programmes, the concept of a farmer field school was developed to meet the ecological conditions of a local field. Farmers were asked to voluntarily participate in the programme. In the training course, farmers were educated and trained in several aspects of IPM. The aim was to empower them with knowledge and skills using a field-based and experiential learning process (ANTHOLT and ZOJP 1995). One positive externality of the programme is the sharing of knowledge among farmers while they are working together in the field. As a means of speeding up the diffusion of farmer field schools at the end of the training, farmers who showed outstanding performance were encouraged to undertake additional field schools in their own or the neighbouring villages with support from the extension organization. Hence, farmer trainers were supposed to gradually establish a semi-private training and learning programme for other farmers (KENMORE 1996; PRANEETVATAKUL *et al.* 2007; VAN DE FLIERT 1993).

As pointed out in chapter 2, the Royal Project Foundation (RPF), with support from the relevant government organizations in the area where this study was conducted, is promoting participatory extension approaches together with other measures that are aimed at increasing the rate of adoption of safer practices in vegetable production. The challenge is to assess the effectiveness of this process. To do this firstly requires the conceptualization of the role of extension programmes in influencing farmers' decision-making process. Hence, in the next section a conceptualization of the role of extension programmes in the process of knowledge acquisition and technology adoption in vegetable production in Thailand is presented.

3.1.2 Conceptualization of the process of knowledge acquisition and technology adoption

Expected utility decision theory states that profit-maximizing producers will adopt a new technology if the expected utility is higher than those of existing practices. One of the first studies in agriculture was carried out by GRILICHES (1975), analysing the factors affecting the adoption of hybrid corn. This study in principle followed ROGERS (1971,) who provided a criterion for measuring the adoption-decision process. He pointed out that profitability of a new technology is only one among several factors that determine adoption. These factors include other attributes of the technology such as compatibility, complexity, and observability affecting producers' attitude toward innovation in the persuasion stage prior to decision-making. ROGERS (2003) also recognizes the important role of knowledge in adoption. In Figure 3.1 the process of adoption, starting with technology development until decision-making, is conceptualized. Suppose a technology supplier conducts research to develop safer vegetable production practices that are more benign to the environment and human health. At the first stage, the vegetable producers can be educated via a training and learning programme. The ability to understand how the practices work, however, depends on personal attributes, socio-economic attributes and communication of vegetable producers (see Figure 3.1). The training may also change the attitudes of the trainees, making them more appreciative of environment and health.

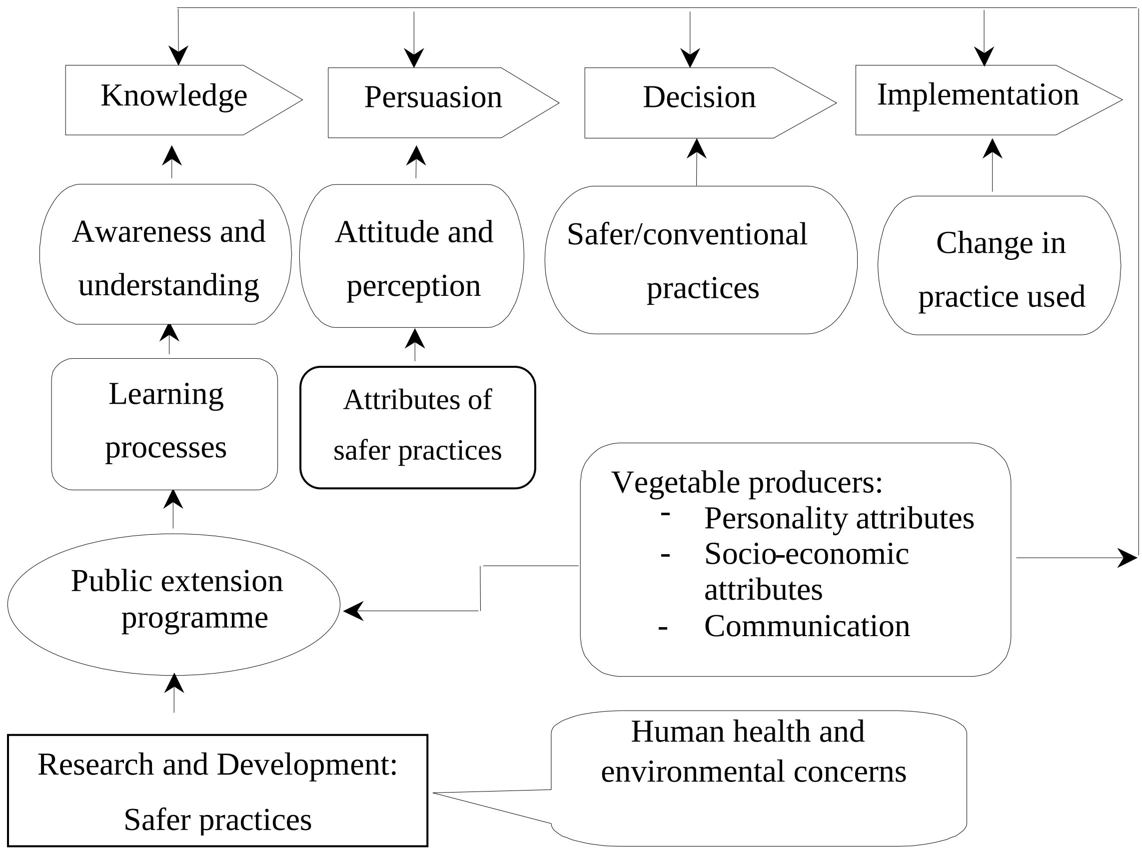

Figure 3.1: The processes of knowledge acquisition and technology adoption
Source: Adapted from ROGERS (2003)

The importance of attitudes towards a new technology in the decision of an individual has been suggested by FISHBEIN (1997) cited in KULSHRESHTHA AND BROWN (1993). He proposed that an individual's determination to adopt a new idea (e.g. towards safer vegetable production practices) is a joint function between his/her attitude toward that idea and his/her beliefs of what is expected for the adoption of those practices. In spite of the fact that an individual may hold a positive attitude towards a new technology, there may be some inconsistency between the expected and actual reaction. For example, in the present case, vegetable producers may recognize a feasible practice in a spectrum of safer vegetable production practices but may not want to use it because of other constraints. After the transformation of information into knowledge and matching this information with existing attitudes of the potential adopter, a vegetable producer has to choose between conventional practices and safer ones. This is called the decision stage. Finally, there is the implementation stage. If an individual producer adopts safer practices, those will then be implemented (see Figure 3.1).

In the adoption-decision processes, knowledge has been discussed as the important constraint for adoption of innovation. Producers with more knowledge will have a higher probability of adopting new technology (ASHBY 2003; FEDER *et al.* 2003; SUNDING and ZILBERMAN 2001; WAIBEL and ZILBERMAN 2007), particularly in the case of knowledge-intensive technology. Increasing producers' knowledge is relevant to improving human capital. WELCH (1970) firstly proposes that differences in human capital in terms of education, and the differences in knowledge of the new technology, enhance the ability to adjust to technological change. WOZNIACK (1984; 1987) subsequently develops a model by integrating the role of the innovative ability as an economic incentive including education, experience and the availability of information to technology adoption. The estimated results from a logistic model show that all indicators used for measurement of the innovative ability significantly contribute to an explanation of the adoption of innovation. Imperfect information increases adoption cost, and thereby reduces the probability of adoption. These results are consistent with the study of SCHULTZ (1975), who states that in the long run introduction of new technology can increase the ability of producers to better allocate resources. RAHM and HUFFMAN (1984) argued that the inefficiencies can be eliminated by enhancing human capital or increasing the stock of knowledge through learning and experimenting. Learning takes place in different categories, mostly dealing with the gaining of new scientific knowledge and incorporating it in innovation (ROSENBERG 1982). The process contains learning by using, and learning by doing (SUNDING and ZILBERMAN 2001). Learning by doing is a source of producers' experience that will reduce a fixed cost of knowledge accumulation, while learning by using will increase skills of producers and will lead to a decline of the real labour cost per unit of output (ROSENBERG 1982; SUNDING and ZILBERMAN 2001).

In an empirical study, FOSTER and ROSENZWEIG (1995) firstly developed a model to examine the role of knowledge in the adoption of high yield varieties (HYV). Their estimated results indicate that imperfect knowledge is the major barrier to HYV adoption. However, learning by doing through own experience and from the experience of neighbours can diminish this barrier. The conceptualisation of the process of extension programme as a source of learning and knowledge provides models that can help to better understand the factors that drive this process and identify possible constraints. However, it is unclear whether programme participation directly affects the adoption of safer vegetable production practices that aim to improve the agricultural resource base. In this study several models will used to examine the participation-knowledge-practice change process.

3.2. Modelling participation, knowledge and adoption

Following the conceptualization of the process of knowledge acquisition and technology adoption for safer vegetable production practices through extension programmes in chapter 3.1.2, the methodological approach used to quantify these processes is described in the following. The different steps used in the analysis are shown in figure 3.2. The model starts with the notion of a technology supplier that uses training and extension approaches to provide technology to potential technology adopters. In this case the technology supplier is the Royal Project Foundation in Thailand, which in cooperation with respective government agencies in Thailand intends to motivate vegetable producers in the mountainous areas in Northern Thailand to adopt safer vegetable production practices. In addition other programmes have been introduced with different approaches but only two have applied the training and learning extension method. They are Integrated Pest Management Practice (IPM) and Good Agricultural Practices (GAP) programme. These two initiatives cooperate with the Royal Project Foundation in the study area and in fact they are the same agencies and even the same people but using different names for the same activities in order to obtain support from foreign donors. Therefore in this study vegetable producers who participated in these two programmes, in addition to registered members of the RPF, were also included in the participant group of the sample.

In the first step, the analysis aims to model vegetable producers' decision to participate in the various activities of the programme (see Figure 3.2). The theoretical basis for this model is classic decision theory based on the decision-maker's expected utility. Hence, it is assumed that vegetable producers will invest in the acquisition of knowledge about new technologies if their expected utility exceeds those of conventional practices. Theoretically, factors affecting the utility of participation include economic factors as well as characteristics of the decision maker such as prior knowledge and experience. In the second step following the participation decision, the effect of the programme on the participants' knowledge is analysed. This model assumes that change in knowledge can be quantified through knowledge scores developed from a set of knowledge-related questions that reflect the essential elements of the new technology. The major hypothesis here is that participation in the knowledge supply programme of the RPF is significantly increasing the knowledge of vegetable producers, as a precondition to adopt safer vegetable production practices. In addition, other variables, including education, experience and the time available of participants are likely to influence the observable change in knowledge.

The third step is to establish the link between the change in knowledge and the adoption of safer practices. Modelling adoption is generally carried out as a yes/no decision, where the dependent variable is formulated as a zero-one variable using 1 for adoption and 0 for non-adoption. Since modelling is done for each practice separately it is necessary to identify the most important out of a set of practices that in principle fall into the category “safer” practices. However, not all of them may be feasible for the production conditions in the study area and some may be less significant in improving health and environmental conditions in the area. Hence, selection of key practices was carried out by an expert panel. Typically, this is measured as dummy variable, i.e. 1 represents use and 0 for represents non-use. As in the knowledge model, a set of independent variables regressed on the zero-one adoption variable was identified based on economic theory. One obvious limitation of this approach to model individual practices is that it does not allow judgement of to what extent this leads to an overall improvement of the health and environmental conditions in the study area. To circumvent this problem an aggregate minimum standard of safer practices was identified by the expert panel. A scoring method was used to allow experts a ranking of key practices selected in a prior consultation process. In total, expert opinion converged on eleven key practices that are all compatible with the principle of the integrated pest management concept. Each practice was weighted by the experts on a scale from 1 to 10 that ranks the practices by their degree of importance with 1 as least important and 10 highly important. The cumulative total was then calculated to establish the aggregate expert standard.

The fourth step of the analysis captures the comparisons between practice scores of participants and non-participants. It is hypothesised that participation in the knowledge supply programme of the RPF should directly motivate vegetable producers to adopt safer practices, i.e. practice scores of participants should be higher than the scores of non-participants. In addition, there may be knowledge diffusion from participants to non-participants, i.e. it is possible that non-participant vegetable producers will also adopt some safer practices. Hence, the comparison between practice scores of participants and non-participants is insufficient to measure the full scale of adoption. On the other hand, it is also possible that there is a gap between vegetable producers’ adoption of existing practices and the standard set by the experts. This was identified in the fifth step.

Lastly in the sixth step, a model was formulated that offers an explanation of the gap between existing practice used by participants and the expert standard. Here, an examination of the direct effects of the programme on the adoption of safer practices among participant vegetable producers is carried out through a simultaneous equation procedure. The model distinguishes between the weighted and the un-weighted practice scores to identify factors responsible for the difference between the existing practices used by participants and the expert standard.

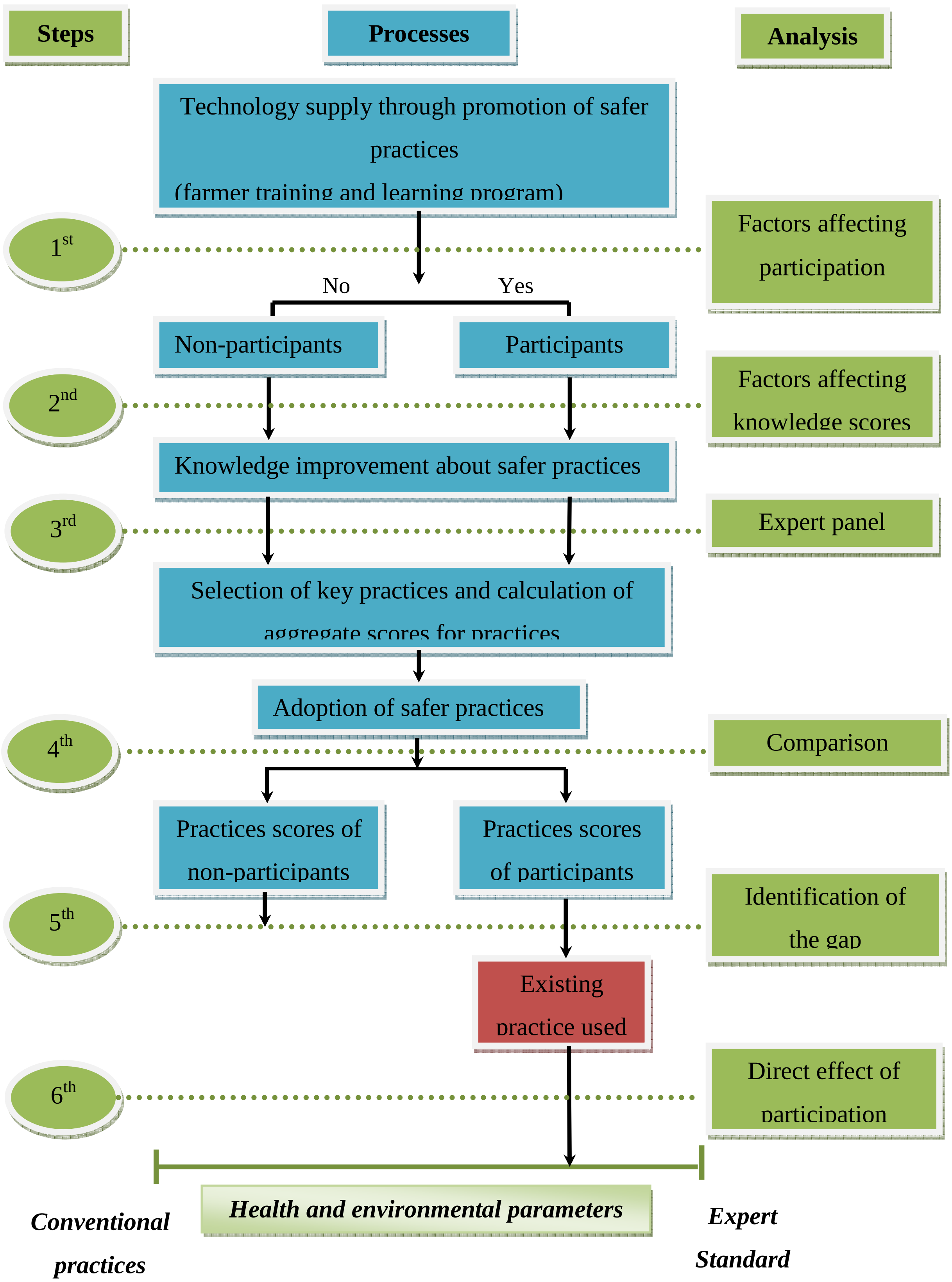

Figure 3.2: Modelling framework

Source: Own presentation

3.3 Model Description

3.3.1 Probit regression model

For modelling factors influencing an individual vegetable producer's decision to participate in the safer practice programmes, a binary choice model is applied. Following classical economics theory, vegetable producers are assumed to be risk-averse, i.e. they will participate in the programme only if their utilities obtained from the programme are greater than those of non-participation. Suppose U^j is the differences of two utility functions: utility function for non-participation ($j = 0$) and for participation ($j = 1$). The utility (U^j) of these producers depends upon their characteristics, human capital, farm resource endowments and other factors. Notation $\mathbf{z}$ is a matrix of these factors and η_j is a vector of two parameters for participation and non-participation. The individual utility function of these choices thereby can be represented as equation (1), provided by the linear random utility model (GREENE 1997):

$$U^j = \boldsymbol{\eta}_{\mathbf{j}}\mathbf{z} + e_j \tag{1}$$

In reality (U^j) is measured through programme participation and non-participation and formulated as a dummy variable y , which equates to 1 if the vegetable producer participates in the program and zero otherwise. The probability of participation is derived as equation (2).

$$\begin{aligned} \Pr(\text{participation} = y_{j=1}|x) &= \Pr(U^1 - U^0 > e_0 - e_1) \\ &= \Pr(\boldsymbol{\eta}_{\mathbf{j}}\mathbf{z} > e_j) \\ &= F(\boldsymbol{\eta}_{\mathbf{j}}\mathbf{z}) \qquad (2), \end{aligned}$$

where $F(\boldsymbol{\eta}_{\mathbf{j}}\mathbf{z})$ is the cumulative distribution function for a random disturbance term (e_j) evaluated $\boldsymbol{\eta}_{\mathbf{j}}\mathbf{z}$. According to Bernoulli distribution, equation (2) can be modelled as a joint probability (GREENE 1997).

$$\Pr(y_j|x) = \prod_{y_{j=0}} \left[1 - F(\eta_j' z)\right] \prod_{y_{j=1}} F(\eta_j' z) \tag{3}$$

The functional form proposed for $F(\boldsymbol{\eta}_{\mathbf{j}}\mathbf{z})$ depends on the assumption of the error term (e_j). If the data set is best shown by a logistic distribution, i.e. F is cumulative logistic, a logistic model should be used. On the other hand, if the distribution is normal, application of a probit model is considered (AMEMIYA 1981). Although a logit regression has advantages over a probit model in terms of mathematical convenience (GREENE 1997) and in terms of the interpretation of results for a wide range of applications (HOSMER and LEMESHOW 2000), in this study a probit model was selected. The reason is that using the instrumental variable technique, the assumption of normal distribution for the error term of the treatment equation holds and the probit model is more efficient (HECKMAN 1979). Hence, a probit model can be modified as shown in equation (4):

$$\Pr(y_i\,|z) = \prod_{y_{j=0}}\left[1-\Phi(\;{}'_{\mathbf{j}}\mathbf{z})\right]\prod_{y_{j=1}}\Phi(\;{}'_{\mathbf{j}}\mathbf{z}) \tag{4}$$

where $\Phi(.)$ is normally distributed with mean and zero unit variance. In general, the probit model involves a nonlinear maximum likelihood estimation, hence the log-likelihood of the joint probability can be described in equation (5):

$$\ln L = \sum_{y_{j=0}}\ln 1-\Phi(\eta'_{\mathrm{j}}z)+\sum_{y_{j=1}}\ln\Phi(\eta'_{\mathrm{j}}z) \tag{5}$$

In chapter 5, where the analysis focuses on the participation of vegetable producers in extension and training programmes, equation (5) is applied and identified as model 1. A general formulation of the model can be written as:

Model 1: $y_j = \boldsymbol{\eta}_{\mathbf{j}}\mathbf{z}+e_{\mathrm{j}}$

To interpret results obtained from model 1, sign and magnitude of a coefficient indicates a direction of an effect of a change in an independent variable and the relative influence that a variable has on the probability of choice, respectively. In practice there are two alternative methods used to interpret the coefficients. The first method is to calculate the marginal effects. These provide a relationship between a change in the probability and a change in an independent variable by taking the derivative of the probability function with respect to the independent variables or by taking the expectation of probability function: $\partial E(y \mid z_j)/\partial z_j = \partial \Pr/\partial z_j = \Phi(\eta_j' z) \times \eta_j$. Using this method of interpretation of the partial derivative evaluated at the mean value of the independent variable, an inaccuracy can arise because the partial derivative has no boundary, which implies that the predicted probability can be outside the zero-one interval (PETERSEN 1985). In addition, direct comparisons of the marginal effects of probabilities between independent variables are limited because of the differences in scale of the independent variables (LECLERE 1992). To eliminate these limitations, an elasticity of probability is proposed. This method is independent in the units that measure the responsiveness of change in the probability to a change in independent variables: $\xi = [z_j / \Phi(\mathbf{\eta_j z})].[\partial \Phi.(\mathbf{\eta_j z}) / \partial z_j$ .A high elasticity of less than 1 implies that probability is very responsive to changes in the independent variable because there is a greater than proportionate change in the probability relative to the exogenous variable. For a low elasticity of more than 1 the interpretation can imply the opposite.

3.3.2 Average treatment effect models

This section discusses models that are used to measure the effect of participation in knowledge provision programmes. To begin, a random vector of vegetable producers' knowledge scores with programme participation ($knowledge_1$) and without programme participation ($knowledge_0$) is defined. In addition, let $\mathbf{x}$ be a vector of observable covariates affecting vegetable producers' knowledge and let β be unknown parameters. The structural equation of knowledge with and without the programme can be written as equation (6):

$$knowledge_1 = \mathbf{x\beta_1} + \varepsilon_1 \quad \text{and} \quad knowledge_0 = \mathbf{x\beta}_0 + \varepsilon_0 \qquad (6),$$

where $\varepsilon_1, \varepsilon_0$ are unobservable factors. An assumption of an independent, identically distributed sample from the population is first made: $E(\varepsilon_0), E(\varepsilon)_1 = 0$. To measure the participation effect of the programme on vegetable knowledge bases, the differences in $knowledge_1$ and $knowledge_0$ are of interest. There are two major methods of measuring these differences: (i) average treatment effect (ATE) and (ii) average treatment effect on the treated (ATET). ATE is the expected effect of participation on a random draw from the population

(ROSENBAUM and RUBIN 1983): $ATE = E(knowledge_1 - knowledge_0 | x)$. ATET is the mean effect of those who actually participate in the programme: $ATET = E(knowledge_1 - knowledge_0 | x, participation=1)$. These two terms, using the assumption of mean independence, would be identical as shown in the underlying derivation.

To decompose and integrate the participation variable in equation (6), the observed knowledge can be specified in the following equation (WOOLDRIDGE 2002):

$$\begin{aligned} knowledge &= (1 - participation).knowledge_0 + participation.knowledge_1 \\ &= knowledge_0 + participation.(knowledge_1 - knowledge_0) \end{aligned} \qquad (7)$$

If $knowledge_0$ and $knowledge_1$ are mean independent of *participation,* $E(knowledge_j \mid \mathbf{x}, part) = E(knowledge_j \mid \mathbf{x}), \quad j = 0,1$. Hence ATE and ATET are indifferent.

$$\begin{aligned} \text{ATE} = \text{ATET} \quad &= E(knowledge \mid \mathbf{x}, participation = 1) \\ &- E(knowledge \mid \mathbf{x}, participation = 0) \end{aligned} \qquad (8)$$

In practice, however, this assumption may not hold because of two problems: (i) the difficulty tin specifying counterfactual scenarios and (ii) the problem of selection bias. For (i), in the case of the RPF programme no baseline data prior to the implementation of the programme were available. For (ii), vegetable producers were not randomly selected to participate in the programme but they decided for themselves. Hence they may differ from those who decided not to participate in the programme, for example, in terms of knowledge and other characteristics. Any difference measured after programme participation may in fact be in part due to other factors. Another kind of selection bias may occur due to the non-random selection of the villages that were included in the survey. To overcome these problems, two statistical techniques can be applied: (i) the *ignorability of treatment technique*, and (ii) the *instrumental variable technique*. The first method contains three approaches: a) regression based; b) propensity scores; and c) matching approaches. The second method is known as the treatment effect model. The robustness of each technique depends on the data set. Since it is unknown and we do not know a priori which method is suitable for the prevailing data in this study, all three methods are applied and results are compared. In the following a description of the different techniques is provided.

3.3.2.1 Ignorability-of-treatment-technique

The *ignorability-of-treatment-technique* is based on the assumption that conditional on outcomes, independent variables ($\mathbf{x}$) and the variable of participation are uncorrelated (ROSENBAUM and RUBIN 1983). In this study, outcomes are knowledge scores of participant vegetable producers and knowledge scores of non-participant vegetable producers. This approach implies that ATE and ATET have the same condition regarding the independent variables. For the ATE approach one can use a) *regression based methods* and b) *propensity score matching* (WOOLDRIGE 2002). Conceptions of these methods are discussed in the following paragraph.

(a) Regression based method

For the regression based methods, two simple models, in the following called model 2a, 2b, and 3, can be estimated. Model 2a and 2b is used as a reference for comparison with more complex models. γ. In model 2a, *knowledge* is simply regressed only on the treatment variable (*participation in program*me), while in model 2b other independent variables are added. The ATE in both equations is represented by the coefficient γ. If there is no selection bias, results from other models should yield similar values to these two models.

Model 2a: $knowledge = \alpha_{model2a} + \gamma'_{model2a}\, participation + \varepsilon_{model2a}$

Model 2b: $knowledge = \alpha_{model2b} + \gamma'_{model2b}\, participation + \mathbf{x}\boldsymbol{\beta}_{model2b} + \varepsilon_{model2b}$

Model 3 is based on a *regression method*, which uses the basic assumption of the *ignorability-of-treatment-technique*. This model is derived from the conditional mean independence, i.e. knowledge is mean independent of participation. In addition, it utilizes a control function to eliminate the selection biases:

Model 3: $$knowledge = \alpha_{model3} + \gamma'_{model3}\, participation + \mathbf{x}\boldsymbol{\beta}_{model3} + participation.(\mathbf{x}-\bar{\mathbf{x}}).\delta_{model3} + \varepsilon_{model3},$$

where β and δ are vectors of unknown parameters, and the term $(\mathbf{x}-\bar{\mathbf{x}}).\delta_{model3}$ before the error term at the right-hand side represents the control function. The idea behind this approach is that adding more independent variables as proxies of unobservable effects will make the participation variable and *knowledge* become uncorrelated. In the estimation procedure, each element of $\mathbf{x}$ would be demeaned by the sample average ($\mathbf{x}-\bar{\mathbf{x}}$), which ensures that the obtained coefficient γ is ATE (WOOLDRIGE 2002). Based on this approach, derivation of an estimation of a conditional ATE can be carried out. For example, if $\mathbf{x}$ refers to the variable 'education of household head', a change in ATE for various levels of education can be estimated over the sample of programme participants as follows:

$$knowledge_{ATE}^{education} = \hat{\gamma} + \{education - mean(education)\}.\hat{\delta}_{model3} \quad (8a)$$

where $\hat{\gamma}$ and $\hat{\delta}$ are obtained from the estimation of model 3. Similarly, a change in ATET can be estimated over the sub-sample of participants by the underlying equation.

$$knowledge_{ATET}^{education} = \hat{\gamma} + \frac{\left[(\sum_{i=1}^{N} participation.(education - mean.(education).\hat{\delta}_{model3}\right]}{(\sum_{i=1}^{N} participation)^{-1}.} \quad (8b).$$

As shown in equation (8c), the proof of equation (8b) indicates that ATE equates ATET in equation (8a). Hence, this ensures that the estimation of ATE under the assumption of the *ignorability-of-treatment-technique* will be equal to ATET.

$$knowledge_{ATET}^{education} = \hat{\gamma} + \{education - mean(education)\}.\hat{\delta} \quad (8c)$$

(b) Propensity score matching method

By utilizing the *ignorability-of-treatment* assumption, ROSENBAUM and RUBIN (1983) pioneered the propensity score method. The propensity score (PS) is defined as the probability of the programme participation conditional on $\mathbf{x}$:

$$p(\mathbf{x}) \equiv \text{Prob}(participation = 1 \mid \mathbf{x}),\ 0 < p(x) < 1 \quad (9).$$

The last condition in equation (9), $0 < p(x) < 1$, is called overlap condition or common support

(CALIENDO and KOPEINIG 2005). It ensures that vegetable producers with the same attributes (*x*) have the same probability of being allocated to participation and non-participation groups (HECKMAN *et al.* 1999). The procedure, thus, is to first estimate the propensity scores (PS) and then check whether the PS distribution satisfies this condition. In this study, PS is the probability of participation in the knowledge supply programme of the RPF, given the observed characteristic of vegetable producers. LECHNER (2002) proposed a simple method consisting of a comparison of the minima and maxima of the PS in both groups, based on the criteria that any observation whose PS is smaller than the minimum and larger than the maximum in the opposite group has to be deleted. Propensity scores can then be used to estimate ATE or ATET[12]:

$$know\hat{l}edge_{ATE/ATET} = N^{-1}\sum_{i=1}^{N}[participation - P\hat{S})]/[P\hat{S} - P\hat{S}^{2}] \quad (10)$$

In equation (10), PS and treatment variables are included as the regressors, and μ_{PS} is the sample average of PS. ROSENBAUM and RUBIN (1983) suggested the prediction of a propensity score (PS) using a logit or probit model by including independent variables $\mathbf{x}$ and various functions of $\mathbf{x}$, including interaction and quadratic terms. They also proposed a general version based on a simple regression for estimating ATE as the underlying equation as in model 4:

Model 4:

$$knowledge = \alpha_{model4} + \gamma'_{model4}.participation + \phi_{model4}.PS + \delta_{model4}.[PS - \mu_{PS}] + \varepsilon_{model4}$$

WOOLDRIGE (2004) suggested a more simple model that included only the PS as the regressor on the dependent variable. He indicated that in this approach the PS is used as the control function that contains all information in the independent variables, leading to consistent estimation of ATE as indicated in model 5:

[12] Since this method is derived under "the ignorability of treatment techniques". ATE is assumed to equate with ATET.

Model 5: $knowledge = \alpha_{model5} + \gamma'_{model5}.participation + \phi_{model5}.PS + \varepsilon_{model5}$,

where the coefficient on part (γ) represents the estimation of the effect of programme participation (WOOLDRIDGE 2004).

All other approaches utilising the PS belong to the category of matching methods, including s*tratification matching, nearest neighbour matching, radius matching,* and *kernel matching*. The basic idea of these four methods is that they use the predicted probability of participants matched with those similar characteristics of the non-participation group. The different matching rules of these algorithms are briefly discussed in the next paragraph.

Beginning with the *stratification matching,* the procedure of this method is to divide the range of variation of the propensity score into a set of intervals. Let *b* represent the number of the blocks defined over the interval of the propensity score, $b \in B$. The average effect within each block is calculated by taking the mean difference in outcomes between participant group and non-participant group as follow:

$$knowledge = [\sum_{i \in I(b)} knowledge_T / N_b^T] - [\sum_{i \in I(b)} knowledge_C / N_b^C], \qquad (11),$$

,

where T and C denote the participant and non-participant/control groups, and $I(b)$ is the set of vegetable producers in each block. N_b^T and N_b^C are the number of vegetable producers in the participant group and the non-participant group in each block b. Subsequently, calculation of ATE is carried out by summing ATE_b and weighting by the distribution of treated units across blocks (BECKER and ICHINO 2002). In the present case, estimation of ATE based on this method is named as model 6.

Model 6: $knowledge = \sum_{b=1}^{B} ATE_b [\sum_{i \in I(b)} participation_i / \sum_{\forall_i} participation_i]$

The second method is *nearest neighbour matching*. The main idea of this method is that each non-participant unit (a vegetable producer in the control group) will search for a participant unit (a vegetable producer in the participant group) who has the closest PS. A set of non-participant vegetable producers (c) matched to the participant vegetable producers t with the PS is: $C(c) = \min_{c} \| PS_t - PS_c \|$, where PS_t *and* PS_c are the PS of the participant and the non-participant units, respectively. Differences between knowledge of the treated units and the matched non-treated units afterwards are calculated in the following model, identified as model 7.

Model 7: $$knowledge = \{(1/N_t^T).(\sum_{t \in T} knowledge_t^T)\} - \{(1/N_t^T).(\sum_{c \in C}(1/N_c^C).knowledge_c^C)\}$$

Two terms N_t^T and N_c^C are the number of vegetable producers in the participant group and the non-participant group, respectively. In the empirical procedure, a unit in the non-participant group can be used more than once as a match, which is called matching with replacement. However, based on this method some participant producers in the nearest neighbour may have a very different PS, leading to a low quality of matching (SMITH and TODD 2005). BECKER and ICHINO (2002) argued that this problem depends on the data used in the analysis. Therefore, that method is also applied in this study.

The other two methods used in this study are *radius matching* and *kernel-based matching*. In practice the procedure for *radius matching* and the *nearest neighbour matching* are quite similar when applying the ATE approach. In the first step each participant vegetable producer is matched with a non-participant vegetable producer whose PS falls in the radius of the participant vegetable producers. The radius is subjectively chosen by the researcher and often set to be 0.1 (BECKER and ICHINO 2002). In radius matching, a set of non-participant vegetable producers (c) matched to the participant vegetable producers t with the PS is: $C(c) = \{PS_c \mid \| PS_t - PS_c \| < radius\}$. This is subsequently used to calculate ATE by following the equation of model 7. The difference between this method and *nearest neighbour matching* is the set of non-participant vegetable producers (c). The structural equation is similar to model 7. Hence, estimation of ATE based on this method is presented as model 8 in this study.

A weakness of the *radius matching* is that if the radius is very small, some participant vegetable producers may not be matched because the non- participant vegetable producers are outside the radius (CALIENDO and KOPEINIG 2005). This problem can be overcome by *kernel-based matching*, which was developed by HECKMAN *et al* (1997). This method uses a nonparametric estimator. The weighted average of all individuals in the non-treated group is used to construct the counterfactual outcomes. The advantage of this method is that it has lower variances when compared to other methods. The ATE based on this method in the study is described in model 9:

Model 9: $$knowledge = (\frac{1}{N^T}).\{knowledge_t^T - [\frac{\sum_{c \in C} knowledge_0 . K((PS_t - PS_c)/h)}{\sum_{k \in C} K((PS_t - PS_c)/h)}]\},$$

where *K(.)* is a weight function calculated from the differences between the PS of participant group and non-participant group. This is also known as the kernel function. h is a bandwidth of the kernel that is determined by the researcher. In the estimation of the average effect, this function is used to weight the knowledge scores of non-participant producers.

3.3.2.2 Instrumental variable techniques

In addition to the models described above, a structural equation based on the instrumental variable (IV) technique that follows the treatment effect model developed by HECKMAN (1978; 1979) is used in the present study. In this model the effect of treatment on the treated[13] and the effect of random sampling to treatment converge because the difference between the two outcomes[14] at any time is the same for all persons with the same observed characteristics (HECKMAN *et al.* 1999). With respect to the participation equation (model 1) and knowledge equation (model 2b), by utilizing the IV technique, two assumptions are required: the unobservable variables (ε) of the knowledge equation are correlated with the treatment, but the error term of the participation equation (e) is uncorrelated with the independent variables used in both equations of knowledge and participation: $(\varepsilon, e) \sim N(0,0,1,\sigma_e, \rho)$ (HECKMAN 1978). Utilizing the assumption of a joint normal distribution of e and ε, the conditional expectation of level of $knowledge$ observed when a vegetable producer decided to participate in the programme can be written as model 10:

Model 10: $$E(knowledge \mid participation = 1, \mathbf{x}, \mathbf{z}) = \gamma'_{model10}.participation + x\beta_{model10} + \rho\sigma_{knowledge}.[-\phi(z'\eta)/(1-\Phi(z'\eta))],$$

---

[13] Treatment in this study refers to program participation.

[14] Outcomes in the study present to knowledge score of participant and non-participant vegetable producers.

where ρ is the correlation between the unobservable independent variables (e, ε), σ is the standard deviation of knowledge equation, and $\mathbf{z}$ is a vector of independent variables influencing the participation decision. According to model 10, the participation variable is endogenous of the knowledge scores, and is called the dummy endogenous variable model (HECKMAN *et al.* 1998). The final term in model 10 shown in the square brackets is the *inverse mills ratio (IMR)*, which can be obtained from the estimation of participation equation. Technically, if IMR is significantly different, a selection bias or a correlation between e and ε exists. It implies that the two equations must be jointly estimated. To estimate model 10, two possible methods are proposed: (i) limited information maximum likelihood (LIML), and (ii) full information maximum likelihood (FIML). The procedure for the first method is to calculate the IMR from model 1 (participation equation), and then the predicted IMR is used in the linear projection of *knowledge* on *participation* and **x** in model 10. By utilizing the FIML method, participation and knowledge equations are estimated jointly by maximizing the bivariate normal likelihood function (GREENE 1997). This method takes account of the endogeneity by directly incorporating the correlation between e and ε into the model. FIML, however, makes a stronger assumption and is more efficient than LIML when correlations between the selectivity term (*participation*) and independent variables used in the knowledge equation are very low. Hence there is a trade-off between robustness to violation of the joint normality assumption and the efficiency gains from fully imposing the bivariate normality. The LIML version is less efficient because it does not fully impose the bivariate normality assumption (HECKMAN *et al.* 1999; NELSON 1984). Hence, FIML is used to estimate this model.

3.3.2.3 Selection biases and endogenous variable

The models until now have focussed on the relationship between the participation in safer practice programmes promoted by the RPF and the influence on vegetable producers' knowledge. The next step is to evaluate the effect of knowledge in the adoption of safer vegetable production practices. This section describes the application of an econometric instrument to test the relationship. Two major econometric problems occur when trying to answer this question: (i) sample selection bias - as mentioned above and (ii) the choice of the endogenous variable. For (i) some unobservable factors influencing vegetable decision-making to participate in the programme (participant group) are correlated with those determining their knowledge. In addition, knowledge may correlate with the disturbance in the participation equation because changes in both vegetable production practices and knowledge may depend on unobservable variables, for example, management skills. According to these mechanisms, the two-stage least squares approach (2SLS) under the condition of selection biases can be applied with the underlying simultaneous equation systems (see also WOOLDRIGE 2002).

$$practices = \mathbf{z}_1\delta_1 + \alpha_1 knowledge + u_1 \quad (11a)$$

$$knowledge = \mathbf{z}\delta_2 + u_2 \quad (11b)$$

$$participation = \mathbf{z}\delta_3 + u_3 \quad (11c),$$

where $\mathbf{z}_1$ is a vector of independent variables affecting vegetable practices' score (*practices*), z covariates influencing participation decision and also some determining knowledge. Knowledge is endogenous to the change in practices used (practice scores). Formally, *practic*es and *knowledge* are observed only when *participation* has a value of 1. Simultaneous estimations of these equation systems can be carried out under the following strong assumptions (WOOLDRIGE 2002): (i) the unobservables of practice scores and participation decision (u_1, u_3) are independent of z; (ii) u_3 ~ *Normal* (0, 1); (iii) E(u_1| u_3)=$\theta_1 u_3$; (iv) endogeneity of knowledge on practice scores– $E(\mathbf{z}'u_2) = 0$ –and identical to the condition needed for identifying equation (11a) in the absence of sample selection– $\mathbf{z}\delta_2 = \mathbf{z}_1\delta_{21} + \mathbf{z}_2\delta_{22}$, $\delta_{22} \neq 0$. Following these assumptions the structural equation for the estimation of the effect of safer practice programmes on the use of safer practices is described in model 11.

Model 11: $$practices_1 = \mathbf{z}_1\delta_1 + \alpha_1 knowledge + \theta_1 lambda + \xi_1$$

In the estimation procedure, δ_3 can be obtained from the participation model estimated by using all observations, i.e. both participant and non-participant vegetable producers. Thereafter the inverse mills ratios or lambda, $\hat{\lambda}_3 = \lambda(w_i\hat{\delta}_3)$ is calculated and used to estimate model 11 by utilizing 2SLS with the selected sub-sample (*participation*=1 for which of the observation of $practices$ and $knowledge$). The covariates ($\mathbf{z}$) and lambda ($\hat{\lambda}_3$) are used as the instruments for the last process, where *knowledge* is required to be endogenous to the practice scores. In addition, at least two elements of z have to be excluded from the knowledge equation (structural equation), i.e. at least one must be selected as an instrument for the knowledge equation and at least one other element as an instrument for the participation equation.

3.4 Summary

This chapter introduces the methodology used in the study in two parts. First, knowledge-intensive technologies are defined and the adoption-decision making process in the acquisition of knowledge through extension programmes is conceptualized by drawing on the literature on the role of extension systems in the delivery of knowledge-intensive technologies in agriculture.

The conceptual framework describes the factors and constraints that influence the decisions of vegetable producers in Northern Thailand to participate in programmes that supply knowledge-intensive technologies. It also describes how programme participation increases knowledge of the participants in order to enable them to adopt safer vegetable production technologies. The framework is implemented by using secondary data from own survey of vegetable producers who participated in the programme and those who did not, as well as from an expert consultation process that helped to identify the essential elements of the technology in order to arrive at an aggregate measure of safer vegetable production practices.

The second part of the chapter provides a detailed description of the models used to quantify the different relationships outlined in the conceptual model. First, a probit regression model is used for the identification of factors that influence vegetable producers' decision to participate in the programme. Second, the application of a model in practice relevant techniques for estimating the effect of the programme are discussed, namely the ignorability of treatment and the instrumental variable techniques. The first set of techniques includes the regression-based method and the propensity score matching methods, while the second technique is the treatment effect model developed by HECKMAN (1978). These two basic econometric models are applied to test for selection biases and endogeneity. Last but not least, a more advanced model used to examine the effect of programme participation on the adoption of safer practices is developed following the two-stage least square method by taking into account selection biases. In the next chapter, the data used in the empirical estimation of the models will be described.

Chapter 4

Data collection

This chapter describes the methodology of data collection. The data were collected from three sources: a) secondary data from government statistics and project reports; b) data generated from an expert panel and consultation process; and c) primary data from a survey of 300 vegetable producers in the province of Chiang Mai in Northern Thailand. The information from secondary information sources was presented in chapter 2 in the course of a general discussion of the development of vegetable production in Thailand. In the following, data collection from an expert panel and consultation process, as well as primary data collections, are described.

4.1 Expert panel and consultation process

One of the problems associated with measuring the adoption of safer vegetable production practices is the identification of a good counterfactual or a reference standard. Although the Government of Thailand has set standards for the quality of agricultural products (e.g. maximum residue levels) and for inputs (e.g. formulation of active ingredients) and has stipulated regulations on the use of agricultural inputs (e.g. waiting periods after harvest), no clear definition exists on either conventional farming or on environmentally safer and healthier production practices. The only exception is organic farming as explained in chapter 2, which has well-specified production practices following either national regulations or international standards. The widely used concept of Integrated Pest Management (IPM) has some 90 definitions but lacks a common legal basis. Hence, there is also a lack of definition of safer practices in contrast to conventional farming. To overcome this problem a process of expert consultation in a workshop, and an opinion survey, were initiated for this research.

4.1.1 Expert workshop

The objectives of the workshop were to identify the definition of safer vegetable production practices, and to discuss factors affecting the adoption of those practices. The workshop included 10 experts on vegetable production and marketing of vegetable products from university, government and the private sector[15]. The workshop consisted of two sessions. In the first session, the conceptual framework of the research and the workshop objectives was introduced. Secondly, a brainstorming and discussion session was conducted in which experts discussed the definition of alternative or safer vegetable production technologies, defined an agreeable minimum level of adoption of safer practices with regards to positive health and environmental effects, and identified the factors that were likely to act as constraints on or stimulants to the adoption of such practices. A card-based brainstorming technique was used to focus the discussion on the three issues. The key idea for brainstorming and discussion of the first issues was based on agricultural systems in Thailand, which will be described below.

As a result of the workshop the experts agreed on a definition of the term “safer vegetable production practices”, which was largely based on the IPM concept promoted by the Department of Agricultural Extension (DOAE) and several NGOs. In addition a set of criteria was formulated allowing the researcher to develop a questionnaire regarding minimum requirements of adopters in relation to producers’ practices and knowledge. The following practices were identified as relevant for implementing safer vegetable production practices:

- Crop rotation practices
- Seed treatment practices
- Regular field observations
- Use of biological control methods
- Detailed knowledge of chemicals used
- Source of pesticides
- Use of sticky trap practice
- Practice of mulching

[15] A total of 19 experts was invited but only 10 were able to attend. Those unable to come cited lack of time as a major reason.

- Use of soil analysis
- Soil improvement measures
- Contour bund planting

The identified practices served as the basis for formulation of key questions in the questionnaire. The experts were also involved in the selection of the study area based on three criteria: (i) year-round vegetable production; (ii) vegetables grown in highland areas; and (iii) areas where projects aimed at the introduction of safer vegetable production practices have been carried out.

4.1.2 Expert opinion survey

An expert's opinion survey was carried out with a total of 23 vegetable experts: four experts are from the field of plant protection research and the others are from extension. Some experts who are from extension have also participated in the expert workshop mentioned in the previous section. The purpose of the survey was to develop an aggregate practices index. Information obtained from this survey served to give an assessment of the gap between practices used by vegetable producers and a minimum requirement for safer practices as identified by the experts. The survey was conducted by mail, and its purposes were explained in a cover letter attached to the questionnaire (see appendix C). The experts were asked to rank priority among safer practices. The key practices (both positive and negative in terms of health and environment) used in the questionnaire were drawn from results of the vegetable producer survey (see next section). Experts were asked to weight practices by importance according to their opinion, choosing a value on a scale from 1-10, where 1 means least important and 10 most important. The application of the expert opinion survey and the results are further explained in chapter 7.

4.2 Vegetable producer survey

4.2.1 Characterization of study area

The criteria used for selecting the study area were determined in the expert workshop (see section 4.1.1). Based on these criteria the highland areas in the province of Chiang Mai were selected. The area is a major forest and watershed protection zone. The farming populations, including vegetable producers, comprise different ethnic minorities (SURASWADI *et al.* 2005) occupying different altitude levels. These differ in environmental conditions and agro-ecosystems, which can broadly be classified as highlands, midlands and lowlands (THOMAS *et al.* 2004). In the past, hill tribe communities living in highlands and midlands had practised shifting agriculture and cleared land for opium cultivation (RERKASEM and RERKASEM 1994). This has caused losses of forest cover and biodiversity, problems with soil erosion and water quality deterioration. Moreover, population growth has led to pressure on land and increasing competition between water users living in highlands and lowlands (KAOSA-ARD and RERKASEM 2000). In response to these problems the King of Thailand launched the Royal Project Foundation (RPF) in 1969 (see chapter 2). The RPF initiated the phasing out of shifting cultivation and introduced alternative cash crops to opium as well as investing in basic infrastructure. Towards the end of the third decade of the project, 85 percent of the opium area was replaced by the alternative crops introduced by these programmes (DIOUF 2004). As a consequence, vegetables are now by far the most important crops measured in terms of quantity and area. However, vegetables are grown in commercialised schemes with high use of agro-chemicals, which causes environmental degradation and water pollution (SURASWADI *et al.* 2005). In 2003, the RPF pointed out that the environmental situation in these areas is in urgent need of rehabilitation, especially for primary forest, soil fertility and water quality (RPF 2003b)

4.2.2 Selection of sample

Cabbage was the major vegetable crop for which safer practices in vegetable production were first introduced. Based on a discussion with the agencies cooperating with the RPF, in the areas where safer practices have been implemented almost all producers have grown cabbage. These are especially the project areas of Mae Hae Royal Project Development Centre (MHRP) and Nhong Hoi Royal Project Development Centre (NHRP). The two centres are located in Chiang Mai Province (Figure 4.1). Since the study only focusses on cabbage producers, the selection of villages was carried out by purposive sampling, i.e. all villages where producers have grown cabbage and located in those two centres were selected. In every village, participants and non-participant producers were randomly selected. Participants are cabbage producers who either are registered members of the RPF or those who joined two safer practice programmes, namely the Integrated Pest Management (IPM) and Good Agricultural Practices (GAP) programme. Non-participants are those who are not the members and did not participate in either of these two programmes. The list of participants was obtained from the agencies of the two projects and the list of cabbage producers in each village from the respective village headmen. In practice, however, actual prior information was not always correct and had to be verified during the conduct of the survey. For example, some vegetable producers, who were identified as non-participants based on prior information, were found to be in the participant group and vice versa. Finally, due to the unwillingness of some respondents to cooperate in an interview, the final sample size amounted to 293 (see Table 4.1).

Table 4.1: Distribution of participants and non-participants

Villages	Non-participants	Participants	Total sample
V1	6	23	29
V2	27	5	32
V3	18	11	29
V4	33	15	48
V5	27	28	55
V6	37	22	59
V7	35	6	41
Total	194	99	293

Source: Own survey (2005)

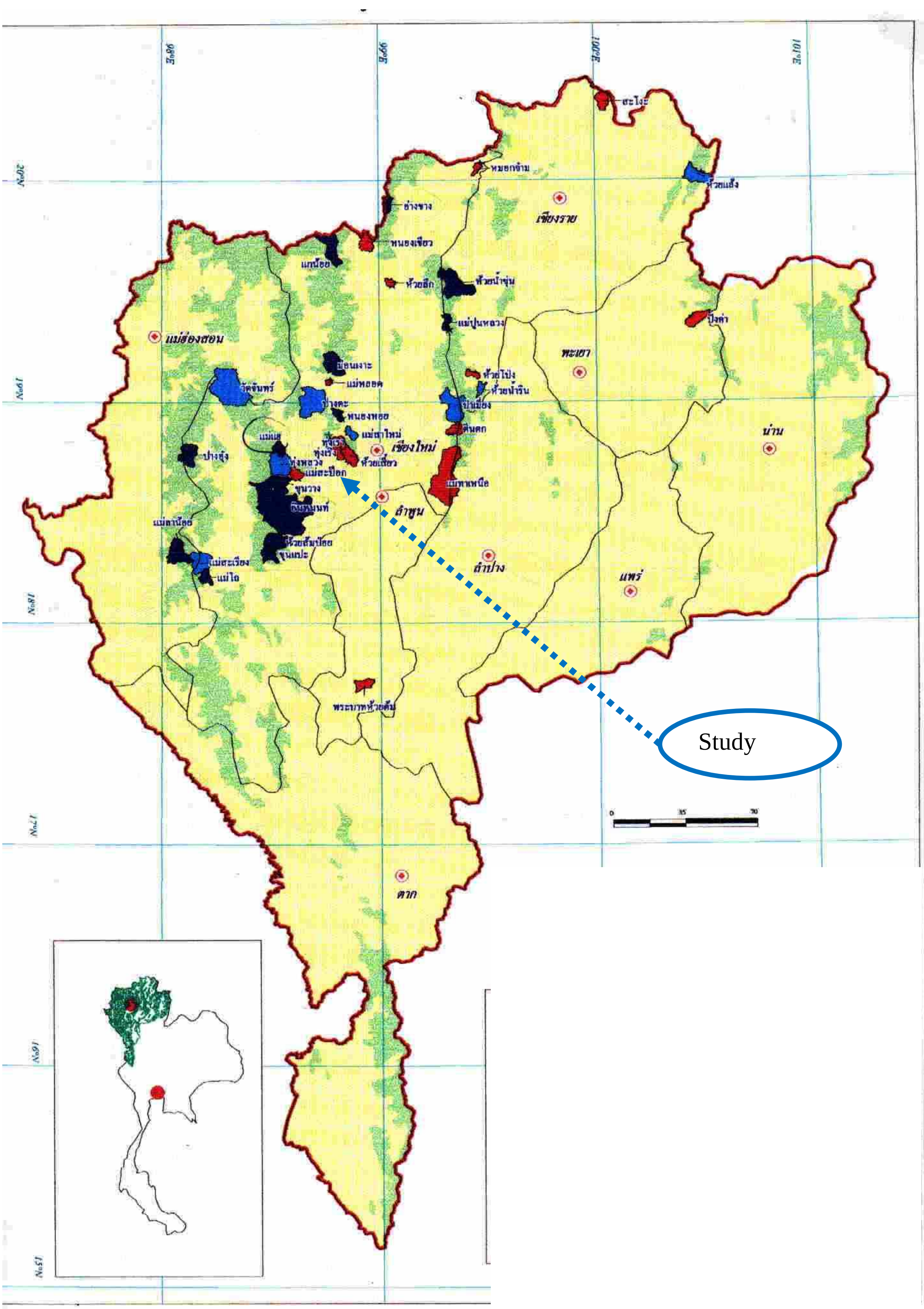

Figure 4.1: Study area

Source: Royal Project Foundation (2003)

4.2.3 Questionnaire design and interview method

In this study, two questionnaires were used: (i) a community questionnaire and (ii) a questionnaire for vegetable producers. The community questionnaire (see appendix A) was used to interview the headman of each village. It focussed on characteristics of the survey villages, the conditions of the local infrastructure, and the prevailing agricultural system. The community data were used only as basic information for the study. The village level information is presented in appendix D

The questionnaire for interviewing vegetable producers was organized in five parts (see appendix B). The first part concentrates on producers' characteristics and the household's resource endowment. The second part deals with the participation of vegetable producers in safer practice programmes and the third part contained questions about vegetable production practices as identified in the expert workshop described above, including soil management and pest management practices. In part four, questions on knowledge and attitude of vegetable producers towards safer practices were formulated. The knowledge questions referred to the vegetables producers' ability to identify pests and natural enemies of cabbage, as well as safety measures for pesticide use. Responses to knowledge questions were classified into three categories: correct, wrong and don't know. Attitudes towards environmental and health aspects of vegetable growing were measured in five categories, i.e. strongly agree, agree, neutral, disagree, and strongly disagree.
The last part of the questionnaire contained questions on technology adoption and diffusion. Here vegetable producers were asked whether or not they had heard about safer vegetable production practices, the reason for non-adoption or adoption, and whether they intended to use such practices in the future. Data was collected through face-to-face interviews. The reporting period was the crop year from April 2004 to May 2005.

4.2.4 Organization of fieldwork

The questionnaire was conducted by enumerators who were masters students of the Department of Agricultural Economics, Chiang Mai University and Maejoe University, located in Chiang Mai province. They are familiar with the nature of socioeconomic research and most importantly speak the Hmong-Mien language[16] used in the study areas. The enumerators were trained on the survey purpose in an enumerator workshop for three days. In the first day, a brief introduction of general understanding of the scope and major objectives of the research project was presented. Thereafter, an agent who has worked in vegetable IPM-FAO projects was invited to give a lecture on the use of IPM in cabbage production, including knowledge on pests and natural enemies. Finally, the enumerators were instructed in the proper administration of the questionnaire. In the last two days of the workshop, a pre-survey was used as a practical enumerators' training exercise. All problems related to the questionnaire and the survey were discussed and the questionnaire was improved to its final form. The survey was conducted from May 2005 to August 2005. Data storage was implemented in Microsoft Access and Microsoft Visual Basic 6.0.

4.3 Summary

The procedure of data collection described in this chapter contains primary and secondary information. General backgrounds about Thai vegetable production systems and problems due to excessive pesticide usage in its production, coping strategies and key organizations who play a major role in research and development and promotion of safer practice programmes were collected from the secondary sources. These included the Department of Agricultural Extension (DOAE), the Department of Agriculture (DOA), the Royal Project Foundation (RPF), etc. In addition, the workshop with vegetable experts in production and marketing was conducted with the aim of identifying the terminology for safer practices and selection of the study area. The results show that this term should be defined based on Integrated Pest Management Practice (IPM) adopted by Thai government as a coping strategy to reduce pesticide use in vegetable production systems. It was promoted as a participatory research programme. However, there is little evidence of widespread use of safer practices by vegetable producers. To identify reasons for non-adoption, the field survey was conducted. As a result of consultations with experts, the area involved with the Royal Project Foundation was selected for the field survey. The standardized questionnaire and the face-to-face interview method were used to interview vegetable producers. As well as the producer survey, an expert opinion survey was carried out to assess the importance of the various available safer practices. The output from the latter survey was used to fill a gap between practices used by vegetable producers and the minimum standard identified by the experts.

[16] This is the local language that the respondents use in the study areas.

Chapter 5

Analysis of programme participation

This chapter examines the participation of vegetable producers in extension and training programmes offered by governmental and non-governmental organizations in order to introduce more benign vegetable production technologies in Northern Thailand. The analysis is performed in two steps. First, the characteristics of vegetable producers in the research area are presented. Here a distinction is made between participants and non-participants in training and extension programmes. Frequencies and means of the variables selected are used to characterize the vegetable producers by chi-square for qualitative variables and by t-test for quantitative variables to test for differences between these two groups. In the second step, the factors that induce vegetable producers to participate in the programme are analyzed by using a binary choice model generally employed in adoption studies. The chapter concludes with a summary of the major findings.

5.1 Comparisons between participants and non-participants

Table 5.1 shows those characteristics of vegetable producers that are believed to be important in explaining differences between producers who participated in training programmes and those who did not. Such variables include, for example, the household size, educational status, resource endowment in terms of land and labour, agricultural assets and others. Comparing the two groups with each other it is found that participants do not differ significantly from non-participants in most characteristics. The major exception is in occupational status. While for most participants, household heads tend to be full-time farmers, the majority of non-participants have other jobs as their main occupation. Approximately 45% of non-participants work as casual labourers in their neighbours' farms or in a non-agricultural sector in the district town or Chiang Mai, the provincial capital. The remainder work in own businesses such as local trade and retail shops. This difference is significant at the 10% level. The observation also indicates that full-time farmers see more benefits in participating in programmes that promise to improve their knowledge in vegetable production, while in households where the head is engaged in other business there is likely to be less interest. Hence, participants and non-participants differ in some important aspects and thus may not be distributed randomly across the population, i.e. self-selection exists. Simple comparisons that ignore the fact that individuals self-select into the programme might result in an upwardly biased estimation of programme effectiveness (HARTMAN 1988). This must be taken into account in the econometric analysis.

Participants, on average, have less experience in vegetable production than non-participants, which supports the notion that they have a higher demand for information. Land holding differences between participants and non-participants are insignificant, whereas labour capacity is higher for participants than non-participants. The observation also discloses that for a given ratio of cropped land to active family labour, there is more labour capacity among participants than non-participants Labour availability might be a major factor determining vegetable producers' decision to participate in the programme because participating in the farmer training and learning programme, like the safer practice programmes, is time-consuming (PRANEETVATAKUL *et al.* 2007; QUIZON *et al.* 2000).

Table 5.1: Selected household and farm characteristics of vegetable producers

Household and farm characteristics	Units	Participants	Non-participants	Test of difference[1/,2/]
Age of household head	Years	40.8	41.6	-0.57
Education of household head	Years	3.0	2.4	1.48
Experience in vegetable production	Years	9.7	13.3	-4.03***
Household size	No.	8.7	7.8	0.93
Total farm area	ha	2.5	2.4	-0.62
Vegetable area	ha	1.9	1.7	-0.84
Labour capacity	Person-days	6.3	5.2	-2.54***
Labour-to-land ratio	Person-day/ha	3.5	2.3	0.78
Vegetable is main occupation of household head	%	62.4	27.5	3.71*
Own pickup truck	%	72.2	66.2	-0.96

Note: [1/] * Significant at 10%, **Significant at 5%, Significant at 1%. Difference is compared using t-test and chi-square. [2/] Number of observations (N) = 287
Source: Own calculations

A major driving force for changing production technology is consumer demand, which is transmitted to the producer by market agents. The Royal Project Foundation (RPF) is actively engaged in the marketing of fruits and vegetables. Hence, it is not surprising that participants tend to sell more of their products to the RPF than do non-participants. More than half of the participants sold their vegetables to the RPF, while almost all non-participants sold their vegetable products to middlemen (Table 5.2). Producers who sell to the RPF command a significantly higher price, with an average cabbage price of 3.4 Baht per kg as compared to 3 Baht for other buyers. Also, producers who participated in the programme received a significantly higher price from the buyers than those who did not participate. Over 70% of participants also used to have their products tested for pesticide residues, while only about one-third of the control group had performed this practice. Following the Thai Food Act of 1979, the sale of products that contain pesticide residues exceeding a defined maximum residue levels (MRL) is illegal. However, enforcement of pesticide contamination testing prior to selling is very poor. Hence, pesticide residue testing can be demanded by any buyer.

Table 5.2: Marketing practices of participants and non-participants

Variables	Units	Participants	Non-participants	Test of difference[1/,2/]
Vegetable buyers				
- Sell to RPF only	%	58.1	25.7	
- Sell to other buyers only	%	28.0	68.6	36.77***
- Sell to RPF and other buyers	%	14.0	5.7	
Testing pesticide contaminations	%	74.2	33.5	41.81***
Vegetable price paid by the buyers	Baht/kg	3.2	2.3	-4.83***
- Vegetable price paid by the RPF	Baht/kg	3.6	2.7	-2.64***
- Vegetable price paid by a middleman	Baht/kg	2.5	2.1	-1.70*

Note: [1/] * Significant at 10%, **Significant at 5%, Significant at 1%. Difference is compared using t-test and chi-square.

[2/] Number of observations (N) = 287

Source: Own calculations

In Thailand, vegetable products that are more benign from a human health and environment point of view are mainly found in supermarkets, green shops and export markets (VANIT-ANUNCHAI 2006). The agencies responsible for the testing of food quality and providing certification for pesticide residues compatible with MRL are the Ministry of Agriculture and Agricultural Cooperatives (MOAC), the Food and Drug Administration, and the Department of Medical Sciences (see chapter 2). The RPF, which sells in supermarkets and to the export market, has close cooperation with these agencies. They provide testing and certification of products purchased from both participants and non-participants.

As mentioned in the previous two paragraphs, the differences between participants and non-participants in terms of their marketing behaviour are partly explained by the requirements of the RPF (RPF 2003c). To be more specific, the following three conditions must be met before a producer is allowed to sell products to the RPF: (1) become a member of the project; (2) pesticide contaminations in vegetable products must not exceed the MRL[17]; and (3) the production processes must meet the standards of good agricultural practices (GAP) (see chapter 2). Hence, there is a strong incentive for participating producers to sell their products to RPF while non-participants who do not meet these quality criteria have to sell to lower-price market outlets.

5.2 Modelling programme participation

5.2.1 Description of variables used in the model

Following the conceptual framework outlined in chapter 3, a model that can explain programme participation is developed. The dependent variable is identified as a binary choice variable, i.e. if a vegetable producer decided to participate in an extension programme during the reference period used in the survey, the dependent variable has the value of 1 and 0 otherwise. This definition meets an initial assumption axiom of a binary choice model: choices are mutually exclusive and exhaustive (TRAIN 1993).

[17] Although this is a legal requirement for all agricultural producers the RPF enforces this standard.

The independent variables used in the model are selected based on some theoretical considerations and some initial analysis presented in the first part of the chapter. The assumption is that these variables are fixed over time or else the variables used in the equation could be influenced by participation itself (SMITH and TODD 2005). In table 5.3, descriptions of each variable are presented.

The variables included in the model can be grouped into four broad categories, namely vegetable producer characteristics, farm resource endowments, human capital and other variables. Firstly, the occupational status of producers is expected to affect participation. Producers who are working only on a farm may be more likely to participate in the programme than those who have additional jobs outside agriculture, which is a common feature of farming in Thailand to date. Participation in extension and training programmes is an investment of current resources in terms of time, in exchange for the accumulation of knowledge. Thus, if a vegetable producer is also engaged in non-farm occupations, his opportunity costs of time likely to be high.

The first category of variables includes the hypothesis that vegetable producers who have experienced health problems due to hazardous production methods, such as spraying of highly toxic chemicals, may be more likely to participate in an extension programme that offers information on safer practices among other technologies. Furthermore, the dummy variable that denotes whether or not a vegetable producer has his own means of transportation (pick-up truck) is used as a proxy of wealth. Generally it can be hypothesised that wealthier farmers are more likely to participate.

For the second group of variables, it is assumed that land and labour resources as measured through farm size and labour capacity of the household may also explain programme participation. Farm size is expected to positively relate to the probability of participation. This may be explained by fixed transaction and information acquisition costs associated with the new technologies, and there may be a lower limit on the size of participating producers such that farms smaller than a certain critical level cannot or will not pay the information costs of the participation (FEDER and O'MARA 1981). FEDER (1985) argued that larger producers have higher transaction costs in the acquisition of hired labour. They have less labour available per unit of land, while small producers often farm more intensively. Thus, the higher labour availability per unit of land better enables producers to participate in the programme. On the other hand, smaller land areas may exert some pressure to farm more intensively, especially when there are few alternative employment opportunities. Hence, this can be a positive factor to participate in the programme. According to the literature cited above, labour to land ratio is considered rather than the use of either household labour or farm size.

The third group of variables relates to human capital. There are two major variables here, namely education and experience. Education is expected to have a positive relationship on the probability of participation. Producers who have higher education are more likely to be willing to gather additional information from any source in order to improve their knowledge and skills. Similarly to the variable for education, producers with more experience in vegetable production are expected to have more motivation for participating in extension programmes because they may have longer planning horizons. In addition, greater experience in vegetable production in an area where degradation of natural resources such as soil erosion and increased pest infestation is widespread may induce a strong interest in learning new practices.

In the category "other" variables, membership in a farmer group and residue testing of vegetables are included. The first variable is expected to have a positive association with the participation decision because group interaction could increase the likelihood of participation. If producers sell to a vegetable buyer who requires pesticide residue testing, the use of such market channels is expected to increase the likelihood of programme participation because vegetable extension programmes offer technologies that can help producers to better reach the required quality standards.

Table 5.3: Description of variables used in the model

Group of variables	Name of variable	Variable type	Description
Dependent variable:			
	Participation[1/]	Dummy	1= if vegetable producers participate in IPM[2/] or GAP[3/] programmes; 0=otherwise
Independent variables:			
Vegetable producer characteristics	Health problem	Dummy	1=if vegetable producer has experienced about health problems related to pesticide used; 0 =otherwise
	Occupation	Dummy	1= if household head engaged only in-in farm activity; 0=otherwise
	Pick-up truck	Dummy	1=if vegetable producer owns a pickup truck; 0=otherwise
Farm resource endowment	Labour-to-land ratio	Continuous	The ratio of household labour working full time on farm to total land (person-day/ha.)
Human capital	Education	Continuous	Years of schooling completed by household head
	Experience	Continuous	Vegetable producers' own cabbage production (years)
Independent variables (continued)”			
Other factors	Member	Dummy	1=if vegetable producer is a member of a farmer group; 0=otherwise
	Market	Dummy	1=if vegetable products are tested for pesticide residues by a buyer; 0= no condition
	Study area	Dummy	1= if the study area is area1; 0=area 2

Source: Own presentation

5.2.2 Model specification and results

A probit model was formulated to identify factors affecting producers' behaviour. Following equation (5) of the general model 1 described in chapter 3, the model for programme participation can be written as:

$$\begin{aligned} partici\hat{p}ation = \ & \hat{\eta}_0 + \hat{\eta}_1.health + \hat{\eta}_2.pickup + \hat{\eta}_3.education + \hat{\eta}_4.experperience \\ & + \hat{\eta}_5.experience^2 + \hat{\eta}_6.labourland + \hat{\eta}_7.member + \hat{\eta}_8.occupation \\ & + \hat{\eta}_9.market + \hat{\eta}_{10}.study\,area \end{aligned}$$

where $\hat{\eta}_0$ is a scalar parameter and $\hat{\eta}_1 ... \hat{\eta}_{10}$ are unknown parameters of each factor. Note that experience is included as a quadratic term (*experience^2*) in order to capture the concavity of the experience earning profile[18]. To estimate this model, the assumption of a random sample, where all observations are randomly distributed over the population is assumed. This ensures that a linear combination of random variables is normally distributed. However, in the field survey, data collection was conducted based on a purposive sampling method for the area and the village levels (see chapter 4). Hence, a basic model assumption is violated. The consequence of this can be clustering effects, leading to narrow confidence intervals but also smaller t-values. To minimise these effects, the standard error can be adjusted using a robust variance matrix (BLAND 2004; WOOLDRIDGE 2002; WOOLDRIDGE 2003) Hence, in this model the robust standard error is used for the estimation of standard errors. In addition, indications of multicollinearity are carried out utilizing a simple correlation matrix between the independent variables: $r = \sum z_1 z_2 / \sqrt{\sum z_1^2 \sum z_2^2}$ where z_1 and z_2 are independent variables and r is a correlation coefficient. Multicollinearity can result in high standard errors, low levels of significance, high R-square value, and a wrong sign of the estimated coefficient (GREENE 1997). If r becomes high in absolute value, i.e. close to 1, multicollinearity exists (PINDYCK and RUBINFELD 1998). As shown in a correlation matrix (Table 5.4), the multicollinearity is not reported.

[18] According to human capital theory, there is a concave relationship between experience and return to experience (Mincer 1974). Applied to the present case, it means that the more experienced producers may expect to receive additional knowledge and skill through participation in the program. However, this expectation may decline after a certain point due a depreciation effect of human capital.

Table 5.4 Correlation matrix of variables used in the probit model

Variables	Participant	Health	Pickup	Education	Experience	Experience^2	Labour-land	Member	Occupation	Market	Study area
Participant	1.00										
Health	0.03	1.00									
Pick-up truck	-0.06	0.03	1.00								
Education	0.09	-0.01	0.08	1.00							
Experience	-0.18	0.04	0.22	-0.02	1.00						
Experience^2	-0.20	0.01	0.20	-0.05	0.89	1.00					
Labour-land	0.05	0.07	-0.19	-0.04	-0.06	-0.08	1.00				
Member	0.21	-0.04	0.05	0.16	-0.18	-0.19	-0.01	1.00			
Occupation	0.13	-0.02	-0.05	-0.11	0.01	-0.02	0.12	-0.05	1.00		
Market	0.38	0.01	-0.11	0.02	-0.20	-0.19	-0.02	0.35	0.03	1.00	
Study area	0.11	-0.05	-0.35	0.00	-0.12	-0.12	-0.03	-0.07	0.02	0.15	1.00

Source: Own calculations

Table 5.5 presents the model results of three equations. First, the complete probit regression model (for further details of model diagnostics see appendix E) is shown. Results show that many of the coefficients have the expected sign but only a few are statistically significant using robust standard error. Among the significant variables are “occupation” and “market”. Hence, producers who are engaged full time in vegetable production are more likely to participate. An increase in the likelihood of the household head working full time on farm will increase the probability of participation in the programme by 34%. Likewise, producers who have their vegetables products tested for pesticide residues are more likely to be participants.

To check the robustness of the model, two models variants were estimated in which subsequently insignificant variables were left out. The restricted models are estimated excluding labour-to-land ratio and education for the first restriction. For the second restriction, only the variable of labour-to-land is excluded. There are two reasons for the variants of the full model: (i) some variables may disturb the estimated coefficients of other variables resulting in a low significance level; (ii) the variable “labour-to-land ratio” was included in the full model because programme participation is time consuming. However, the variable is only an imperfect measure of the actual opportunity cost of time.

Results show that the statistical quality of the models does not differ much and that the direction of signs and the coefficients are almost identical. Both variables “occupation” and “market” stay significant in addition to the constant term, indicating that the full model may be robust. However, the variable “education” becomes significant at the 10% level in both reduced models. Hence, an additional year of schooling increases the probability of participation by 1.3%.

Table 5.5: Coefficient estimates of the participation decision (Model 1)

Variables	Unrestricted model[1,/2/]		1st restricted model[1,/2/]		2nd restricted model[1,/2/]	
	Coefficient	Robust SE.	Coefficient	Robust SE.	Coefficient	Robust SE.
Intercept	-1.4301***	0.3762	-1.2288***	0.3198	-1.1241***	0.2734
Health	0.1259	0.1667				
Pick-up truck	0.0743	0.1928				
Education	0.0357	0.0244	0.0392*	0.0239	0.0388*	0.0239
Experience	0.0329	0.0376	0.0339	0.0378	0.0343	0.0383
Experience^2	-0.0022*	0.0014	-0.0023*	0.0014	-0.0024*	0.0014
Labour-to-land	0.0137	0.0191	0.0129	0.0189		
Member	0.2006	0.2103				
Occupation	0.6155**	0.2623	0.5880**	0.2602	0.6124**	0.2597
Market	0.9399***	0.1832	1.0085***	0.1704	1.005***	0.1690
Study area	0.1357	0.1771				
Log likelihood	-150.86		-151.85		152.05	
Wald-chi^2	54.99***		52.09***		52.69***	
Pseudo R^2	0.17		0.16		0.159	
Percent correctly predicted (%)	73.52		72.82		71.80	
Area under ROC curve	0.76		0.757		0.75	
AIC	323.73		317.70		316.12	
BIC	363.98		343.32		338.07	
N = 287						

Note: [1/]* Significant at 10%; ** Significant at 5%; Significant at 10%.

[2/]Robust standard error is controlled for clustering effects.

Source: Own calculations

Overall, the statistical tests of three models, including the log likelihood ratio (LR), R-square, percentage of correct prediction and area under the Receiver Operating Characteristic (ROC) differ only slightly. Comparing the models on the basis of these criteria makes it difficult to determine which is preferable. Some literature indicates that selection of independent variables should be based on economic theory and previous empirical studies (CALIENDO and KOPEINIG 2005). However, from an econometric viewpoint, the question is always whether the parameter restrictions can be supported by (PINDYCK and RUBINFELD 1998). To answer this question, the

Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) that test a statistical significance of a combined effect of the independent variables in the model can be used. A model that minimises a loss of information will yield relatively small AIC or BIC (MENARD 1995). Based on these criteria, the two restricted models are preferable to the unrestricted model. Comparing the two restricted models with each other suggests some slight preference for not considering the "labour-to-land ratio" variable.

The interpretation based on the coefficients in a probit model that represents a linear regression of the z-score of participation probability on the independent variables can be problematic. It does not directly provide an understanding of the effect of independent variables on the probability of participation. As discussed in chapter 3, two methods are possible for the interpretation. The first method is to derive the marginal effects from the regression coefficients, calculated from a partial derivative as a marginal probability. This can be illustrated using the variable for education and experience as an example. Formally, an additional unit increase in education of the household head will increase the probability of participation by 1.3% and 1.2% respectively. However, in the absence of a boundary and the lack of a reference for independent education variables due to different scales (LECLERE 1992) such interpretation is ambiguous. To compare which variable has more effect in raising the probability of participation, interpretations should be based on the elasticity of probability (table 5.6). This second method constructs an elasticity of probability by scaling the partial derivatives without units. Hence, direct comparison among independent variables and the estimation of the relative effect of the various independent variables on the probability choice are allowed. Similarly to the previous interpretation that was based on the marginal probability, the effects of education and experience on the probability of participation differ only slightly.

Table 5.6 shows that the probability of participation in the programme is more elastic with respect to own experiences in vegetable production than to the education of the household head. This shows in both 1st and 2nd restricted models. The increase in probability is 0.48 for a change in own experience in absolute value but only 0.12 for a change in education. This suggests that own experience is more crucial for participation than variable formal education of the household head. Also, the effect of occupation on participation, in absolute value, is greater than the effect of "market". Note that the latter variable must be cautiously interpreted. It can only be viewed as a rough approximation because both are dichotomous (LECLERE 1992).

Table 5.6: Marginal effects and elasticity of probability of independent variables of 1st and 2nd restricted models

Variables	1st restricted model		2nd restricted model	
	Marginal effects	Elasticity of probability	Marginal effects	Elasticity of probability
Education	0.0134	0.1183	0.0133	0.1173
Experience	0.0116	0.4864	0.0117	0.4920
Experience-square	-0.0008	-0.5488	-0.0008	-0.5580
Land-to-labour	0.0044	0.1217		
Market	0.2205	0.0652	0.2301	0. 0679
Occupation	0.3411	0.5553	0.3400	0.5534
Predicted probability at mean	0.2905		0.2905	

Source: Own calculations

5.3 Summary

This chapter investigated the factors that are likely to explain why vegetable farmers may or may not participate in extension programmes that enable them to learn about healthier and more environmentally benign vegetable practices. Using chi-square and t-tests, some significant differences between participants and non-participants could be detected. A major factor is that those who participate tend to be full-time farmers, while a higher proportion of non-participants work not only in their farms but also in casual labour in both agricultural and non-agricultural sectors. On the other hand, non-participants have longer experience in vegetable production. However, in terms of some other household characteristics and in terms of resource endowments no significant difference between the two groups was observed.

Nonetheless, the fact that there are differences in major variables suggests that the use of a simple adoption model to investigate differences in vegetable production practices is not adequate. Hence, a probit regression with the objective to establish some causality between programme participation and household and farm characteristics has been developed. The model took account of the possible clustering effects in the data by calculating the robust standard error. The results from the probit regression model clearly identified that the degree to which a producer is engaged in vegetable production, i.e. whether or not vegetables are his/her major occupation, has a major effect on a decision to participate in extension programmes. This is a plausible result that compares well with findings in the literature (e.g. QUIZON *et al.* (2000); PRANEETVATAKUL *et al.*(2007); and DALTON *et al.*(2007)). Those previous studies indicate that the opportunity cost of time may play a role in training programmes that are time-consuming. While the full probit model had only a few significant variables, the coefficients remain consistent for two different reduced forms of the model. In the next chapter, the analysis of the effect of programme participation on the vegetable producers' knowledge is carried out.

Chapter 6

The effect of programme participation on knowledge and attitudes of vegetable producers

In the previous chapter, factors affecting vegetable producers' decision to participate in the safer practice programmes offered by the Royal Project Foundation (RPF) and related programmes have been identified. This chapter examines the effects of participation on the knowledge and attitudes of vegetable producers with regard to the possibility of adopting environmentally more benign crop and pest management practices. The chapter is structured into four sections. The first section gives a comparison between some relevant knowledge parameters for participants and non-participants. In the second section, the same comparison is conducted for attitudes of both groups of producers. In section three, an in-depth examination of its effects on knowledge are carried out using several variants of an econometric model. The fourth section summarizes the results of the analysis presented in this chapter.

6.1 Knowledge

During the field survey, vegetable producers were asked questions regarding their knowledge on various aspects of pest management and on their ability to identify pests and natural enemies that are often found in vegetable fields. For the latter, pictures of pests were shown to them for identification. The answer was either right or wrong. Respondents were also asked a set of knowledge questions relating to crop management in cabbage (Table 6.1). These questions were believed to be appropriate for measuring vegetable growers' ability to adopt safer production practices in cabbage. For example, respondents were offered statements like: "*Keeping some weeds in the surrounding of the field decreases pests.*" *or* "*All insects are pests*". The answer could be either right or wrong.

As shown in Table 6.1, in all but one case the percentage of correct answers is higher for participants than for non-participants. In five out of 11 knowledge questions, the difference was significant in favour of the participant group. In one case (crop rotation) non-participants had a higher percentage of correct answers. Overall the correct answers vary considerably across the different questions. They are generally higher for questions regarding pests and pesticides but lower for cultural practices, such as the use of trap crops. The lowest percentage was obtained for a question in which respondents actually had to calculate the rate of fertilizer use. The proportion of wrong answers is not surprising, as many extension workers would also have difficulties with that question. Knowledge of practices to contain beneficial organisms also received a low percentage of correct answers in both groups.

Table 6.1: Knowledge on various aspects of crop management in cabbage

Crop Management Knowledge Questions	Participants		Non-participants		Total		Test of difference[1/, 2/]
	Correct	Wrong	Correct	Wrong	Correct	Wrong	
Components of fertilizer	3.2	96.8	3.1	96.9	3.1	96.9	0.63
Components of hormone	50.5	49.5	42.8	57.2	45.3	54.7	1.54
All insects are pests	77.4	22.6	70.1	29.9	72.5	27.5	2.30
Furadan is allowed to be sold in the market	79.6	20.4	56.7	43.3	64.1	35.9	14.29***
Life cycle of Diamond Back moth	76.3	23.7	55.2	44.8	62.0	38.0	14.55***
Crop rotation	54.8	45.2	57.2	42.8	56.4	43.6	5.01*
Monoculture	41.9	58.1	34.5	65.5	36.9	63.1	2.29
Trap crop	66.7	33.3	45.9	54.1	52.6	47.4	13.78***
Keeping some weeds in the surrounding of the field	12.4	87.6	8.6	91.4	11.1	88.9	1.11
Labelling of insecticides	44.3	55.7	44.1	55.9	44.3	55.7	0.10
Mulching practice	48.4	51.6	34	66	38.7	61.3	7.33**

Note: [1/] Differences are compared using chi-square test; * = Significant at 10%; *** = Significant at 1%.
[2/] Number of observations (N) = 287.
Source: Own calculations

Table 6.2 shows the frequencies for correct and incorrect answers for pests and beneficial organisms. The results show that there is little difference between participants and non-participants in the identification of insect pests of cabbage. The vast majority of vegetable producers are able to correctly identify pests, sometimes having their own names for them.

Out of the six pests that they were asked to identify, in five cases recognition was over 80%. The results are different for beneficial organisms, i.e. insects that can control pests. For all six species the proportion of participants with correct answers was significantly higher than for non-participants. Some respondents in the non-participant group claimed that some of these organisms (black ant and long fly) are actually pests. This result illustrates that the focus of the training for safer pest management by the RPF and related programmes seems to fill some existing knowledge gaps of vegetable producers. However, the overall level of recognition is lower for beneficial organisms than for pests (see Table 6.2), which indicates that further gaps in knowledge exist.

Table 6.2: Knowledge on the identification of pests and beneficial organisms

Knowledge	Participants		Non-Participants		Total		Test of difference[1/,2/]
	Correct	Wrong	Correct	Wrong	Correct	Wrong	
Name of Insect Pest							
Pieris	93.5	6.5	93.3	6.7	93.4	6.6	0.01
Fleas beetle	84.5	15.5	77.4	22.6	82.2	17.8	5.57*
Ahphid	91.4	8.6	90.2	9.8	90.6	9.4	0.13
Plutella	100.0	0.0	99.5	0.5	99.7	0.3	0.48
Armyworm	100.0	0.0	98.5	1.5	99.0	1.0	1.45
Trichoplusia	60.2	39.8	55.7	44.3	57.1	42.9	1.13
Name of Beneficial Organism							
Aranease	67.7	32.3	27.5	72.5	40.6	59.4	42.23***
Mantidae	65.6	34.4	28.9	71.1	40.8	59.2	35.11***
Black ant	66.7	33.3	41.8	58.2	49.8	50.2	15.61***
Long fly	40.9	59.1	12.4	87.6	21.6	78.4	30.13***
Parasitoid	38.7	61.3	10.3	59.7	19.5	80.5	32.29***
Vesphid	55.9	44.1	17.5	82.5	30.0	70.0	44.14***

Note: [1/] Differences are compared using chi-square test; * = Significant at 10%; *** = Significant at 1%.
[2/] Number of observations (N) = 287.

Source: Own calculations

6.2 Attitude toward safer practices

In the survey, vegetable producers were asked to agree or disagree with certain knowledge questions, using a ranking from 1 to 5 where 1 represented strongly disagree and 5 represented strongly agree. A total of 13 statements concerning the role of safer practices related to human health and environment were presented. A high score in each question indicates a positive attitude towards safer practices because all statements were phrased positively. Generally, vegetable producers have positive attitudes towards safer practices. The mean scores are mostly around 4. Also, the majority of answers fall in the category "agree". Only in one case, i.e. in the statement "*spraying affects farmer health*" (see Table 6.3) did the majority of participants strongly agree. In five out of the thirteen statements there was a significant difference between participants and non-participants. The questions in which differences occurred generally fall into the category of externalities, health and agro ecosystems aspects of pest management. To ensure the validity of the attitude, some statements were inverted. For example, "*high chemical use makes yield and income more stable*". Here, over 50% of respondents in both groups disagreed and the difference was not significant.

Almost all producers have the same opinion that "*crop rotation is better than mono-cropping*" and "*information given by technicians from pesticide companies* cannot be *trusted*". Here the agreement is higher for participants and the difference is significant. Over 80% of producers in both groups believe that product quality of organic vegetable is better than that of conventional vegetables. However the difference between groups was not significant. Approximately 70% of the respondents agree that vegetables damaged by pests but without pesticides residues are preferable even if prices are lower, and about half of them agree to the statement that "*to plant vegetables in a separate field for own home consumption is good*".

The results regarding attitude questions show some inconsistencies in the answers of both groups. For example, both groups agree on the negative effects of spraying pesticides, while the percentage of agreement regarding lower priced vegetables damaged by pests but having lower or no pesticide residues rather than "good-looking" and contaminated vegetables is quite low. These results demonstrate the trade-off that exists between the negative effects of pesticides on the one hand and the perceived negative economic consequences of a change in strategy on the other hand. Overall, however, the results suggest that participation in RPF and related programmes is likely to have an effect on the attitude of vegetable producers towards a safer and more environmentally benign crop and pest management in cabbage.

Table 6.3: Vegetable producers' attitude towards safer practices and natural resource management

Attitude	Group[1/]	Percent of each group					Test of difference[1/,2/]	Mean scores
		5	4	3	2	1		
Spraying pesticides affect farmer health	P	50.5	47.3	0	2.2	0	5.6	4.46
	NP	39.2	55.7	1.5	2.1	1.5		4.29
	Total	42.9	53.0	1.0	2.1	1.0		4.31
Spraying pesticides affect a neighbour's field	P	30.1	54.8	3.2	1.8	0	10.7**	4.08
	NP	20.1	50.5	10.8	15.5	3.1		3.69
	Total	26.1	39.4	15.7	16.7	2.1		3.80
Use of toxic chemicals has negative environmental effects on the long term	P	35.5	51.6	5.4	7.5	0	5.3	4.15
	NP	24.2	57.7	6.7	9.8	1.5		3.93
	Total	27.9	55.7	6.3	7.1	1.0		4.00
Pesticides are a cause of decreasing fish population in my natural well	P	34.4	37.6	11.8	14.0	2.0	5.6	3.88
	NP	22.2	40.2	17.5	18.0	2.1		3.62
	Total	23.3	51.9	8.4	14.3	2.1		3.71
Spiders in my fields are sign of healthy environment	P	19.4	36.6	37.6	4.3	2.2	10.9**	3.67
	NP	8.8	40.2	35.1	12.9	3.1		3.39
	Total	12.2	39	35.9	10.1	2.8		3.48
High chemical use makes yield more stable	P	16.1	30.1	7.5	35.5	10.8	4.9	3.05
	NP	17.5	36.1	9.8	32.0	4.6		3.3
	Total	17.1	36.1	9.8	32.0	4.6		3.22

Note: [1/] P and NP present participation and non-participation, respectively.
[2/] 1 = strongly disagree; 2=disagree; 3=natural (neither agree nor disagree); 4=agree; 5=strongly agree.
[3/] Differences are compared using chi-square test; * = Significant at 10%; *** = Significant at 1%. [4/]Number of observations (N) = 287.

Source: Own calculations

Table 6.3: (continued)

Attitude	Group[1/]	Percent of each group[2/]					Test of difference[3/,4/]	Mean scores
		5	4	3	2	1		
High chemical use makes yield and income more stable	P	11.8	25.8	4.3	41.9	16.1	5.9	2.75
	NP	10.3	29.9	11.9	35.1	12.9		2.9
	Total	10.8	28.6	9.4	37.3	13.9		2.85
Non-chemical pesticides are better than synthetic pesticides even though they are expensive	P	26.9	39.8	15.1	18.3	0	18.2***	3.75
	NP	12.4	38.7	32	13.9	3.1		3.43
	Total	17	39	26.5	15.3	2.1		3.54
Crop rotation is better than mono-cropping	P	55.9	36.6	2.2	5.4	0	9.5**	4.43
	NP	39.7	44.8	8.2	6.2	1.0		4.16
	Total	44.9	42.2	6.3	5.9	7.0		4.25
Information of technicians from pesticide companies is not trustful	P	31.2	33.3	15.1	11.8	8.6	10.8**	3.67
	NP	20.6	28.4	21.6	24.2	5.2		3.35
	Total	24	30	19.5	20.2	6.3		3.45
Pest-damaged vegetables without pesticides residue are better even if the price is lower.	P	40.9	33.3	1.1	15.1	9.7	7.1	3.81
	NP	37.6	43.8	3.6	10.3	4.6		3.99
	Total	38.7	40.4	2.8	11.8	6.3		3.93
Organic vegetable product is better than conventional products for consumer health	P	45.2	48.4	5.4	1.1	0	5.7	4.38
	NP	33.3	55.7	6.7	3.6	1.0		4.16
	Total	36.9	53.3	6.3	2.8	0.7		4.23
Organic vegetable product is better than conventional products for consumer health	P	45.2	48.4	5.4	1.1	0	5.7	4.38
	NP	33.3	55.7	6.7	3.6	1.0		4.16
	Total	36.9	53.3	6.3	2.8	0.7		4.23
Plant vegetables in a separate field are good for own household consumption	P	22.6	26.9	5.4	29.0	16.1	8.4*	3.11
	NP	21.1	26.8	16.0	26.8	9.3		3.20
	Total	21.6	26.8	12.5	27.5	11.5		3.20

Note: [1/]P and NP present participation and non-participation, respectively.
[2/]1 = strongly disagree; 2=disagree; 3=natural (neither agree nor disagree); 4=agree; 5=strongly agree. [3/] Differences are compared using chi-square test; * = Significant at 10%; *** = Significant at 1%. [4/]Number of observations (N) = 287.

Source: Own calculations

6.3 Modelling factors affecting vegetable producers' knowledge

As outlined in chapter 3, two econometric techniques can be used to estimate the effects of programme participation on the knowledge of vegetable producers: (i) the ignorability of treatment method and (ii) the instrumental variable techniques. Subsequently the estimation procedures of the models are explained and the results are discussed. Prior to the description of the models, a discussion of the variables included in the models is presented.

6.3.1 Variable description

The dependent variable used in all models is vegetable producers' knowledge as measured in term of scores as described in chapter 3. The independent variables of the models in principle are those used in the model that was developed to explain participation (see chapter 5). Additional variables were included based on economic theory and previous empirical findings. The variables can be grouped into four categories, i.e. programme participation, farm resource endowment, human capital and other variables. A summary of the variables is shown in Table 6.4. In the following the rationale for the inclusion of these variables in the model is provided.

Variables related programme participation: There are two variables in this group. First, *the treatment variable* is a zero-one variable for programme participation. As shown by the mean differences of the knowledge scores there are significant differences (see Table 6.5). Hence, it can be hypothesized that programme participation has a positive effect on vegetable producers' knowledge. This hypothesis is also supported by the results of similar studies (ASHBY 2003; DALTON *et al.* 2007; FEDER *et al.* 2004; ROLA *et al.* 2002; THIELE *et al.* 2001). These found that trained farmers have a higher level of knowledge than those who did not attend the training. The second variable in this group refers to "*information from other farmers*". Studies have shown that neighbouring farmers can be a key source of information (FEDER *et al.* 1985; FEDER *et al.* 2004). Obtaining such information incurs low transaction costs and the information is generally considered to be trustworthy.

Human capital variables: There are two variables in this group, i.e. education and experience. There is ample evidence in the literature that education provides the capabilities to assess information under disequilibria (SCHULTZ 1975), especially for complex information. This largely holds for knowledge-intensive technologies related to natural resources and crop management (CASWELL *et al.* 2001). The second variable is experience. The effect of experience on knowledge is similar to that of education. Longer experience in vegetable production can be expected to help accumulate knowledge. Hence, both variables are expected to have a positive effect on knowledge scores.

Farm resource endowment: The resources land and labour are important determinants in the adoption of many technologies in agriculture, mainly because of economies of scale effects. In relation to knowledge-intensive technologies it is likely to be the land to labour ratio that may have an effect on the investment in knowledge acquisition. It can be argued that on the one hand knowledge acquisition has fixed information costs and at the same time is labour demanding. Hence, larger producers have lower per unit information costs than smaller producers. On the other hand, producers with the higher labour availability per unit of land may have the time to acquire more information than producers with a low land to labour ratio.

Other variables: In this category three variables are included (see Table 6.4) First, specialized producers, i.e. those who are engaged in agriculture only may have more knowledge about vegetable production than those who are also engaged in off-farm work. Second, membership in a farmer group might have an effect on knowledge because of the possibility of accessing information from other members of the group. Third, the two study locations identified in chapter 4 can be taken as a proxy for other sources of variation in vegetable producer knowledge, e.g. due to differences in infrastructure.

Table 6.4: Data descriptions of dependent and independent variables used in each model

Group of variables	Name of variables	Variable type	Description
Dependent variable	Knowledge	Continuous	Vegetable producers' knowledge scores
Independent variables			
Variable related to participating in the programme	Participation	Dummy	1= if vegetable producers participate in IPM or GAP programmes; 0 = otherwise
	Source_1	Continuous	1= if producer mainly gathers information from other farmers; 0 = otherwise
Human capital	Education	Continuous	Years of schooling completed by household head
	Experience	Continuous	Vegetable producers' on cabbage production (years)
Farm resource endowment	Labour to land ratio	Continuous	The ratio of household labour working full time on farm to total land (person-day/ha.)
Vegetable producer characteristics	Occupation	Dummy	1= if household head engaged only in-farm activity; 0 = otherwise
Other factors	Member	Dummy	1= if vegetable producer is a member of a farmer group; 0 = otherwise
	Study area	Dummy	1=if the study area is area1; 0= if area2

Source: Own presentation

In Table 6.5 the results for the dependent variable are presented. It is shown that there is a significant difference in the overall knowledge score between participants and non-participants. In terms of the different knowledge components, identification of pests was not significant in the comparison of mean scores. Hence, in the models, total scores excluding knowledge score of identification of pests were used as the dependent variable.

Table 6.5: Knowledge test scores for participants and non-participants

Knowledge scores	Participation		Non- participation		Test of difference[1/, 2/]
	Mean	SD	Mean	SD	
Identification of pests	5.55	0.71	5.61	0.63	0.61
Identification of natural enemies	3.33	1.64	1.24	1.14	-12.55***
Various aspects of safer practices	5.52	1.76	3.76	1.88	-4.21***
Total scores	13.31	2.89	10.6	2.1	-8.29***

Note: [1/] Differences are compared using t-test; *** = Significant at 1%.

[2/] Number of observations (N) = 287.

Source: Own calculations

6.3.2 Average treatment effect on the treated models

In the following the specification and the results of the average treatment effect on the treated models are presented. In these models all variables that were described in the foregoing section are included. Based on treatment models discussed in chapter 5 the specification of the knowledge models can be re-written as follows:

$$\widehat{participation} = \hat{\eta}_0 + \hat{\eta}_1.health + \hat{\eta}_2.pickup + \hat{\eta}_3.education + \hat{\eta}_4.experperience + \hat{\eta}_5.experience^2 + \hat{\eta}_6.labourland + \hat{\eta}_7.member + \hat{\eta}_8.occupation + \hat{\eta}_9.market + \hat{\eta}_{10}.study\,area$$

$$\widehat{knowledge} = \hat{\alpha} + \hat{\gamma}.participation + \hat{\beta}_1.source1 + \hat{\beta}_2.member + \hat{\beta}_3.education + \hat{\beta}_4.experience + \hat{\beta}_5 experience^2 + \hat{\beta}_6 labourland + \hat{\beta}_7 study\,area$$

To estimate the effect of the safer practice programmes (Average Treatment on the Treated= ATET) on knowledge, this model is applied using nine different variants as discussed in chapter 3, i.e. application from model 2 to model 10. The purpose in running the different variants of the model is to test the problem of selection bias and to test for the robustness of the estimations. Regarding the multi-co linearity problem, a correlation matrix was identified in Table 6.6. Since a clustering effect can appear in case of non-random sample selection, as explained in chapter 4, a robust variance matrix is used to estimate standard errors in each model. The statistical programme STATA, version 9.1, was used for these estimations.

6.3.2.1 Simple regression models

Two simple regression models, i.e. model 2a and 2b, were estimated. In model 2a only the treatment variable is included and for model 2b all independent variables are added. Results show that some variables are insignificant. Hence re-estimation was carried out by re-running the model with only the significant variables, identified as the "restricted model". When comparing F-test and R-square between two models, there are only slight differences. Also, the estimated coefficients of the two models differ somewhat. Hence, the unrestricted model is used as a base model. Table 6.7 presents results received from the estimation of model 2a and 2b (see detail of model 2a and 2b estimation results provided by STATA in appendix F).

Table 6.6: Correlation matrix of variables used in model 2 to model 10

Variable	Particip[1/]	Health	Pickup	Knowledge	Education	Source_1	Exp[1/]	Exp[1/2]	Labour-land	Member	Occupation	Market	Study area
Particip[1/]	1.00												
Health	0.03	1.00											
Pickup	-0.06	0.03	1.00										
Knowledge	0.48	0.05	0.07	1.00									
Education	0.09	-0.01	0.08	0.29	1.00								
Source_1	0.15	0.05	-0.09	0.18	-0.05	1.00							
Exp[1/]	-0.18	0.04	0.22	0.02	-0.02	-0.01	1.00						
Exp^2	-0.20	0.01	0.20	-0.04	-0.05	0.04	0.89	1.00					
Labour-land	0.05	0.07	-0.19	0.00	-0.04	0.10	-0.06	-0.08	1.00				
Member	0.21	-0.04	0.05	0.14	0.16	0.08	-0.18	-0.19	-0.01	1.00			
Occupation	0.13	-0.02	-0.05	0.08	-0.11	-0.07	0.01	-0.02	0.12	0.05	1.00		
Market	0.38	0.01	-0.11	0.17	0.02	0.01	-0.20	-0.19	-0.02	0.35	0.03	1.00	
Study area	0.11	-0.05	-0.35	0.01	0.00	0.01	-0.12	-0.12	-0.03	0.07	0.02	0.15	1.00

Note: [1/]Particip = participation, Exp = Experience

Source: Own calculations

Table 6.7: Average treatment effect on the treated of the model 2a and 2b

Variables	Model 2a[1/,2/, 3/]		Model 2b[1/,2/, 3/]			
			Unrestricted model		Restricted model	
	Coefficient	Robust SE.	Coefficient	Robust SE.	Coefficient	Robust SE.
Constant	10.6031***	0.1548	9.5296***	0.4579	9.3167***	0.3506
Participation	2.7087***	0.4481	2.4970***	0.3556	2.5353***	0.3347
Source_1			1.9039***	0.5296	1.7934***	0.5376
Education			0.1979***	0.0384	0.1940***	0.0374
Experience			0.1000***	0.0350	0.1017***	0.0360
$Experience^2$			-0.0024**	0.0012	-0.0023**	0.0012
Labour to land			-0.0214	0.0311		
Member			0.0361	0.3083		
Occupation			0.5341	0.4844		
Study area			-0.1635	0.2623		
F-test	36.54***		15.85***		25.21***	
R-square	0.23		0.33		0.33	

Note: [1/] ** Significant at 5%; *** Significant at 1%.

[2/] Standard errors are controlled for clustering effects. SE=standard error.

[3/] Number of observations (N) = 287.

Source: Own calculations

6.3.2.2 Ignorability of treatment technique

In models 3 to 9, the average treatment effect on the treated (ATET) is estimated using the *ignorability-of-treatment-technique*. To begin with model 3, the demeaning variables education, experience and land-labour ratio are used as a control function to control for selection biases. The model is first estimated by including all independent variables, i.e. the unrestricted model. Next, estimation of the restricted model (in which all insignificant independent variables are excluded) is carried out. Results obtained from both calculations are presented in Table 6.8 (see detail of model 3 estimation results provided by STATA in appendix G). Similarly to model 2b, the restricted and the unrestricted model have slightly different explanatory powers. Also the regression coefficients do not differ much. Hence, the unrestricted model can be used.

Table 6.8: Average treatment effect on the treated of the model 3

Variables	Unrestricted model[1/,2/, 3/]		Restricted model[1/,2/, 3/]	
	Coefficient	Robust SE.	Coefficient	Robust SE.
Intercept	9.1456***	0.5174	9.0045***	0.4029
Participation	2.3800***	0.3908	2.3984***	0.3575
Source_1	2.0034***	0.5457	1.9391***	0.5587
Education	0.1598***	0.0486	0.1552***	0.0466
Experience	0.1434***	0.0445	0.1449***	0.0451
Experience-square	-0.0030**	0.0014	-0.0030**	0.0014
Labour to land	-0.0117	0.0336		
Member	0.1057	0.3113		
Occupation	0.4351	0.4823		
Study area	-0.2116	0.2600		
Demeaned variables				
Wheadeduc	0.1073	0.0774	0.1124	0.0769
Wexp	-0.0872*	0.0518	-0.0867*	0.0513
Wlabour-to-land	1.4287	5.0690		
F-test	14.83***		22.23***	
R-square	0.34		0.34	

Note: [1/] ** Significant at 5%; *** Significant at 1%.

[2/] Standard errors are controlled for clustering effects. SE=standard error.

[3/] Number of observations (N) = 287.

Source: Own calculations

The next method is the propensity score approach, which has the advantage that it helps to randomly assigned respondents between participant and non-participant groups, i.e. they will have the same propensity to participate in a safer practice programme. Since propensity scores are estimated with only observed independent variables, it is assumed that unobserved independent variables would not have changed when the model was measured. Hence, it is reasonable to assume that approximately unbiased estimates for the participation effect can be obtained (ROSENBAUM and RUBIN 1983). To estimate average participation effect, the propensity score (PS) have to be predicted first. In this step, only significant independent variables as discussed in the previous chapter (chapter 5) are used to predict the PS by means of a probit regression model, since inclusion of all non-significant variables can increase the variance of the estimator. Second a test of the overlap condition or common support is carried out in order to ensure that vegetable producers with the same attributes have the same probability of being allocated to participation and non-participation groups. Results show that the region of common support is between 0.08289 and 0.88946. Table 6.9 is a depiction of the estimated propensity score in the region of common support. In total, 25 observations that were smaller or higher than this rank were removed, so a total of only 267 observations remained. The average propensity scores of participant and non-participant groups do not differ (see details of this test in appendix H).

Table 6.9: Estimation of propensity scores (PS)

Percentiles		Smallest
1%	0.0860	0.0829
5%	0.1096	0.0848
10%	0.1194	0.0860
25%	0.1526	0.0871
50%	0.3229	-
		Largest
75%	0.5075	0.7847
90%	0.6171	0.8078
95%	0.6789	0.8170
99%	0.8078	0.8895
Number of observation	267	
Mean	0.3443	
Std. Dev.	0.2002	

Source: Own calculations

The third step used was to test the balancing property for each variable. Results show that the balancing property is satisfied, implying that the matching quality is fulfilled (see details for the test of balancing score in appendix J). Thus the calculation of ATET, is straightforward, and was carried out in different model variants, i.e. models 4 to 9.

Model 4 was specified based on the suggestion of ROSENBAUM and RUBIN (1983). Here knowledge scores are regressed only on the treatment variable, the PS and an interaction term between the treatment variable and the unobserved heterogeneity (Wpropensity). Model 5 follows an approach suggested by WOOLDRIDGE (2004), i.e. the linear projection of knowledge on the PS and those control variables is estimated (see details of models 4 and 5 estimation results also in Appendices H and I). The results of both unrestricted and restricted models are shown in Table 6.10.

Table 6.10: Average treatment effects of models 4 and 5

Variables	Model 4[1/,2/,3/]		Model 5[1/,2/,3/]			
	Unrestricted model		Unrestricted model		Restricted model	
	Coefficient	Robust SE.	Coefficient	Robust SE.	Coefficient	Robust SE.
Constant	10.6749***	0.2580	9.3748***	0.5339	9.0800***	0.4473
Participation	2.3710***	0.4105	2.4268***	0.3734	2.4242***	0.3702
Propensity score	-0.2751	0.7714	0.6594	0.9700	0.7060	0.8364
Wpropensity	2.9780*	1.8239				
Source 1			1.9149***	0.5378	1.8021***	0.5464
Education			0.1922***	0.0400	0.1874***	0.0389
Experience			0.1017***	0.0345	0.1032***	0.0353
Experience-square			-0.0022*	0.0012	-0.0021*	0.0012
Labour to land			-0.0233	0.0308		
Member			-0.0805	0.3458		
Occupation			0.3996	0.5048		
Study area			-0.1930	0.2661		
F-test	25.92***		14.41***		22.01***	
R-square	0.24		0.33		0.33	

Note: [1/] ** Significant at 5%; *** Significant at 1%.

[2/] Standard errors are controlled for clustering effects. SE=standard error.

[3/] Number of observations (N) = 287.

Source: Own calculations

Other models, i.e. models 6 to 9, used four different matching algorithms (see chapter 3), (i) stratification matching, (ii) nearest neighbour matching, (iii) radius matching, and (iv) kernel matching. Table 6.11 shows the estimated results obtained from these approaches, which are is significantly different at 1%. As stated in Smith (2000) all PS estimators should yield the same results in the case of large sample sizes. As shown in Table 6.11 results obtained from different matching algorithms in this study should be robust (see details of the estimation results of models 6 to 9 in Appendices M to P).

Table 6.11: Estimated results of the models 6 to 9

Matching methods[1/]	Participation (No.)	Non-participation (No.)	ATET	Robust SE.	t-value
Unrestricted model					
Stratification (model 6)	85	182	2.59	0.37	7.06***
Nearest Neighbour (model 7)[19]	93	53	2.15	0.55	3.89***
Radius (model 8)	36	51	2.57	1.05	2.46**
Kernel (model 9)	93	178	2.48	0.41	6.05***
Restricted model					
Stratification (model 6)	85	182	2.59	0.33	7.94**
Nearest Neighbour (model 7)	93	159	2.86	0.36	7.85**
Radius (model 8)	62	141	2.57	0.38	6.76***
Kernel (model 9)	93	188	2.63	0.34	7.68***

Note: [1/]** Significant at 5%; *** Significant at 1%.

[2/] SE=standard error.

[3/] Number of observations (N) = 287.

Source: Own calculations

6.3.2.3 Instrumental variable technique

The treatment effect model of HECKMAN (1979) is finally applied with the full information maximum likelihood approach (FIML), described as model 10 (see chapter 3.3.2.2). The unrestricted knowledge model, including all independent variables that are hypothesized as affecting knowledge scores, was estimated in a first step. Subsequently insignificant variables were dropped, giving the restricted model. Table 6.12 presents the estimated coefficients of the restricted and unrestricted models.

[19] The estimated ATET received from the nearest neighbour algorithm is smaller than other methods as some observed producers in the non-participant group were discarded due to low quality of matching.

Table 6.12: Estimated results of model 10

Variables	Unrestricted model[1/,2/, 3/]		Restricted model[1/,2/, 3/]	
	Coefficient	Robust SE.	Coefficient	Robust SE.
Constant	9.4104***	0.4947	9.1182***	0.4147
Participation	3.0128***	0.7308	3.0020***	0.6255
Source 1	1.8986***	0.5285	1.7816***	0.5409
Education	0.1931***	0.0387	0.1950***	0.0370
Experience	0.1012***	0.0340	0.1023***	0.0352
Experience-square	-0.0022*	0.0011	-0.0021*	0.0012
Labour to land	-0.0233	0.0306		
Member	-0.0661	0.3270		
Occupation	0.4165	0.4986		
Study area	-0.2123	0.2665		
Rho	-0.1571	0.1869	-0.1507	-0.1571
Lambda	-0.3412	0.4129	-0.3284	-0.3412
Wald chi2(8)	98.97***		80.01***	
Log likelihood	-778.93		-781.12	
Test of select (Rho= 0)	0.68		0.760	
ATET	2.1846	SD=0.3294	2.2155	SD=0.3262

Note: [1/]** Significant at 5%; *** Significant at 1%.

[2/] Standard errors are controlled for clustering effects. SE=standard error.

[3/] Number of observations (N) = 287.

Source: Own calculations

Similarly to the models used in the previous section, no selection biases show up in the estimated results. Hence, the null hypothesis of the correlation term (ρ =0) is accepted. When comparing the explanatory power and the estimated coefficients between unrestricted and restricted models, they are somewhat different (see details of model estimation in appendix N). Hence the interpretation is based on the unrestricted model. Based on this model, ATE seems to be larger than results obtained from other approaches. This may be caused by a high correlation between the selectivity term (*participation*) and the independent variable used in the knowledge equation. To check this, testing the co-linearity problem of the data was carried out by calculating R-square of the linear projection of the inverse mills ratio on the explanatory variables used in the knowledge equation (PUHANI 2000). The calculated R-square shown in appendix P is about 0.3978, indicating that co-linearity is not very high. Thus, the results obtained from Heckman's model are also robust. Unlike in the *ignorability of treatment technique* where ATE is assumed to be equal to ATET, the coefficients obtained by this method represent ATE instead of ATET. Hence, a calculation of ATET needs to be carried out by means of the estimated results of this model (see procedure of calculation in appendix O). The calculated ATET was found to be 2.1846 for the unrestricted model and 2.2155 for the restricted model.

6.2.4 Synthesis of results obtained from different model variants

As stated in the theory, in the absence of selection bias different approaches should yield similar results. This was found in the case presented here. The results obtained from different approaches show that participation in the safer practice programmes as provided by the RPF and related programmes significantly increases vegetable producers' knowledge, which confirms the hypothesis of the study. Results also confirm those of previous empirical studies that evaluated similar programmes for rice and potato farmers (FEDER *et al.* 2003; FEDER *et al.* 2004; GODTLAND *et al.* 2003; PRANEETVATAKUL *et al.* 2007).

Considering the factors influencing vegetable producers' knowledge, all the models show that labour to land, member, main occupation and the study area have no effect on knowledge scores. On the other hand, human capital variables like *education and experience* are highly significant. Hence for knowledge-intensive technologies it can be confirmed that education affects the ability to acquire information. Similarly, experience affects knowledge through learning-by-doing by increasing skills. These results are consistent with the findings of Schultz (SCHULTZ 1975) regarding the role of human capital in agricultural development.

Furthermore, results of this study indicate that information from other vegetable producers is complementary to the knowledge effect of the training. This underlines the role of farmer networks as a reinforcing factor in the acquisition of knowledge. This finding is similar that of the study of YAMAZAKI and RESOSUDARMO (2007) who found a significant diffusion of knowledge from participants in farmer field schools in Indonesia to non-participants in the same village.

6.3 Summary

This chapter examined whether the safer practice programme can improve vegetable producers' knowledge. The initial findings show that the knowledge level of programme participants is significantly higher than for non-participants. The difference is particularly pronounced in the identification of natural enemies and some other aspects of crop and pest management. However, knowledge levels of both groups are quite low in regard to some complex practices.

Regarding attitude, almost all vegetable producers appreciate the benefits of safer practices, including the benefits in terms of the conservation of natural resources and the environment. Significant differences of attitudes towards negative effects of spraying pesticide and the trustfulness of information provided by pesticide agents are found between participant and non-participant producers.

Results of the modelling exercise utilizing several approaches in which the non-random nature of the sample is taken into account, and various counterfactual scenarios are established, show similar results. This implies robustness of the models. The models consistently confirm that the programme significantly enhances vegetable producers' overall knowledge of crop and pest management, which is a pre-condition for applying safer practices in their fields. It must be stressed that education and experience are the most important variables for the knowledge of vegetable producers, enabling them to perform better crop management. In addition, information dissemination was found to be also an important factor. The next chapter will examine what effect participation in safer practice programmes has on the actual practices used by vegetable producers in the study area.

Chapter 7

Participation in extension programmes, improvement in knowledge and safer management practices in vegetable production

The previous chapter examined the effect of participation in safer practice programmes of the Royal Project Foundation (RPF) and related programmes on knowledge, skills and attitude of vegetable producers. This chapter analyzes the direct effect of such programmes on the practices used by vegetable producers. Adoption of safer and more environmentally benign practices is the ultimate goal of investments in agricultural extension and participatory farmer training. This chapter is divided in five sections. First, the existing crop management practices in cabbage are described. Generally practices are divided into those that have positive effects on health and environment and those with opposite effects. Hence, in the second part the association between positive and negative practices is analyzed more in-depth. The third section explains the establishment of a standard for safer practices as identified by experts in the absence of a clear definition of legally binding or market-based standard for safer vegetable production. In this section the gap between the actual practices used by vegetable producers and the standard defined by the experts is investigated. In section four, the direct effects of programme participation on change in practices is modelled as a two-stage process using a simultaneous equation approach. The final section summarizes the results of this chapter.

7.1 Prevailing crop and pest management practices

In this part, the actual crop management practices used in cabbage production in the study area are presented. The practices are divided into different three categories: (i) soil management; (ii) seed management; and (iii) pest management. During the survey, vegetable producers were asked about their crop management practices and especially about the pesticides they had used during the crop year April 2004 to May 2005. Respondents were also asked the reasons for choosing certain practices. This information allows researchers to assess the farmers' perception of the various aspects of safer practices.

7.1.1 Soil management practices

The ecological conditions of the study area determine that almost all vegetable producers grow vegetables on steep slopes. Hence, soil erosion is a major problem (2003; RPF 1996). To reduce the risk of soil erosion, soil conservation practices have been promoted by the RPF. The initial results indicate that about 32% of respondents have planted vegetable on contour bunds with a growing grass strip. Approximately 51% of producers rotate their vegetables with rice, maize and other crops. The percentage of producers who practice crop rotation is significantly higher in participants than non-participants. The remainder use fallow land in order to improve soil fertility and keep down weeds (see Table 7.1). Almost all respondents in both groups ploughed the field before planting. This practice is known to aggravate the problem of soil erosion.

Table 7.1: Use of Planting on contour bunds with growing grass strip, crop rotation and ploughing

Practices[1/]	Non-participation	Participation	Test of difference[2/, 3/]	Total
Planting on contour bunds with growing grass strip	28.0	34.0	1.1^{ns}	32.1
Crop rotation	46.4	61.3	5. 9**	51.2
Ploughing	93.3	96.8	1.4^{ns}	94.4
Reason of ploughing				
• Preventing soil erosion	47.6	58.2		51.1
• Convenience for bedding	52.3	41.8		48.9

Note: [1/] Percentage within each group (participant and non-participant).
[2/] Differences are compared using chi-square test; *** = Significant at 1%.
[3/] Number of observations (N) = 287
Source: Own calculations

About 29% of respondents use limestone to improve the soil in their vegetable fields. The percentage is higher in the participant group than in the non-participant group but the difference is not significant (see Table 7.2). Nearly 70% of the respondents gave as the reason for the use of this practice that it can reduce soil acidity. However, only about 15% of them referred to a reduction in soil pH.[20] Approximately 14% give the fact that it can both improve soil pH and prevent diseases that damage the roots of vegetables. Results show that the main motivation for the use of practices is convenience of crop management rather than soil conservation.

Table 7.2: Use of soil improving by limestone

Practices[1/]	Non-participation	Participation	Test of difference[2/,3/]	Total
Soil improvement using limestone	26.8	33.3	1.3[ns]	28.9
Reason of soil improvement using limestone (%)				
• Improve PH level of soil	73.2	66.7		71.1
• Preventing diseases	13.4	18.3		15.0
• Improve PH level of soil and preventing disease	13.4	15.1		13.9

Note: [1/] Percentage within each group (participant and non-participant).

[2/] Differences are compared using chi-square test; [ns] = Non-significant;

[3/] Number of observations (N) = 287

Source: Own calculations

The recommendation of scientists is to use soil analysis as a basis for making a decision on the rate of fertilizer application since it can provide initial information on plant nutrient availability in the soil (FAO 2004). This helps vegetable producers in reducing fertilizer costs.

Table 7.3 shows the results of the basis vegetable producers use to decide about fertilizer use. About 22% of respondents report that they analyzed soil before applying fertilizers. The rest decided to apply fertilizer based on routine practice and their opinion. The percentage of vegetable producers who based their fertilizer application rates on a visual assessment of soil analysis is higher in participant than non-participant producers. Overall, vegetable producers

[20] Soil pH level is a measure of the acidity and alkalinity. If the soil solution is too acid, vegetables cannot utilize nutrients they need (http://thailand.ipm-info.org).

(84%) analyzed soil by assessing soil colour and soil characteristics. They report that if soil colour is black and mouldy, it indicates that the soil has high fertility. Only 3% of vegetable producers who analyzed soil asked the "soil doctor"[21] to test their soil before applying fertilizer, while 13% analyze soil by an observation of living organisms within the soil. Considering the types of fertilizers applied, about 80% of respondents used chicken manure in both the seeding and the planting stages with the aim of reducing the use of chemical fertilizers and reducing the total variable costs of vegetable production. The quantity of chicken manure used in the seeding stage, on average, is not significantly different between the two groups but the differences in the planting stage are. No significant differences in fertilizer amount could be detected between these groups.

7.1.2 Pest management practices

7.1.2.1 Seeds

Only 20% of respondents used multiple varieties of seed instead of single varieties. This percentage was the same for participant and non-participant producers. Considering the criteria of seed selection given by participants shown in Table 7.4, approximately 83% of respondents selected seeds based on disease- and pest-resistance. According to the recommendation of scientists, seed treatment is still important even though varieties are resistant to pests and diseases since some diseases may still remain in these seeds. The percentage of vegetable producers treating seed before seeding is about 38.3 and there is no difference between groups. Overall, the participants treat seed with chemical (93.7%) rather than soak seed in warm water or mix seeds with herbs (7.3%).

[21] Soil doctor is a local a volunteer living in the village who has been trained in soil analysis by the Department of Land Development, Ministry of Agriculture and Cooperative.

Table 7.3: Use of selected soil fertility management practices

Practices[1/]	Non-participation	Participation	Test of difference[2/,3/]	Total
Soil analysis (%)	19	28	2.5*	22.3
Method of soil analysis				
• Test soil	0	7.7		3.1
• Observe living thing within soil	10.5	15.4		12.5
• Observe soil colour and soil characteristic	89.5	76.9		84.4
Use of chicken manure (%)	79.9	80.6	80.1[ns]	0.1
Average quantity of chicken manure and chemical fertilizer used (kg/ha.)				
• Use of chicken manure in seeding stage	1,394.9	1,712.5	0.7[ns]	1,497.8
• Use of chicken manure in planting stage	1,928.2	1,062.2	3.3*	1,643.6
• Use of chemical fertilizers in seeding stage	227.1	363.3	1.7[ns]	271.3
• Use of chemical fertilizers in planting stage	1,134.6	1167.2	0.1[ns]	1,145.2

Note: [1/] Percentage within each group (participant and non-participant).

[2/] Differences are compared using chi-square test for qualitative variable and quantitative variable. * = Significant at 10%; [ns] = Non-significant

[3/] Number of observations (N) = 287.

Source: Own calculations

Table 7.4: Seed management practices

Practices[1/]	Non-participation	Participation	Test of difference[2/,3/]	Total
Use of multiple verities	18.6	20.4	0.1 ns	19.2
Criteria for seed selection				
• Depending on market demand	9.8	8.7		9.5
• Diseases- and pest- resistance	82.4	83.7		82.8
• Following other producers	7.7	7.6		7.7
Seed treatment (%)	33.3	40.7	1. 5 ns	38.3
Method of seed treatment				
• Soak seeds in warm water for 20-30 minutes or mix seeds with herbs	6.3	9.7		7.3
• Mix seeds with chemical	93.7	90.3		92.7

Note: [1/] Percentage within each group (participant and non-participant).

[2/] Differences are compared using chi-square; ns = Non-significant.

[3/] Number of observations (N) = 287.

Source: Own calculations

7.1.2.2 Weeds

About 43% of respondents in the areas cover the fields with straw or chaff. There is an insignificant difference between participant and non-participant producers (see Table 7.5). About 72% of vegetable producers carrying out that practice gave the reason that it can prevent evaporation of moisture. In contrast, only 21% of participants said the practice can prevent weeds. For non-participants (vegetable producers who did not use the practice), there are four major reasons: (i) no benefits for their vegetables, (ii) mulching materials being expensive, (iii) laborious practice, and (iv) lack of knowledge about the practice.

More than 70% of participant producers controlled weeds by using mechanical methods (loosening soil in the vegetable field) with significant difference at 1% when compared to non-participant vegetable producers. The given reason by participants is that it can move weeds from a vegetable field and help to scarify the soil; meanwhile, almost all non-participants claimed that it has no benefits for their vegetables.

Table 7.6 shows the use of herbicides by vegetable producers. The average quantity of herbicides used is about 0.4 formulated kg/ha, with insignificant differences between participant and non-participant vegetable producers. Surprisingly, the majority of respondents used salts as herbicides. The percentage of users is higher among programme participants, but the average quantity used is insignificantly different between these groups. Programme participants claimed that salt is cheaper than chemical herbicides and also not harmful to their vegetables and their health. Applying salts may cause of degradation of soil fertility in the long term because there is a risk of salt accumulation in the soil, damaging border plants (GRIFFITHS and C. M. ORIANS 2004).

Beside salts, the use of the herbicide *Paraquat* belonging to WHO class II, highly toxic to the skin and mucous membranes (http://thailand.ipm-info.org), is reported. Vegetable producers usually sprayed chemical herbicides before ploughing a field, while the users of salts or *Urea* fertilizer applied it at the planting stage.

Table 7.5: Use of mulching and soil loosening practices

Practices[1/]	Non-participation	Participation	Test of difference[2/,3/]	Total
Mulching	44.8	39.8	0.7[ns]	43.2
Reason given by users				
• Preventing weeds	18.4	27.0		21.0
• Keep moisture within soil	67.2	73.6		71.8
• Preventing weeds and keeping moisture within soil	0	2.7		0.8
• No reason	8	2.7		6.5
Reason given by non-users				
• Laborious	23.4	17.9		21.5
• High expenditure	22.4	33.9		26.4
• No benefits	40.2	37.5		39.3
• Lack of knowledge	14	10.8		12.8
Loosening soil	56.7	74.2	8.2***	62.4
Reason of given by users				
• Increasing soil scarification	21.8	21.7		21.8
• Kill weeds and increasing soil scarification	59.4	70.9		66.5
• No reason	18.8	7.3		11.7
Reason of given by non-users				
• Laborious	22.6	25		23.1
• High expenditure	7.1	8.3		7.4
• No benefits	63.1	62.5		63.0
• Lack of knowledge	7.2	4.2		6.6

Note: [1/] Percentage within each group (participant and non-participant). [2/] Differences are compared using chi-square; [ns] = Non-significant, *** = Significant at 10%. [3/] Number of observations (N) = 287.

Source: Own calculations

Table 7.6: Different common names of herbicides used in the survey

Herbicide	WHO[5/]	Non-participation	Participation	Test of difference[3/,4/]	Total
Herbicide used (kg/ha)[1/]	-	0.47	0.28	1.45	0.4
Percentage of herbicides used[2/]					
Glyphosate	Not list	17.5	14.1	0.6	16.4
Haloxyfop	Not list	9.3	1.1	6.8***	6.6
Oxyfluorfen	IV	13.1	2.2	10.0***	9.8
Paraquat dichloride	II	27.8	22.6	0.9	26.1
Salts	-	37.1	30.1	1.4	34.8
Urea	-	1.0	2.2	0.6	1.4

Note: [1/] Mean of herbicide used by kg. formulated.

[2/] Percentage within each group (participant and non-participant).

[3/] Difference is compared using chi-square for qualitative variable and t-test for quantitative variable; [ns] = Non-significant; *** = Significant at 1%.

[4/] Number of observations (N) = 287.

Source: Own calculations

7.1.2.3 Insects and diseases

For insect and disease management, the most important practice is regular field observation. This practice can help vegetable producers to assess the condition of a crop and make timely decisions for the application of control measures (FAO 2004). Table 7.7 shows that over 80% of respondents in both groups observe their vegetable fields before making a decision to spray pesticides. However, rationale and method of observation differ between the two groups. Programme participants more frequently report that they check the field thoroughly, while non-participants follow a more casual approach to field observations, i.e. they just look around the field or they look at the plants.

Table 7.8 shows that the aim of field observations, as reported by both groups, is to reduce insecticide cost or to identify the pests damaging their vegetable fields. The percentage of vegetable producers who regularly observed their vegetable is significantly higher in participant than non-participant producers.

Table 7.7: Selected insect management practices

Practices[1/]	Non-participation	Participation	Test of difference[2/,3/]	Total
Criteria before spraying				
• Regular field observation	81.9	83.2	3.019	0.389
• Calendar spraying	18.1	16.8		16.0
Method of field observation				
• Go inside and look around	20.8	13.4	14.01***	18.3
• Go inside and look at plants	28.9	13.4		23.7
• Go inside and carefully observe evidence of pest attack	50.3	73.2		58.1
Reason given by user for field observation				
• Safe pesticide costs	52.8	56.1		53.9
• In order to know what kind of pest attack their vegetables	45.9	43.9		45.2
• No reason	1.3	0		0.8

Note: [1/] Percentage within each group (participant and non-participant).
[2/] Differences are compared using chi-square test; [ns] = Non-significant,
*** = Significant at 10%, [3/] Number of observations (N) = 287.

Source: Own calculations

The other practices in the study areas that are kind to the health of humans and the environment are the use of “bio-pesticides”, “biological control agents”, and “sticky yellow trap”, shown in Table 7.8.

Table 7.8: Selected insect management practices

Practice[1/]	Non-participant	Participant	Test of difference[2/,3/]	Total
Use of bio-pesticides	2.6	11.8	10.2**	5.6
Reason given by nonuser				
• Lack of knowledge	70.5	0		48.2
• Imperfect knowledge[22]	8.5	63		25.7
• Laborious	6.3	8.6		7
• Ineffective	10.2	11.1		10.5
• Difficult to find a product in the market	4	9.9		5.8
• Product is expensive	0.6	7.4		2.7
Use of biological control agents	1	2.2	0.6	
Reason given by nonuser				
• Don't have knowledge	68.9	0		46.8
• Imperfect knowledge	20.2	86.8		41.5
• Laborious	8.3	5.5		7.4
• Ineffective	1.6	2.2		1.8
• Difficult to find a product in the market	1.0	5.5		2.5
Use of sticky yellow trap	29	32.5	0.4	31.6
Reason given by nonuser				
• Lack of knowledge	61.1	0		41.1
• Imperfect knowledge	9.2	67.2		28.2
• Laborious	19.1	7.8		15.4
• Ineffective	8.4	20.3		12.4
• Product is expensive	2.3	4.7		3.1

Note: [1/] Percentage within each group (participant and non-participant).
[2/] Differences are compared using chi-square test; [ns] = Non-significant, ** = Significant at 5%. [3/] Number of observations (N) = 287.

Source: Own calculations

The percentages of growers using these practices are quite low in both groups. The existing

[22] They know but don not have an in-depth understanding, with imperfect information about the practice.

bio-insecticide used is *Bacillus thuringiensis* (Bt) that can control caterpillars (larvae of moths and butterflies). Bio-agent controls that are available in the study area are “Ladybugs”, “Mantidae”, and “Cotesia”. The first two agents are predators and the latter is a parasitoid (FAO 2005). In the safer practice programmes, the Royal Project Foundation (RPF) has provided these products for participant producers on a credit basis (Key informant interview with extension workers of the RPF 2005).

The percentage of vegetable producers who use Bt is significantly higher among participants than among non-participants. However, differences are not found for the use of bio-control agents and in the use of sticky yellow trap. Lack of knowledge was reported to be the major reason by non-participants who did not use these practices. For participants the reason is lack of “in-depth understanding of these practices”. In addition, some vegetable producers in the participant group stated that they have experience in these practices but those biological control agents did not survive in the field. They also lack information about where to access bio-control agents. These findings carry two messages. First, the use of complex practices requires knowledge and understanding about the life cycle of pests and the functions of the ecosystem. Hence, participants may have to invest more in the acquisition of knowledge and learn how to use these practices. Secondly, inputs such bio-pesticides and bio-control agents are often not available due to lack of local markets for such inputs.

With regard to the use of insecticide and fungicides, in general participants and non-participants follow the recommendations of the RPF as this information can easily spread from participants to non-participants. In addition, the RPF provides recommended chemical inputs for its members on a credit basis. However, some producers still believe in chemicals that were introduced by pesticide sale agents. Insecticides and fungicides used are classified into different chemical families as shown in table 7.9. The average quantities of insecticides and fungicides used per hectare, excluding bio-pesticide, are significantly lower among participants than non- participants. Different fungicides found in the study are registered and classified in the ‘not’ list of WHO.

Table 7.9: Different chemical families of insecticide used found in the survey

Variable	Non-participation	Participation	Test of difference[3/, 4/]	Total
Percentage of insecticide[1/]				
Dimethylaminopropane 1	57.2	78.5	12.4***	64.1
Avermectin	14.9	23.7	3.3*	17.8
Bio-pesticide	2.6	10.8	10.2***	5.6
Organophosphate	25.8	24.7	0.1	25.4
Banned pesticide	5.2	11.8	4.1**	7.3
Quantity of insecticide used (kg/ha)[2/]	0.59	0.30	5.6***	0.5
Percentage of fungicide [1/]				
Benzimidazole	53.6	67.7	5.2**	58.2
Sinorganic (Copper oxychloride)	25.8	31.2	0.9	27.5
Organic (Sulfur)	8.2	7.5	0.1	8.0
Quantity of fungicides used (kg/ha)[2/]	0.2	0.2	5.6***	0.1

Note: [1/] Percentage within each group (participant and non-participant).

[2/] Mean of insecticide and fungicide used by kg. formulated

[3/]Difference is compared using chi-square for qualitative variable and t-test for quantitative variable; [ns] = Non-significant; *** = Significant at 1%.

[4/]Number of observations (N) = 287.

Source: Own calculations

Approximately 25% of respondents used insecticides classified as being in the organophosphate family. These chemicals generally have long-term effects on the environment and human health as they do not degrade rapidly (http://thailand.ipm-info.org/). The use of “Mevinphos” and “Endosulfan” is banned, but these were also found in the survey. Significantly more participants than non-participants use banned pesticides, which indicates that law enforcement is practically non-existent.

7.2 Definition of standard for safer practices

7.2.1 Selection of key practices

During the process of consultations with experts (see also chapter 4), key management practices for cabbage were identified. The practices are the basis for the construction of a standard for safer and environmentally benign practices and allowed the definition of an aggregate practices score. The selected practices were derived from the concept of Integrated Pest Management (IPM) technology as it has been developed for the conditions of Thailand (see also chapter.2). These were described in the IPM manual developed for cabbage production (FAO 2005). In addition, information from the survey of vegetable producers was used. In conclusion eleven practices were thus selected, which are described in Table 7.10.

The key practices contain two sets: (i) pest management practices and (ii) soil conservation practices. In the set of pest management practices, "regular field observations" is perhaps the major component of safer vegetable production following the principles of IPM (BENBROOK 1996). This practice is a pre-condition for rational decision-making for chemical and non-chemical methods of control. It is also necessary to qualify this practice. Thus only vegetable producers who apply intensive field observations are identified as users of the practice. The second practice is "crop rotation". It can suppress pest populations by breaking the pest cycle that builds up when growing the same species of vegetable repeatedly. At the same time, crop rotation gives a measure of weed control (FAO 2005). "Seed treatment" and "mulching" practices are typical mechanical and physical control methods that are standard components of IPM.

In relation to the production of seedlings and in newly planted fields, the use of a plastic covering or organic material (mulching) is recommended for covering seedbeds or vegetable-beds to prevent weeds, increase soil scarification, and reduce the number of pest populations and diseases (FAO 2005). The "use of bio-pesticides" and "biological control agents" are non-chemical methods of control based on the concept of using ecological systems to manage pests and are also chosen. One of the bio-pesticides found in the study area is *Bacillus thuringiensis* (Bt). In contrast, biological control agents are beneficial organisms that occur naturally in the environment and are typified by beneficial insects in the form of parasitoids and predators (CGIAR 2006). The control measure here is the conservation of these organisms through culturing measures. In addition, the "yellow sticky traps" are used to catch insects as both a monitoring device and a control method.

Table 7.10: Descriptions of key practices in a set of safer practices

Practice[1/]	Description [2/]
Pest management	
1. Regular field observations	Intensive observations of the pest situation in the vegetable field.
2. Crop rotation	Modifications of the cropping pattern
3. Seed treatment	Use of hot-water-treated seed or chemicals before planting.
4. Mulching	Use of plastic material or organic mulching.
5. Bio-pesticides	Use of commercially available beneficial organisms.
6. Biological control agents	Augmentation of beneficial organisms like predators and parasitoids occurring naturally in the environment.
7. Yellow sticky trap	Trap that is designed using yellow sticky glue to catch insects and for monitoring.
8. Use of multiple varieties	Use of multiple varieties instead of single varieties.
Soil conservation	
9. Soil analysis	Provided information of soil health
10. Soil improvement measures	Use of manure and organic matter to improve soil fertility and keeping the soil healthy.
11.Planting contour bunds	Planting vegetable on the contour bund with growing grass strip

Source: [1/] Own presentation. [2/](CGIAR 2006; FAO 2005)

The set of soil conservation practices includes "soil analysis", as basis for obtaining information about nutrient contents and as a means for deciding on the type and amount of fertilizer to be applied. Soil improvement measures refer to the use of organic materials that help to improve soil fertility and reduce pest pressure; selected as another key practice for soil. The third practice is the planting of "contour bunds" as a practice to reduce soil erosion when vegetables are grown on steep slopes.

7.2.2 Establishment of expert standard

In order to assess the practices used by vegetable producers (see section 7.1) the judgement of experts regarding the weighting of the selected key practices, is presented in Table 7.11.

Table 7.11: Experts assessment of key practices

Variable	Mean[1/].	SD.	Min	Max
Pest management				
Regular Field Respondents	8.8	1.7	4	10
Use of bio-pesticides	8.2	1.5	5	10
Use of biological control agents	7.7	1.9	4	10
Crop rotation	7.6	1.5	5	10
Seed treatment	7.0	1.7	4	9
Use of trap practices	6.7	1.7	3	10
Mulching	6.6	1.8	3	9
Use of multiple varieties	5.3	1.8	3	8
Soil conservation				
Soil analysis	7.9	0.7	7	9
Soil improvement	7.6	1.6	5	10
Planting contour bunds	7.6	1.6	5	10
Total	81			

Note: [1/]Number of observation (N) = 23

Source: Own expert survey (2005)

Results confirm the priorities that are revealed in the literature, e.g. “regular field observation” (BENBROOK 1996) received the highest score followed by “use of bio-pesticides”. The scores assigned to “crop rotation” and “use of biological control agents” are almost identical. Among soil conservation practices, “soil analysis” received the highest score, while the remaining two practices received identical rankings. Summing the expert scores yields an expert standard with a total score of 81.

Expert assessments are used to weight the practices applied by vegetable producers and hence to assign scores. For example, a producer who reports the use bio-pesticide will receive 8.2 points. In Table 7.12 the mean, minimum and maximum scores of the two groups of producers are shown. Statistical analysis using the t-test shows that participants have significantly higher scores although the difference is not very great. One possible explanation for a relatively small difference between the two groups is that there is the possibility of farmer-to-farmer technology transfer. Non-participants may learn from neighbouring participants. However, the distribution of scores shows that there is a significant difference and that participants have a much higher percentage in the score category 50 to 60.

Table 7.12: Average weighted practice scores by treated and non-treated group

Practice scores	Non-participants	Participants	Total
Maximum	53.02	58.21	58.21
Minimum	0	6.67	0
Mean[1/,2/]	27.92	33.46	29.71
SD.	11.42	11.92	11.85
Test of difference: T-test = -3.80***			

Note: [1/] Differences are compared using chi-square test for qualitative variable and t-test for quantitative variable; [ns] = Non-significant;

[2/] Number of observations (N) = 287

Source: Own calculations

Comparing the practice scores of both groups of producers with the expert standard, none of the respondents comes close to the expert standard of score 81, even for vegetable producers in the participant group (see Table 7.13). In the next section an analysis of the deviation of the scores of participant vegetable producers from the expert standard is carried out. This will give the reasons for the gap between the expert standard and existing practices used by participants. It is hypothesized that more knowledge will increase practice scores, implying that knowledge is a major factor affecting adoption.

Table 7.13: Average weighted practice scores by treated and non-treated group

Practice scores	Non-participants	Participants	Total
Rank of scores (%)			
Less than 10	6.7	4.3	5.9
10 < score <=20	18	5.4	13.9
20< score <=30	31.4	26.9	30
30< score <=40	28.9	37.6	31.7
40< score <=50	12.9	12.9	12.9
50< score <=60	2.1	12.9	5.6
Great than 60	0	0	0
Test of difference: Chi-square = 23.06***			

Note: [1/] Differences are compared using chi-square test for qualitative variable and t-test for quantitative variable; [ns] = Non-significant;
[2/] Number of observations (N) = 287

Source: Own calculations

7.3 Relationships among the multiple steps to vegetable producers' decision

To examine the direct effect of programme participation on adoption of safer practices, a simultaneous equation systems model, described as model 11 in chapter 3, is applied. Firstly, a description of the variables used in the model is presented. Secondly, the estimation procedure and tests of specification errors are described. As mentioned in the modelling framework (chapter 3), two models that distinguish between the weighted and the un-weighted practice scores are presented. The purpose of estimating two models is to assess the effect of an expert standard on the factors that determine the adoption of safer practices. Finally, results of both models are discussed.

7.3.1 Description of variables

The two dependent variables used in the simultaneous equation model are (i) the un-weighted practice score which is the cumulative total of the key practices applied by vegetable producers and (ii) the weighted practice score, which is the same as (i) but the scores are based on the weights assigned by the experts. The cumulative scores are taken as an aggregate measure of adoption of safer crop and pest management practices in cabbage.

The factors that were hypothesized to explain the degree of adoption are those that have been described for modelling participation (see chapter 5) and knowledge (see chapter 6). In the models used in this section, additional variables were included, and were mainly drawn from the literature on the adoption of Integrated Pest Management (IPM) practices. Similarly to the knowledge equation discussed in chapter 6, four categories of independent variables can be specified, namely information and knowledge, human capital, farm resource endowments and other variables.

Information and Knowledge: Information from neighbours (expressed as dummy variable "source_1") is expected to have a positive indirect effect on practice change. This hypothesis is based on FOSTER and ROSENZWEIG (1995) who developed a model to incorporate learning by doing and learning from neighbours as a determinant of adoption. The second variable in this group is knowledge, which is assumed to be a key variable in the equation systems with regard to adoption of safer practices. Knowledge is acquired by participation in extension programmes that promote safer practices as described in chapter 3. As shown in several studies, the participatory approach, which was also applied in these programmes, is effective in stimulating a change in practices. (DALTON *et al.* 2005; FEDER *et al.* 2004; PARK and LOHR 2005; RAMIREZ and SHULTZ 2000). Such knowledge enhancement can also stimulate innovation by adopters (ASHBY 2003; DALTON *et al.* 2005; FEDER *et al.* 2004), which is especially important in the field of natural resource management (WAIBEL and ZILBERMAN 2007).

Human capital: Two proxies are used in the model to measure the level of human capital, i.e. education and years of experience. As shown in the human capital model of SCHULTZ (1975) education is important in the ability of farmers to efficiently allocate limited resources (WELCH 1970). Hence, education can affect the speed and effectiveness of the adoption process (RAHM and HUFFMAN 1984; WAIBEL *et al.* 1999; WOZNIACK 1984). The effect of experience is similar to that of education. Since producers with longer experience are likely to be more efficient in processing information, as long as this information corresponds with their area of experience, and that factor may speed up the adoption decision (PARK and LOHR 2005; WOZNIACK 1987). GLADWIN (1979) argued that using complex practices requires specialized skills, which can be acquired through participatory learning. Based on these studies, it can be hypothesized that both human capital variables included in the models here will be positively related to the adoption of safer practices.

Farm resource endowments: Classic adoption studies demonstrate that size of operation is positively related to adoption of innovations (BARHAM *et al.* 2004; FERNANDEZ-CORNEJO *et al.* 1992; JUST and ZILBERMAN 1983). Generally, larger producers find it easier to experiment with new technologies on a portion of their land (GEBRESELASSIE and SANDERS 2006). Also, some studies argue that producers with higher labour availability per unit of land may be likely to adopt more labour intensive technologies than smaller producers (FEDER *et al.* 1985). In this study therefore it seems reasonable to use the labour to land ratio. This ratio may be positively correlated with the use of safer practices because these are generally labour-intensive (MCNAMARA *et al.* 1991).

Other variables: There are three variables classified in this group and used in the "adoption equation": (i) major occupation, (ii) marketing condition, and (iii) study area. The three variables are expected to be positively correlated with adoption. The variable occupation may have a positive influence on adoption as farmers who are full-time vegetable producers will have more incentive to use practices that they believe to have positive effects on health and environment. This hypothesis can be derived from several studies that often found that off-farm employment can be a constraint on IPM adoption (FERNANDEZ-CORNEJO 1996; FERNANDEZ-CORNEJO *et al.* 1994; MCNAMARA *et al.* 1991). The variable "marketing conditions" refers to the requirement for pesticide residue testing by a vegetable buyer. It is hypothesized that compliance with this requirement has a positive effect on the use of safer practices, because producers can avoid the risk of failure to sell their produce. The third variable is study area, which is used as a proxy for other sources of variation that can affect the behaviour of vegetable producers.

7.3.2 Estimation procedure

With reference to model 11 (chapter 3), the simultaneous equation model can be specified as follows:

$$
\begin{aligned}
pra\hat{c}tice &= \delta_{10} + \hat{\alpha}_1.knowledge + \hat{\gamma}.lambda + \hat{d}_{12}.experience + \hat{d}_{13}.experience^2 \\
&+ \hat{d}_{14}.landlabour + \hat{d}_{15}.member + \hat{d}_{16}.occupation + \hat{d}_{17}.market \\
&+ \hat{d}_{18}.studyarea \\
kno\hat{w}ledge &= \hat{\delta}_{20} + \hat{\beta}.lambda + \hat{d}_{21}education + \hat{d}_{22}source\_1 + \hat{d}_{23}.experience \\
&+ \hat{d}_{24}.experience^2 + \hat{d}_{25}.labourland + \hat{d}_{26}member + \hat{d}_{27.}occupation \\
&\hat{d}_{28.}market + \hat{d}_{29}studyarea \\
pati\hat{c}ipation &= \hat{\delta}_{30} + \hat{d}_{31}health + \hat{d}_{32}pickup + \hat{d}_{33}.headeducate + \hat{d}_{34}.experience \\
&+ \hat{d}_{35}.experience^2 + \hat{d}_{36}.labourland + \hat{d}_{37}.member + \hat{d}_{38}.occupation \\
&+ \hat{d}_{39}.market + \hat{d}_{310}.studyarea,
\end{aligned}
$$

where $\hat{\delta}_{ij}$ is the estimated unknown parameter of variable j used in equation i in these systems, j=0, 1,…,11 and i=1, …,3, and $\hat{\beta}$ and $\hat{\gamma}$ are the unknown parameters of *lambda* used for the knowledge and practice equations, respectively. This term is used as the control function to account for selection biases.

The estimation of model 11 contains two steps. The first step is to start with the participation equation. This model has already been estimated by a probit regression in chapter 5. The results of the model are used to calculate the *lambda* as follows: the normal distribution of the predicted value of the probability of participation is divided by the normal density function of this predicted probability (i.e. $lambda = norm(\delta z) / normden(\delta z)$), where z are independent variables. In the second step, the estimated lambda is used to estimate model 11 by adopting a 2SLS approach with the selected sub-sample of programme participants. Although we use a simultaneous model, it is nevertheless necessary to test for possible endogeneity that can exist between knowledge and change in practice. Such reverse causality (RENDERS and GAEREMYNCK 2006) leads to a correlation between knowledge scores and the unobserved characteristics affecting the practice scores, i.e. the error terms of the adoption equation. If there is no endogeneity, use of ordinary least square (OL) for the estimation of model 11 should give similar results.

7.3.3 Result of testing specification error

A test of endogeneity between knowledge and practice is carried out. Results show (Table 7.14.) that endogeneity exists. However, although in the unweighted model it is only slightly significant, the effect is significant in the weighted model.

Table 7.14 Specification tests

Model	Unweighted model		Weighted model	
Test	Chi-square	P-value	Chi-square	P-value
Heteroskedasticity[1/]	6.29	0.0029***	6.29	0.0029***
Identification	9.85	0.0073***	9.85	0.0073***
Endogeneity	4.43	0.109*	6.31	0.0427**
Over-identifying restrictions	0.759	0.3838	1.60	0.2059

Note: [1/] * Significant at 10%, **Significant at 5%, Significant at 1%.

[2/] Number of observations (N) = 93.

Source: Own calculations

In addition, two other important tests are performed before the estimation of the 2SLS model is carried out. The first test determines whether the instrumental variables (IVs) used in the knowledge equation are exogenous, i.e. all instrumental variables are uncorrelated with the error term of the practice equation. If the null hypothesis is accepted, the overall set of IVs used is appropriate. The criterion used to select the IVs is that such variables should have a high correlation with knowledge and are not in the adoption equation. In this study, the variables *education* and *source_1* are used as IVs. According to WOOLDRIDGE (2006) testing the over-identifying restrictions needs to be carried out if more than one IV is used.

Secondly, the test of heterogeneity is used to test whether the IVs have a strong effect on the endogenous variable (knowledge). Table 7.14 presents results of these tests. It is shown that no instrument variables are correlated with the error term, i.e. *education* and *source_1* are appropriate IVs.

7.3.4 Factors influencing the adoption of safer practices

The OLS procedure is used first to estimate coefficients of the two models. Results in Table 7.15 and 7.16 show that the lambda coefficients in both models are significantly different at 5%. This is evidence of the existence of selection bias. Therefore the *lambda* term must be included in the knowledge and practice equations (i.e. model 11).

Table 7.15: The estimation of unweighted models by OLS[1/]

Variables	Without lambda		With lambda	
	Coefficient[3/]	Robust SE[4/]	Coefficient[3/]	Robust SE[4/]
Intercept	15.2134	3.5744	-44.7537	26.0794
Lambda[2/]			35.9965**	15.7001
Knowledge	0.7753***	0.2634	0.7103***	0.2644
Source_1	0.4424	3.4419	25.9495**	11.6799
Education	0.2736	0.2012	1.3023**	0.4869
Experience	0.2150	0.1973	0.7249**	0.2970
Experience^2	-0.0030	0.0061	-0.0477	0.0208
Labour to land	0.3196***	0.1553	0.4405***	0.1602
Member	-0.5629	1.7830	2.9408	2.4327
Occupation	2.8067	2.2890	18.9376**	7.3035
Marketing condition	4.8542***	1.4208	29.8461**	10.9050
Study area	-2.9784***	1.3433	-0.9365	1.6041
F-test	4.76***		5.55***	
R-square	0.1306		0.1462	

Note: [1/] Number of observations (N) = 93.

[2/] Lambda is predicted from participation equation.

[3/] * Significant at 10%, **Significant at 5%, ***Significant at 1%.

[4/] Robust standard errors are controlled for the clustering effects.

Source: Own calculations

Table 7.16: The estimation of weighted models by OLS[1/]

Variables	Without lambda		With lambda	
	Coefficient[3/].	Robust SE[4/]	Coefficient[3/].	Robust SE[4]
Intercept	1.6835	0.4924	-5.3967	3.5758
Lambda[2/]			4.2500**	2.1489
Knowledge	0.1242***	0.0363	0.1165***	0.0364
Source_1	0.1759	0.4845	3.1875**	1.5976
Education	0.0367	0.0280	0.1582**	0.0669
Experience	0.0305	0.0310	0.0907**	0.0431
$Experience^2$	-0.0005	0.0010	-0.0058	0.0029
Labour to land	0.0576***	0.0206	0.0719***	0.0213
Member	-0.0195	0.2403	0.3942	0.3257
Occupation	0.3002	0.2920	2.2047**	1.0038
Marketing condition	0.7115***	0.1910	3.6623**	1.4945
Study area	-0.5615***	0.1813	-0.3204	0.2172
F-test	6.24***		6.55***	
R-square	0.1695		0.1807	

Note: [1/] Number of observations (N) = 93.

[2/] Lambda is predicted from participation equation.

[3/] * Significant at 10%, **Significant at 5%, ***Significant at 1%.

[4/] Robust standard errors are controlled for the clustering effects.

Source: Own calculations

Due to the evidence of endogeneity of the knowledge variable shown in both the weighted and the unweighted models (see Table 7.14), further analysis is based on the 2SLS procedure. As stated above the *lambda* that was estimated from the participation equation is included in knowledge and practice equations as an independent variable. In this step, all variables that are hypothesized to affect the adoption of safer practices are included. This model is considered to be unrestricted in that all variables, regardless of their level of significance, are included. The results are presented in Table 7.17 for both models, i.e. using the weighted and the unweighted practice scores as the dependent variable. It is shown that two variables, i.e. *member* and *study area* are insufficient to explain the adoption of safer practices in either model. To check the robustness of these models, those variables are left out and the models re-estimated. These are identified as the restricted models and results are shown in Table 7.18.

Table 7.17: The estimation of unrestricted model models by 2SLS[1/]

Variables	Unweighted practice scores		Weighted practice scores	
	Coefficient.	Robust SE[3/]	Coefficient	Robust SE[3/].
Intercept	-2.8981	2.6865	-17.4623	19.9520
Lambda[1/]	1.3227*	0.6941	9.6818**	5.1213
Knowledge	0.2703*	0.1481	1.8653*	1.0824
Experience	0.1440**	0.0588	0.8999**	0.4391
Experience^2	-0.0068***	0.0024	-0.0433***	0.0182
Labour to land	0.1102***	0.0337	0.6748***	0.2676
Member	0.3915	0.3270	2.3050	2.5307
Occupation	0.9914**	0.3920	8.9272**	2.9139
Marketing condition	1.3862***	0.4679	10.2680***	3.4506
Study area	-0.3184	0.3292	-2.8788	2.4281
F-test	3.56***		3.32***	
R-square	0.30		0.26	

Note: [1/] Number of observations (N) = 93.

[2/] Lambda is predicted from the participation equation.

[3/] * Significant at 10%, **Significant at 5%, ***Significant at 1%.

[4/] Robust standard errors are controlled for the clustering effects.

Source: Own calculations

Considering both the restricted and unrestricted models, the explanatory values (R-square) for the models and the significant levels of the estimated coefficients differ. The explanatory power of the unrestricted model is greater than that of the restricted model (see Table 7.17 and 7.18). From the econometric point of view, dropping some exogenous variables is ineffective (WOOLDRIDGE 2002). In this case the unrestricted model has more meaningful results. Thus further interpretations are based on the unrestricted model, shown in Table 7.17.

Table 7.18: The estimation of restricted models by 2SLS[1/]

Variables	Unweighted practice scores		Weighted practice scores	
	Coefficient[3/]	Robust SE[4/]	Coefficient[3/]	Robust SE[4/]
Intercept	-2.1097	2.2546	-15.5066	16.2908
Lambda[2/]	1.0454*	0.5910	8.7633**	4.2512
Knowledge	0.2404*	0.1359	1.7898*	0.9899
Experience	0.1446**	0.0568	0.8796**	0.4353
$Experience^2$	-0.0064***	0.0024	-0.0391***	0.0178
Labour to land	0.1016***	0.0320	0.6252***	0.2511
Member				
Occupation	0.8348**	0.3848	8.2302**	2.9389
Marketing condition	1.1878***	0.4638	9.2844***	3.3307
Study area				
F-test	3.91***		3.51***	
R-square	0.2919		0.2446	

Note: [1/] Number of observations (N) = 93.

[2/] Lambda is predicted from participation equation .

[3/] * Significant at 10%, **Significant at 5%, ***Significant at 1%.

[4/] Robust standard errors are controlled for the clustering effects.

Source: Own calculations

Results in Table 7.17 show that in both models all except two variables, i.e. study area and membership in farmer groups other than participation in the RPF programme, are significant. Hence, adoption is similar in the two sites of the RPF although they differ in infrastructure and distance to market. The lambda variable that measures the direct effect of programme participation on adoption of practices shows a higher level of significance in the weighted model. This suggests that adoption is concentrated on more complex practices that receive more weighting in the expert ranking. For example, for practices like intensive field observations, use of bio-pesticides and bio-control agents, the knowledge effect is more pronounced in the weighted model. Hence the expert standard reinforces the knowledge-intensive nature of safer and more environmentally benign vegetable production. Incomplete knowledge is the reason for non-adoption of some complex practices that are proven to be beneficial (COMER *et al.* 1999; PARK and LOHR 2005).

Other significant variables affecting practice scores include experience, labour to land ratio, main occupation, and marketing conditions. The significance level of these variables does not differ between the un-weighted and weighted model, but the estimated coefficients do differ in magnitude.

The labour to land ratio has a positive effect on adoption and is significant at the 1% level. This underlines the assumption that the use of safer practices may affect the labour organization on a vegetable farm. It has also been suggested in the studies of BECKMANN and WESSELER (2003; MAUMBE and SWINTON 2003) and MAUMBE and SWINTON (2003), which show labour organization is one of the factors affecting adoption of practices available in the set of IPM technologies.

Having household heads working full-time on a farm has a positive effect on adoption as expected, due to lower opportunity costs of labour. Full time farmers have more motivation to invest in knowledge accumulation in order to improve their productivity. Being a full-time vegetable producer will cause an increase in adoption by 0.9 points as measured on the practice scores in the unweighted model and 8.9 points in the weighted model. This suggests that adoption of more comprehensive practices is more labour demanding. That finding is supported by the study of CASWELL *et al.* (2001) and PARK and LOHR (2005)that off-farm employment motivates the use of time-intensive technologies such as organic practices.

The market variable (residue testing) also significantly increases the degree of adoption. This may also imply that risk-averse vegetable producers are more likely to adopt safer practices. On the other hand, results of the weighted model suggest that risk-averse producers will use more complex practices because of the higher level of importance of these practices. This suggests that extension programmes that aim to introduce safer practices should give priority to some practices and put less emphasis on others, thus reducing the complexity of the training approach.

7.4 Summary

This chapter presented the analysis of the direct effect of participation in safer practice programmes on the crop and pest management practices used by vegetable producers. The existing crop management practices in cabbage were described, comparing participants and non participants. It was found that participants tend to use practices that are more complex and which tend to be more oriented towards health and environmental issues. The main reasons given for non-use of some practices were lack of knowledge and market availability of biological factors of control.

The second section explains the establishment of a standard for safer practices as identified by experts. Eleven key practices were selected in the expert consultation process: eight practices for pest management and three for soil conservation. The priority among these practices was established by means of an expert opinion survey. Experts assigned weights to the selected practices and a cumulative score of 81 was derived as the expert standard. Results show that on applying the expert scores programme, on average participants achieve significantly higher practice scores than non-participants. However, the maximum scores of both groups are almost identical.

In the third part of this chapter the direct effects of programme participation on change in practices is modelled as a two-stage process using a simultaneous equation approach. The model accounted for selection bias and endogeneity of knowledge in the adoption of safer practices. Also, un-weighted and weighted models were formulated in order to assess the effect of the expert standard on the factors that determine the adoption of safer practices. Results show that the factors are the same in both models, but the magnitude of the effect differs. It was also shown that participation in a safer practice programme is a significant factor that stimulates adoption of safer practices. Adoption was found to be concentrated on the more complex practices as illustrated by the higher magnitude of the coefficients in the weighted model. The results support findings in the literature, which state that adoption of technologies related to natural resource management technologies is strongly dependent on the process of knowledge acquisition (SUNDING and ZILBERMAN 2001; WAIBEL and ZILBERMAN 2007). In addition, experience was found to reinforce the knowledge effects. However, results suggest that there are also some barriers to adoption, i.e. occupation and marketing conditions. These barriers have implications for the development of safer crop and pest management technologies and for the design and implementation of extension programmes in vegetable production.

Chapter 8

Summary, conclusions and recommendations

8.1 Summary

This research has involved an in-depth analysis of the process of knowledge acquisition and adoption of safer vegetable production practices in Northern Thailand. Evidence exists that current production technologies, especially in vegetables, carry considerable health risks for consumers and producers and are damaging the environment. Hence, producers need to change their current practices by adopting technologies that are safer and more environmentally benign. A major feature of such technologies is that they are knowledge-intensive and they belong to the category of natural resources management technologies; these are generally more complex than the classic agricultural technologies, which are usually related to seeds, fertilizers and pesticides.

The overall objective of the research was to contribute to a better understanding of technology adoption in vegetable production. Four major issues were investigated:

1. The determinants that lead vegetable producers to participate in extension programs that promote the use of safer and more environmentally benign production methods.
2. The effect of such programs on vegetable producers' knowledge of new practices.
3. The specific role of knowledge in the adoption of safer vegetable production technologies.
4. The evaluation of vegetable producers' practices in the light of standards formulated by experts form research and extension in Thailand.

The research began with a summary of some background information on the institutional conditions for achieving the government's goal of producing vegetables that are safe for producers and consumers. It was shown in chapter 2 that a large number of government agencies are given the responsibility to contribute to this goal. In particular, the role of the Royal Project Foundation (RPF), a Non Governmental Organisation founded by the King of Thailand, has been identified as being pivotal in the promotion of safer cropping technologies in the environmentally sensitive areas of the Northern highlands. The analysis of secondary data made it clear that so far there is little evidence of a widespread adoption of safer vegetable production technologies, which have been developed by research. The situation analysis has also has shown some constraints on achieving the goal. These constraints are largely overlapping tasks and imprecisely defined roles of the government institutions assigned to implement specific programmes. Another problem identified was that there is discontinuity and inconsistency in the agricultural, environmental and health policies at the national level, which generates a policy environment that is not always conducive to the adoption of safer crop and pest management technologies.

The methodological framework applied in this study provides a conceptualization of the role of extension systems in the delivery of knowledge-intensive technologies. The framework describes factors and constraints that influence the decisions of vegetable producers to participate in extension and describes how program participation can increase the knowledge of participants and how knowledge in turn relates to the adoption of safer vegetable production technologies. The analysis proceeded in several steps. First, a probit regression model to identify the determinants for program participation of vegetable producers was developed. Thereafter the estimation of the programme participation effect on knowledge was carried out. In this procedure two techniques, namely the *ignorability of treatment* and the *instrumental variable techniques* that account for the problems of selection biases and endogeneity, were applied. Finally, the link between programme participation, change in knowledge and the adoption of safer practices was established by using two-stage simultaneous equation procedure.

The data that were used to estimate the models came mainly from two sources: (i) a survey of some 300 vegetable producers in the province of Chiang Mai and (ii) consultations with experts via a workshop and a questionnaire administered among some 23 vegetable experts from Thailand.

The first model, using a simple probit regression, investigated the factors responsible for the participation of vegetable producers in the extension programs of the Royal Project Foundation and related agencies. The model took account of the possible clustering effects in the data by calculating the robust standard error. Results showed that there are several factors that explain programme participation. Firstly, whether or not vegetable production is the major occupation is instrumental for the decision of a producer to participate. Another factor was the influence of the market. If the vegetable buyer requires the testing of pesticide residues in vegetables, this was found to be a motivating factor towards participation in such programmes.

Results of the second model showed that program participation significantly enhances vegetable producers' knowledge. Other significant variables found were the level of education and experience in vegetable growing. In addition, information dissemination was also significant. Thus, exchange of information among neighbours may reinforce the effects of the training and learning programme. The robustness of the models was confirmed by applying different tests that accounted for the non-random nature of the sample.

The model also confirmed the statistical comparisons between program participants and non-participants. Results showed that the difference in knowledge is particularly pronounced in the identification of beneficial organisms as a natural method of pest control and some other aspects of crop and pest management. However, it was also found that knowledge levels of both groups are quite low in the case of some complex practices. In terms of attitudes the difference between participants and non-participants is less clear. Almost all vegetable producers agree on the benefits of safer practices for the conservation of natural resources and the environment. However, significant differences were found in attitudes toward the negative effects of spraying pesticide and the trustfulness of information provided by pesticide agents. Here, participants showed a more critical attitude than non-participants.

The final model used a simultaneous equation approach in order to establish a linkage between programme participation, knowledge and adoption of safer crop and pest management practices of vegetable producers. The model accounted for selection bias and endogeneity of knowledge in the adoption of safer practices. The analysis began by describing the existing crop management practices in cabbage and comparing participants with non-participants. The general impression was that participants tend to use more complex practices, which are assumed to be closer to the environmental and public health goals formulated by the government. Two models were compared. One, where key practices identified by expert consultations were summarized by means of a weighted aggregate adoption scale and another one where the same practices were measured as a total count, as a proxy for adoption. The comparison between the un-weighted and weighted models allows the assessment of adoption in the light of scientific requirements as compared to the field situation, in the absence of an official standard for safer practices in vegetables. Results showed that the factors that explain adoption are the same in both models, but the magnitude of the effect differs. However, participation in a safer practice programme is a significant factor that not only improves knowledge but also stimulates adoption. Hence improving knowledge can be considered to be a pre-condition for the adoption of knowledge-intensive technologies. The models revealed that adoption was concentrated on the more complex practices, as illustrated by the higher magnitude of the coefficients in the weighted model. Furthermore, the model results also identify some barriers to adoption, such as occupation and marketing conditions. Hence, the result of this stepwise approach is to allows exploration of the extension-knowledge-adoption process in order to draw some conclusions and to derive some recommendations that can provide guidance in the development of new technologies in vegetable production.

8.2 Conclusions and recommendations

The ongoing problem of natural resource degradation in agriculture in Thailand (and in other countries of South East Asia) requires agricultural technologies that take environmental and human health concerns more strongly into account. . Crucial factors in the adoption of such technologies are knowledge and education as well as an effective marketing system for such research products (Waibel and Zilberman 2007). Extension programmes can be an effective tool to enhance farmer’s knowledge as a pre-condition for their ability to adopt of such technologies.

This study has shown that in order to be effective in promoting knowledge-intensive natural resource management technologies among vegetable producers, research and extension need to go beyond the classic technical support approach. The nature of the problem and the type of technologies require more modern methods of farmer education and training. The Royal Project Foundation in Thailand is one institution that has been instrumental in implementing alternative extension approaches that generally followed the participatory principle. However, adequate technology supply is no guarantee of technology adoption as many factors come into play. Therefore, rigorous *ex post* impact assessment of extension programmes is needed. To conduct such an analysis is a challenge since the true gains attributable to particular innovations are difficult to establish, particularly under the prevailing conditions of developing countries (DOUTHWAITE *et al.* 2003). Major methodological problems are selection bias, heterogeneity among adopters and the difficulty in establishing valid counterfactual scenarios. The failure to control for these problems in econometric models can lead to overestimation of both the rate of adoption and the programme benefits (BARRETT *et al.* 2004)

As shown by the scientific discussion surrounding the impact of participatory training methods in integrated pest management (IPM), researchers sometimes fail to establish solid evidence of programme effects on the changes in farmer attitude, adoption and economic benefits (DALTON *et al.* 2005; DALTON *et al.* 2007; FEDER *et al.* 2003; FEDER *et al.* 2004; PRANEETVATAKUL *et al.* 2007; YAMAZAKI and RESOSUDARMO 2007).

In this study an attempt was made to overcome some of the problems that were evident in similar research. The results point to two major conclusions: (i) a stepwise analysis of the extension programme knowledge acquisition and adoption process is effective in identifying the factors that influence the intermediate and final outcomes of this process and (ii) a careful use of econometric techniques can help to overcome some of the data problems that usually limit the application of more rigorous models (e.g. difference in difference models), especially in the establishment of counterfactual scenarios and in capturing heterogeneity of the sampling population.

The empirical results allow some important conclusions, which in part verify some hypotheses formulated in previous studies. For example, in promoting vegetable production technologies, education and experience are important in influencing producers' adoption decisions. Other findings, however, were less frequently mentioned in the literature, namely the role of market agents. For example, the requirement of buyers to test the product for pesticide residues stimulates the demand for extension information and of knowledge for safer practices. Hence, training of vegetable producers should not only concentrate on the crop and pest management aspects but also include marketing topics in the training agenda.

Strengthening the role of markets for safer products can indeed be identified as a strategy to better integrate the consumer and producer sides. VANIT-ANUNCHAI (2006)) recommends that willingness to pay of consumers in Thailand for safe and environmentally friendly produced vegetables is high but standards have to be assured. In the long run, special projects like the

RPF that return significantly higher market prices cannot be an overall solution to the problems of externalities of vegetable production because of limitation in scale. Hence, additional marketing channels need to be developed that effectively communicate product quality on the one hand and consumer preferences on the other hand. Unless the market rewards producers for supplying safer vegetables, the incentive to adopt technologies that are more complex and often more labour demanding will be severely impaired (JAYAMANGKALA 2005). Hence, these issues require more the attention at the national and regional policy levels.

Furthermore, it can be concluded that extension programmes in vegetable production need to be better tailored towards the socioeconomic conditions of producers. In other words, producers who are engaged full time in vegetable production require different incentives to motivate their participation in extension programmes than those who are part-time vegetable producers with other occupations, e.g. outside agriculture. This confirms results of some recent studies (DALTON *et al.* 2007; PRANEETVATAKUL *et al.* 2007; QUIZON *et al.* 2000),

Unfortunately, the results of this analysis do not allow any conclusions to be drawn regarding the efficiency of investments in extension programmes as no data on change in income or programme costs were collected. However, some solid conclusions can be drawn regarding the direct effects of programme participation. With respect to results of the *average treatment effect* model is clear that these programs significantly improve vegetable producers' knowledge, as an important precursor to the adoption of such technologies. Thus the results in the classic adoption studies of ROGERS (2003) and some recent empirical studies (DALTON *et al.* 2005; GODTLAND *et al.* 2003; PRANEETVATAKUL *et al.* 2007; YAMAZAKI and RESOSUDARMO 2007) are confirmed. Hence, the investment in farmer training can be assumed to be effective, meaning that the money spent on programmes like RPF is probably justified. Perhaps in the future such programmes could put more emphasis on the promotion and use of farmer networks in spreading information. Model results suggest that information transfer from other vegetable producers has an effect on knowledge and adoption.

The study also allows the suggestion of some recommendations for further research. One reason for non-adoption is the complexity of safer practices. For example, field observation methodologies are often developed from the point of view of the scientist, who does not face time constraints in assessing vegetable fields. Hence, techniques should be developed that provide an acceptable compromise between time and precision. A further project would be to develop marketing systems for biological control agents in such a way that they are accessible to vegetable producers. There is still a lack of understanding about optimal market outlets and appropriate incentives for the development of such small-scale village level enterprises. Respective government organisations like the Department of Agriculture, in cooperation with the Royal Project Foundation, should give more attention to these issues. The ongoing national research and development efforts in organic farming, including input suppliers of biological control agents, can be considered as a good starting point(ELLIS *et al.* 2006).

Finally additional research needs can be postulated. It must be emphasised that adoption of complex natural resource management technologies under small-scale farmer conditions in developing countries takes place as a stepwise, often non-continuous, process (BYERLEE and POLANCO 1986; RAMIREZ and SHULTZ 2000). Hence, data collection approaches need to be designed in a way that facilitate the development of a dynamic adoption model. Also, such a model may benefit from recent insights into behavioural economics and could integrate other decision theories such as cognitive dissonance or prospect theory.

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Appendices

Appendix A: Community questionnaire

Economic and Behavioural Factors Affecting the Adoption of Environmentally Friendly and Healthy Vegetable Production Systems in Thailand
Respondent……………………………………Address………………Village………………
Sub-district………………...………District……………………..Province……..…………….
Parentage………………………….
Enumerator ……………………………Date……………Month……………………...2005
Note: This study is a part of the Ph.D. research program of the University of Hannover, Germany. The information from the interview will not be disclosed.

Section 1: Infrastructures and institutions

Physical and social Infrastructure	Yes/No	If infrastructure is not in the village, please specify distance from village to infrastructure (Km.)
Kindergarten		
School		
Irritation system		
Road		
Water supply		
Health care centre		
Electricity		
Post office		
Market place		
Communication		
Credit institution		

Section 2: Local organization

2.1 Is there a religious organization in the village?

(1) No (go to 2.1.3) (2) Yes

2.2 If yes, what is a major role of this organization in the village?

(1) Introduction of the religion (specify)………………………

(2) Education (3) Other (specify)………………… ………

2.3 Are there foreigners living in the village?

(1) No (go to 2.1.4)

(2) Yes, please specify number…………… persons(s)

2.4 Is there a government organization in the village?

(1) No

(2) Yes, please specify number..

2.5 If yes, what is a major role of that organization in the village?

…………………………………………………………………………………………

…………………………………………………………………………………………

Section 3: Development projects in the village during the past five years

Project	Institution	Type of activity	Project age (Month or year)

Thank you for your distribution

Appendix B: Adoption questionnaire

Economic and Behavioural Factors Affecting the Adoption of Environmentally Friendly and Healthy Vegetable Production Systems in Thailand

Respondent……………………………………Address………………Village………………

Sub-district………………...………District……………………..Province……..…………….

Parentage………………………….

Enumerator ……………………………Date……………Month……………………...2005

Note:

This study is a part of the Ph.D. research program of the University of Hannover, Germany.

The information from the interview will not be disclosed.

The questionnaire is divided into five parts: (1) Socio economics parameters of farm and farm household; (2) Crop management practices; (3) Knowledge of EHVT practices; (4) Attitude of environment and health aspects of vegetable farming: (5) Diffusion of the safer and healthier vegetable production technologies.

Section 1 Socio economic parameters of farm and farm household

1. Farm and farm household information

1.1 How many household members usually reside in your household? ………………………person (s)

No.	Relation with head of household	Gender	Age (year)	Education	Main occupation	Secondary occupation	Number of day for working at farm (days/year)

1.2 What equipment do you have?

Asset	Just tick ✔ if available	Number
Machine, equipment and animal utilization		
Worker house (s)		
Tractor 2 wheel (s)		
Tractor 4 wheel (s)		
Water pump (s)		
Springer (s)		
Tank (s)		
Pipe (s)		
Hose (s)		
Knapsack (s)		
Engine sprayer (s)		
Hoe (s)		
Spade (s)		
Cattle (s)		
Buffalo (s)		
Pig		
Other…………….		
Other…………….		
Other…………….		
Other…………….		
Other…………….		

Asset	Just tick ✔ if available	Number
Harvesting and transportation equipment		
Truck 6 wheel (s)		
Pickup (s)		
Motorcycle (s)		
Bicycle (s)		
Other…………		
Other………….		
Other asset		
Mobile phone (s)		
Television (s)		
Video (s)		
Video disc (s)		
Video game (s)		
Radio (s)		
Refrigerator (s)		
Washing machine (s)		
Rice cooking machine		
Other………………		
Other………………		

1.3 Land tenure and land use during May 2004 – 2005

1.4 How many parcels of land holding do you have? ……………..parcel (s)

Parcel	Size (rai)	Tenure status (LT)	Crop			Water supply	Distance of water supply to farm (km.)
			Dry season	Rainy season	Winter season		

Code of LT:
1= Owner
2= Lease
3= Tenant
4= Other (specify)……

Code of crop:
1 = Rice (specify)……..
2 = Vegetable (specify)…………
3 = Field crop
4 = Permanent crop intercrop with vegetable (specify)……….
5 = Permanent crop
6 = Other (specify)...……………

Code of water supply:
1 = Ground water
2 = Well water
3 = Water supply from mountain
5 = Other (specify)...…………

2 Cabbage management practices

2.1 Cabbage production technology

2.1.1 How long have you been growing cabbage? ………………..year (s)

2.1.2 How would you describe cabbage production technology you are currently using i.e. what is the major component of this technology?

(1) Chemical practice (2) Chemical safe practice

(3) Organic practice (4) Other (specify)……………………

2.1.3 Who is the decision maker to use practice in question of 2.1.2?

(1) Head of household

(2) Other (specify)…………………………………

2.1.4 Did you use chemical safe practice or organic practice compare to five years in the past?

(1) Yes (2) No *(go to 2.2)*

2.1.5 If yes, why did you return to chemical practice you have specified in question 2.1.2?

(1) Difficult to buy a bio-agent control in the market

(2) Other (specify)…………………… …….

2.2 Seed management

2.2.1 Which brand of cabbage seed do you use? (specify)…………………..…

2.2.2 What is your main criterion of seed selection?

(1) Depend on market demand

(2) Disease- and pest-resistance

(3) Other (specify)……………………

2.2.3 What is your practice for prevention of seed born disease?

(1) Leave seeds to soak in warm water for 20-30 minutes

(2) Mix with chemical (specify name of chemical)………………………

(3) Mix with herb (specify name of herb)…………………………..

(4) Other (specify)……………………………………

2.3 Soil management practice

2.3.1 What is your practice after harvesting cabbage?

(1) Crop rotation (2) Fallow

(3) Other (specify)…………………………..

2.3.2 What is your growing technique of cabbage?

(1) Contour technique

(2) Sloping technique (go to 2.3.4)

(3) Other (specify)………………… (go to 2.3.4)

2.3.3 Why do you use contour technique?

(1) Soil conservation (2) Other (specify)………………………

2.3.4 Land preparation

Activity	Practice (1 = No 2 = Yes)	Labour (Man-day/rai)	Type of labour	Reason for using this practice
Plough 1				
Plough 2				
Rotary				
Lime				
Chaff				
Other (specify)…				
Other (specify)…				

Code of labour:
1= Family labour
2= Hired labour
3= Exchange labour

Code of reason for using this practice:
1 = Increasing organic matter
2 = Reduce acid within soil
3 = Weed control
4 = Increasing soil friable
5 = Other (specify)……………… ……..

2.3.5 How do you make a decision about fertilizer use?

(1) Soil analysis
(2) Other (specify)………………

2.3.6 How do you analyse soil? (Ask only farmer who analyses soil)

(1) Observe leaving things within soil, e.g. earthworm
(2) Ask soil Dr.[23] to testing soil
(3) Observe vegetable product from the last crop
(4) Other (specify)………………………….

[23] Soil Dr., who is a volunteer living in the village, has been trained in soil analysis

2.3.7 Use of fertilizers

Fertilizer application (please specify name of fertilizer)	Use rate (kg./rai)	Reason for using fertilizer	Labour (Man-day/rai)
Land preparation and seedling			
Planting			

Code of reason for using fertilizer:

1 = Nourish stem and branch of cabbage

2 = Other (specify)……………….…………

2.4 Weed management practice

2.4.1 What kind of practice do you use for broadcasting?

(1) Follow from a use rate in label *(go to 2.4.3)*

(2) Use a high seed rate technique

(3) Other (Specify)………………………………

2.4.2 Why do you use a high seed rate technique?

(1) Preventing weed

(2) Increase sprouted rate

(3) Other (specify)…………………………….

2.4.3 Do you use mulching technique after seeding?

(1) Yes, specify mulching material……………

(2) No (go to 2.4.5)

Code of mulching material:

1 = Straw 2 = Chaff 3 = Plastic 4 = Other (specify)………….

2.4.4 If yes, why do you use mulching technique?

(1) Preventing weed (2) Other (specify)…………..………

2.4.5 If no, why do you not use mulching technique?

(1) Laborious (2) High cost

(3) Other (specify)………………………………………..

2.4.6 Do you prune soil after seedling transplant?

(1) Yes (2) No (go to 2.4.8)

2.4.7 If yes, why do you use hoeing technique?

……………..……………………………………………...………………

2.4.8 If no, why do you not use hoeing technique?

(1) Laborious *(2) High cost*

(3) Other (specify)………………………………………..

2.4.9 What kind of practice do you use for weed control?

(1) Use weeding technique only (go to 2.5)

(2) Use weeding technique and herbicide

(3) Other (specify)……………………….

2.4.10 Use of herbicide (including bio-herbicide)

Name	Use rate (kg. or cc /rai)	When do you spray herbicide?	Practice	Labour (Man-day/rai)	Type of Labour	Source of purchase

Code of spraying:

1 = See weed in cabbage field

2 = Other specify)……

Code of practice:

1 = Spraying herbicide only

2 = Mix herbicide with other chemicals (specify)………

3 = Other (specify)………………

Code of source of purchase:

1 = Shop in the village

2 = Shop in district/province

3 = Royal Project

4 = Other (specify)……………

2.5 Insect management practices

2.5.1 What kind of practice do you use for insect management?

(1) Use insecticide only

(2) Use observation technique sometime including insecticide

(3) Other (specify)………………………

2.5.2 Why do you use observation technique?

(1) Reducing chemical cost

(2) Other (specify)…………………

2.5.3 How do you observe your crop (field observation)?

(1) Go inside cabbage field and look around

(2) Go inside cabbage field and a close look

(3) Go inside cabbage field and observe detail (look at in front of, behind branch and take a sample and open the stem of vegetable including other plant situation)

Other (specify)…………………………………..

2.5.4 Use of insecticide (including bio-insecticide)

Name	Use rate (kg. or cc /rai)	When do you spray insecticide?	Practice	Reason for using insecticide	Labour (Man-day/rai)	Type of labour	Source of purchase

Code of spraying:

1 = Every week after planting

2 = Spray insecticide when see a few of insect in cabbage field

3 = Spray insecticide when see a vast amount of insect in cabbage field

4 = Other (specify)……………..…

Code of practice:

1 = Spraying insecticide only

2 = Mix insecticide with other chemicals (specify)…

3 = Other (specify)……..….

Code of reason for using:

1 = Kill all insects

2 = Kill insect (specify)………

3 = Other (specify)…………..

Code of place:

1 = Shop in the village

2 = Shop in district/province

3 = Royal Project

4 = Other (specify)……… …

2.5.5 Why do you not use bio-insecticide? (Ask farmer, who does not use bio-insecticide like BT, NPV or Trichodoma, only)

(1) Do not have enough knowledge

(2) Laborious

(3) Other (specify)…………………

2.5.6 Do you make use of natural enemies?

(1) Yes (2) No (go to 2.5.9)

2.5.7 If yes, which ones do you use?

(1) Parasitic (specific)………………………………………….

(2) Predator (specific)………………………………………….

2.5.8 How do you make use of them? (explain)…………………………………

2.5.9 If no, why do you not use natural enemies?

(1) Do not have enough knowledge

(2) Laborious

(3) Other (specify)………………………………………………..

2.5.10 Do you use trap practice?

(1) Yes, (specify)……………………..…

(2) No (Go to 2.5.12)

2.5.11 If yes, why do you use it and how do you use it?

(1) Use to attract white fly (explain)………………………………………..

(2) Other (specify)………………… ………………………………………..

2.5.12 If no, why do you not use trap technique? …………………………….

(1) Do not have enough knowledge

(2) Laborious

(3) Other (specify)………………………………………………..

2.6 Disease management practices

2.6.1 Disease problem in cabbage production (specify)… …………………….

2.6.2 What kind of practice do you use to cover that disease?

(1) Use chemical only (2) Other (specify)………………………

2.6.3 Use of chemical (including bio-chemical)

Name	Use rate (kg. or cc /rai)	When do you spray fungicide?	Practice	Reason for using fungicide	Labour (Man-day/Rai)	Type of labour	Source of purchase

Code of spraying:
1 = Every week after planting
2 = Other (specify)………..…

Code of practice:
1 = Spraying fungicide only
2 = Mix fungicide with other chemicals (specify)…………………………..
3 = Other (specify)……………….

Code of reason for using:
1 = Control all diseases
2 = Other (specify)…………

Code of place:
1 = Shop in the village
2 = Shop in district/province
3 = Royal Project
4 = Other (specify)…………

2.7 Technology Supplier

2.7.1 Participation in a project on the safer and healthier vegetable production technologies (If farmer did not participate in a project on the safer and healthier vegetable production technologies please go to 3.2)

Project	Year of participation	Type of crop	Type of activity	Follow-up by extension agent after introduction
Hygienic fresh fruit and vegetable production pilot project of DOA				
Hygienic vegetable production technologies of DOAE				
Hygienic vegetable production technologies of Royal project				
IPM programme				
Good agricultural product project (GAP)				
Others (specific)…………………………………..				
Others (specific)…………………………………..				

Code of crop:

1 = Vegetable (specify)…………………….….

2 = Rice

3 = Permanent crop (specify)…………………..

4 = Other (specify)…………………………….

Code of activity:

1 = One week training 2 = Several meeting

3 = Some visiting of extension agent

4 = Distribution of extension material

5 = Other (specify)…………… ………………

Code of follow-up:

1 = Yes, please specify number of follow-up……

2 = No

2.7.2 Do you continue gathering information about safer and healthier vegetable production practice after participation?

(1) No (go to 3.1.4) (2) Yes

2.7.3 If yes, what is a main source of information gathering?

(1) Neighbor in village (2) Neighbor from other village

(3) Extension official (4) other (specify)………………

2.7.4 Local institution

Name	Membership of a local institution	Benefit of a local institution extending to you
Royal Project (specify)…………………		
Hygienic vegetable production group		
Good agricultural production group		
Others (specify)…………………………		
Others (specify)…………………………		

Code of member:

1 = No

2 = Yes

Code of benefit:

1 = Knowledge on (specify) …………………………..…

2 = Marketing information

3 = Marketing power

4 = Other (specify)………… …………………....

2.8 Knowledge questions

2.8.1 Identification of pest and predator (Show pictures or specimens) Tick ✔ the right box for each of the names listed below.

Name	Pests	Predators (Beneficial insects)	Don’t Know
Araneae (Spider)			
Ant			
Mantidae (Dragon fly)			
longer Fly			
Parasitoid			
Vespid			
Pieris (White butterfly)			
Flea beetle			
Aphid			
Plutella xylostella (Diamond back moth)			
Armyworm			
Trichoplusia			

2.8.2 Knowledge test Tick ✓ ”Yes”, “No” or “Don’t know” to each question

Knowledge	Yes	No	Don’t know
In a 50 kg. of bag of 16-20-0 fertilizer, there is of Nitrogen 16 kg, of Potassium 20 kg, and of Phosphorus 0 kg			
There are boron and calcium, which are important for cabbage, in a hormone such as Wee Thong[24].			
Red label insecticides are just as dangerous as yellow labels.			
Furadan is allowed to sell in the market.			
Mulching decreases weed.			
All insects are pests.			
The life cycle of Diamond back moth includes four stages, egg, masses, pupa and moths.			
Crop rotation increases pest pressure.			
Trap crop increases pest population.			
Growing cabbage after cabbage on the same field increases pest problems.			
Keeping some weeds in the surrounding of the field decreases pest pressure.			

[24] Wee Thong is a hormone that most of farmer uses in cabbage production.

2.9 Attitude of environment and health aspects of vegetable farming Tick ✔ your answer in the right box to each question

Attitude	Strongly agree	Agree	Natural	Disagree	Strongly disagree
Spraying pesticides for a long time affect farmer health					
Use of toxic chemicals has negative environment effects on the long term.					
High chemical use makes yield more stable.					
High chemical use makes income more stable.					
Non-chemical pesticides like Bt, NPV, Trichodoma, or some herb are better than chemical pesticides even though they are expensive.					
Pest-damaged vegetable without pesticides residue are better even if the price is lower.					
Organic vegetable product is better than conventional products for consumer health.					
Crop rotation is better than mono-cropping.					
The information of technicians from pesticide companies is not trustful.					
Plant vegetables in a separate field are good for own household consumption.					
Spiders in my fields are a sign of healthy environment.					
Pesticides are a cause of decreasing fish population in my natural well.					
Pesticide spraying can affect a neighbour's field.					

Section3: Organizations

3.1 Price and market conditions

Type of cabbage	Place of sale	Distance from farm to place of sale* (km.)	Transportation cost from farm to place of sale* (baht)	Price (baht/kg)	Farm gate price** (baht/kg)	Market condition

* If farmer is marketing himself; ** Calculated by enumerator

Code of place:

1 = Sell to middle man at farm

2 = Sell to the middle man at farm before harvesting

3 = Sell to food market (specify)…

4 = Sell to Royal project (explain)……………… …

5 = Other (specify)…………………………………

Code of market condition:

1 = Pesticide residues test (explain) …………………………

2 = Other (specify)…………………………………………………

3.2 Do you have a marketing problem?

(1) No

(2) Yes (specify)…………………………………… …………

3.3 Main source of marketing information

(1) Farmer group (2) Neighbour

(3) Head of village (4) Local trader

(5) Extension agent (6) Radio

(7) Television (8) Newspaper

(9) Other………………………………

3.4 Do you have a marketing contract for cabbage with an institution?

(1) No *(go to 2.6)* (2) Yes

3.5 If yes, which institution do you have a marketing contract?

(1) Royal project (explain)………………… ………………………………..…………

(2) NGOs (explain)…………………………………………………………………..

(3) Private company (explain)……………………………………………………..…

(4) Other (specify) ……………………………………………….………………..

3.6 Debt: Source of credit

Source of credit	Type of credit	Purpose for using credit

Code of source of credit:
1 = Farmer group 2 = Community fund
3 = Cooperative 4 = BAAC*
5 = Relative 6 = Neighbour
7 = Merchant 8 = Other (specify)……….

Code of type of credit:
1 = Cash
2 = Non-cash (specify)……

Code of purpose:
1 = Consumption and agricultural production
2 = Agricultural production
3 = Other (specify)…………….

*Bank of Agriculture and Agricultural Cooperatives

Section 4: Diffusion of SEFVP

(Ask only farmer who does not participate in a project that promote the safer and healthier vegetable production technologies)

4.1 Have you heard about the safer and healthier vegetable production technique?

(1) No (Stop to interview) (2) Yes

4.2 What is a main source of information about the safer and healthier vegetable production technique?

(1) Neighbor in village (2) Neighbor in closed village

(3) Head of village (4) Personal official of agricultural extension

(5) Merchant (6) News paper

(7) Television (8) Other (specify)………………………….

4.3 Do you plan to use these technologies?

(1) No (2) Yes (go to 5.6)

4.4 If no, why do you not plan to use the safer and healthier vegetable production practice?

(1) Not enough information

(2) Complicate and laborious practice

(3) Other (specify)…………………………………..

4.5 If yes, what is your main motivation to use the safer and healthier vegetable production practice?

(1) Higher price

(2) Reducing cost

(3) Avoid health problem due to pesticide

(4) Follow a sound of food safety

(5) Other (specify)…………………………………..

Thank you for your distribution

Appendix C: Expert questionnaire

1. Background

In the case of the research project “Adoption of alternative vegetable production in Thailand” of Leibniz University of Hannover, first results were produced. We have analysed farmer’s practices and farmer’s knowledge based on the integrated pest management practice (IPM) in cabbage production. This analysis is based on a survey in the area where alternative vegetable production technologies have promoted through two Royal Project Stations, Nhong Hoi and Mae Hae, in Chiang Mai Province, Thailand.

We now would like to draw some conclusion on the reason for adoption or non-adoption of these practices. In order to do this we would like to ask your kind help in identifying the priorities among those practices. We would like to have your opinion whether for example use of Bacillus Thuringiensis (BT) is better than farmers making regular observation. Such assessment by vegetable experts is necessary for drawing a conclusion on importance of factors for adoption and non-adoption. Our final goal is to construct an IPM adoption index, which is necessary in order to capture the many practices that exist in IPM.

2. Question on practices

In our survey, positive practices and negative practices were found. Positive practices are practices that are benign to environment and farmer’s health. Negative practices are the contrary effect. For each practice you can choose a value on a scale from 1-10, where 1 means least important and 10 most important. It is possible that you assign the same weight to two different practices. In the following table you are able to weight those practices by importance according to your opinion.

2.1 Positive practices on IPM cabbage production systems

2.1.1 Pest management practices

Positive practice	Score
Regular observation field	
Crop rotation	
Seed treatment	
Use high seed rate	
Mulching	
Use botanical/bio pesticides	
Use bio agent control	
Use trap practice	
Use multiple vegetable varieties rather than single vegetable varieties	

2.1.2 Other natural resource management practices

Positive practice	Score
Soil analysis	
Soil improvement	
Contour bund	

2.2 Negative practices on IPM cabbage production systems

Negative practices	Score
Use salt as herbicide	
Use paraquat dichloride	
Use banned pesticide	
Use pesticide on the WHO Ia and Ib	
Use pesticide classified in organophosphate group	
Spraying mixture pesticides	

3. Question on knowledge

These knowledge questions were asked to farmers during the field survey to find out their level of knowledge. Responses were defined with three levels: correct, don't know, and false, respectively.

Here we would like to ask you the expert to judge which of those questions is more important, which one is less important. If it is a very important knowledge that the farmer should know then the score should be high. In contrast, if the knowledge is not so important then the score should be low. To do this please uses again a scale from 1-10.

Knowledge	Score
In a 50 kg bag of 16-20-0 fertilizers, there is of N 16 kg, of P 20 kg and K 0 kg.	
There are Boron and Calcium, which are important for cabbage, in a hormone such Wee Thong.	
Mulching decrease weed.	
Furadan is allowed to sell in the market.	
All insects are pests.	
The life cycle of Diamond back moth includes four stages: eggs, masses, pupa and moths.	
Crop rotation increases pest pressure.	
Trap crop increases pest population.	
Growing cabbage after cabbage in the same field increases pest problems.	
Keeping some weeds in the surrounding of the field decreases pests.	
Red label Insecticides is just as dangerous as yellow label.	

4. Other suggestion/information

………………………………………………………………………………………….

………………………………………………………………………………………….

….We kindly appreciate for your contribution…

Appendix D: Selected characteristic of the study area and surveyed villages

Description of the study area

The two study areas, NHRP and MHRP, were initiated in 1969 and 1978, respectively. Both located in Chiang Mai province share similar ecological conditions. Up to date, the two areas encompass four districts with 30 villages, 4,033 households and 11,631 inhabitants. In these areas, infrastructures including primary school, public health centers and roads are in place. However, additional public health care centers and improved quality of drinking water are still needed (surveyed village headmen 2005 and RPF 2003). Major sources of agricultural producers' income are temperate fruit tree and commercial vegetable production. Off-farm incomes are mostly from wage labour and trade. In both areas, cabbage and other vegetable in cabbage family can be grown throughout the year and fruit trees are grown as intercrop. Paddy, upland rice and maize are still grown for home consumption and for animal feed.

Regarding environmental situations in the two study areas, producers generally initiate shifting cultivation in the primary forest as watershed protection areas (SURASWADI *et al.* 2005) and often grow their crops on the steeper slope (Angkasith 2004). Intensive land use by continued vegetable cultivation in the same land can aggravate the number of pests leading to a heavy use of external inputs. As results of the RPF in 2003 pointed out that the environmental situation of these areas has a high need of rehabilitation, especially for primary forest, soil fertility and water quality (RPF 2003a).

General background of the surveyed villages

Almost all vegetable producers are strong animists; however there is some Christian influence in both areas, with Christian missionaries providing knowledge about conservation of the environment and different services such as public health to those villages. Christian churches were found in both areas and only one Buddhist temple was found in V7. Infrastructures such as nursery, primary school and high school have been installed and improving by the RPF and its collaborators. Three primary schools were found in both study areas – they are located in V1, V4 and V7. Source of drinking water mostly comes from mountain. Electricity and telecommunication were found in every surveyed village. A net of paved roads connects the surveyed villages to the two Royal Projects Development Centres, which locate in V1 and V5 (see Table A.1).

Table A.1: Infrastructures of the surveyed villages

Indicator	MHRP				NHRP		
	V1	V2	V3	V4	V5	V6	V7
Religion institutions (Located in the village or neighbouring village)	✓	✓	×	✓	✓	✓	✓
Public health centre	✓	✓	✓	✓	×	×	✓
Children development centre	×	✓	×	×	✓	✓	✓
Kindergarten	✓	✓	×	✓	✓	×	×
Primary-secondary school (9 years) (Located in the village or neighbouring village)	✓	✓	×	✓	✓	✓	✓
High school	✓	×	×	✓	×	×	×
Library	✓	✓	×	✓	✓	✓	✓
Village pavilion	✓	✓	×	✓	✓	✓	✓
Public park	✓	✓	✓	✓	✓	✓	✓
Public telephone	✓	✓	✓	✓	✓	✓	✓
Water supply	✓	✓	✓	✓	✓	✓	✓
Credit institution (cooperation)	✓	×	×	×	✓	×	✓
Pave road within a village	6 km.	0.5 km.	1 km.	3 km.	6 km.	19.15 km.	4.50 km.
Gravel/soil road within a village	2 km.	1.5 km.	2 km.	0	0	0.667 km.	0
Distance access to market in province	60	72	65	60	35	38	35

Source: Own survey (2005)

Livelihood activities

Major income sources for vegetable producers in the survey villages are cabbages, lettuce, Chinese cabbage and temperate fruits trees[25]. Paddy, upland rice and maize are grown in crop rotation for own consumption and livestock feed. Some of vegetable producers work off-farm at the MHRP and NHRP and some as wage labourers for other cabbage growers with a large farm size. The average income per household of each surveyed village in Thai Baht seems to be indifferent. Unfortunately, primary data for a statistical test is unavailable (see Table A.2).

Table A.2: Selected characteristics of the survey area

Variable	MHRP					NHRP			
	V1	V2	V3	V4	Average	V5	V6	V7	Average
Number of household[1/]	127	183	71	122	126	137	162	148	149
Agricultural area (Ha)[1/]	305.6	261.8	157.6	132.8	214.4	144.0	102.9	172.3	186.4
Average income (Thai Bath/year/HH)[1/]	24,370	23,770	14,155	27,620	22,480	22,410	22,465	26,060	24,370
Distance from village to the royal project[2/]	0.0	12.0	5.0	0.5	4.4	0.0	3.0	6.0	3.9

Source: [1/]Rural Development Information Centre, Thailand (2006)

[2/] Own calculations

Selected demographic characteristics of vegetable producers

Average household size is the same in both survey areas. The comparison of age and education of household heads, on average, insignificantly differ between the two areas. Almost all household heads are male and the average age is about 44 years (see Table A.3). Nearly 57% of heads of household have no education; however they claimed that they had participated in non-formal school provided by Christian missionaries in the villages. Looking at farm assets, almost all vegetable producers in the surveyed villages have their own equipments for vegetable cultivation. The average number of equipments owned is insignificant when compare between the study areas, except engine sprayer. The average number of car owned, however,

25 Temperate fruit trees that are grown in the surveyed villages are Japanese apricot, pears, plum, and persimmon.

is significantly higher in NHRP than in MHRP (see Table A.4).

Table A.3: Selected vegetable farmer characteristics

Variable	MHRP					NHRP			
	V1	V2	V3	V4	Total[1/]	V5	V6	V7	Total
Number of household member (no.)	4.9[a] (1.3)	8.9[bc] (5.7)	7.2[bc] (2.8)	8.2[bc] (5.0)	7.5[ns] (4.5)	6.4[b] (2.7)	9.2[c] (4.6)	6.6[b] (2.4)	7.5 (3.7)
Age of household head (years)	47.7[a] (15.3)	44.7[a] (9.3)	44.9[a] (11.9)	44.8[a] (11.4)	45.4[ns] (11.9)	41.3[a] (11.5)	46.1[a] (12.3)	42.8[a] (13.9)	43.4 (12.6)
Education level of head of household (%)									
• No school	58.6	56.3	51.7	62.5	58.0	45.5	71.7	48.8	55.7
• Fourth grade in primary school	17.2	21.9	31.0	14.6	20.3	21.8	7.5	29.3	18.8
• Primary school	6.9	12.5	10.3	16.7	12.3	27.3	11.3	14.6	18.1
• High school	17.2	3.1	6.9	6.3	8.0	5.5	9.4	7.3	7.4
• Certification	0.0	6.3	0.0	0.0	1.4	0.0	0.0	0.0	0.0
Farmers' experience in cabbage production	6.8[a] (4.8)	14.7[b] (6.4)	13.6[b] (8.9)	9.4[c] (6.6)	10.9** (7.4)	10.6[a] (6.8)	15.7[b] (5.9)	13.1[bc] (7.8)	13.1 (7.1)

Note: [1/]Difference of mean between the two areas; ** indicate significant at 5% and [ns] is non-significant. Different letters a, b, c indicates significant difference of mean between the surveyed village at 5%; Numbers in parentheses are standard deviations.

Source: Own calculations

Table A.5: Average number of asset per household

Asset	Mae Hae					Nhong Hoi			
	V1	V2	V3	V4	Total	V5	V6	V7	Total
Water pump	0.5^{a}	0.3^{a}	0.5^{a}	0.5^{a}	0.5^{ns}	0.4^{a}	0.4^{a}	0.3^{a}	0.4
	(0.5)	(0.5)	(0.6)	(0.8)	(0.6)	(0.7)	(0.7)	(1.0)	(0.8)
Sprinkler	15.6^{a}	76.5^{ab}	79.2^{ab}	45.7^{ab}	47.6^{ns}	28.5^{ab}	42.6^{b}	39.0^{ab}	44.0
	(13.7)	(106.8)	(122.7)	(88.7)	(82.1)	(28.5)	(46.3)	(77.7)	(94.7)
Knap-sack	1.5^{a}	1.7^{a}	2.7^{a}	2.1^{a}	2.0^{ns}	1.7^{a}	2.4^{a}	1.6^{a}	1.9^{a}
	(0.7)	(1.1)	(3.5)	(1.1)	(1.8)	(1.3)	(1.8)	(1.2)	(1.5)
Engine sprayer	0.1^{a}	0.5^{abc}	0.2^{ac}	0.5^{b}	0.4***	0.7^{b}	1^{b}	0.5^{b}	0.7
	(0.7)	(0.6)	(0.4)	(0.6)	(0.5)	(0.7)	(1.4)	(0.5)	(0.9)
Cattle	3.4^{a}	3.4^{ab}	1.0^{ab}	0.1^{b}	1.7***	0^{b}	0.1^{b}	0^{b}	0
	(4.5)	(7.5)	(2.3)	(0.4)	(4.5)	(0)	(0.6)	(0)	(0)
Pig	3.8^{a}	3.4^{ac}	7^{a}	6.8^{b}	5.4***	1.2^{b}	3.3^{ac}	4.4^{a}	2.9
	(2.4)	(4.2)	(4.8)	(3.8)	(4.2)	(2.1)	(3.3)	(4.1)	(3.4)
Chicken	11.1^{a}	27.8^{ab}	19.1^{ab}	29.9^{b}	23.2***	11.7^{a}	13.1^{a}	13.5^{a}	12.7
	(10.4)	(29.2)	(18.3)	(28.4)	(24.8)	(18.9)	(13.1)	(14.7)	(15.8)
Pickup	0.3^{a}	0.9^{a}	0.8^{b}	0.8^{b}	0.7***	1.0^{b}	1.2^{b}	1.0^{b}	1.1
	(0.5)	(0.8)	(0.7)	(0.8)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)
Motorcycle	1.5^{a}	1.3^{a}	1.8^{a}	1.5^{a}	1.5***	1.2^{a}	0.8^{b}	0.7^{b}	0.9
	(0.8)	(0.9)	(1.4)	(0.8)	(1.0)	(0.9)	(0.8)	(0.9)	(0.9)
Mobile phone	0.6^{ab}	0.4^{ab}	0.4^{ab}	0.6^{ab}	0.5***	0.7^{ab}	0.9^{a}	0.6^{b}	0.8
	(0.8)	(0.6)	(0.7)	(0.7)	(0.7)	(0.9)	(0.6)	(0.7)	(0.8)
Television	0.9^{ab}	0.8^{b}	0.8^{ab}	0.8^{ab}	0.8^{ns}	0.9^{a}	0.9^{ab}	0.8^{b}	0.9
	(0.4)_	(0.4)	(0.5)	(0.6)	(0.5)	(0.6)	(0.7)	(0.5)	(0.6)

Note: [1/]Difference of mean between the two areas; ** indicate significant at 5% and ^{ns} is non-significant. Different letters a, b, c indicates significant difference of mean between the surveyed village at 5%; Numbers in parentheses are standard deviations.

Source: Own calculations

Appendix E: Results of model 1

Model 1 (Unrestricted)

probit particip health dpickup headeduc exp sqEXP labourland member moccup markt location, robust

Probit regression — Number of obs = 287; Wald chi2(10) = 54.99; Prob > chi2 = 0.0000; Pseudo R2 = 0.1655

Log pseudolikelihood = -150.86342

particip	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
health	.1258469	.1667669	0.75	0.450	-.2010102	.4527041
dpickup	.0743427	.1928322	0.39	0.700	-.3036013	.4522868
headeduc	.0357435	.0244421	1.46	0.144	-.0121621	.0836492
exp	.0327612	.0376161	0.87	0.384	-.0409649	.1064873
sqEXP	-.0022329	.0013788	-1.62	0.105	-.0049354	.0004696
labourland	.0136816	.0191809	0.71	0.476	-.0239123	.0512755
member	.2006346	.210306	0.95	0.340	-.2115576	.6128268
moccup	.6155151	.2623051	2.35	0.019	.1014066	1.129624
markt	.9399018	.183201	5.13	0.000	.5808344	1.298969
location	.1357257	.1770852	0.77	0.443	-.2113549	.4828063
_cons	-1.430117	.3762266	-3.80	0.000	-2.167507	-.6927261

Model 1 (1st Restricted)

probit particip headeduc exp sqEXP labourland moccup markt , robust

Probit regression — Number of obs = 287; Wald chi2(6) = 52.09; Prob > chi2 = 0.0000; Pseudo R2 = 0.1600

Log pseudolikelihood = -151.85037

particip	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
headeduc	.0392365	.0239035	1.64	0.101	-.0076134	.0860864
exp	.033949	.0377651	0.90	0.369	-.0400692	.1079672
sqEXP	-.0023361	.0014101	-1.66	0.098	-.0050999	.0004277
labourland	.0129121	.0188837	0.68	0.494	-.0240992	.0499235
moccup	.5880041	.2602048	2.26	0.024	.0780121	1.097996
markt	1.008462	.1704268	5.92	0.000	.6744319	1.342493
_cons	-1.22884	.3198038	-3.84	0.000	-1.855644	-.6020359

Appendix F: Results of model 2

Model 2a

```
reg tcknowsc particip

      Source |       SS       df       MS              Number of obs =     287
-------------+------------------------------           F(  1,   285) =   85.45
       Model |  461.249466     1  461.249466           Prob > F      =  0.0000
    Residual |  1538.39513   285  5.39787766           R-squared     =  0.2307
-------------+------------------------------           Adj R-squared =  0.2280
       Total |   1999.6446   286  6.99176433           Root MSE      =  2.3233

------------------------------------------------------------------------------
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.708735   .2930287     9.24   0.000      2.13196     3.28551
       _cons |   10.60309   .1668056    63.57   0.000     10.27477    10.93142
------------------------------------------------------------------------------

reg tcknowsc particip, robust

Linear regression                                      Number of obs =     287
                                                       F(  1,   285) =   69.05
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2307
                                                       Root MSE      =  2.3233

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.708735   .3259795     8.31   0.000     2.067102    3.350368
       _cons |   10.60309   .1474389    71.92   0.000     10.31289     10.8933
------------------------------------------------------------------------------
```

Model 2b (unrestricted)

```
reg tcknowsc particip source1 headeduc exp sqEXP labourland member moccup location, robust

Linear regression                                      Number of obs =     287
                                                       F(  9,   277) =   15.85
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3298
                                                       Root MSE      =  2.1995

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.496971   .3555535     7.02   0.000      1.79704    3.196901
     source1 |   1.903864   .5295627     3.60   0.000     .8613851    2.946342
    headeduc |   .1979149   .0383921     5.16   0.000     .1223375    .2734923
         exp |    .099987    .034992     2.86   0.005      .031103    .1688709
       sqEXP |  -.0023504   .0011723    -2.01   0.046    -.0046581   -.0000428
  labourland |  -.0213641   .0311407    -0.69   0.493    -.0826666    .0399385
      member |   .0360967    .308294     0.12   0.907    -.5708001    .6429935
      moccup |   .5341388   .4843556     1.10   0.271    -.4193468    1.487624
    location |  -.1635021   .2622922    -0.62   0.534    -.6798414    .3528371
       _cons |   9.529559   .4578657    20.81   0.000      8.62822     10.4309
------------------------------------------------------------------------------
```

Model 2b (restricted)

```
reg tcknowsc particip source1 headeduc exp sqEXP , robust

Linear regression                                      Number of obs =     287
                                                       F(  5,   281) =   25.21
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3250
                                                       Root MSE      =  2.1917

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.535258   .3346989     7.57   0.000     1.876423    3.194094
     source1 |   1.793424   .5376307     3.34   0.001     .7351289    2.851719
    headeduc |   .1939617   .0374039     5.19   0.000     .1203344    .2675891
         exp |   .1016683   .0359562     2.83   0.005     .0308906    .1724459
       sqEXP |  -.0023279   .0011897    -1.96   0.051    -.0046699     .000014
       _cons |   9.316743   .3506262    26.57   0.000     8.626555    10.00693
------------------------------------------------------------------------------
```

Appendix G: Results of model 3

Unrestricted

```
reg tcknowsc particip  source1 headeduc exp sqEXP labourland member moccup  location wheadeduc
wexp w labourland, robust

Linear regression                                     Number of obs =     287
                                                      F( 12,   274) =   14.83
                                                      Prob > F      =  0.0000
                                                      R-squared     =  0.3439
                                                      Root MSE      =  2.1882
------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.380028   .3908323     6.09   0.000     1.610612    3.149443
     source1 |   2.003389   .5456692     3.67   0.000     .9291517    3.077625
    headeduc |   .1597741   .0486363     3.29   0.001     .0640257    .2555225
         exp |   .1433827    .044496     3.22   0.001     .0557852    .2309802
       sqEXP |  -.0030273   .0013667    -2.22   0.028    -.0057178   -.0003369
  labourland |  -.0116858   .0335516    -0.35   0.728    -.0777376     .054366
      member |   .1056974   .3112663     0.34   0.734    -.5070801    .7184749
      moccup |   .4351178   .4823189     0.90   0.368    -.5144039     1.38464
    location |   -.211578   .2599582    -0.81   0.416    -.7233472    .3001912
   wheadeduc |   .1072502    .077375     1.39   0.167    -.0450748    .2595753
        wexp |  -.0872011   .0517864    -1.68   0.093    -.1891509    .0147486
 wlandlabour |   1.428717   5.069049     0.28   0.778    -8.550515    11.40795
       _cons |   9.145594   .5174432    17.67   0.000     8.126924    10.16426
------------------------------------------------------------------------------
```

Restricted

```
reg tcknowsc particip  source1 headeduc exp sqEXP wheadeduc wexp , robust
Linear regression                                     Number of obs =     287
                                                      F(  7,   279) =   22.23
                                                      Prob > F      =  0.0000
                                                      R-squared     =  0.3393
                                                      Root MSE      =   2.176
------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.398358   .3574975     6.71   0.000     1.694623    3.102093
     source1 |   1.939114    .558747     3.47   0.001     .8392184    3.039009
    headeduc |   .1552031    .046578     3.33   0.001     .0635142    .2468921
         exp |   .1449049   .0450911     3.21   0.001     .0561429    .2336668
       sqEXP |  -.0030414   .0013883    -2.19   0.029    -.0057743   -.0003086
   wheadeduc |    .112416   .0768714     1.46   0.145    -.0389056    .2637376
        wexp |  -.0867263   .0513383    -1.69   0.092    -.1877859    .0143332
       _cons |   9.004472   .4028971    22.35   0.000     8.211368    9.797577
------------------------------------------------------------------------------
```

Appendix H: Results of model 4

```
Estimation of the propensity score  (PS)

pscore  particip  headeduc  exp  sqEXP  labourland  member  moccup  markt,  pscore(myscore)
blockid(myblock) comsup numblo(5) level> (0.005)
The treatment is particip

   particip |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |        194       67.60       67.60
          1 |         93       32.40      100.00
------------+-----------------------------------
      Total |        287      100.00

Estimation of the propensity score
Probit regression                                 Number of obs   =        287
                                                  LR chi2(7)      =      58.71
                                                  Prob > chi2     =     0.0000
Log likelihood = -151.42207                       Pseudo R2       =     0.1624
------------------------------------------------------------------------------
    particip |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    headeduc |   .0357693   .0240518     1.49   0.137    -.0113713    .0829099
         exp |   .0325072   .0372175     0.87   0.382    -.0404378    .1054522
       sqEXP |  -.0022228   .0014548    -1.53   0.127    -.0050742    .0006285
  labourland |   .0129349   .0200366     0.65   0.519     -.026336    .0522059
      member |   .1809435   .1952303     0.93   0.354    -.2017008    .5635878
      moccup |    .604355   .2892628     2.09   0.037     .0374105      1.1713
       markt |   .9583602   .1774976     5.40   0.000     .6104714    1.306249
       _cons |  -1.249567   .3093577    -4.04   0.000    -1.855897   -.6432375
------------------------------------------------------------------------------

Note: the common support option has been selected
The region of common support is [.08288845, .88945645]
Description of the estimated propensity score
in region of common support
                 Estimated propensity score
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .0859938       .0828885
 5%     .1095851       .0848395
10%     .1194041       .0859938       Obs                 267
25%     .1525799       .0871211       Sum of Wgt.         267
50%     .3228796                      Mean            .344285
                        Largest       Std. Dev.      .2001951
75%     .5075211       .7847385
90%     .6171234       .8078292       Variance       .0400781
95%     .6788585       .8169539       Skewness       .4268419
99%     .8078292       .8894565       Kurtosis       1.983489
```

```
****************************************************
Step 1: Identification of the optimal number of blocks
Use option detail if you want more detailed output
****************************************************
The final number of blocks is 6
This number of blocks ensures that the mean propensity score
is not different for treated and controls in each blocks

********************************************************
Step 2: Test of balancing property of the propensity score
Use option detail if you want more detailed output
********************************************************
The balancing property is satisfied

This table shows the inferior bound, the number of treated
and the number of controls for each block

  Inferior |
  of block |       particip
of pscore  |         0          1 |     Total
-----------+----------------------+----------
  .0828885 |        84         17 |       101
        .2 |        40         12 |        52
        .4 |        37         46 |        83
        .6 |        12          8 |        20
        .7 |         0          8 |         8
        .8 |         1          2 |         3
-----------+----------------------+----------
     Total |       174         93 |       267

Note: the common support option has been selected

End of the algorithm to estimate the pscore
```

Appendix I: Results of model 5

Unrestricted

```
regress tcknowsc particip propensity, robust

Linear regression                                      Number of obs =     287
                                                       F(  2,   284) =   35.79
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2336
                                                       Root MSE      =  2.3229

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.557862   .3639351     7.03   0.000      1.84151    3.274214
  propensity |   .7763347   .7731298     1.00   0.316     -.745457    2.298126
       _cons |   10.40047   .2552586    40.74   0.000     9.898029    10.90291
------------------------------------------------------------------------------

end of do-file
regress tcknowsc particip propensity wepscore,robust

Linear regression                                      Number of obs =     287
                                                       F(  3,   283) =   25.92
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2436
                                                       Root MSE      =  2.3118

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.370982   .4104633     5.78   0.000     1.563034    3.178931
  propensity |  -.2750872   .7714114    -0.36   0.722    -1.793519    1.243345
    wepscore |   2.978044   1.823861     1.63   0.104    -.6120111      6.5681
       _cons |   10.67489   .2579696    41.38   0.000     10.16711    11.18267
------------------------------------------------------------------------------
```

```
regress tcknowsc particip propensity source1 headeduc exp sqEXP labourland member moc
location, robust

Linear regression                                      Number of obs =     287
                                                       F( 10,   276) =   14.41
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3310
                                                       Root MSE      =  2.2015

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.426768   .3734445     6.50   0.000     1.691607     3.16193
  propensity |   .6593654    .969955     0.68   0.497    -1.250085    2.568815
     source1 |    1.91493   .5378056     3.56   0.000     .8562079    2.973652
    headeduc |   .1922437   .0400448     4.80   0.000     .1134117    .2710757
         exp |   .1016694     .03449     2.95   0.003     .0337725    .1695663
       sqEXP |  -.0022057   .0011723    -1.88   0.061    -.0045134     .000102
..labourland |  -.0233252    .030797    -0.76   0.449     -.083952    .0373017
      member |   -.080536   .3458223    -0.23   0.816    -.7613205    .6002485
      moccup |   .3996267   .5047997     0.79   0.429    -.5941202    1.393374
    location |  -.1930093    .266057    -0.73   0.469    -.7167682    .3307496
       _cons |   9.374824   .5338846    17.56   0.000     8.323821    10.42583
------------------------------------------------------------------------------
```

Restricted

```
regress tcknowsc particip propensity source1 headeduc exp sqEXP  , robust

Linear regression                                      Number of obs =     287
                                                       F(  6,   280) =   22.01
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3269
                                                       Root MSE      =  2.1924
------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    particip |   2.424177   .3701899     6.55   0.000     1.695468    3.152886
  propensity |   .7060069   .8364195     0.84   0.399     -.940462    2.352476
     source1 |   1.802115   .5463711     3.30   0.001     .7265989    2.877632
    headeduc |   .1874174   .0388955     4.82   0.000     .1108527    .2639822
         exp |   .1031789   .0352549     2.93   0.004     .0337805    .1725773
       sqEXP |   -.002117   .0011855    -1.79   0.075    -.0044506    .0002167
       _cons |   9.080003   .4472873    20.30   0.000      8.19953    9.960475
------------------------------------------------------------------------------
```

Appendix J: Results of model 6

Unrestricted model

```
Bootstrapping of standard errors
command:  atts tcknowsc particip source1 headeduc exp sqEXP labourland member moccup markt
location , pscore(myscore) blockid(myblock) comsup
statistic:    atts       = r(atts)
note: label truncated to 80 characters
Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100

------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
        atts |   100  2.594554 -.0063792   .367553    1.86525   3.323859   (N)
             |                                       1.948681   3.255168   (P)
             |                                       1.948681   3.255168  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected
ATT estimation with the Stratification method
Bootstrapped standard errors

---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------
       85         182       2.595       0.368       7.059
```

Restricted model

```
Bootstrapping of standard errors
command: atts tcknowsc particip source1 headeduc exp sqEXP , pscore(myscore) blockid(myblock)
comsup
statistic:    atts       = r(atts)
Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100

------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
        atts |   100  2.594554 -.0485715  .3267602   1.946191   3.242918   (N)
             |                                       1.889034   3.109818   (P)
             |                                       2.058062   3.192248  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected

ATT estimation with the Stratification method
```

```
Bootstrapped standard errors
---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------

       85         182       2.595       0.327       7.940

---------------------------------------------------------
```

Appendix K: Results of model 7

Unrestricted model

```
Bootstrapping of standard errors
command:        attnd tcknowsc particip source1 headeduc exp sqEXP labourland member moccup
markt location , pscore() comsupstatistic:    attnd      = r(attnd)
note: label truncated to 80 characters
Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100

------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
       attnd |   100  2.150538  .3263478  .5523701   1.054516    3.24656   (N)
             |                                       1.317647   3.509615   (P)
             |                                       1.195402   2.892857  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Bootstrapped standard errors

---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------

       93          53       2.151       0.552       3.893

---------------------------------------------------------
Note: the numbers of treated and controls refer to actual
nearest neighbour matches
```

Restricted model

```
Bootstrapping of standard errors
command:      attnd tcknowsc particip source1 headeduc exp sqEXP , pscore() comsup
statistic:    attnd      = r(attnd)

Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100

------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
       attnd |   100  2.854677 -.1638671  .3635622   2.133291   3.576064   (N)
             |                                       1.973202   3.331668   (P)
             |                                       2.288176   3.618448  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Bootstrapped standard errors

---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------

       93         159       2.855       0.364       7.852

---------------------------------------------------------
Note: the numbers of treated and controls refer to actual
nearest neighbour matches
```

Appendix L: Results of model 8

Unrestricted model

```
Bootstrapping of standard errors
command:      attr tcknowsc particip source1 headeduc exp sqEXP labourland member moccup markt
location , pscore() comsup radius(.001)
statistic:    attr       = r(attr)
note: label truncated to 80 characters
Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100
------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
        attr |   100  2.572917 -.3395345  1.044565   .5002738    4.64556   (N)
             |                                       .3351352   4.400922   (P)
             |                                       .8309404   4.489286  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected
ATT estimation with the Radius Matching method
Bootstrapped standard errors
---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------
       36          51       2.573       1.045       2.463
---------------------------------------------------------
Note: the numbers of treated and controls refer to actual
matches within radius

Restricted model
Bootstrapping of standard errors
command:      attr tcknowsc particip source1 headeduc exp sqEXP , pscore() comsup radius(.001)
statistic:    attr       = r(attr)
note: label truncated to 80 characters
Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100
------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
        attr |   100  2.577262 -.1862827  .3814043   1.820473   3.334051   (N)
             |                                       1.746266   3.147696   (P)
             |                                       1.985723   3.371578  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected
```

```
ATT estimation with the Radius Matching method
Bootstrapped standard errors
---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------
       62         141       2.577       0.381       6.757
---------------------------------------------------------
Note: the numbers of treated and controls refer to actual
matches within radius
```

Appendix M: Results of model 9

Unrestricted

```
Bootstrapping of standard errors
command:      attk tcknowsc particip source1 headeduc exp sqEXP labourland member moccup markt
location , pscore() comsup bwidth(.06)statistic:    attk       = r(attk)
note: label truncated to 80 characters
Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100
------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
        attk |   100  2.483347  .1680708  .4106482   1.668532   3.298163   (N)
             |                                       1.981613   3.601333   (P)
             |                                       1.463126   3.087583  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected
ATT estimation with the Kernel Matching method
Bootstrapped standard errors
---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------
       93         178       2.483       0.411       6.047
---------------------------------------------------------
```

Restricted model

```
Bootstrapping of standard errors
command:      attk tcknowsc particip source1 headeduc exp sqEXP , pscore() comsup bwidth(.06)
statistic:    attk       = r(attk)
Bootstrap statistics                              Number of obs    =       287
                                                  Replications     =       100
------------------------------------------------------------------------------
Variable     |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
-------------+----------------------------------------------------------------
        attk |   100  2.629004 -.0441648  .3422829    1.94984   3.308168   (N)
             |                                       1.983453   3.366115   (P)
             |                                       2.162234   3.376707  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected
ATT estimation with the Kernel Matching method
Bootstrapped standard errors
---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------
       93         188       2.629       0.342       7.681
---------------------------------------------------------
```

Appendix N: Results of model 10

Unrestricted

```
treatreg    tcknowsc  source1  headeduc  exp  sqEXP  labourland  member  moccup  location  ,
treat(particip  =  health   dpickup   headeduc  exp  sqEXP  landlabour   member  moccup  markt
location)robust
Treatment-effects model -- MLE                    Number of obs   =        287
                                                  Wald chi2(9)    =      98.97
Log pseudolikelihood = -778.93133                 Prob > chi2     =     0.0000
------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
tcknowsc     |
     source1 |   1.898568   .5285301     3.59   0.000     .8626676    2.934468
    headeduc |   .1931009   .0386787     4.99   0.000     .1172921    .2689097
         exp |    .101176   .0340141     2.97   0.003     .0345097    .1678424
       sqEXP |  -.0022213   .0011481    -1.93   0.053    -.0044716     .000029
  labourland |  -.0233469   .0306195    -0.76   0.446    -.0833599    .0366662
      member |  -.0660604   .3269599    -0.20   0.840    -.7068901    .5747693
      moccup |   .4164642   .4985953     0.84   0.404    -.5607647    1.393693
    location |  -.2123251   .2665491    -0.80   0.426    -.7347518    .3101015
    particip |   3.012821   .7307526     4.12   0.000     1.580572     4.44507
       _cons |   9.410427   .4947048    19.02   0.000     8.440824    10.38003
-------------+----------------------------------------------------------------
```

```
particip     |
      health |   .1360753   .1651502     0.82   0.410    -.1876132    .4597639
     dpickup |    .104891   .1991359     0.53   0.598    -.2854082    .4951902
    headeduc |   .0345467   .0243854     1.42   0.157    -.0132477    .0823411
         exp |   .0346464   .0381671     0.91   0.364    -.0401599    .1094526
       sqEXP |   -.002387   .0014651    -1.63   0.103    -.0052585    .0004845
  labourland |   .0130486   .0192131     0.68   0.497    -.0246084    .0507056
      member |   .1980301   .2108231     0.94   0.348    -.2151756    .6112357
      moccup |   .6048949   .2607894     2.32   0.020     .0937571    1.116033
       markt |    .934215   .1832214     5.10   0.000     .5751076    1.293322
    location |   .1456248   .1776458     0.82   0.412    -.2025547    .4938042
       _cons |  -1.445208   .3685025    -3.92   0.000    -2.167459   -.7229562
-------------+----------------------------------------------------------------
     /athrho |  -.1583282   .1915901    -0.83   0.409    -.5338378    .2171814
    /lnsigma |   .7760551   .0541997    14.32   0.000     .6698256    .8822846
-------------+----------------------------------------------------------------
         rho |  -.1570184   .1868664                     -.4883093    .2138299
       sigma |   2.172884   .1177697                      1.953897    2.416414
      lambda |  -.3411827    .412862                     -1.150377    .4680119
------------------------------------------------------------------------------
Wald test of indep. eqns. (rho = 0): chi2(1) =     0.68   Prob > chi2 = 0.4086
------------------------------------------------------------------------------
```

Restricted

treatreg tcknowsc source1 headeduc exp sqEXP, treat(particip = health exp sqEXP labourland member moccup markt location)robust

```
Treatment-effects model -- MLE                   Number of obs   =        287
                                                 Wald chi2(5)    =      80.01
Log pseudolikelihood = -781.11709                Prob > chi2     =     0.0000
------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
tcknowsc     |
     source1 |   1.781627   .5409369     3.29   0.001       .72141    2.841844
    headeduc |   .1950114   .0369543     5.28   0.000     .1225824    .2674404
         exp |    .102298   .0352104     2.91   0.004     .0332868    .1713092
       sqEXP |  -.0021399   .0011783    -1.82   0.069    -.0044492    .0001694
    particip |   3.002031    .625529     4.80   0.000     1.776017    4.228045
       _cons |    9.11819   .4146652    21.99   0.000     8.305461    9.930919
-------------+----------------------------------------------------------------
particip     |
      health |   .1306136   .1654402     0.79   0.430    -.1936432    .4548704
         exp |   .0363575   .0368311     0.99   0.324    -.0358301    .1085451
       sqEXP |  -.0023989   .0013918    -1.72   0.085    -.0051269     .000329
 labourland  |   .0089322   .0191607     0.47   0.641    -.0286221    .0464866
      member |   .2474399   .2065966     1.20   0.231     -.157482    .6523619
      moccup |   .5826276    .260596     2.24   0.025     .0718688    1.093386
       markt |   .9144277   .1820865     5.02   0.000     .5575446    1.271311
    location |   .0972763   .1689517     0.58   0.565    -.2338629    .4284154
       _cons |  -1.238644   .3430213    -3.61   0.000    -1.910953   -.5663345
```

```
-------------+----------------------------------------------------------------
     /athrho |  -.1518734   .1739479    -0.87   0.383     -.492805    .1890582
    /lnsigma |   .7789757   .0549336    14.18   0.000     .6713078    .8866436
-------------+----------------------------------------------------------------
         rho |  -.1507164   .1699966                     -.4564399    .1868374
       sigma |   2.179239   .1197134                      1.956795     2.42697
      lambda |  -.3284471   .3779683                     -1.069251    .4123571
------------------------------------------------------------------------------
Wald test of indep. eqns. (rho = 0): chi2(1) =     0.76   Prob > chi2 = 0.3826
------------------------------------------------------------------------------
```

Appendix O: Calculation of ATET

The calculation of average treatment effect on the treated (ATET) is divided into 4 steps as follow:

(1) Predict the probability of the positive outcome of participation, $I\hat{P}M > 0$;

(2) Calculate the probability density function (pdf) on $I\hat{P}M > 0$ that is equal the numerator of the Inverse Mill Ratio; $(1/\sqrt{(2*\pi)})*\exp(-0.5*I\hat{P}M^2)$ where π =3.141593.

(3) Predict ATET by using all predicted values from the previous steps

$$ATET = ATE + 2*(lambda)*((pdf(I\hat{P}M)/(\Pr(I\hat{P}M > 0))$$
$$=3.012821 + 2*(-.3411827)*((pdf(I\hat{P}M)/(\Pr(I\hat{P}M > 0))$$

where the term $lambda$ and ATE can be taken from the estimated results of the unrestricted model shown in appendix M.

(4) sum ATETU ATETR

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
       ATETU |       287    2.184582    .3388859  -.0750905   2.830176
       ATETR |       287    2.215498     .326236   .0401745   2.836993
```

Appendix P: Test of collinearity between the IMR and the independent variables

```
reg invmill  source1 headeduc exp sqEXP llabourand member moccup location
      Source |       SS       df       MS              Number of obs =     287
-------------+------------------------------           F(  8,   278) =   22.95
       Model |  326.374718     8  40.7968398           Prob > F      =  0.0000
    Residual |  494.169909   278   1.7775896           R-squared     =  0.3978
-------------+------------------------------           Adj R-squared =  0.3804
       Total |  820.544627   286  2.86903716           Root MSE      =  1.3333
------------------------------------------------------------------------------
     invmill |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     source1 |   2.893781   .4020689     7.20   0.000     2.102295    3.685268
    headeduc |   .2271109   .0234314     9.69   0.000     .1809854    .2732364
         exp |   .1026155   .0249249     4.12   0.000     .0535499    .1516811
       sqEXP |  -.0031801   .0008363    -3.80   0.000    -.0048263   -.0015339
  labourland |   .0055993   .0191782     0.29   0.771    -.0321535    .0433522
      member |   .5433438   .1897465     2.86   0.005     .1698213    .9168662
      moccup |   .7417368   .2743447     2.70   0.007       .20168    1.281794
    location |   .2731024   .1595547     1.71   0.088    -.0409864    .5871912
       _cons |   9.785462   .2761153    35.44   0.000     9.241919      10.329
------------------------------------------------------------------------------
```

Appendix Q: Results of unrestricted model of model 11 (unrestricted model)

Q1: Unweighted model

```
reg NIPM tcknowsc headeduc source1 exp  sqEXP labourland  member moc markt location , robust
Linear regression                                      Number of obs =     287
                                                       F( 10,   276) =    6.24
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1695
                                                       Root MSE      =  1.5131
------------------------------------------------------------------------------
             |               Robust
        NIPM |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    tcknowsc |   .1241581   .0362627     3.42   0.001     .0527715    .1955447
    headeduc |   .0367013   .0280051     1.31   0.191    -.0184296    .0918321
     source1 |    .175921   .4845463     0.36   0.717    -.7779551    1.129797
         exp |   .0305149   .0310066     0.98   0.326    -.0305246    .0915544
       sqEXP |  -.0005148   .0010213    -0.50   0.615    -.0025254    .0014957
 labourland  |   .0575865    .020645     2.79   0.006     .0169448    .0982281
      member |  -.0194598   .2402585    -0.08   0.936    -.4924318    .4535121
      moccup |   .3002004   .2919505     1.03   0.305    -.2745322    .8749331
       markt |   .7115351   .1910214     3.72   0.000      .335491    1.087579
    location |  -.5615241   .1812903    -3.10   0.002    -.9184115   -.2046367
       _cons |   1.683542    .492359     3.42   0.001     .7142861    2.652798
------------------------------------------------------------------------------
```

```
veg wpp tcknowsc headeduc source1  exp  sqEXP labourland  member moc markt  location, robust
Linear regression                                      Number of obs =     287
                                                       F( 10,   276) =    4.76
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1306
                                                       Root MSE      =  11.112
------------------------------------------------------------------------------
             |               Robust
         wpp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    tcknowsc |   .7752605   .2634346     2.94   0.004     .2566642    1.293857
    headeduc |   .2735615   .2011734     1.36   0.175    -.1224677    .6695906
     source1 |   .4424366   3.441862     0.13   0.898      -6.3332    7.218073
         exp |   .2150279   .1973244     1.09   0.277    -.1734241    .6034799
       sqEXP |  -.0029741   .0061491    -0.48   0.629    -.0150792    .0091311
 labourlaand |   .3196019   .1552735     2.06   0.040     .0139309    .6252728
      member |  -.5628604   1.783037    -0.32   0.752     -4.07294    2.947219
      moccup |   2.806696   2.288961     1.23   0.221    -1.699344    7.312736
       markt |   4.854186   1.420796     3.42   0.001     2.057213    7.651159
    location |  -2.978369   1.343334    -2.22   0.027    -5.622852   -.3338861
       _cons |   15.21341   3.574356     4.26   0.000     8.176947    22.24988
------------------------------------------------------------------------------
```

```
reg NIPM lambda tcknowsc headeduc source1 exp  sqEXP labourland  member moc markt location,
robust
Linear regression                                      Number of obs =     287
                                                       F( 11,   275) =    6.55
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1807
                                                       Root MSE      =  1.5056

------------------------------------------------------------------------------
             |               Robust
        NIPM |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lambda |   4.250033   2.148917     1.98   0.049      .019616     8.48045
    tcknowsc |   .1164919   .0363551     3.20   0.002     .0449222    .1880616
    headeduc |   .1581618    .066851     2.37   0.019     .0265571    .2897665
     source1 |   3.187486   1.597648     2.00   0.047     .0423111    6.332661
         exp |   .0907103   .0430751     2.11   0.036     .0059115    .1755092
       sqEXP |  -.005799   .0028747    -2.02   0.045    -.0114582   -.0001397
  labourland |   .0718555   .0213098     3.37   0.001     .0299044    .1138066
      member |   .3942053   .3257155     1.21   0.227    -.2470073    1.035418
      moccup |   2.204743   1.003775     2.20   0.029     .2286834    4.180802
       markt |   3.662277   1.494528     2.45   0.015     .7201074    6.604446
    location |  -.3204498   .2171714    -1.48   0.141    -.7479795    .1070799
       _cons |  -5.396652   3.575798    -1.51   0.132    -12.43607    1.642764
------------------------------------------------------------------------------

reg wpp  lambda tcknowsc headeduc source1 exp  sqEXP labourland  member moc markt location ,
robust
Linear regression                                      Number of obs =     287
                                                       F( 11,   275) =    5.50
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1462
                                                       Root MSE      =  11.032
------------------------------------------------------------------------------
             |               Robust
         wpp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lambda |   35.99648   15.70007     2.29   0.023     5.088889    66.90407
    tcknowsc |   .7103298   .2644371     2.69   0.008     .1897515    1.230908
    headeduc |   1.302295   .4868911     2.67   0.008      .343788    2.260803
     source1 |   25.94947   11.67993     2.22   0.027     2.956034    48.94291
         exp |   .7248647   .2970216     2.44   0.015     .1401396     1.30959
       sqEXP |  -.0477292   .0208346    -2.29   0.023    -.0887447   -.0067136
 labourland  |   .4404564    .160209     2.75   0.006     .1250644    .7558484
      member |   2.940756   2.432746     1.21   0.228    -1.848416    7.729928
      moccup |   18.93759     7.3035     2.59   0.010     4.559712    33.31546
       markt |   29.84606   10.90497     2.74   0.007     8.378244    51.31388
    location |   -.936544   1.604073    -0.58   0.560    -4.094366    2.221278
       _cons |  -44.75367    26.0794    -1.72   0.087     -96.0943    6.586966
------------------------------------------------------------------------------
```

Stage 1 (Unrestricted model)

```
ivreg2 NIPM (tcknowsc= headeduc source1) lambda exp  sqEXP labourland  member moc markt
location if particip==1,first robust
First-stage regression of tcknowsc:
OLS regression with robust standard errors

                                                      Number of obs =       93
                                                      F( 10,    82) =     4.13
                                                      Prob > F      =   0.0001
Total (centered) SS     =  725.9569892                Centered R2   =   0.2220
Total (uncentered) SS   =        17206                Uncentered R2 =   0.9672
Residual SS             =  564.7940838                Root MSE      =    2.624
------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lambda |   5.625814   6.009224     0.94   0.352    -6.328447    17.58008
         exp |   .2980639   .1330477     2.24   0.028     .0333896    .5627382
       sqEXP |  -.0170654   .0088058    -1.94   0.056     -.034583    .0004522
 labourland  |   -.038854   .0599233    -0.65   0.519    -.1580606    .0803526
      member |   .3346276   .7868955     0.43   0.672    -1.230758    1.900014
      moccup |   2.429512   2.501745     0.97   0.334    -2.547257    7.406281
       markt |   4.455289   3.907024     1.14   0.257    -3.317025     12.2276
    location |  -.1939723   .7386259    -0.26   0.794    -1.663334     1.27539
    headeduc |     .42154   .1582123     2.66   0.009     .1068054    .7362746
     source1 |   5.155989   3.809433     1.35   0.180    -2.422188    12.73416
       _cons |   2.510189   9.939809     0.25   0.801    -17.26326    22.28364
------------------------------------------------------------------------------
```

Test of heteroskedasticity

```
Partial R-squared of excluded instruments:   0.1005
Test of excluded instruments:
  F(  2,    82) =     6.29
  Prob > F      =   0.0029
Summary results for first-stage regressions
                Shea
Variable    | Partial R2    |    Partial R2    F(  2,    82)    P-value
tcknowsc    |   0.1005      |      0.1005           6.29         0.0029
NB: first-stage F-stat heteroskedasticity-robust
```

Test of identification

```
Underidentification tests:
                                                 Chi-sq(2)      P-value
Anderson canon. corr. likelihood ratio stat.        9.85         0.0073
Cragg-Donald N*minEval stat.                       10.39         0.0055
Ho: matrix of reduced form coefficients has rank=K-1 (underidentified)
Ha: matrix has rank>=K (identified)
Weak identification statistics:
Cragg-Donald (N-L)*minEval/L2 F-stat       4.58
```

```
Test of endogeneity
Anderson-Rubin test of joint significance of
endogenous regressors B1 in main equation, Ho:B1=0
  F(2,82)=       1.95      P-val=0.1482
  Chi-sq(2)=     4.43      P-val=0.1090
NB: Anderson-Rubin stat heteroskedasticity-robust

Number of observations N           =         93
Number of regressors   K           =         10
Number of instruments  L           =         11
Number of excluded instruments L2  =          2
```

Stage 2 (Unrestricted model)

```
IV (2SLS) regression with robust standard errors

                                                      Number of obs =       93
                                                      F(  9,    83) =     3.56
                                                      Prob > F      =   0.0009
Total (centered) SS     =  241.2258065                Centered R2   =   0.3029
Total (uncentered) SS   =         2111                Uncentered R2 =   0.9203
Residual SS             =  168.1560572                Root MSE      =    1.345

------------------------------------------------------------------------------
             |               Robust
        NIPM |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    tcknowsc |   .2703112    .148052     1.83   0.068    -.0198653    .5604878
      lambda |   1.322702   .6940681     1.91   0.057     -.037646    2.683051
         exp |   .1440098   .0587578     2.45   0.014     .0288467     .259173
       sqEXP |  -.0068239   .0024415    -2.80   0.005    -.0116091   -.0020387
 labourland1 |   .1102191     .03366     3.27   0.001     .0442466    .1761915
      member |   .3914668   .3269518     1.20   0.231     -.249347    1.032281
      moccup |   .9913649   .3919814     2.53   0.011     .2230954    1.759634
       markt |   1.386214   .4679032     2.96   0.003     .4691407    2.303288
    location |  -.3184255   .3291729    -0.97   0.333    -.9635925    .3267414
       _cons |   -2.89811   2.686527    -1.08   0.281    -8.163607    2.367386
------------------------------------------------------------------------------
Anderson canon. corr. LR statistic (identification/IV relevance test):   9.849
                                                   Chi-sq(2) P-val =    0.0073
------------------------------------------------------------------------------
Hansen J statistic (overidentification test of all instruments):         0.759
                                                   Chi-sq(1) P-val =    0.3838
------------------------------------------------------------------------------
Instrumented:         tcknowsc
Included instruments: lambda exp sqEXP labourland member moccup markt location
Excluded instruments: headeduc source1
------------------------------------------------------------------------------
```

Stage 1 (Restricted model)

```
ivreg2 NIPM (tcknowsc= headeduc source1) lambda exp sqEXP labourland moccup markt if
```

```
particip==1,first robust
First-stage regression of tcknowsc:
OLS regression with robust standard errors

                                                      Number of obs =       93
                                                      F(  8,    84) =     5.06
                                                      Prob > F      =   0.0000
Total (centered) SS     =  725.9569892                Centered R2   =   0.2186
Total (uncentered) SS   =        17206                Uncentered R2 =   0.9670
Residual SS             =  567.2798165                Root MSE      =    2.599

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lambda |   4.664924   3.356877     1.39   0.168    -2.010595    11.34044
         exp |   .2857997   .1102408     2.59   0.011     .0665737    .5050256
       sqEXP |  -.0157288   .0064337    -2.44   0.017    -.0285229   -.0029346
 labourland  |  -.0460594   .0549033    -0.84   0.404    -.1552406    .0631218
      moccup |   2.000441     1.4916     1.34   0.183    -.9657688     4.96665
       markt |   3.788408   2.427224     1.56   0.122    -1.038394     8.61521
    headeduc |   .4004258   .1033602     3.87   0.000     .1948828    .6059689
     source1 |   4.561262   2.248375     2.03   0.046     .0901221    9.032401
       _cons |   4.061659   5.534411     0.73   0.465    -6.944123    15.06744
------------------------------------------------------------------------------
Partial R-squared of excluded instruments:   0.1219
Test of excluded instruments:
  F(  2,    84) =     8.38
  Prob > F      =   0.0005
```

Test of heteroskedasticity

```
Summary results for first-stage regressions
                Shea
Variable    | Partial R2    |    Partial R2    F(  2,    84)    P-value
tcknowsc    |   0.1219      |      0.1219           8.38         0.0005

NB: first-stage F-stat heteroskedasticity-robust
```

Test of identification

```
Underidentification tests:
                                                 Chi-sq(2)      P-value
Anderson canon. corr. likelihood ratio stat.       12.09         0.0024
Cragg-Donald N*minEval stat.                       12.91         0.0016
Ho: matrix of reduced form coefficients has rank=K-1 (underidentified)
Ha: matrix has rank>=K (identified)
Weak identification statistics:
Cragg-Donald (N-L)*minEval/L2 F-stat       5.83
```

Test of endogeneity

```
Anderson-Rubin test of joint significance of
endogenous regressors B1 in main equation, Ho:B1=0
  F(2,84)=       1.29      P-val=0.2800
  Chi-sq(2)=     2.86      P-val=0.2390
NB: Anderson-Rubin stat heteroskedasticity-robust

Number of observations N           =         93
Number of regressors   K           =          8
Number of instruments  L           =          9
Number of excluded instruments L2  =          2

Stage 2 (Restricted model)
IV (2SLS) regression with robust standard errors

                                                      Number of obs =       93
                                                      F(  7,    85) =     3.91
                                                      Prob > F      =   0.0010
Total (centered) SS     =  241.2258065                Centered R2   =   0.2919
Total (uncentered) SS   =         2111                Uncentered R2 =   0.9191
Residual SS             =  170.8093827                Root MSE      =    1.355
------------------------------------------------------------------------------
             |               Robust
        NIPM |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    tcknowsc |   .2404497   .1359287     1.77   0.077    -.0259656     .506865
      lambda |   1.045371    .591001     1.77   0.077    -.1129695    2.203712
         exp |    .144561     .05678     2.55   0.011     .0332743    .2558477
       sqEXP |  -.0063692   .0023585    -2.70   0.007    -.0109918   -.0017465
 labourland  |   .1015936   .0320435     3.17   0.002     .0387896    .1643977
      moccup |   .8348072   .3848462     2.17   0.030     .0805226    1.589092
       markt |   1.187832   .4637572     2.56   0.010     .2788845    2.096779
       _cons |  -2.109722    2.25456    -0.94   0.349    -6.528578    2.309134
------------------------------------------------------------------------------
Anderson canon. corr. LR statistic (identification/IV relevance test):  12.092
                                                   Chi-sq(2) P-val =    0.0024
------------------------------------------------------------------------------
Hansen J statistic (overidentification test of all instruments):         0.127
                                                   Chi-sq(1) P-val =    0.7219
------------------------------------------------------------------------------
Instrumented:         tcknowsc
Included instruments: lambda exp sqEXP labourland moccup markt
Excluded instruments: headeduc source1
------------------------------------------------------------------------------
```

Q2: Weighted model

Stage 1 (Unrestricted mode)

```
ivreg2 wpp (tcknowsc= headeduc source1) lambda exp  sqEXP labourland markt location if
particip==1,first robust
First-stage regression of tcknowsc:
OLS regression with robust standard errors

                                                      Number of obs =       93
                                                      F( 10,    82) =     4.13
                                                      Prob > F      =   0.0001
Total (centered) SS     =  725.9569892                Centered R2   =   0.2220
Total (uncentered) SS   =        17206                Uncentered R2 =   0.9672
Residual SS             =  564.7940838                Root MSE      =    2.624

------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lambda |   5.625814   6.009224     0.94   0.352    -6.328447    17.58008
         exp |   .2980639   .1330477     2.24   0.028     .0333896    .5627382
       sqEXP |  -.0170654   .0088058    -1.94   0.056     -.034583    .0004522
 labourland  |   -.038854   .0599233    -0.65   0.519    -.1580606    .0803526
      member |   .3346276   .7868955     0.43   0.672    -1.230758    1.900014
      moccup |   2.429512   2.501745     0.97   0.334    -2.547257    7.406281
       markt |   4.455289   3.907024     1.14   0.257    -3.317025     12.2276
    location |  -.1939723   .7386259    -0.26   0.794    -1.663334     1.27539
    headeduc |     .42154   .1582123     2.66   0.009     .1068054    .7362746
     source1 |   5.155989   3.809433     1.35   0.180    -2.422188    12.73416
       _cons |   2.510189   9.939809     0.25   0.801    -17.26326    22.28364
------------------------------------------------------------------------------
```

Test of heteroskedasticity

```
Partial R-squared of excluded instruments:   0.1005
Test of excluded instruments:
  F(  2,    82) =     6.29
  Prob > F      =   0.0029
Summary results for first-stage regressions
                Shea
Variable    | Partial R2    |    Partial R2    F(  2,    82)    P-value
tcknowsc    |   0.1005      |      0.1005           6.29         0.0029
NB: first-stage F-stat heteroskedasticity-robust
```

Test of endogeneity

```
Underidentification tests:
                                                 Chi-sq(2)      P-value
Anderson canon. corr. likelihood ratio stat.        9.85         0.0073
Cragg-Donald N*minEval stat.                       10.39         0.0055
```

```
Ho: matrix of reduced form coefficients has rank=K-1 (underidentified)
Ha: matrix has rank>=K (identified)

Weak identification statistics:
Cragg-Donald (N-L)*minEval/L2 F-stat       4.58
```

Test of endogeneity

```
Anderson-Rubin test of joint significance of
endogenous regressors B1 in main equation, Ho:B1=0
  F(2,82)=       2.78      P-val=0.0679
  Chi-sq(2)=     6.31      P-val=0.0427
NB: Anderson-Rubin stat heteroskedasticity-robust
Number of observations N           =         93
Number of regressors   K           =         10
Number of instruments  L           =         11
Number of excluded instruments L2  =          2
```

Stage 2 (Restricted)

```
IV (2SLS) regression with robust standard errors

                                                       Number of obs =       93
                                                       F(  9,    83) =     3.32
                                                       Prob > F      =   0.0017
Total (centered) SS     =  12990.53305                 Centered R2   =   0.2607
Total (uncentered) SS   =  115023.9799                 Uncentered R2 =   0.9165
Residual SS             =  9603.457773                 Root MSE      =    10.16
------------------------------------------------------------------------------
             |               Robust
         wpp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    tcknowsc |   1.865267   1.082356     1.72   0.085    -.2561125    3.986646
      lambda |   9.681772   5.121262     1.89   0.059    -.3557161    19.71926
         exp |   .8998517   .4390561     2.05   0.040     .0393176    1.760386
       sqEXP |  -.0433048   .0181848    -2.38   0.017    -.0789465   -.0076632
 labourland  |    .674821   .2676119     2.52   0.012     .1503113    1.199331
      member |   2.304955   2.530735     0.91   0.362    -2.655194    7.265105
      moccup |   8.927167   2.913862     3.06   0.002     3.216103    14.63823
       markt |   10.26798   3.450631     2.98   0.003     3.504871     17.0311
    location |  -2.878813   2.428149    -1.19   0.236    -7.637898    1.880271
       _cons |  -17.46232   19.95195    -0.88   0.381    -56.56743    21.64278
------------------------------------------------------------------------------
Anderson canon. corr. LR statistic (identification/IV relevance test):   9.849
                                                  Chi-sq(2) P-val =    0.0073
------------------------------------------------------------------------------
Hansen J statistic (overidentification test of all instruments):         1.600
                                                  Chi-sq(1) P-val =    0.2059
------------------------------------------------------------------------------
Instrumented:         tcknowsc
Included instruments: lambda exp sqEXP labourland member moccup markt location
Excluded instruments: headeduc source1
------------------------------------------------------------------------------
```

Stage 1 (Restricted mode)

```
ivreg2  wpp  (tcknowsc=  headeduc  source1)  lambda  exp   sqEXP  labourland   moc  markt   if
particip==1,first robust
First-stage regressions
First-stage regression of tcknowsc:
OLS regression with robust standard errors

                                                      Number of obs =       93
                                                      F(  8,    84) =     5.06
                                                      Prob > F      =   0.0000
Total (centered) SS     =  725.9569892                Centered R2   =   0.2186
Total (uncentered) SS   =        17206                Uncentered R2 =   0.9670
Residual SS             =  567.2798165                Root MSE      =    2.599
------------------------------------------------------------------------------
             |               Robust
    tcknowsc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lambda |   4.664924   3.356877     1.39   0.168    -2.010595    11.34044
         exp |   .2857997   .1102408     2.59   0.011     .0665737    .5050256
       sqEXP |  -.0157288   .0064337    -2.44   0.017    -.0285229   -.0029346
 labourland  |  -.0460594   .0549033    -0.84   0.404    -.1552406    .0631218
      moccup |   2.000441     1.4916     1.34   0.183    -.9657688     4.96665
       markt |   3.788408   2.427224     1.56   0.122    -1.038394     8.61521
    headeduc |   .4004258   .1033602     3.87   0.000     .1948828    .6059689
     source1 |   4.561262   2.248375     2.03   0.046     .0901221    9.032401
       _cons |   4.061659   5.534411     0.73   0.465    -6.944123    15.06744
------------------------------------------------------------------------------
Partial R-squared of excluded instruments:   0.1219
Test of excluded instruments:
  F(  2,    84) =     8.38
  Prob > F      =   0.0005
```

Test of heteroskedasticity

```
Summary results for first-stage regressions
-------------------------------------------
                Shea
Variable    | Partial R2    |    Partial R2    F(  2,    84)    P-value
tcknowsc    |   0.1219      |      0.1219           8.38         0.0005
NB: first-stage F-stat heteroskedasticity-robust
```

Test of identification

```
Underidentification tests:
                                                 Chi-sq(2)      P-value
Anderson canon. corr. likelihood ratio stat.       12.09         0.0024
Cragg-Donald N*minEval stat.                       12.91         0.0016
Ho: matrix of reduced form coefficients has rank=K-1 (underidentified)
Ha: matrix has rank>=K (identified)
Weak identification statistics:
Cragg-Donald (N-L)*minEval/L2 F-stat       5.83
```

Test of endogeneity

```
Anderson-Rubin test of joint significance of
endogenous regressors B1 in main equation, Ho:B1=0
  F(2,84)=       1.75      P-val=0.1792
  Chi-sq(2)=     3.89      P-val=0.1433
NB: Anderson-Rubin stat heteroskedasticity-robust
Number of observations N           =        93
Number of regressors   K           =         8
Number of instruments  L           =         9
Number of excluded instruments L2  =         2
```

IV (2SLS) regression with robust standard errors

```
                                                     Number of obs =       93
                                                     F(  7,    85) =     3.51
                                                     Prob > F      =   0.0023
Total (centered) SS     =  12990.53305               Centered R2   =   0.2446
Total (uncentered) SS   =  115023.9799               Uncentered R2 =   0.9147
Residual SS             =  9812.897232               Root MSE      =    10.27
------------------------------------------------------------------------------
             |               Robust
         wpp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    tcknowsc |   1.789807   .9899445     1.81   0.071    -.1504483    3.730063
      lambda |   8.763347   4.251214     2.06   0.039     .4311207    17.09557
         exp |   .8795618   .4353409     2.02   0.043     .0263093    1.732814
       sqEXP |  -.0391112    .017817    -2.20   0.028    -.0740319   -.0041905
 labourland  |   .6251733   .2511154     2.49   0.013     .1329961     1.11735
      moccup |   8.230229   2.938909     2.80   0.005     2.470073    13.99038
       markt |   9.284372   3.330721     2.79   0.005     2.756279    15.81246
       _cons |  -15.50662   16.29077    -0.95   0.341    -47.43593     16.4227
------------------------------------------------------------------------------
Anderson canon. corr. LR statistic (identification/IV relevance test):  12.092
                                                  Chi-sq(2) P-val =    0.0024
------------------------------------------------------------------------------
Hansen J statistic (overidentification test of all instruments):         0.754
                                                  Chi-sq(1) P-val =    0.3851
------------------------------------------------------------------------------
Instrumented:         tcknowsc
Included instruments: lambda exp sqEXP labourland moccup markt
Excluded instruments: headeduc source1
```