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By

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ABSTRACT

ESSAYS ON THE ECONOMIC EVALUATION OF INTEGRATED PEST MANAGEMENT EXTENSION IN NICARAGUA

By

Ricardo Antonio Labarta Chávarri

This dissertation assesses the economic impact of delivering integrated pest management (IPM) training through farmer field schools (FFS) in Nicaragua. The three essays are based on a cross sectional survey of 436 bean growers. The first essay presents evidence that prior experience with the environmental and health (E&H) effects of pesticides affect household decisions about pest management, but only when farmers are using toxic or highly toxic pesticides. When facing high health risks, farmers also tend to use protective strategies like hiring pesticide applicators.

The second essay evaluates FFS impacts on households' pest management, bean crop income and E&H outcomes. The E&H outcomes are represented by changes in the incidence of acute health symptoms and changes in the observed level of beneficial insects. One analytical complication is that FFS participants are not randomly selected from the population of farmers; they tend to be better managers on average. Results show that failing to correct econometrically for the endogeneity effects of this nonrandom selection associated with FFS participation can exaggerate the impacts of FFS. After correction for endogeneity this dissertation finds FFS performance to be inferior to other IPM training programs, at inducing IPM adoption, raising net income from beans and improving E&H outcomes.

The third essay explores the causes of poor FFS performance in Nicaragua by evaluating whether FFS impacts are influenced by the characteristics of the specific non-governmental organizations (NGOs) that implemented FFS. Two categories of NGO-specific effects make a difference, their institutional characteristics and the characteristics of their FFS on-farm research. Effective NGOs conducting successful FFS have many years of experience working with the targeted farmers, they have more extensionists, and most of their extensionists are trained in IPM (not necessary in FFS). When NGOs deviate from the original FFS focus on IPM training and shift the FFS focus to other institutional interests like promotion of credit programs, the FFS become less effective at disseminating IPM and improving farm benefits. Given the participatory research focus of FFS, the outcomes of on-farm FFS field experiments were also important. Farmers who observed higher yields or net incomes in the IPM plot compared with the conventional pest control plot were more likely to adopt IPM and reduce pesticide use. However, most comparisons between an IPM plot and a conventional plot resulted in lower yields and lower net revenues in the IPM plots.

Con mucho Amor a:

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Emilio y Ana, mis padres

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LIST OF ABBREVIATIONS

ADDAC:	Asociación para la Diversificación y Desarrollo Agrícola Comunal
APP:	Acute Pesticide Poisoning
BCN:	Banco Central de Nicaragua
CARITAS:	Caritas Diocesana
CECOTROPIC:	Centro de Estudios de Eco-desarrollo para el Trópico
E & H:	Environmental and Health
ESETECA:	Empresa de Servicios Técnicos Agropecuarios
FFS:	Farmer Field Schools
FIDER:	Fundación para la Investigación y el Desarrollo Rural
INEC:	Instituto Nacional de Estadísticas y Censos
INTA:	Instituto Nicaragüense de Tecnología Agropecuaria
IPM:	Integrated Pest Management
MAGFOR:	Ministerio de Agricultura, Ganadería y Forestales
MARENA:	Ministerio de Ambiente y Recursos Naturales
NGO:	Non-Governmental Organization
ODESAR:	Organización para el Desarrollo Comunal
PAHO:	Pan American Health Organization
PANNA:	Pesticide Action Network North America
PROMIPAC:	Programa para el Manejo Integrado de Plagas de América Central
T & V:	Training and Visit extension method
UNAG:	Unión Nacional de Agricultores y Ganaderos

INTRODUCTION

The new conceptualization of agricultural extension services in developing countries has introduced many changes in the delivery of agricultural technologies (Qamar 2002, Suleiman & Hall 2004). The operational capacity of public extension has been dramatically reduced after following criticism for insufficient impacts and the recent wave of structural adjustment programs (Farrington 1994). New extension providers and new methods for delivering agricultural technologies have emerged, producing significant changes to the traditional means of delivering extension services.

A diversity of decentralized private providers and non-governmental organizations (NGO) are replacing the large and centralized public institutions in charge of delivering technologies (Rivera 2001, World Bank 2002). Also new approaches to extension have been proposed in order to improve the adoption of agricultural technologies. These new approaches use participatory techniques and favor a more active participation of farmers in the search for combining scientific knowledge with farmers' experience and interests (Kenmore 2002). Measuring the impacts of the "new" extension system in developing countries has become a major challenge for agricultural economists.

This dissertation contributes to the economic impact assessment of this "new" extension system by analyzing the delivery of integrated pest management (IPM) through the farmer field schools (FFS) extension approach that has received increasing support from development agencies as the preferred means for disseminating IPM (Feder et al 2004). IPM is a knowledge-intensive set of management practices that aim to reduce environmental and health (E & H) risks related to pesticide use by using chemical pest control methods only when strictly necessary and by offering alternative non-chemical pest control methods. FFS is an intensive IPM training program that incorporates farmers' priorities and a "learning by doing" approach to skill development among farmers. FFS proponents expect it to increase the rate of IPM adoption compared to traditional extension approaches, notably the training and visit system.

This dissertation uses the recent implementation of FFS in Nicaragua as a case study and addresses different aspects of the impact of the delivery of IPM through FFS among bean growers. Nicaragua is one of the poorest and least developed countries in Latin America; two thirds of its rural inhabitants are poor and more than 25% are extremely poor (World Bank 2003). Agriculture remains the main productive activity and is responsible for 29% of the total gross domestic product (BCN 1998). Small farmers dominate the Nicaraguan agriculture, with 48% of farmers having less than 7 hectares of land (INEC 2001). Most of the small farm households are led by males (84%) but women's contributions to household income generation have been increasing, especially with a greater participation on off-farm activities. However, the gap between women's and men's earnings remains large, with women earning on average 44% of the male wage (INEC 2001). During 2003 the average rural wage across Nicaragua ranged between 20 and 40 cordobas per day (between 1.25 and 2.50 US$).

Few crops are responsible for most of the agricultural production in Nicaragua. Maize and beans are by far the most widely planted crops at 392,525 and 229,215 hectares, respectively. Other major crops include coffee (129,910 ha), sorghum (81,145 ha), plantain (63,491 ha) and rice (52,495 ha). Most of these crops are grown in different regions according to where the agro climatic conditions are most favorable. The western departments of Jinotega and Matagalpa are the main areas for producing maize, beans and coffee, Sorghum are mainly grown in the coastal departments of León and Managua, plantain in the Región Autónoma del Atlántico and the department of Rivas, and rice in the central departments of Granada and Matagalpa (INEC 2001).

Beans are cultivated by 57% of Nicaraguan farmers, with 40% of these farmers owning less than 7 hectares of land. Among the grain crops (maize, beans and sorghum) that constitute around 40% of the total value of agricultural production in Nicaragua, only maize production is more important among small farmers (INEC 2001). Although Jinotega and Matagalpa are the main areas of bean production, the crop is also important in Región Autónoma del Atlántico Sur (40,371 ha), Región Autónoma del Atlántico Norte (34,347 ha) and the department of Estelí (17,588 ha). In all these regions beans are mainly considered a subsistence crop; however, bean sales can also constitute an important source of income among Nicaraguan producers.

Nicaragua has two major crop farming seasons known as *primera* (May- August) and *postrera* (September-December). A third minor season known as *apante* (January-April) is limited to certain areas that have longer rainy seasons than the traditional *postrera*. Beans are mainly produced during the *postrera* season (53%) and in less quantity during the *primera* (30%) and *apante* seasons (17%) (MAGFOR 2003). Average bean yields are around 650 kg/ha (MAGFOR 2003) and are directly affected by insects like whitefly and bean pod weevil, and by diseases like web slight and angular leaf spot. Several types of weeds are also a big problem among bean growers. Given the severe damage that these insect pests, diseases and weeds can produce in beans, pest management is important to bean producers. Most Nicaraguan bean growers rely on chemical pest and weed control, with 75% using insecticides and 60% using herbicides. The main insecticides used are methamidophos, malathion, methyl-parathion and chlorpyrifos, while the main herbicides are paraquat, 2,4-D and glyphosate. Non-chemical control options are not widely diffused due to limited farmer access to technical assistance and credit programs.

Agricultural extension has been the responsibility of the public sector, especially the Instituto Nicaragüense de Tecnología Agropecuaria (INTA). However during recent years, a structural adjustment process led by the central government for reducing fiscal deficits has led to reduce public services and encouraged the entrance of several non-governmental organizations (NGOs) and private institutions as major extension providers. By 2001, only 12% of Nicaraguan farmers had access to technical assistance. Of this total, 40% were served by NGOs, only 28% by public entities and 11% by private extension providers (the rest by different small types of organizations) (INEC 2001).

In this context, the new extension providers have increased their participation in delivering agricultural technologies and in new extension approaches. One of these cases has been the delivery of IPM that has for many years produced a low adoption rate. Many NGOs are increasingly assuming the responsibility of conducting IPM training programs and most recently a group of them have committed to implement the IPM training trough the novel FFS approach. The three essays of this dissertation analyze in detail the implementation of 13 FFS among bean growers in Nicaruagua.

This dissertation is based on data from a cross sectional survey of 436 bean growers that was carefully designed using a double stratification (Deaton 1997) to compare the effects of alternative IPM training programs (FFS and others) as well as to include farmers not participating in IPM training programs.

The first essay aims to test the underlying assumption of many of IPM delivery programs that the E&H effects of pesticide use will encourage farmers to reduce pesticide use and seek alternative pest control methods. To do so, this essay evaluates econometrically whether farmers' awareness of and experience with acute pesticide poisoning symptoms and beneficial insects (E&H effects associated with IPM adoption) affect their decisions about pesticide use, adoption of non-chemical pest control methods and the hiring of laborers to spray pesticides.

The second essay evaluates the FFS implementation in Nicaragua and measures econometrically the impacts of FFS in four dimensions: 1) the adoption of IPM practices (insect scouting, botanical insecticides and insect yellow traps), 2) toxicity of pesticides used, 3) bean yields, and 4) net revenues. This essay also incorporates FFS impacts on E&H outcomes represented by changes in the incidence of acute health symptoms and changes in the level of observed beneficial insects. The evaluation controls for potential endogenity due to non-random placement FFS and farmer participation in IPM training programs.

The third essay, which is motivated by results from essay 2, explores whether the specific characteristics of the institutions involved in implementing FFS in Nicaragua have influenced the FFS impacts. Controlling for endogeniety and for the clustered and stratified sample design, this essay uses econometric techniques to explore how the FFS treatment effect is influenced by NGO institutional focus, resource capacity, experience and expertise.

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DO ENVIRONMENTAL AND HEALTH CONCERNS INFLUENCE FARMERS' INPUT DECISIONS? EVIDENCE FROM PESTICIDE USE AND ADOPTION OF INTEGRATED PEST MANAGEMENT IN NICARAGUA

ESSAY ONE

1. Introduction

An assumption underlying many Integrated Pest Management (IPM) diffusion programs has been that the environmental and health (E&H) effects of pesticide use will encourage farmers to reduce the use of agrochemicals and to adopt alternative IPM practices. Although farmers' awareness of these pesticide-ascribed E&H effects is extensively recognized, the influence of this awareness on farmer production decisions has not been clearly established.

The international development literature has largely discussed the nature of decisions by households, which naturally produce and consume at the same time. The key issue has been whether production decisions can be made independently from consumption and other utility-related decisions. If input and output markets function perfectly, farmers can make production decisions independently of the potential effects that these decisions could have on household welfare (Singh et al 1986). But if farmers face market imperfections or other resource constraints, optimal production decisions may entail meeting household consumption objectives without market intermediation (DeJanvry et al 1991, Strauss and Thomas 1998). The absent markets for ecosystem services and imperfections in the markets for preventative and curative health care make these attributes likely to be nonseparable from profitability-related attributes in farmers' agrochemical input demand decisions.

Evidence of the relationship between E & H effects, and farmers' production decisions is scarce and contradictory. While Pitt and Rosenzweig (1986) found that farm profits among Indonesian rice growers were independent of household health changes that affect their utility, Van Dusen and Taylor (2005) provided evidence that crop diversity on Mexican farms is not only a consequence of production characteristics, it also depends on migration, wealth and farmers' age and education. Also Beach and Carlson (1993) found in a hedonic analysis of herbicides that there is a statistically significant relationship between farmer herbicide selection and the user safety and water quality characteristics that herbicide inputs embody; however both turned out to be minor components in this production decision. In an IPM diffusion setting, although negative health effects of pesticide use can affect farm productivity (Antle & Pingali 1994) there is no evidence on how pesticide-ascribed E & H effects affect farmers' decisions about pesticide use, alternative pest control adoption and other production decisions.

This paper uses farm level data from Nicaraguan bean growers in order to test econometrically a) whether Nicaraguan farmers are aware of the E & H effects of pesticide use, b) whether farm households have experienced these effects and c) whether awareness and/or experience of E & H effects influence farmers' decisions on pesticide use, adoption of IPM practices, and family labor allocation. The unexpected results have important repercussions for ongoing IPM training programs across Central America and perhaps more widely.

2. Pesticide use, environmental and health effects, and the adoption of Integrated Pest Management in Nicaragua

Central American agriculture is characterized by high pesticide use compared to most developing countries. In Nicaragua, a recent survey reported that 88% of small farmers use pesticides while only 8% use non-chemical pest control (4% did not report any pest control)(MARENA 1999). Pesticide imports in the region grew from 34 to 45 million Kg between 1994 and 2000. This situation makes Central America the area with the highest rate of pesticide consumption per capita in the developing world with 1.5 Kg per person per year (PAHO 2002).

The relatively high pesticide consumption among small farmers has started to harm human health and insect biodiversity in this area. The Pan American Health Organization (PAHO) estimates that incidence of acute pesticide poisoning (APP) in Central America is roughly 20 cases per 100,000 population. In Nicaragua and El Salvador this rate is estimated to exceed 35 cases per 100,000 population (PAHO 2002). Worse yet, a recent study estimates that underreporting in the region's official statistics approaches 98%, implying that 400,000 poisonings may occur each year with 5% of people exposed to pesticides experiencing illness symptoms (PANNA 2002). It is also reported that farmers in Central America recognize that the overuse of pesticides is destroying the beneficial insect population (Bentley and Andrews 1996). These facts have encouraged the search for alternative less harmful pest management options.

Integrated Pest Management (IPM) is a group of pest control methods aimed to reduce H & E risks by keeping a crop pest infestation below an economic threshold level: the pest level at which control measures are necessary to prevent decline in net returns (Fernandez-Cornejo et al 1998, Bajwa and Kogan 2002). Pest control methods may include pesticides when necessary but also non-chemical inputs and specialized practices such as agro-ecological analysis[1], botanical insecticides, insect sticky traps and others (Fernandez-Cornejo et al 1998). The combination of profitability and lower E & H risks of IPM is expected to encourage small farmers to adopt broadly IPM practices.

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[1] This practice consists in a permanent observation of the crop field and the use of insect scouting as the main activity. It will determine whether pest infestation has reached the economic threshold level.

IPM training has a history of more than 20 years in Nicaragua and the rest of Central America. Many research and development institutions have been developing extension programs targeted to reduce the use of pesticides and to disseminate IPM (Staver & Guharay 2003). However, pesticides remain the preferred pest control, and the adoption of IPM practices has been low in Nicaragua (PROMIPAC 2001, Bentley et al 2001). In recent years the Program for IPM in Central America (PROMIPAC) has proposed Farmer Field Schools (FFS) as an alternative extension method that could produce a broader IPM adoption.

FFS were first established in Asia at the end of the 1980's with the intent to increase the delivery of IPM by using participatory techniques and the "learning by doing" approach (Gallagher 1998). The first attempts to measure FFS impacts reported positive results that led development agencies to support FFS implementation worldwide as the preferred method for delivering IPM (Feder et al 2004). This new extension approach started in Central America in 2001, but whether and why it is or is not effective remains to be determined.

3. The analytical framework

3.1 Farmers' awareness and experience of E & H effects

The first step toward identifying the correlation between pesticide-ascribed E & H effects and farmers' production decision is to determine the extent of farmers' awareness and experience with these E & H.

The literature about pesticide use finds most farmers to be aware of the potential E & H risks from pesticide use (Van der Hoek et al 1998, Heong et al 2002) with some exceptions in the African continent (Maumbe & Swinton 2003). This awareness can result from farmers' exposure to training or informative programs, learning from neighbors' experiences or from direct experience of these effects. However, each of these can produce different perceptions of the E & H effects and hence different farmer reactions. Tucker and Napier (2001) found that although some Midwestern US farmers were aware of potential negative consequences of pesticide use, they doubted the seriousness of the E & H hazard and still relied heavily on chemical control. Other studies have also reported a general awareness of pesticide secondary effects, but it seems that this awareness does not necessarily influence farmers' production behavior (Ecobichon 2001, Heong et al 2002).

Given the importance of awareness and perception of pesticide E & H hazards for management decisions, this article will explore the level of Nicaraguan farmers' awareness. It will also examine the effect of having directly experienced acute E & H hazards of pesticide exposure. But in order to determine whether pesticide E & H effects influence farmers input decisions, a conceptual model of farmer behavior is needed.

3.2. Chemical and non-chemical input decisions among small farmers

A household model provides a framework to understand how small farmers make their decisions about agrochemical use, the adoption of alternative pest control options and labor allocation. The household production model approach (Singh et al 1986) can be used to analyze the interaction between pesticide use and alternative pest control adoption (typical production decisions) and the pesticide-ascribed health and environmental effects experienced by household members. Consider the household utility function as:

$$U = U(X_1, X_2, \ell, H) \qquad (1)$$

Where the household derives utility from consumption of on-farm and off-farm goods (X_1 and X_2 respectively), leisure (ℓ) and household health (H). Let on-farm goods and household health can be produced according to the following household production functions:

$$Q_{X1} = Q_{X1}(L(H), Z_c, Z_{nc}, E, A \ / \ C_H) \qquad (2)$$

where $E = E(E_0, Z_c \ / \ C_H)$

$$H = H(X_1, X_2, Z_h, Z_c \ / \ C_H) \qquad (3)$$

The production of on-farm goods (Q_{X1}) depends on labor (L) that could be family (L_f) or hired (L_h), chemical inputs (Z_c), non chemical inputs (Z_{nc}), environmental services (E) and fixed inputs (A) like land. Environmental services do not directly affect household utility, but they benefit household welfare by enhancing crop production (Q_{X1}). E is represented by beneficial insects which have a natural endowment (E_0) and are affected negatively by chemical use ($E'(Z_c) \leq 0$). All of these inputs contribute positively to crop production. Health is expected to contribute to farm labor supply ($L'(H)>0$). Health can be augmented by consuming goods (especially food) and health inputs (Z_h) like health care services and protective devices, but health is diminished by use of chemical inputs ($H'(Z_c) \leq 0$). The three production functions are influenced by exogenous household characteristics (C_H), socioeconomic, cultural and otherwise.

The household faces an income constraint represented by:

$$P_{X1}.X_1 + P_{X2}.X_2 + P_{Zc}.Z_c + P_{Znc}.Z_{nc} + P_{Zh}.Z_h \leq \Pi + Y \qquad (4)$$

Where P_{X1} and P_{X2}, are the output market prices, P_{Zc}, P_{Znc} and P_{Zh} are input market prices, Y is non-farm income, and gross revenues are defined as: $\Pi = P_{X1}. X_1 - w^*L$. Thus gross revenues are conditional on shadow wage (w^*) which is the relevant measure of the marginal cost of labor under labor market imperfections (Singh et al 1986) like those in Nicaragua.

The optimal solution to this constrained utility maximization problem depends on whether farmers make input use decisions considering their potential impact on household welfare (like on household health and environmental services) or whether these decisions are made independently meaning that production and consumption decisions are separable. This paper will focus on the chemical input use, IPM adoption (non-chemical inputs) and labor allocation optimal decisions.

If production and consumption decisions are made jointly (non-separably) and farmers believe that pesticide use can produce secondary effects, the optimality conditions for chemical use, non chemical use and labor use imply the following:

$$P_q \frac{\partial Q}{\partial Z_c} = P_{Zc} - \frac{\frac{\partial U}{\partial H}\frac{\partial H}{\partial Z_c} + \frac{\partial U}{\partial E}\frac{\partial E}{\partial Z_c} + \frac{\partial U}{\partial L}\frac{\partial L}{\partial H}\frac{\partial H}{\partial Z_c}}{\lambda} \qquad (5)$$

$$P_q \frac{\partial Q}{\partial Z_{nc}} = P_{Znc} - \frac{\frac{\partial U}{\partial Q}\frac{\partial Q}{\partial Z_{nc}}}{\lambda} \qquad (6)$$

$$P_q \frac{\partial Q}{\partial L} = w - \frac{\frac{\partial U}{\partial Q}\frac{\partial Q}{\partial L}}{\lambda} \qquad (7)$$

Now the marginal value product of chemical inputs (Z_c) no longer equals just its market price, but rather its market price plus the marginal effects of pesticide use on household utility through E & H, divided by the marginal utility of income (λ). If farmers perceive the negative impact of pesticide use on health and natural environment, they will reduce pesticide use from the profit maximizing level. In the case of non-chemical inputs and labor allocation optimal conditions, the marginal cost in both cases also includes the marginal effect of both production inputs on household utility. Of course, if production and consumption decisions are separable (Singh et al 1986), and farmers believe that E & H effects will not affect their household welfare, then the marginal value product of each production input would equate, as usual, to its market price.

Evidence exists both for and against separability of pesticide input decisions from household welfare. Many studies have referred to developing countries as regions where markets are underdeveloped and subject to endemic imperfections like inadequate access for small farmers, lack of information, high transaction costs or input heterogeneity (DeJanvry et al 1991, Van Dusen and Taylor 2005). The non- separability hypothesis under these conditions is likely to hold. On the other hand, many development projects target market-integrated farmers who have permanent access to product markets, on-farm and off-farm work opportunities and reasonable access to technical assistance, health services and credit markets. Also recent studies have shown that farmers are able to value some of the E & H effects related to pesticide use (Higley and Wintersteen 1992, Cuyno et al 2001). These conditions can support the competing separability hypothesis.

A better market integration could lead small farmers to use available averting measures to avoid E & H effects of pesticide exposure and make them believe that these effects would not really affect their household welfare. Households could hire labor for pesticide application, avoiding the negative effects on their family members. They can also have access to protective devices (i.e. masks, gloves) or to curative health care if farmers get poisoned reducing the potential effects of pesticides on household health. Finally, if farmers are able to value ecosystem services and health effects, these farmers will be able to compare their valuation of the hidden cost of E & H effects with the potential economic loses if they modify their profit maximizing input decision. Whether farmers consider E & H effects on their input decisions become an empirical question and we develop a separability test in order to evaluate the correlation between the pesticide-ascribed E & H effects and the household demand for pesticides, IPM practices and labor.

4. Model empirical implementation

4.1. The separability test

The separability hypothesis can be tested by examining whether the marginal value product of each input equates to its market price (chemical input price, non chemical input price and wage) (Benjamin 1992). The alternative hypothesis in all the cases is that farmers deviate from the standard rule, and this deviation is correlated with variables that affect household welfare (E & H effects and household characteristics). In other words, the alternative hypothesis implies that each input's marginal value product equates to an input shadow price that depends on variables that affects household welfare. Defining β and γ as the vectors of coefficients that will be estimated for health effects and environmental effects, the null hypothesis can be stated as:

$H_0 = \beta = \gamma = 0$

If we fail to reject the null hypothesis, there would be evidence that market imperfections cause farmers to consider health and environmental effects while making decisions about pesticides, adoption of IPM practices and the use of labor for spraying chemicals.

For implementing this test we derive the following input demand functions for pesticides, IPM practices and labor for applying pesticides from the optimal conditions described above:

$$Z_c = Z_c(P_q, P_{Zc}, P_{Znc}, w, A, H, E; C_H) \tag{8}$$

$$Z_{nc} = Z_{nc}(P_q, P_{Zc}, P_{Znc}, w, A, H, E; C_H) \tag{9}$$

$$L_d = L_d(P_q, P_{Zc}, P_{Znc}, w, A, H, E; C_H) \tag{10}$$

4.2. The Data

Farm level data for this study were collected between May and August 2004 via a cross-sectional survey of 436 households of Nicaraguan bean growers in the departments of Estelí, Matagalpa, Jinotega, Madriz, Masaya and Carazo. The survey was designed following a double stratification (Deaton, 1997) based on exposure to IPM training participation in FFS and other programs. Households in 74 rural communities were interviewed, including 13 where FFS were implemented, 9 where FFS graduates lived but no FFS were held, 26 communities selected randomly where no FFS exists but where

IPM extension services were available, and 26 communities selected randomly where no IPM extension was present. In each community, households were selected randomly and included both clients and non clients of NGOs. The sample distribution includes FFS graduates, farmers participating in other IPM programs, FFS graduates who also attended other IPM programs, and farmers who had no prior contact with formal IPM extension.

4.3. The econometric estimation

4.3.1. Potential econometric problems

The sample design poses secondary econometric problems of a clustered and stratified sample that can bias the parameter estimates (Wooldridge 2002a). To deal with the clustering problem, this paper adjusts the variance matrix and includes dummy variables for each cluster using survey regression methods (Wooldridge 2003). This method is suitable given the nature of the sample design that has small clusters (six households per village on average) and a large number of clusters (74 villages). To correct the unbalanced representation of farmers (especially FFS trainees) in the sample, this paper uses a weighting scheme as suggested by Wooldridge (2002a) (see appendix A.3 for details).

Another potential problem for the econometric estimation is the possibility of measurement error of the E & H variables that can bias the estimation of their effects over the production decisions, and therefore invalidate the conclusions about separability. However as measurement error is correlated with the true E & H variables and not with the observed variables in the sample, standard models like OLS and multinomial logit can still be produce consistent estimates (Wooldridge 2002) see appendix A.4 for details).

4.3.2. The econometric specification

This paper specifies four linear models for pesticide demand, a multinomial logit model for the adoption of IPM practices, and three linear models for the labor use. All models have the same set of explanatory variables and the general model structure is:

$$X_j = P_k\beta_{jp} + H_h\beta_{jH} + E\beta_{jE} + C_H\beta_{jCH} + C_C\beta_{jCC} + U_j \quad ;\text{ for } j=1,\ldots,8 \qquad (11)$$

The J dependent variable depends on vectors of k output and input prices (P_k), h self-reported past acute health symptoms (H_h), perceived beneficial insect population levels (E), socioeconomic and other household characteristics (C_H) and community fixed effects (C_C), with disturbances assumed to be independently distributed (U_i).All variables used in the econometric estimation are described in detail in the following subsections.

4.3.3. The dependent variables

Household demand for insecticides, herbicides, fungicides and molluscicides[2] are represented by the quantity of pesticide active ingredients used by each household in bean production during the last season weighted by acute human toxicity. A human toxicity index is calculated for each household i as the sum over all m pesticide active ingredients (ai_{ik} in kg/ha, k=1,…,m) divided by each active ingredient's mammalian toxicity (measured by the minimum dose per gram of body weight that is lethal to 50% of a test rat population or LD50, as reported in USDA, 1998). The human toxicity index, show below, is proportional to the LD50 and is increasing in lethality.

[2] Insecticides are mainly used to control white fly (*Bemisia tabaci* (Genn)) and diabrotica beetles (*Diabrotica sp*); fungicides to control anthracnose and angular leaf spot, and molluscicides to control mainly slugs (*Vaginulus plebeius* (Fisher)). The main active ingredients used in Nicaragua are metamidophos (insecticides), paraquat (herbicides), mancozeb (fungicides) and metaldehyde (molluscicides).

$$HTI_i = \sum_k \frac{ai_{ik}}{LD50_{ik}} \quad (12)$$

The adoption of IPM practices is represented by binary variables that indicate whether a household adopted individually or simultaneously agro-ecological analysis, botanical insecticides and/or yellow insect traps. These are the most promoted IPM practices in Nicaragua and the only three that were common across different IPM training programs and within each of them. The latent variable is defined as:

Z_{ncj} = 0 if household did not adopt any IPM practice

1 if household adopted only insect scouting

2 if household adopted only botanical insecticides

3 if household adopted only yellow traps

4 if household adopted a combination of two practices

5 if household adopted the three IPM activities

Finally, labor demand is represented by the natural logarithm of the family labor, hired labor and total farm labor.

4.3.4. The explanatory variables

Output prices are selling prices for bean and maize reported in US$/kg. Input prices include bean seed, metamidophos insecticide, gramoxone (paraquat) herbicide and mancozeb fungicide[3]. The bean the net revenue function also included the price of

[3] Metamidophos, paraquat and mancozeb were by far the main active ingredients among insecticides, herbicides and fungicides on the Nicaraguan farms surveyed in 2004

fertilizers[4]. Other prices and price proxies are the transport cost to the nearest market of a sack of beans or maize and the distance between each farm and the municipal capital. Other production variables include the most recent farming season that bean were grown: *primera*, *postrera* or *apante*, the use of disease resistant bean varieties, altitude (proxy for rainfall and temperature) and farmers' observed level of bean pests and diseases (high or not).. For pesticide demand, we also include the adoption of the three defined IPM activities that were observed to occur prior to pesticide use decision. We also include a variable for exposure to IPM extension training.

Health variables in this paper refer mainly to past health events or pre-existing conditions at the beginning of the most recent bean season prior to the 2004 survey. As 97% of the surveyed households reported awareness of pesticide-ascribed health problems, this variable is dropped from the econometric analysis because it could not explain pesticide use or IPM adoption variability. We do include the number of acute health symptoms suffered by household members in the past and the frequency of the following acute symptoms: diarrhea, respiratory difficulties, head ache, dizziness, vomiting, stomach ache, blurred vision, eye irritation and skin rash. Symptom frequencies measure four level of incidence of a specific symptom after applying chemical inputs: never, rarely, sometimes or frequently. Other health variables include whether household members had to visit a city doctor or become hospitalized due to pesticide poisoning, whether these household members lost workdays after pesticide poisoning, whether the household hired labor or used family labor for most pesticide applications, and how many purchased or home-made protective devices (e.g. mask,

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[4] we use the price of the most common combination of nitrogen, phosphorus and potassium (12-30-10)

gloves or special clothing) for applying chemicals were on hand before the most recent bean production season.

The environmental variables are represented by the respondent's awareness of beneficial insects and the reported level of beneficial insect population in the previous bean season. Although many farmers could measure whether this population was greater, lower or unchanged compared to the previous season, almost all of the respondents to this question were farmers who had received IPM training. For this reason we include these variables as an interaction with IPM training participation and with IPM adoption (Table 1.1). For the same reason beneficial insects are not included in the IPM adoption model.

Household characteristics are represented by two groups of variables: (1) measures of household assets: farm size, area under irrigation, number of cattle, whether family has electricity at home, and whether the household receives remittances from relatives working in foreign countries; and (2) measures of household composition: gender of household head, age and years of education of household head, percentage of females, and percentage of family members under 14 years old. Finally dummy variables are included for community-level fixed effects with one of them kept as a control. The 73 community dummies are used for the pesticide and labor demand, but are substituted by municipality dummy variables (9 out of the 10 municipalities) in order to avoid the computational problems of the multinomial logit estimation in the IPM demand.

5. Results

5.1. Farmer awareness of pesticide-ascribed health and environmental effects

Most of the respondent households used pesticides during the previous bean season. Seventy five percent applied insecticides, 60% herbicides, 22% fungicides and

18% molluscicides. This pesticide use was accompanied by uneven farmers' awareness of potential health and environmental effects. While 97% of the interviewed households were aware of the potential negative effects that pesticide use can have on human health, only 38% recognized the existence of beneficial insects and the possibility that these beneficial insects can help to control farm pests (Table 1.1). Large educational campaigns carried out by the Nicaraguan government and some international and national development agencies explain the high farmer awareness of these health effects (PLAGSALUD 1997), but information about beneficial insects has only been diffused by limited IPM training efforts in Nicaragua (Bentley and Andrews 1996). If we consider the over sampled number of households exposed to IPM training (Table 1.1), the true level of awareness of beneficial insects would be much lower.

The prevalent awareness of potential pesticide risks to human health among Nicaraguan farmers rules out lack of awareness as a plausible explanation for not adopting pesticide risk reduction strategies, including IPM practices. For this reason this variable will be dropped from the econometric analysis.

5.2. Farmers' direct experience with environmental and health effects

At least 68% of the farm households reported having suffered at least one of a variety of acute illness symptoms and to have experienced on average 3 symptoms after applying pesticides. The most common symptom reported was headache (48% of respondents) and the least common was diarrhea (only 3% of respondents). The frequency of these symptoms was far from homogenous. While most of the symptoms were never experienced by households, headache and eye irritation were reported to be experienced "always" by 19% and 16% respectively of the households after applying pesticides.

Table 1.1. Summary statistics on key variables. 436 Nicaraguan bean growers, 2003-04⁺

Variables	Mean	Std Dev.
Dependent Variables		
Index of active ingredients of insecticides weighted by toxicity (x 100)	2.9	5.1
Index of active ingredients of herbicides weighted by toxicity (x 100)	0.5	0.7
Index of active ingredients of fungicides weighted by toxicity (x 100)	0.1	0.6
Index of active ingredients of molluscicides weighted by toxicity (x 100)	0.1	0.2
Adopted only agro-ecological analysis (%)	4.4	
Adopted only botanical insecticides (%)	11.7	
Adopted only insect yellow traps (%)	2.8	
Adopted two IPM practices (%)	14.9	
Adopted three IPM practices (%)	10.8	
Quantity of family labor for applying agrochemicals (man-days)	3.1	3.4
Quantity of hired labor for applying agrochemicals (man-days)	0.8	1.6
Health variables⁺		
Awareness of pesticide ascribed health effects (%)	96.8	
Households who suffered from		
Headache	48.2	
Eye irritation	43.1	
Stomachache	23.4	
Skin rash	29.0	
Blurred vision	27.6	
Muscle pain	26.2	
Respiratory difficulties	11.2	
Diarrhea	3.2	
Visited city doctor after pesticide poisoning (%)	6.8	
Hospitalized after pesticide poisoning (%)	5.3	
Reported workdays lost after pesticide poisoning (%)	17.4	
Number of purchased protective devices	0.4	0.7
Number of homemade protective devices	0.3	0.5
Households hire a pesticide applicator (%)	18.0	
Beneficial insect variables		
Awareness of beneficial insects (%)	38.0	
Awareness of beneficial insects and IPM training	33.0	
Households that observed a higher level of beneficial insects (%)	8.0	
Observed higher beneficial insects and adopted AAE	8.0	

+ Details about other variables used in the econometric analysis can be found in detail in Appendices A.5 and A.6

The past experience of interviewed households also includes severe cases of acute health illness after applying pesticides. Seven percent of the farmers had to go to a city doctor after getting poisoned and 5% had to be hospitalized for the same reason (Table 1.1). Getting in to a hospital could take up to more than 4 hours for some of the places we visited. In addition, 17% of those interviewed reported having lost work days due to pesticide poisoning.

Of the 62% of the sample that received IPM training and the 38% that recognized the existence of beneficial insects, only 22% were able to observe beneficial insects during the previous bean season and to evaluate whether the level of these beneficial insect had changed. Of that 22%, 8% of the households observed an increase in the level of beneficial insects, 10% the same level and 4% a lower level compared with the previous season.

5.3. The influence of E & H effects on household production decisions

5.3.1. Demand for pesticides

Pesticide ascribed E & H effects influence use of the four classes of pesticides in different ways. Only in the instance of insecticides could we reject the null hypothesis that E & H effects jointly have no effect on the household demand for pesticides (Table 1.2). We would reject this null hypothesis in the herbicide case with only 82% confidence and cannot reject the null hypothesis of no E & H effect in the instance of fungicide and molluscicide use. These results are consistent with the fact that the most toxic pesticides used in Nicaragua are insecticides (metamidophos) and herbicides (paraquat). Table 1.3 summarizes the regression results of the four chemical demand models which display good fit considering the cross sectional nature of the data.

Table 1.2. The jointly effect of E & H variables on household input decisions, F-test for 436 Nicaraguan bean growers, 2003-04

Model	F-statistic	P-value
Pesticide demand		
Insecticides	1.91	0.0317
Herbicides	1.37	0.1852
Fungicides	1.06	0.3970
Molluscicides	0.95	0.5132
IPM adoption	65.76	0.0000
Labor demand		
Family	3.87	0.0000
Hired	1.87	0.0295
Total	2.10	0.0123

The toxicity-weighted demand for insecticides was significantly affected by prior experience with individual acute poisoning symptoms and farmer awareness of beneficial insects (Table 1.3). However the magnitude of these effects measured as standard deviation (s.d.) of the dependent variables are relatively small (Table 1.3). Households that had suffered more frequent diarrhea and skin rash reduced the toxicity weighted use of insecticides by 0.08 and 0.02 s.d., but households that suffered more frequent headaches significantly *increased* the use of these insecticides by 0.03 s.d. This contradictory behavior is explained by farmers' explanation that headaches are difficult to avoid after insecticide use (Table 1.1), but they are easily treated with headache pills.

Households that had more severe health effects and experienced workdays lost after applying pesticides also reduced the use of insecticides during the previous bean season by 0.05 s.d.. Farmers who were aware of beneficial insects reduced their use of insecticides by 0.07 s.d.. The insecticide reduction response came only among respondents aware of beneficials who had IPM training, not the subset who had adopted agro-ecological analysis.

Table 1.3. Influence of E & H effects on pesticide use, Linear survey regression results for 436 Nicaraguan bean growers, 2003-04[+]

	Insecticide	Herbicide	Fungicide	Molluscicide
IPM trained & beneficial awareness	**-0.336***		-0.059	
	(2.96)		(0.78)	
AAE & more beneficials	-0.171		0.337	
	(1.16)		(1.32)	
Number of symptoms	0.012	0.070	-0.003	-0.010
	(0.37)	(1.37)	(0.14)	(0.39)
Frequency of eye irritation	-0.009	-0.027	0.002	0.002
	(0.15)	(0.47)	(0.04)	(0.04)
Frequency of diarrhea	**-0.398***	-0.048	0.013	-0.118
	(1.74)	(0.47)	(0.13)	(1.01)
Frequency of respiratory difficulty	0.084	0.012	-0.020	-0.055
	(0.86)	(0.14)	(0.35)	(0.62)
Frequency of skin rash	**-0.106***	-0.028	-0.017	0.013
	(1.65)	(0.52)	(0.42)	(0.28)
Frequency of stomach ache	0.039	0.035	-0.067	-0.048
	(0.54)	(0.33)	(1.58)	(0.62)
Frequency of head ache	**0.177****	0.002	-0.050	-0.029
	(2.26)	(0.03)	(1.41)	(0.60)
Frequency of muscle pain	0.052	-0.012	0.088	-0.040
	(0.87)	(0.21)	(1.47)	(0.74)
Frequency of blurred vision	-0.017	**-0.137***	-0.029	0.060
	(0.16)	(1.98)	(0.56)	(0.61)
Lost workdays	**-0.233***	-0.033	-0.000	-0.040
	(1.65)	(0.30)	(0.00)	(0.43)
Visited city doctor	-0.022	0.078	0.051	-0.031
	(0.13)	(0.54)	(0.39)	(0.26)
Hospitalized	-0.128	0.241	0.068	-0.053
	(0.52)	(1.53)	(0.40)	(0.39)
Purchased protective devices	**0.212*****	-0.046	0.028	-0.003
	(3.57)	(0.85)	(0.78)	(0.08)
Homemade protective devices	**-0.178***	-0.146	0.039	-0.034
	(1.73)	(1.49)	(0.45)	(0.41)
Hired applicator	**0.189***	**0.222***	0.082	0.104
	(1.89)	(1.72)	(1.06)	(1.08)
R-squared	0.46	0.52	0.37	0.39

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] Complete regression results are shown in appendix A.7

Although the evidence shows that Nicaraguan bean growers reduce insecticide use in response to direct experience with acute illness symptoms and beneficial insects, parallel evidence shows that when averting measures to avoid pesticide exposure are available in the market, households will buy them and keep using more pesticides. Farmers who use more purchased protective devices or hired a pesticide applicator *increased* their use of toxicity-weighted insecticides by 0.04 s.d. in both cases. On the other hand, farmers who used homemade protective devices reduced their use of insecticides (Table 1.3). The opposite effects of protective devices may be explained by the lower quality of homemade products like simple plastic or handkerchiefs to cover the body or face, which may not reduce the toxicity risk of pesticide exposure.

Although E & H effects do not jointly influence the herbicide use decision, households that had more frequent suffered blurred vision decreased their use of herbicides by 0.03 s.d. Households that hired a pesticide applicator also increased the use of herbicides by 0.04 s.d.

5.3.2. IPM adoption

The adoption of IPM practices is also significantly influenced by prior experience with pesticide poisoning symptoms. We reject the null hypothesis that all health variables jointly have no effect on the adoption of agro-ecological analysis, botanical insecticides and insect yellow traps (Table 1.2). Table 4 shows the results of the multinomial logit estimation of this adoption decision. As the survey multinomial logit results could not be expressed in marginal probabilities, we only discuss the sign of these results.

Although only 4% of respondents adopted only agro-ecological analysis (Table 1.1), various acute illness effects and the severity of these symptoms influence significantly and positively the adoption of this IPM practice. An extra number of acute symptoms and having experienced more frequently skin rash make households more likely to adopt agro-ecological analysis (Table 1.4). Households that faced severe cases of pesticide poisoning and had to visit a city doctor or be hospitalized were also more likely to adopt this IPM practice. The fact that some households lost work days due to pesticide poisoning seems to reduce the adoption of agro-ecological analysis. Finally, a greater use of purchased protective devices seems to complement IPM adoption, because a farmer who increased the use of these devices increased the probability of IPM adoption.

The use of botanical insecticides is the IPM practice with the greatest individual adoption (11.7%), which is consistent with the history of IPM training in Nicaragua promoting this practice. However, the likelihood of adopting this practice is affected differently by experience with different acute symptoms. While an extra number of acute symptoms or specifically having suffered more frequently headache made households more likely to adopt botanical insecticides, households with more frequency of eye irritation, dizziness and blurred vision were less likely to adopt these botanical insecticides (Table 1.4). This partial discouragement of adopting botanical insecticides is associated with some negative effects that the use of some natural products can have over human health. Many botanical insecticides are made base on chile (*Capsium anum*), manure, alcohol and some plants like *Gliricidia cepium* or *Azadarichata indica* that can affect the applicator's health.

Yellow sticky traps for insects constitute the least adopted individual IPM practice (2.8%) and it is not influenced by past acute illness symptoms experienced by households (Table 1.4). Most of the 16% of respondents who reported having adopted

Table1.4. Influence of E & H effects on the adoption of different IPM activities. Survey multinomial logit results for 436 Nicaraguan bean growers, 2003-04⁺

	Agro-ecol. Analysis	Botanical Insecticides	Insect traps	Two IPM practices	Three IPM practices
Number of symptoms	**0.569*** **	**0.768*** **	5.127	0.179	0.053
	(2.77)	(3.56)	(1.44)	(0.75)	(0.20)
Frequency of eye irritation	0.268	**-0.757** **	-6.854	-0.058	0.467
	(0.54)	(2.19)	(1.10)	(0.22)	(1.54)
Frequency of dizziness	-0.243	**-1.880*** **	19.919	**-0.640* **	-0.566
	(0.53)	(3.67)	(1.16)	(1.78)	(1.28)
Frequency of respiratory difficulty	0.021	0.891	-18.574	**1.995*** **	1.347
	(0.03)	(1.57)	(1.29)	(3.20)	(1.52)
Frequency of skin rash	**0.894* **	0.032	11.439	0.162	**1.027*** **
	(1.75)	(0.09)	(1.10)	(0.36)	(3.08)
Frequency of Stomach ache	0.449	-0.314	12.612	0.007	0.182
	(1.18)	(0.81)	(1.07)	(0.02)	(0.39)
Frequency of head ache	-0.290	**0.630** **	4.179	0.420	**0.817** **
	(0.67)	(2.41)	(1.06)	(1.45)	(2.58)
Frequency of muscle pain	0.304	-0.553	12.274	-0.681	-0.302
	(0.44)	(1.41)	(1.12)	(1.55)	(0.75)
Frequency of blurred vision	-0.900	**-1.100** **	-10.756	-0.845	**-1.651** **
	(1.50)	(2.22)	(1.14)	(1.59)	(2.59)
Lost workdays	**-4.032** **	-0.405	-33.518	-0.810	-0.290
	(1.99)	(0.57)	(1.28)	(0.88)	(0.36)
Visited city doctor	**3.377* **	-1.105	-8.263	-2.079	**-5.862*** **
	(1.64)	(0.84)	(1.05)	(1.42)	(3.01)
Hospitalized	**47.373*** **	0.767	8.726	-0.861	**42.351*** **
	(15.34)	(0.66)	(0.86)	(0.64)	(19.94)
Purchased protective devices	**0.785* **	0.197	18.881	0.295	0.244
	(1.95)	(0.74)	(1.23)	(1.20)	(0.58)
Homemade protective devices	1.699	0.551	14.538	0.554	**1.553** **
	(1.53)	(1.16)	(1.31)	(1.00)	(2.29)
Hired applicator	-0.421	**1.237** **	-52.568	-0.827	-0.882
	(0.33)	(2.00)	(1.27)	(1.16)	(0.91)

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
⁺ Complete regression results are shown in appendix A.7.

insect traps did so jointly with agro-ecological analysis or botanical insecticides. The simultaneous adoption of two IPM practices is also affected by past acute health symptoms but differently. While greater frequency of respiratory difficulties increased the probability of adopting IPM practices, greater frequency of dizziness reduced this probability. This last effect was associated with the main adoption of botanical insecticides, which as noted could produce acute health symptoms.

Finally, households having experienced a greater frequency of skin rash, headache, and hospitalization after getting poisoned were more likely to adopt the three IPM practices (Table 1.4). As the adoption of botanical insecticides is reduced among households having suffered of blurred vision, the same is true of the adoption of all three IPM practices (Table 1.4). Similarly, households having visited a city doctor due to pesticide poisoning are less likely to adopt the three IPM practices that include botanical insecticides presumably due to the latter's potential negative health effects.

5.3.3. Labor demand

E & H effects also significantly influence the demand for family, hired and total labor for applying pesticides. All three labor demand models produced R squared values over 0.35, implying sound explanatory power (Table 1.5).

Households that had suffered from blurred vision reduced by around 0.6 the number of family labor days per hectare spent applying chemicals (0.18 s.d. of this dependent variable). They also reduced by 0.7 man-days per hectare the hired labor for applying pesticides (0.43 s.d.). By contrast, households that had suffered a greater frequency of eye irritation increased the use of hired labor for applying pesticides by 0.6 man-days per hectare (0.4 s.d.). The frequency of prior diarrhea linked to pesticide use had no effect on either family or hired labor, but it did reduce total labor on beans by 0.9 man-days per hectare (0.18 s.d.) (Table 1.5). Behind this aggregate effect, there were many households that responded to having suffered diarrhea by reducing the use of family labor and increasing the use of hired labor.

Table 1.5. Influence of E & H effects on labor demand for pesticide application. Linear survey regression results for 436 Nicaraguan bean growers, 2003-04[+]

	Family labor	Hired labor	Total labor
IPM trained & beneficial awareness	**-1.856*** **	0.778	-0.894
	(2.87)	(1.12)	(1.63)
AAE adoption & more beneficials	**-1.872** **	-0.269	**-1.636** **
	(2.36)	(0.20)	(2.12)
Number of symptoms	-0.078	0.253	0.015
	(0.59)	(1.32)	(0.15)
Frequency of eye irritation	-0.277	**0.640** **	-0.180
	(1.20)	(2.02)	(0.96)
Frequency of diarrhea	-0.431	1.032	**-0.886***
	(0.58)	(1.33)	(1.67)
Frequency of respiratory difficulty	0.095	0.548	-0.163
	(0.28)	(1.22)	(0.52)
Frequency of skin rash	-0.169	**-0.689***	-0.371
	(0.64)	(1.86)	(1.52)
Frequency of stomach ache	0.158	-0.496	0.113
	(0.54)	(1.11)	(0.45)
Frequency of head ache	0.163	-0.537	0.046
	(0.77)	(1.60)	(0.26)
Frequency of muscle pain	0.346	-0.163	0.245
	(1.54)	(0.41)	(1.33)
Frequency of blurred vision	**-0.620*** **	-0.248	-0.259
	(2.67)	(0.48)	(1.46)
Lost workdays	-0.542	-0.766	-0.543
	(0.80)	(1.06)	(1.00)
Visited city doctor	-0.981	-0.144	-0.813
	(1.02)	(0.16)	(0.97)
Hospitalized	0.515	-1.149	0.224
	(0.65)	(0.84)	(0.32)
Purchased protective devices	**0.426***	-0.287	0.099
	(1.70)	(1.02)	(0.43)
Homemade protective devices	-0.712	-0.316	**-0.765***
	(1.56)	(0.61)	(1.81)
R-squared	0.43	0.37	0.46

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] Complete regression results are shown in appendix A.7.

Awareness of beneficial insects affected only the use of family labor (Table 1.5). Farmers trained in IPM and who reported being aware of the existence of beneficial insects reduced the use of family labor in pesticide application by 1.9 man-days per hectare (0.55 s.d.). The same occurred among farmers who adopted agro-ecological analysis and who observed a greater level of beneficial insects (Table 1.5).

6. Conclusions

These results have implications for policy makers designing IPM delivery programs. The findings support the underlying assumption of most IPM training efforts that farmers' awareness of and direct experience with pesticide-ascribed E & H risks can reduce the use of pesticides and increase the adoption of non-chemical IPM practices. However the validity of these non-separable assumptions is limited to certain conditions: First, perceived E&H hazards are only important enough to influence farmer practices when farmers are using toxic or highly toxic pesticides. Below that level Nicaraguan bean growers ignore the potential E & H risks or treat them as separable from their production input decisions. Second, when farmers face high health risks, they tend to use protective strategies for avoiding direct exposure to pesticides. In addition to using recommended protective devices while applying pesticides, Nicaraguan bean growers shift risk by hiring pesticide sprayers and transferring the potential health hazards out of the household. This finding is consistent with the separability hypothesis because it treats the health of hired workers as external to household input decisions.

Non-chemical IPM practices can constitute an alternative or a supplement to an entirely chemical-based pest management strategy. However, some non-chemical practices, such as certain botanical insecticides, also produce negative health effects. The risks of these practices should be communicated to potential IPM adopters in order to encourage them to use protective devices to avoid direct exposure.

IPM training efforts need to address all of these challenges and improve their educational component. Farmers trained in IPM need also to be aware of off-farm and long run E & H effects that are not easily perceived. This paper did not incorporate these indirect and chronic effects but farmers with more comprehensive information about secondary effects of pesticide use might reduce pesticide use even farther and increase their adoption of non-chemical IPM practices, rather than shift risk outside of the household.

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DOES PARTICIPATION IN FARMER FIELD SCHOOLS IMPROVE GRADUATES' FARM, HEALTH AND ENVIRONMENTAL OUTCOMES? THE CASE OF NICARAGUAN BEAN GROWERS

ESSAY TWO

1. Introduction

The delivery of integrated pest management (IPM) has challenged the effectiveness of national extension services in developing countries for not achieving desired adoption levels (Addo et al 2001, Chaves & Riley 2001, Or 2003). IPM is a complex knowledge-intensive technology that is expected to reduce environmental and health (E&H) risks associated with pesticide use without affecting crop profitability (Fernandez-Cornejo et al 1998, Kenmore 2002). These combined benefits should encourage farmers to adopt IPM broadly, but the empirical evidence seems to indicate that either extension systems have failed to communicate adequately all the potential benefits of IPM adoption or that adopting IPM has not provided all expected benefits.

Farmer field schools (FFS) have recently received major support from development agencies as an alternative extension method that would improve the delivery of IPM (Feder et al 2004a). By using participatory techniques and the "learning by doing" approach FFS seek to combine the scientific knowledge and the practice of IPM with farmers' experience and interests, making these farmers the main actors of the technology development (Gallagher 1998, Kenmore 2002). In addition, it is expected that FFS graduates will convince other farmers about the value of IPM and increase its diffusion (Fleischer et al 1999). The farmer based orientation of FFS is believed to be especially suitable for dealing with the complexity of IPM and its combined potential benefits.

Economic impact analysis of IPM adoption and FFS implementation in developing countries has mainly concentrated on changes on the level of knowledge about IPM (Hussain et al 1994, Godtland et al 2004, Feder et al 2004b) or on measuring farm level effects (Walker & Crissman 1996, Feder et al 2004a, Swinton 2005). While farmers' knowledge of IPM usually increases after participating in IPM training programs, studies of IPM profitability have shown mixed results and no clear advantages of IPM over chemical control options (Morse & Buhler 1997, Feder et al 2004a). In spite of the growing recognition that there exist hidden costs related to the environmental and health effects derived from pesticide use (Rola & Pingali 1993, Crissman et al 1998 and Maumbe & Swinton 2003), and that IPM adoption could help to reduce them, these costs have been omitted from virtually all prior impact studies of IPM adoption. Incorporating these environmental and health effects in the analysis could help to improve understanding of farmers' decisions about pest control.

This paper expands the traditional impact assessment of IPM delivery by adding the E&H effects derived from its adoption. The recent implementation of farmer field schools (FFS) among Nicaraguan bean growers serves as a case study. Using farm level data from a recent cross sectional survey among Nicaraguan bean growers, this paper first measures econometrically the standard economic impacts of farmer participation on IPM training on pesticide use, adoption of IPM non-chemical practices and on bean yields and net revenues. This farm level analysis distinguishes between FFS participation and traditional IPM training programs, and it controls for the potential endogeneity associated with participation in extension programs (Strauss et al 1991, Owens et al 2003, Feder et al 2004a) using instrumental variables. It also tests whether the diffusion effect of FFS exists. Next, the paper incorporates the E&H impacts and measures the effect that FFS and other IPM training programs have had on human health and environmental services. Health impacts are represented by farmers' self-reported acute illness symptoms, and environmental impacts are represented by self-reported on-farm populations of beneficial insects.

Results highlight the importance of correcting for endogeneity in program participation. The paper shows how failure to correct for endogeneity sharply exaggerates benefits from FFS participation. Not only did FFS produce no significant gain in graduates' bean yields and incomes, FFS in Nicaragua failed to improve household health and levels of beneficial insects in comparison with alternative IPM training programs. The paper discusses how farmers' production conditions, the complexity of IPM and the length of FFS training in Nicaragua can explain these results and identify more promising IPM extension approaches.

2. Farmer field schools and the delivery of IPM

Integrated Pest Management (IPM) is a group of pest management practices aimed to reduce E&H risks using information about pest biology. One cornerstone principle is the idea of keeping a crop pest infestation below an economic threshold level: the pest level at which control measures are necessary to prevent decline in net returns (Fernandez-Cornejo et al 1998, Bajwa and Kogan 2002). Pest control methods may include pesticides when necessary, but also non-chemical inputs and specialized practices such as agro-ecological analysis[5], botanical insecticides, insect sticky traps and others (Fernandez-Cornejo et al 1998).

The potential benefits of IPM are expected to encourage farmers to adopt IPM broadly. However, IPM is a complex knowledge-intensive management approach that poses big challenges to the extension channels in charge of its diffusion (Sorby et al

[5] This practice consists in a permanent observation of the crop field and the use of insect scouting as the main activity. It will determine whether pest infestation has reached the economic threshold level.

2003). The delivery of IPM requires knowledgeable extensionists with sophisticated communication skills (Lagnaoui et al 2004).

Like most of extension efforts in developing countries, the delivery of IPM has mainly followed the training and visit (T&V) approach (Benor et al 1984), based on short field visits to selected farmers who are put in charge of delivering technical packages to neighbor farmers (Piccioto & Anderson 1997). This extension approach has been criticized for being "top down" and for failing to organize farmers adequately (Hussein et al 1994). Training and visit methods are alleged not to have provided the farmer-based approach required for dealing with the complexity of IPM and have failed to disseminate all potential benefits associated with IPM adoption (Cowan & Gunby 1996). The result has been low adoption rates of IPM within the developing world (Addo et al 2001, Chaves & Riley 2001, Or 2003).

In the search for more suitable IPM extension approaches, Farmer Field Schools (FFS) have received major support from development agencies that include the FAO and the World Bank (Feder et al 2004a). FFS were first established in Asia at the end of the 1980's. FFS use participatory techniques and combine the scientific knowledge and the practice of IPM with farmers' experience and interests under the learning by doing approach (Gallagher 1998). Within this new approach, farmers are believed to incorporate their priorities, develop more skills and become the main actors in the decision making process of the technology adoption (Kenmore 2002). In addition it is expected that FFS graduates will be more able to convince other farmers about the IPM value and increase its adoption (Fleischer et al 1999, Quizon et al 2001).

Following reports of beneficial impacts from the first FFS attempts, FFS have been implemented worldwide as the preferred method for delivering IPM. Unfortunately, most of the positive, early assessments were not based in economic impact studies that properly controlled for pre-existing differences among FFS graduates, other IPM training program participants and farmers insulated from any IPM exposure (Feder et al 2003, Godtland et al 2004). The failure to address this potential endogeneity problem could have caused extension impact estimates to be overestimated (Strauss et al 1991, Owens et al 2003). In addition, most economic impact studies of IPM delivery (FFS and otherwise) have ignored the expected E & H impacts, concentrating instead on farmers' knowledge of IPM and farm level profitability (Rola et al 2002, Feder et al 2004a & 2004b, Godtland et al 2004). This paper addresses both the endogeneity problem and the E&H impacts in a comprehensive assessment of FFS among Nicaraguan bean farmers.

3. FFS experience among Nicaraguan bean growers

Nicaraguan agriculture is characterized by high agrochemical use compared to most developing countries. It has one of the highest rates of pesticide consumption per capita in the developing world with 1.5 Kg per person per year (PAHO 2002). The relatively high pesticide consumption among small farmers has started to harm human health and insect biodiversity in the area. A recent study estimates that 400,000 pesticide poisonings may occur each year with 5% of people exposed to pesticides experiencing illness symptoms (PANNA 2002). It is also reported that farmers in Central America recognize that the overuse of pesticides is destroying the beneficial insect population (Bentley and Andrews 1996). These problems have led to a search for less harming farming systems.

IPM training in Nicaragua is not new, and efforts to deliver this technology have existed for the past 20 years. Following IPM initiatives that started in developed countries, many local and regional research and development institutions have organized IPM training programs in order to reduce the use of pesticides and to increase the adoption of IPM practices (Bentley & Andrews 1996, Cobbe 1998, Staver & Guharay 2003). Unfortunately, up to 2001 adoption of IPM had not reached desired levels (Bentley et al 2001, PROMIPAC 2001).

In order to improve the adoption of IPM in Nicaragua, the Project for Integrated Pest Management in Central America (PROMIPAC) has promoted the implementation of Farmer Field Schools (FFS) since 2001.In this country, FFS have been implemented by a group of non-governmental organizations (NGOs). Most of these NGOs had previous experience in delivering IPM and have simultaneously kept using the training & visit approach with other clients while implementing FFS. This feature allows a natural comparison of FFS and T&V. All the NGOs had a common starting point in the FFS implementation: sending extension agents to participate in an intensive training for trainers program. In this program, extension agents learned their new role as facilitators on the extension process, several participatory research techniques, and many new scientific concepts related to IPM (PROMIPAC 2001). At the end of the training program, facilitators were able to offer different alternatives to solve farmers problems, especially ones related to pest control. Based on the training of trainers, differences in curricula among individual FFS should only be attributed to different farmers' preferences, not NGO implementation.

Nicaraguan FFS were developed to last for only one year conducting 13 weekly sessions[6] and developing a curricula that included IPM concepts (pest biology, diseases, predators, biological control, etc), field practices (mainly three IPM practices: Agro-ecological analysis, botanical insecticides and yellow sticky traps) and on-farm group experimentation (comparison of an IPM plot with a conventional crop plot, different level of fertilization, alternative varieties resistant to diseases). There were no follow up activities planned after FFS graduation. Before finalizing the training program, each FFS organized open field visits with community neighbors in order to share graduates' new knowledge and experience (PROMIPAC 2002, 2003). The rate of graduation reached more than 80%, and more than 1000 farmers participated in Nicaraguan FFS between 2001 and 2003. Out of this total, around 200 farmers participated in the 13 bean FFS (PROMIPAC 2001). According to preliminary evaluations, FFS graduates increased their IPM knowledge by 40% (PROMIPAC 2001). However the impact of this knowledge improvement on health and environmental outcomes remained unknown. The rest of the paper conducts an expanded economic impact study.

4. The analytical framework

In order test the impacts of FFS and other IPM training programs on households' outcomes, this paper presents a brief model of farm household behavior. Under the agricultural production household approach (Singh et al 1986) the following utility function is assumed:

$$U=U(X_f, X_{nf}, X_l, H) \qquad (1)$$

[6] This is the average time for a crop season in Nicaragua

Each household derives utility from the consumption of farm goods (X_f), non-farm goods (X_{nf}), leisure (X_l) and household health (H). Farm goods are produced according to the following household production function:

$$Q_{Xa} = Q_{Xa}[D(P, Z_c(K), Z_{nc}(K)), L(H), A, E \ / \ C_H] \qquad (2)$$

where

$$K = K(T \ / \ C_H)$$

The level of farm production (Q_{Xa}) depends on a damage function (D), the use of labor (L), household assets (A) and environmental services (E). It is also influenced by household characteristics and other shifters (C_H). The damage function represents the potential damage that pest and diseases can cause to farm production and depends on the pest pressure (P), the use of chemical inputs (Z_c) and the use of non-chemical inputs (Z_{nc}) like IPM practices. In addition, both the level of chemical (pesticide) and non-chemical input use are determined by the knowledge (K) that farmers have about the pest and diseases and about the available pest controls. This level of knowledge is influenced by IPM training (T) and household characteristics (C_H). It is expected that labor is increasing in household health that has the following household production function:

$$H = H(H_0, X_a, Z_h, Z_c \ / \ C_H) \qquad (3)$$

Household health has a natural status (H_0) that are determined by early nutrition, health care and others factors not analyzed in this research. Health can be augmented by consuming goods (especially food) and health inputs (Z_h) like health care services and protective devices, but health is assumed to be diminished by the use of chemical inputs ($H'(Z_c) \leq 0$). Environmental services (E) do not directly affect household utility, but they benefit household welfare by enhancing crop production. E is represented by beneficial insects and has the following production function

$$E = E(E_0, Z_c / C_H) \qquad (4)$$

Beneficial insects have a natural endowment (E_0) and are affected negatively by chemical use ($E'(Zc) \leq 0$). The level of beneficial insect population can be also affected by household characteristics.

IPM training has an indirect effect on farm production through knowledge and hence chemical and non-chemical input use. We can expect that $X_a'(Z_c)$ and $X_a'(Z_{nc})$ will be positive because a greater use of both inputs will reduce crop damage and less crop damage will increase farm production (positive cross partial derivatives). However, the effect that better knowledge will have on chemical and non-chemical input use ($Z_c'(K)$ and $Z_{nc}'(K)$) is unknown. Households with better knowledge about pests and controls will know better when the pest pressure has reached the economic threshold and what is the best control for that situation. But better information could imply higher use of chemical and non-chemical inputs if the pest pressure becomes high. It could also mean less of both inputs if the agro-ecosystem analysis results on a low requirement for control. Similarly, the effect of IPM training on household health and beneficial insect populations is also analytically indeterminate.

Each IPM training method (T) has a different influence on the level of knowledge about pests and their management. Greater exposure to IPM training will increase participants' knowledge (K'(T)>0). It is also expected that farmers exposed to IPM training will disseminate that training via interaction with neighbors.

The household utility maximization problem is completed by incorporating the household full income constraint:

$$Y = P_a X_a + wL_s - P_{Zc} Z_z - P_{Znc} Z_{nc} - P_{Zh} Z_h - wL_h \quad (5)$$

where P_a, w, P_{Zc}, P_{Znc} and P_{Zh} are the exogenous prices for agricultural goods, labor, chemical inputs, non-chemical inputs and health inputs. Solving the household utility maximization problem we can derive the reduced form for the factor demand functions for chemical inputs (Z_c) (pesticides) and non-chemical inputs (Z_{nc}) (IPM practices), as well as the household demand for health (H) and environmental services (E), and the bean yield (Q_{Xa}) and net revenue function (Y_b)s based on some set of explanatory variables:

$$B = Y_b(P_a, P_{Zc}, P_{Znc}, P_h, w, A, T, C_H) \quad (6)$$

where B is a vector representing Z_c, Z_{nc}, H, E, Q_{Xa} and Y_b.

The main task in this paper is to measure econometrically the coefficients of the T vector that contains the estimated impacts of FFS, other IPM training methods and the expected diffusion effect on the above input demand, output supply and net income functions. Five testable hypotheses are related to the assumptions underlying most of IPM delivery programs:

- IPM training and especially FFS should:

  a) Increase the adoption of IPM practices

  b) Decrease pesticide use

  c) Increase crop yields and net revenues.

- Similarly it is also expected that

  d) Farmers in direct contact with FFS graduates will experience similar effects.

  e) FFS and other IPM training methods will improve H & E outcomes (presumably a side effect of decreased pesticide use)

5. Empirical Analysis

5.1. Data

Farm level data were collected for this study between May and August 2004 via a cross-sectional survey of 436 households of Nicaraguan bean growers in the departments of Estelí, Matagalpa, Jinotega, Madriz, Masaya and Carazo. The sampling design followed a double stratification (Deaton 1997) based on exposure to IPM training in FFS and other programs and covering diverse production settings in the main bean production areas. Households were interviewed in 74 rural communities, including 13 where FFS were implemented, 9 where FFS graduates lived but no FFS were held, 26 communities selected randomly where no FFS existed but other IPM extension services were available[7], and 26 communities selected randomly where no IPM extension was present. In each community, households were selected randomly and included both clients and

[7] Other IPM extension services refers to the training and visit (T&V) approach that was mainly provided by the same NGOs in charge of FFS implementation but usually targeted for NGOs clients who did not participate in FFS.

non-clients of NGOs. The final sample included FFS graduates, farmers participating in other IPM programs, farmers who experienced double IPM training (by both FFS and other means), neighbor farmers of FFS graduates and farmers with no prior contact with formal extension.

5.2. Potential econometric problems

The main potential econometric problem of this research is endogeneity associated with self selection of farmer participants in IPM extension programs and the non-random placement of these programs. Many studies have recognized that failure to correct this problem produces biased estimates of the extension service impact, that usually result in overestimates (Strauss et al 1991, Owens et al 2003, Feder et al 2004a).

The FFS in Nicaragua were located at sites with good access for meetings and experimentation that could capitalize on pre-existing farmer-NGO relationships. Farmers with good pre-existing relationships with NGOs could have been more willing to participate in IPM training whereas those with poor NGO relationships could have been less so.

This paper evaluates first the convenience of using two stage least squares (2SLS) estimation to correct selectivity bias in the econometric estimation, which is the preferred method in linear models with cross sectional data (Wooldridge 2002a). Some models in this paper have a clear non-linear nature and would be more suitable for a trivariate probit, ordered probit or multinomial logit specification, but correcting selectivity bias in non-linear models through the recommended "control function approach" generates computational problems that can only be applied under normality conditions (Wooldridge 2002a, Wooldridge 2002b, Blundell & Powell 2004). But as Angrist (2001) pointed out, standard instrumental variable estimation can still be applied to non-linear models when the objective is to estimate the causal effect of the endogenous variables. Wooldridge (1997) also showed that 2SLS could still be applied in a random coefficient model with a binary endogenous variable when this variable follows a linear probability model, the linear approximation of models with binary dependent variables as the adoption of IPM practices case. Even recognizing the non-linear nature of some models, this paper will mainly use 2SLS procedures. Only when exogeneity cannot be rejected in some linear approximations, this paper prefers non-linear models.

The sample design poses secondary econometric problems of a clustered and stratified sample that can bias the parameter estimates (Wooldridge 2002a). To deal with the clustering problem, this paper adjusts the variance matrix and includes dummy variables for each cluster using survey regression methods (Wooldridge 2003). This method is suitable given the nature of the sample design that has small clusters (six households per village on average) and a large number of clusters (74 villages). To correct the unbalanced representation of farmers (especially FFS trainees) in the sample, this paper uses a weighting scheme as suggested by Wooldridge (2002a) to adjust results to the population of bean all bean growers (see Appendix A.3 for details).

5.3. The econometric specification

This paper specifies three linear models for pesticide demand, one linear model and three linear probability models for the adoption of IPM practices, one linear model for the bean yield function, one linear model for the bean net revenue function, four ordered probit models for the household health demand and one ordered probit and one probit for the household demand for environmental services. All linear specifications are estimated by 2SLS. The non-linear models are used when the exogeneity could not be rejected in the linear approximations of these models.

All models have the same set of explanatory variables, following the general model structure:

$$D_J = P_K\beta_P + T_T\beta_T + C_H\beta_{CH} + C_C\beta_{CC} + U \quad ; \text{For } j=1,\ldots 13 \qquad (7)$$

Each dependent variable (Z_c, Z_{nc}, H, E, Q_{Xa} and Y_b) depends on vectors of K output and input prices (P_K), household participation in the T IPM training program (T_T), socioeconomic and other household characteristics (C_H) and community fixed effects (C_C), with disturbances assumed to be independently distributed (U_i). All variables used in the econometric estimation are described in detail in the following subsections.

This paper uses the predicted probability of each IPM training program participation (FFS and other programs) as generated instruments of the true program participation in all the 2SLS models. Each predicted probability is estimated using a probit specification that has as explanatory variables the original exogenous variables and some redundant variables that explain the variation of FFS and other IPM program participation (Wooldridge 2002a). The structure of each probit specification uses the same set of explanatory variables as the previous models plus a vector of Z variables containing the redundant variables related to participation in IPM training, but believed to be uncorrelated with the disturbance term of the IPM adoption, pesticide demand, bean yields, net revenue and E&H outcomes equations (see second table of Appendix A.8).

5.3.1. The dependent variables

Household input demand for insecticides, herbicides and fungicides is represented by the quantity of pesticide active ingredients used by each household in bean production during the most recent season in 2003 weighted by acute human toxicity. A human toxicity index is calculated for each household i as the sum over all m pesticide active ingredients (ai_{ik} in kg/ha, k=1,...,k) divided by each active ingredient's mammalian toxicity (measured by the minimum dose per gram of body weight that is lethal to 50% of a test rat population or LD50, as reported in USDA, 1998). The human toxicity index, show below, is proportional to the LD50 and is increasing in lethality.

$$HTI_i = \sum_k \frac{ai_{ik}}{LD50_{ik}}$$

The adoption of the three specific IPM practices promoted in FFS is represented by binary variables that indicate whether a household adopted agro-ecological analysis, botanical insecticides and/or yellow insect traps and a variable that measures whether a household adopted one, two or the three IPM practices. As explained before this paper uses a linear approximation for these non-linear models.

Health outcomes are measured as changes in the incidence of four acute illness symptoms among household members (respiratory difficulties, eye irritation, stomach ache and blurred vision[8]). Each dependent variable measures whether a household experienced a decrease, no change or an increase (-1, 0, 1) in the incidence of each acute

[8] Other models were considered for changes in the number of acute symptoms and for changes in the incidence of diarrhea, headache, skin rash, dizziness and muscle pain but the null hypothesis of the joint significance of the overall model could not be rejected.

symptom during the most recent season in 2003 compared to average symptom incidence prior to FFS participation or contact.

The beneficial insect outcomes are represented by two responses. The first was a 3 point Likert scale of on-farm beneficial insect population levels during the most recent bean season[9]. The second was whether farmers reported having observed an adequate level of beneficial insects for controlling, at least partially, their pest problems in beans.

As the beneficial insect observation was restricted to farmers participating in FFS and other IPM training programs, the sample size is reduced in both models to 144 and 212 observations respectively.

Bean yield is a continuous variable measured in kg/ha during the most recent season in 2003. Bean net revenue is an expected measure in US$/ha based on farmers' self-reported revenues and cost for the same bean season.

5.3.2. The explanatory variables

Output prices are selling prices for bean and maize reported in US$/kg. Input prices include bean seed, metamidophos insecticide, gramoxone (paraquat) herbicide and mancozeb fungicide[10]. The bean yield and net revenue functions also included the price of fertilizers[11]. Other prices and price proxies are the transport cost to the nearest market of a sack of beans or maize and the distance between each farm and the municipal capital. Other production variables include the most recent farming season that bean were grown: *primera*, *postrera* or *apante*, the use of disease resistant bean varieties, altitude (proxy for

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[9] The main beneficial insects related to bean production in Nicaragua are: *Eretmocerus serious*, *Chysopa oculata*, *Hippodamia convergens* and *Encarsia spp.*

[10] Metamidophos, paraquat and mancozeb were by far the main active ingredients among insecticides, herbicides and fungicides on the Nicaraguan farms surveyed in 2004

[11] we use the price of the most common combination of nitrogen, phosphorus and potassium (12-30-10)

rainfall and temperature) and farmers' observed level of bean pests and diseases (high or not).

IPM training participation is specified for FFS graduates, other IPM training program participants and the interaction of the two[12]. Neighboring farmers influenced by FFS graduates are also specified, and households without IPM training contact are kept as the control group. It is also included the number of years after FFS graduation. Given that each FFS took place during only one year, this variable measures the years that farmers had for implementing what they learned after FFS graduation.

Household characteristics are represented by two groups of variables: (1) measures of household assets: farm size, area under irrigation, number of cattle, whether family has electricity at home, and whether the household receives remittances from relatives working in foreign countries; and (2) measures of household composition: gender of household head, age and years of education of household head, percentage of females, and percentage of family members under 14 years old. Other conditioning variables include whether the household relied upon hired labor or family labor for pesticide application and whether household members used protective devices like mask, gloves or special clothing while applying chemicals. Dummy variables are included for community-level fixed effects, with one of them kept as a control. The 73 community dummies are used for the 2SLS estimations, but are substituted by municipality dummy variables (9 out of the 10 municipalities) in the estimation of the predicted probability of FFS and other IPM training participation.

Finally, redundant variables are used to control for endogeneity of extension participation. All these variables measure pre-existing linkages between individual NGO

[12] There were 35 FFS graduates who had previous participation in other IPM training programs

and client farmers, including whether households received previous credits from the NGO, whether they received food assistance or any cash support, and whether they adopted soil conservation practices prior to their IPM training (terraces, contour lines and live fences). As shown in Appendix A.8, many of these redundant variables meet the first condition for a good instrument by significantly explaining farmer participation in FFS and other training programs. These variables seem to also meet the second condition for a good instrument: they not be correlated with the variables that explain part of the variability of the household demand models but were not observed. Credits and other NGO support received by farmers prior to the most recent bean season should not influence their decisions about the level of pesticide use or the adoption of IPM practices during the season. Neither should E&H effects derived from pesticide use decisions be correlated with redundant variables that are unrelated to the most recent bean season. Nor should prior adoption of soil conservation practices condition farmers' decisions about pesticides and non-chemical practices used during the most recent bean season. The adoption of terraces, contour lines and live fences are not related to the levels of pests and diseases or the associated pest control measures. The characteristics of these variables make them suitable for specifying robust IV models that will be tested for correcting endogeneity of farmer participation in FFS and other IPM programs.

6. Results

Table 2.1 presents the main differences in households' farm, health and environmental outcomes among the five different groups of farmers according to their exposure to IPM training. Although less pesticide use is expected among farmers exposed to IPM training, only FFS graduates reported a lower proportion of insecticide users (even lower for FFS

Table 2.1. Differences in pesticide use, adoption of IPM practices and bean yields and net revenues among five groups of Nicaraguan bean growers during 2003 bean season.

	FFS	Other IPM	FFS&IPM	Influenced	Insulated
Number of farmers	90	129	35	51	131
Pesticide user on beans					
Insecticides (%)	66	82*	54*	80*	78*
Herbicides (%)	56	50	43*	61	64
Fungicides (%)	19	29**	34***	17	12*
IPM adoption (%)					
Agro-ecological Analysis	61	32***	69	2***	1***
Botanical Insecticides	56	55	83**	3***	2***
Insect traps	30	22	48**	1***	1***
Bean yields (kg)	708	678	916**	884*	637*
Bean net revenues (US$)	132	120	190**	190**	109
Gross revenues	240	233	304**	274	209*
Total cost	108	113	114	84*	100
Pesticide cost	16	18	10**	17	19
Farmers with losses (%)	24	26	17**	10***	17**
Changes health outcomes(%)					
Decreased resp. difficulties	5.6	6.7*	5.7	9.7**	8.4**
Increased resp. difficulties	0.0	0.7	0.0	0.0	0.8
Decreased eye irritation	15.6	28.9***	42.9***	22.6**	28.2***
Increased eye irritation	1.1	0.7	0.0	0.0	0.0
Decreased stomachache	13.3	16.1*	11.4	19.4**	13.7
Increased stomachache	0.0	0	0.0	0.0	0.8
Decreased blurred vision	10.0	22.1**	17.1*	35.5***	18.3**
Increased blurred vision	2.2	2.7	2.9	0.0	0.8
Changes beneficial insects+					
Observed higher level	35.1	52.6	67.9		
Observed lower level	45.6	15.8	14.3		
Adequate level	21.1	4.7	37.1		

Significantly different from FFS at 10% (*), 5% (**) and 1% (***) levels using $\chi 2$ test.
+ Only farmers exposed to IPM training observed beneficial insects.

graduates who had participated previously in other IPM training programs). However, farmers exposed to T&V IPM extension and FFS neighbor had the greatest proportion of insecticide users. There were very few significant differences across groups of farmers in the proportion of herbicide users; only a double (FFS plus other) IPM training reduced the proportion of users. Finally, fungicide users were unexpectedly more common among participants in any IPM training program. This could have resulted from IPM training improving farmers' ability to determine the economic threshold for disease control, so it is not necessarily a bad outcome.

The adoption of IPM practices is restricted almost exclusively to farmers directly exposed to IPM training. There was no spillover effect of FFS to farmer neighbors of FFS graduates. FFS showed no significant advantage over the T&V approach at inducing greater adoption of IPM practices. FFS were more likely to adopt agro-ecological analysis, but no more likely to adopt botanical insecticides and insect sticky traps than other IPM-exposed farmers (Table 2.1).

Bean yields and net revenues were significantly higher among farmers exposed to double IPM training and among neighbor farmers expected to be influenced by FFS graduates. These results are another reason for testing a potential endogeneity problem in FFS participation. More productive and profitable farmers could have been excluded from FFS or could have not elected to participate.

Health outcomes improved significantly among all groups, but FFS graduates experienced the lowest improvement in the incidence of the four acute health symptoms associated with pesticide use (Table 2.1). Even farmers with no IPM training participation had better health outcomes during the 2003 bean season closest to the early 2004 farm survey. Farmers who participated in other IPM training programs or experienced both FFS and other IPM training had a greater reduction in the incidence of eye irritation (Table 2.1). Environmental outcomes were observable only among farmers who had attended IPM training programs. Forty six percent of FFS graduates observed a lower level of beneficial insects on their farms in comparison with the most recent 2003 bean season while 35% observed higher level of these beneficial insects. Other IPM training participants and farmers who received a double IPM training observed more beneficial insects.

Table 2.2. Descriptive statistics for selected variables used in the survey least squares for 436 Nicaraguan bean growers, 2003-04+

Variable description	Mean	Std Dev.
Dependent Variables		
Index of insecticides weighted by toxicity (x 100)	2.9	5.1
Index of herbicides weighted by toxicity (x 100)	0.5	0.7
Index of fungicides weighted by toxicity (x 100)	0.1	0.6
Adopted agro-ecological analysis (%)	28.2	
Adopted botanical insecticides (%)	35.1	
Adopted insect yellow traps (%)	15.8	
Adopted only one IPM practice (%)	19.1	
Adopted two IPM practices (%)	14.9	
Adopted three IPM practices (%)	10.8	
Bean yields (kg/ha)	688.0	578.0
Bean net revenue (US$/ha)	91.2	124.9
Changes in Acute illness symptoms		
Number	-1.8	2.4
Respiratory difficulties (-1,0,1)	-0.1	0.3
Eye irritation (-1,0,1)	-0.3	0.5
Stomachache (-1,0,1)	-0.1	0.4
Blurred vision (-1,0,1)	-0.2	0.4
Level of beneficial insects (1,2,3) (N=144)	2.1	0.9
Observed enough beneficials (%)	9.0	
IPM training		
FFS participation (%)	20.6	
Other IPM training participation (%)	34.2	
FFS and other IPM participation (%)	8.0	
Influenced by FFS graduates	12.0	
Years after FFS graduation	2.3	1.7

+ Complete list of variables in Table A.3.1 (appendix)

Descriptive statistics for variables in the econometric analysis are summarized in Table 2.2, while selected regression results related to the impact of FFS and other IPM training programs on farm, health and environmental outcomes are showed in tables 2.3, 2.4, 2.5, 2.6 and 2.7. Hausman tests were performed in all models in order to test the need for endogeneity correction in 2SLS models. The three pesticide demand models and both the bean yield and net revenue models have a clearly linear nature, so using 2SLS seems to be the most appropriate to control for endogeneity of training program participation. In most of these models, the exogeneity hypothesis was rejected (Tables 2.3 & 2.5) suggesting that the IV estimates are more suitable. Only in the fungicide demand model could the exogeneity hypothesis not be rejected (Table 2.3), making the OLS estimates preferred in this case.

The adoption of IPM practices, the changes in the incidence of acute illness symptoms and the level of beneficial insects are integer dependent variable models that are clearly non-linear. However, after performing Hausman tests to their linear approximation, the null hypothesis of exogeneity could not be rejected in any of the health and environmental models (See appendix A.8 for details), so ordered probit and probit specifications are used. Two 2SLS models are used to estimate IPM adoption due to evidence of endogeneity in all adoption decisions except insect yellow traps (Table 2.4).

Econometric results show that the assumptions underlying most IPM programs did not hold for FFS. FFS participation had no significant impacts on pesticide use (hypothesis a), adoption of IPM practices (hypothesis b), bean yield or bean net revenue (hypothesis c) (Tables 2.3, 2.4 and 2.5). There was strong evidence of endogeneity in FFS participation and failing to control for this problem provides erroneous estimates of FFS impacts. Like many previous studies, the OLS estimates indicate that FFS graduates adopted more IPM practices than farmers without IPM training, increased the probability

Table 2.3. The effect of FFS and other IPM training on IPM adoption. Survey least squares regression results for 436 Nicaraguan bean growers, 2003-04[+]

	Number of practices	IV Number of. practices	Scouting[++]	IV Scouting	Botanical insecticides	IV botanicals insecticides	Insect traps	IV Insect traps
FFS	1.188***	0.907	0.665***	0.139	0.372**	0.534	0.166	0.180
	(3.80)	(0.82)	(3.96)	(0.24)	(2.04)	(0.85)	(1.39)	(0.44)
Other IPM	0.692***	1.286***	0.155***	0.381**	0.398***	0.647***	0.141***	0.249**
	(9.70)	(3.71)	(3.35)	(2.15)	(7.43)	(3.48)	(5.03)	(2.01)
FFS & IPM	-0.118	1.463	-0.240	0.591	0.002	0.713	0.518	0.291
	(0.37)	(1.11)	(1.31)	(0.95)	(0.01)	(0.93)	(0.87)	(0.65)
Influenced	-0.172*	0.025	-0.037	0.003	-0.067	0.032	-0.065*	-0.018
	(1.67)	(0.12)	(0.91)	(0.03)	(0.83)	(0.25)	(1.79)	(0.26)
Years after grad.	0.066	-0.175	-0.060	0.020	0.090	-0.178	0.044	-0.000
	(0.43)	(0.36)	(0.69)	(0.08)	(1.11)	(0.63)	(0.74)	(0.00)
Hausman test								
F statistic		4.68		2.13		3.88		0.38
P value		0.0015		0.0808		0.0052		0.8223

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] Complete regression results are shown in appendix A.8. (including the first-stage model for the IV estimation)
[++] Insect scouting is the main activity of agro-ecological analysis

of adopting insect scouting and botanical insecticides, and reduced slightly the toxicity-weighted insecticide use.

These results on FFS impacts in Nicaragua are consistent with Feder et al's (2004a) findings among Indonesian FFS graduates, but not all their explanations about FFS poor performance are applicable to the Nicaraguan case. One possible cause of the failure of Indonesian FFS was complexity of the IPM knowledge gained (Feder et al., 2004). However, in the Nicaraguan case, participants in the "other IPM" training (following T & V approach) were able to significantly increase the likelihood of adopting insect scouting by 38%, botanical insecticides by 65% and insect scouting by 25%.

Table 2.4. The effect of FFS and other IPM training on pesticide use. Survey least squares regression results for 436 Nicaraguan bean growers, 2003-04⁺

	Insecticide	IV Insect.	Herbicides	IV Herb.	Fungicide	IV Fung.
FFS	-0.027**	-0.106	0.003	-0.007	0.001	0.001
	(2.38)	(0.90)	(1.42)	(0.65)	(0.75)	(0.29)
Other IPM	0.004	-0.002	0.001	0.001	0.000	0.002
	(0.53)	(0.09)	(1.47)	(0.84)	(0.58)	(1.20)
FFS & IPM	0.007	-0.156	-0.007*	-0.026*	-0.001	-0.001
	(0.54)	(1.04)	(1.94)	(1.66)	(0.80)	(0.17)
Years after grad.	0.007	0.042	-0.002*	0.003	-0.000	0.000
	(1.12)	(0.93)	(1.86)	(0.77)	(0.32)	(0.25)
Influenced	0.003	-0.017	0.001	-0.001	-0.001	-0.000
	(0.53)	(0.83)	(0.94)	(0.33)	(0.90)	(0.06)
Hausman test						
F statistic		4.36		2.01		1.46
P value		0.0024		0.0971		0.2179

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
⁺ Complete regression results are shown in appendix A.8.

Hence, complexity of IPM methods cannot explain the lack of beneficial impacts among FFS graduates. Unfortunately, farmers trained first in IPM through T&V did not improve their farm outcomes after repeating the IPM training through FFS (Tables 2.3, 2.4 & 2.5)

On the other hand, poor production conditions among small farmers related to soil and pest levels could reduce impacts of IPM extension in ways that could be difficult to measure through econometric analysis in Indonesia and Nicaragua (Feder et al 2004a). In the Nicaragua case, this can be observed among farmers who participated in both FFS and other IPM training. Although these farmers had the greatest bean yields and net revenues among all the interviewed farmers (Table 2.1), the IV regression results indicate that participating in both types of IPM training has no effect on bean yields and net revenues. If this happens with the best group of farmers, it is very likely that some variables related to production characteristics that are not observed by the analyst could explain these outcomes.

Table 2.5. The effect of FFS and other IPM training on bean yields and net revenue. Survey least squares regression results for 436 Nicaraguan bean growers, 2003-04+

	Yield	IV Yield	Net revenue	IV Net revenue
FFS	-0.439	-19.670	264.924	-276.0538
	(0.19)	(1.25)	(0.43)	(0.99)
Other IPM	-0.577	-2.650	-191.449	21.22
	(0.56)	(0.74)	(0.70)	(0.36)
FFS & IPM	1.234	0.715	-23.459	33.91
	(0.44)	(0.005)	(0.03)	(0.09)
Influenced	2.068	0.980	627.566	42.602
	(1.01)	(0.32)	(1.17)	(0.87)
Years after graduation	0.114	8.983	-114.307	136.4294
	(0.11)	(1.44)	(0.41)	(1.25)
Hausman test				
F statistic		3.29		2.59
P value		0.0132		0.0396

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ Complete regression results are shown in appendix A.8.

Hypothesis (d) seeks to test for the spillover effects of FFS implementation. Our results strongly support Feder et al's (2004a) findings FFS graduates did not produce any significant influence on their neighbors' IPM adoption or performance (Tables 2.3, 2.4 & 2.5).

Hypothesis (e) tests for the E & H effects that are expected to bring extra benefits to FFS graduates and other farmers exposed to IPM training. Although all groups of farmers experienced decreased incidence of acute illness symptoms during the most recent 2003 bean season compared to previous years (Table 2.1), FFS graduates gained less. In Table 2.6, the positive coefficients for changes in the incidence of respiratory difficulties and eye irritation do not imply an increase on the incidence of these symptoms, but they do imply that FFS participation induced a lower improvement in these health outcomes. This effect was partially offset by farmers with more years after FFS graduation in the instance of respiratory difficulty (Table 2.6). In addition, farmers who were first trained in IPM through T&V and then graduated from a FFS reduced the incidence of respiratory difficulties and eye irritation.

Table 2.6. The effect of FFS and other IPM training on household health outcomes. Survey ordered probit regression results for 436 Nicaraguan bean growers, 2003-04[+]

	Respiratory diffic.	Eye irritation	Stomachache	Blurred vision
FFS	1.137**	1.002*	0.156	-0.021
	(2.18)	(1.89)	(0.28)	(0.04)
Other IPM	0.009	0.218	-0.092	0.155
	(0.03)	(1.15)	(0.42)	(0.75)
FFS & IPM	-0.950*	-1.204*	-0.082	0.120
	(1.69)	(1.92)	(0.13)	(0.19)
Influenced	-0.341	0.636**	-0.276	-0.332
	(0.84)	(2.30)	(0.83)	(1.17)
Years after graduation	-0.452*	-0.156	-0.185	0.230
	(1.69)	(0.64)	(0.70)	(0.95)

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] Complete regression results are shown in appendix A.8

FFS also performed poorly on environmental outcomes. FFS alone do not have any significant effect on the level of beneficial insects by either measure (Table 2.7). Farmers who had attended other IPM extension programs observed greater levels of beneficial insects and were more likely to report an adequate level of beneficial insects to control bean pests. This group of farmers did not improve their environmental outcomes after receiving a second IPM training through FFS.

Table 2.7. The effect of FFS and other IPM training on environmental outcomes. Survey ordered probit and probit regression results for 436 Nicaraguan bean growers, 2003-04[+]

	Adequate level of beneficials	Level of beneficial insects
	N=212	N=144
FFS	0.747	-0.187
	(0.98)	(0.23)
Other IPM	0.873**	1.864***
	(2.35)	(4.91)
FFS & IPM	0.820	-0.281
	(0.99)	(0.36)
Years after graduation	0.464	0.492
	(1.35)	(1.35)

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] Complete regression results are shown in appendix A.8.

The inferior impact of the Nicaraguan FFS in comparison with other IPM training approaches can also be explained in part by the length of exposure to IPM training. While T&V extension used to keep their IPM programs for many years with most of the same farmers, FFS in Nicaragua lasted only one year with no follow up activities.

7. Conclusions

Impact analysis of educational activities requires accounting for pre-training differences among participants and among the control or comparison group. The Nicaraguan FFS experience shows that failing to correct for endogeneity associated with IPM training participation created a misleading impression of beneficial FFS impacts.

OLS regression estimates suggest that FFS graduates were more likely to adopt IPM practices and reduced the toxicity of their insecticide and herbicide use . However, after controlling for the endogeneity of farmer program participation through instrumental variable estimation, the results show no significant impacts of FFS among Nicaraguan bean growers.

FFS have received growing support from development agencies for delivering IPM, in spite of their high costs compared to other IPM training programs (Quizon et al 2001, Feder et al 2004b). Aid agencies usually expect that FFS will provide their graduates with greater farm, health and environmental benefits than the traditional Training and Visit (T&V) extension approach. Our results do not support these expectations. Instead, they show inferior performance of FFS compared to other IPM training programs in Nicaragua. Moreover, there was no evidence of an FFS diffusion effect among the neighbors of FFS graduates.

Why did FFS fail to make a difference? First, as Feder et al (2004a) found in Indonesia, the poor soil and high pest infestation levels associated with small farmers in developing countries could have limited the potential impacts of FFS. Even the group of surveyed farmers with the highest bean yields and net revenues had lower yields and incomes than average Nicaraguan levels in 2003 (FAOSTAT). Second, contrary to Feder et al's (2004a) claim that the complexity of IPM strongly impedes its delivery, the length of the implementation of IPM training programs seems to be more a relevant explanatory factor. In Nicaragua, bean farmers trained in IPM through the T&V approach increased their adoption of non-chemical IPM practices whereas FFS training had no effect. The main difference is that Nicaraguan FFS training lasted only one year, whereas the T& V

IPM training although less intensive was more continuous resulting in better farm, health and environmental outcomes.

Given the high cost of delivering IPM through FFS (Quizon et al 2001, Feder et al 2004bthe FFS extension approach should be reconsidered. This paper's findings support the recommendation of cost cutting and curricula prioritization in FFS programs (Feder et al 2004a). But they also suggest a need to prolong IPM training programs in order to guarantee more interaction between farmers and facilitators and an improved feedback process. Longer IPM training should not mean repeating the current costly FFS over many years. Rather the redesigned FFS should take advantage of cost savings from reduction and prioritization of FFS curricula while maintaining the active participation of farmers. Less investment per year could allow longer training without increasing extension costs. The combination of these two changes could overcome potential difficulties posed by the complexity of IPM and its delivery.

Although FFS did not provide better environmental and health benefits to their graduates, it is important to include these benefits in the economic impact analysis of IPM extension. This paper demonstrates that under the right conditions, the delivery of IPM can increase a farm's level of beneficial insects, which could help to control crop pests and eventually reduce the use of pesticides. Given the unknown direction of pesticide use under many IPM approaches, it is important to measure health outcomes. Farmer health should be improved by IPM training but as the Nicaraguan case shows, exposure to IPM training can sometimes result in negative health outcomes.

Future research is needed in order to improve the methods of incorporating E&H effects into an economic impact analysis. In addition to more accurate measures of acute health symptoms and beneficial insect populations (with the help of scientists from other disciplines), it would be desirable to include long-term health outcomes and off-farm environmental effects that are usually not observed by farmers who make pesticide use decisions.

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MULTI-INSTITUITIONAL IMPLMENTATION OF FARMER FIELD SCHOOLS AMONG NICARAGUAN BEAN GROWERS. DO DIFFERENT NGOS PERFORM DIFERENTLY?

ESSAY THREE

1. Introduction

The reduction of the public agricultural extension services in many developing countries has induced the entrance of new extension providers. Among these new providers, non-governmental organizations (NGOs) have received special support from international donor agencies (World Bank 1991, Wallace 1997) and have increased their participation in the delivery of agricultural technologies. Often, NGOs are seen as more efficient and cost-effective extension providers than governmental entities (Farrington et al 1993, Edwards & Hulme 1996, Reuchelin 2003) and as a better means to reaching poor farmers (Carney 1998). The increasing participation of NGOs in extension systems has also increased the pluralism of providers, usually highlighted as a desirable condition for increasing the extension supply (Qamar 2002, Sulaiman & Hall 2004). However, many other papers have warned that pluralism also introduces a variety of organizational characteristics and could affect the extension performance (Rivera & Gustafson 1991, Hashemi 1992, Hassan 1993, Robinson 1993, Christopolos 1996, Garforth & Lawrence 1997).

The impact of agricultural extension services has been broadly studied, but most of these studies have concentrated on measuring the impact on farmers' knowledge, technology adoption or farm productivity (Feder et al 1987 Birkhaeusen et al 1991, Strauss et al 1991, Hussain et al 1994, Owens et al 2003, Akobundu et al 2004). It has been recognized that impact assessment usually ignores the institutional framework of the extension process and the characteristics of the actors who facilitate this process (Raina

2003). The issue of how an increasing diversity of NGOs engaging in extension activities affects extension outputs has received no attention in the literature.

This essay analyzes how different characteristics of NGOs working as extension providers affect the delivery of agricultural technologies to farmers beneficiaries of this extension service. To achieve this objective we analyze the Nicaraguan experience implementing a multi-institutional project of farmer field schools (FFS) for disseminating integrated pest management (IPM) among bean growers. Using farm level data this essay 1) measures the effect of FFS participation on farmers' pesticide use, adoption of IPM practices and bean net benefits and 2) evaluates whether the FFS effect is influenced by the different characteristics of the different NGOs participating on the FFS implementation.

This paper first provides a summary of the increasing participation of NGO in the extension services of developing countries in section II and specifically describes the Nicaraguan case in section III. Section IV presents the analytical framework of the paper that includes the sample design and the empirical strategy. Section V presents the results and finally section VI summarizes policy implications and conclusions.

2. NGOs and their participation as extension providers in developing countries

Public agricultural extension in developing countries has been largely criticized for not being relevant and for having produced insufficient impact (Rivera & Gustafson 1991, Chapman & Tripp 2003). In addition, the recent wave of structural adjustment programs has produced severe budget cuts that have reduced the presence of governmental entities in the national extension services (Farrington 1994). The generated shortage of extension services in developing countries induced the entrance of new providers that include non-governmental organization and private institutions (Carney 1998, Qamar 2002).

The debate persists on whether developing countries can succeed in promoting broader private extension services (Rivera 2001, Eaton & Shepard 2001, Rivera & Zijp 2002). So far many papers have highlighted the private sector's limitations for reaching all potential beneficiaries (Berdegué 1997, Rivera 2001, World Bank 2002). Non-governmental organizations are considered more efficient and cost-effective providers than public institutions (Farrington et al 1993, Edwards & Hulme 1996, Reuchelin 2003) and especially the best mean to reach the poorest and to develop strong relationships with local farmer organizations (Carney 1998, Farrington and Bebbington 1994). These characteristics have led international donor agencies to support greater participation of NGOs in developing countries' extension systems (World Bank 1991, Wallace 1997).

NGOs have been encouraged to initiate extension services because a pluralism of extension providers is considered desirable for the new conceptualization of national extension systems (Qamar 2002, Sulaiman & Hall 2004). However, this pluralism has also introduced a diversity of institutional characteristics that vary from institution to institution and have led some studies to question the accepted wisdoms of NGO advantages for delivering agricultural technologies (Bebbington & Thiele 1993, Vivian 1994). Some NGO characteristics favor successful extension outcomes but others produce an ambiguous effect on extension performance or to even impede it. Larger NGOs are expected to perform better because they have more resources and extension agents to deliver technologies (Hassan 1993). However, smaller NGOs tend to have better local knowledge and a better relationship with farmer communities that are necessary for a successful extension program (Farrington & Bebbington 1994, Garforth & Lawrence 1997). NGOs are more likely to succeed when they manage few and simple extension projects (Christopolos 1996). However, for the sake of increased funding tend to make NGOs sometimes accept a large number of projects, thereby decreasing the efficacy of each of them (Edwards & Hulme 1996). Funding pressure has also forced NGOs to expand their geographical areas of influence, but often at the cost of not reaching the poorest (Hashami 1992) and expanding into activities less relevant for national development (Robinson 1993). Many NGOs have also been criticized for having staff with inadequate scientific training (Garforth & Lawrence 1997, Chapman & Tripp 2003). Longer experience in specific areas can constitute an advantage for NGO's disseminating technologies, but new NGOs have an unavoidable trend to start their extension service only in new areas (Carney 1998). Finally, a broad number of NGOs participating in the same extension project can also introduce diversity among institutional interests about the emphasis that the project should follow (i.e, priorities on project activities, targeted beneficiaries, etc) affecting the extension performance. Many NGOs tend to emphasize activities of interest of their main funding providers that do not necessarily match with specific project goals and (Van der Ban 2000, Rivera & Qamar 2003).

Multi-institutional extension projects could benefit from a pluralistic institutional environment, but the diversity among each of the institutions participating in these projects can also condition the performance of the extension outputs. This empirical question has however been absent on previous impact studies about delivery of agricultural technologies. This paper takes a first step toward inclusion of these institutional characteristics in the analysis of agricultural extension impacts and tests whether extension provider characteristics related to size and resource capacity, expertise and experience, and institutional focus affect farm outcomes of participants in extension programs. The rest of the paper analyzes a case study for implementing a recent multi-institutional project of farmer Field Schools (FFS) in Nicaragua.

3. The extension service in Nicaragua and the delivery of IPM through a multi-institutional FFS project

Agricultural extension started in Nicaragua in the 1970's with the large public extension structure developed with the support of the U.S. Agency for International Development (USAID) and was maintained during the 1980's by the Sandinista government. In both periods, extension services were targeted mainly toward large farmers (Christopolos 2001). At the beginning of the 1990's a financial crisis in Nicaragua led to reform of the public extension service, resulting in the creation of the Instituto Nicaragüense de Tecnología Agropecuaria (INTA) and the entrance of the first NGOs into the extension system. The major reform introduced was the expansion of extension services to small farmers (Christopolos 2001). The number of extension providers remained relatively low up to 1998, when after Hurricane Mitch, a wave of international funding promoted a massive entrance of more NGO's with a diversity of characteristics to the extension service (Lavard & Marin 2000). In 2001, with World Bank support, the national government started a major reform of public extension programs reducing the presence of INTA in many areas and promoting the creation of more NGOs to replace INTA work in some areas (Barandun 2001). The influx of new extension providers occurred at a time when outreach programs were increasingly called upon to diffuse complex technologies like integrated pest management (IPM) (Bentley & Andrews 1996, Hruska and Corriols 2002, Staver & Guharay 2003).

Integrated Pest Management (IPM) is a group of pest control methods aimed to reduce environmental and health risks to farmers by keeping a crop pest infestation below an economic threshold level. This level is the pest population density at which control measures are necessary to prevent a decline in net returns (Fernandez-Cornejo et al 1998, Bajwa and Kogan 2002). Pest control methods may include pesticides when necessary but also non-chemical inputs and specialized practices such as agro-ecological analysis[13], botanical insecticides, insect sticky traps and others (Fernandez-Cornejo et al 1998). In Central America the first three IPM practices has been widely disseminated as non-chemical pest control and are the focus in this essay.

IPM extension in Nicaragua has mainly followed the training and visit (T&V) approach (Benor et al 1984). The T & V system is based on short field visits to selected farmers who are put in charge of delivering technical packages to neighbor farmers (Picciotto & Anderson 1997). It has been criticized for being "top down" and for failing to organize farmers (Hussain et al 1994).This traditional extension approach has usually been indicated as the main responsible for the low rate of IPM adoption in Nicaragua (PROMIPAC 2001).

In order to improve the adoption of IPM, the Project for Integrated Pest Management in Central America (PROMIPAC) has promoted the implementation of Farmer field Schools (FFS) since 2001. FFS were first established in Asia at the end of the 1980's with the intent of increasing the dissemination of knowledge among farmers.

[13] This practice consists in a permanent observation of the crop field and the use of insect scouting as the main activity. It will determine whether pest infestation has reached the economic threshold level.

FFS uses participatory techniques and combines the scientific knowledge and the practice of IPM with farmers' experience and interests under the learning by doing approach (Gallagher 1998). With this new approach, farmers now incorporate their priorities, develop more skills, and become the main actors in the decision making process of technology adoption (Kenmore 2002). It is also expected that FFS graduates will be more able to convince other farmers about the value of IPM and thereby accelerate its adoption (Fleischer et al 1999).

Following the existing trends of extension services in many developing countries, FFS in Nicaragua have been implemented by a group of NGOs trough a multi-institutional project. As stated before, this extension approach increases the number of extension providers available for targeted farmers, but it can also introduce a diversity of institutional characteristics related to extension capacity and focus of each NGO that may condition the delivery of IPM. Some of the participating NGOs had had experience in delivering IPM, but the others had their first IPM experience with FFS. Most of the NGOs with no previous IPM training experience grew out of the partial privatization of the extension services funded by the World Bank.

Differences among NGOs participating in the FFS project are not restricted to past experience with IPM. They also include differences in NGO size, resources for delivering IPM and institutional interests. As shown in Table 3.1, the NGOs participating in the FFS project differed in number of total extension agents, extension agents trained in IPM or in FFS, number of projects being developed by each institution and the area of influence of each of them. Also the seven NGOs present different institutional emphasis in their extension work that range from credit programs to soil conservation practices

Table 3.1. Description of NGOs working on FFS implementation in Nicaragua

Institution	Acronym	Number of extension agents			Number of projects	Institutional emphasis	Number of districts (influence)
		Total	With IPM training	With FFS training			
Asociación para Diversificación y Desarrollo Agrícola Comunal	ADAAC	4	3	2	6	Soil conservation, local organization	4
Caritas Diosesana (Jinotega)*	CARITAS	6	6	4	5	Credit, local organization	4
Centro de Estudios de Eco-desarrollo para el Trópico	CECOTROPIC	8	3	3	1	Woman work, environment	2
Empresa de Servicios Técnicos Agropecuarios	ESETECA	8	2	2	2	Fruits, coffee	10
Fundación para la Investigación y el Desarrollo Rural (Estelí)*	FIDER	8	7	6	5	Credit, organic crops	6
Organización para el Desarrollo Municipal	ODESAR	6	2	1	5	Soil conservation, water wells	7
Unión Nacional de Agricultores y Ganaderos (Estelí)*	UNAG	8	5	2	3	Credit, local organization	6

* Those NGOs work in larger areas, but statistics are referred to the office of one Department.

(Table 3.1). These differences could have affected farmer participation in IPM training or their subsequent likelihood of adopting IPM.

The starting point for FFS in Nicaragua was common to all NGOs: Each of them sent some extension agents to participate in a two-month intensive training-for-trainers program. This training program was conducted by FFS trainers experienced in participatory research methods. At the end of the training experience, extension agents were expected to understand their new role as facilitators, replacing the T&V role of delivering agricultural technologies (PROMIPAC 2001). With the variety of participatory techniques that facilitators learned in the training-for-trainers' course they were also expected to be able to offer different alternatives to solve farmers problems, especially those related to pest control. Differences among individual FFS curricula conducted by different NGO's should thus only be attributed to different farmers' preferences.

The implementation of FFS in Nicaragua, however, brought some differences related to the special emphasis that each NGO decided to give to each FFS under its control. Table 3.2 shows the individual curricula developed by each of the 13 FFS for bean producers in Nicaragua. Except for the fact that all bean FFS promoted agro-ecosystem analysis, and almost all of them used botanical insecticides[14], each curriculum was developed differently according to individual NGO priorities. Only CECOTROPIC, FIDER and UNAG promoted yellow sticky traps in their FFS, because only these institutions had experience with this practice. ADDAC and ODESAR were the only

[14] The use of botanical insecticides was however very diverse among FFS according to individual NGO experience and knowledge. For example, FIDER promoted the use of detergent + oil and chile (*Capsium anum*) + alcohol, CARITAS promoted the use of chile + garlic + onions and Neem (*Azadarichata indica*), UNAG promoted the use of madero negro (*Gliricidia cepium*), sugar and ashes, while ESETECA did not promote any.

Table 3.2. Curricula and other activities developed by each bean FFS in Nicaragua.

FFS Community	Institution	IPM activities included in FFS curricula			Other activities developed		FFS experiments	Field comparison of IPM vs. Conventional	
		Agro-ecosyst. Analysis	Botanical Insecticides	Yellow traps	Soil Conserv.	Health		Yield	Net revenue
Llanos 2	ADAAC	X	X		X	X		Less	Less
Cacao arriba	CARITAS	X	X					Less	Less
Santa Teresa	CECOTROPIC	X	X	X			Varieties	Less	Less
Las Crucitas	ESETECA	X						More	Less
Fátima	ESETECA	X				X	Fertilization	More	Less
Cusmají	FIDER	X	X	X			Fertilization	Less	Less
El Quebracho	FIDER	X	X				Varieties	More	More
El Japón	FIDER	X	X			X	Varieties	More	More
Cerro la mina	ODESAR	X	X		X				
Llanos 1	UNAG	X	X	X					
El Tule	UNAG	X	X	X					
Las Puertas	UNAG	X	X	X					
El Bramadero	UNAG	X	X	X					

NGOs that included soil conservation activities in their FFS curricula. In these cases, both NGOs decided to solve first the problems of soil erosion and low productivity that they identified as their work priority in the communities where they implemented FFS. Although health effects derived from pesticide use should be a special component of IPM training, only 3 FFS included explicitly this activity in their curricula (Table 3.2).

According to the training received by facilitators, field experimentation should be a strong component in each FFS, and the comparison of a plot under IPM management with a plot under a community traditional management was suggested as part of each FFS curricula. However, ODESAR and UNAG did not conduct this experiment (Table 3.2). Also not all the FFS conducted other complementary experiments (only 6 out of 13) and the type of experiments were usually different across FFS (Table 3.2).

Differences among institutions in charge of the FFS project and differences in the implementation of individual FFS could have conditioned the overall FFS impact in Nicaragua. This paper examines this empirical question by testing whether individual characteristics of NGO serving bean growers enhanced or limited the FFS impact on FFS graduates' adoption of IPM practices, pesticide use and bean net revenue (whether these NGO characteristics constitute part of the FFS treatment effect).

4. The Analytical Framework

The evaluation of program impacts is usually done using the counterfactual analysis where targeted outcomes are measured for some individuals receiving the program (treated group) and for some individuals that do not (counterfactual group) (Rubin 1974, Ravallion 2005). This paper extends this methodology for evaluating the average impact of IPM training on farmers by examining the effects of individual NGO

Characteristics. Given the multi-institutional nature of the FFS implementation in Nicaragua, this paper incorporates a group of NGO characteristics that differs among participating NGOs that could enhance or limit the FFS impact on participating farmers' outputs. Characteristics related to NGOs' size and resource capacity, NGOs' expertise and experience with IPM and targeted farmers, and NGOs' institutional focus are included in this program evaluation framework.

Under an agricultural household model framework, we assume that an FFS educational effect is linked to household utility through improved knowledge (Feder et al 2003). Such improved knowledge about pests and pest controls could potentially influence farmers' input decisions and farm net revenues. We propose to test econometrically for this effect on input use, as well as to test the hypothesis that the delivery of knowledge could be influenced by individual characteristics of NGOs in charge of the delivery programs. In the rest of this section we provide details of the data collection and econometric strategies for conducting this program evaluation.

4.1. The sample design and data collection

A set of farm level data was collected between May and August 2004 with a cross-sectional survey of 436 households of Nicaraguan bean growers in the departments of Estelí, Matagalpa, Jinotega, Madriz, Masaya and Carazo. The sampling design followed a double stratification (Deaton, 1997) to compare the effect of different IPM training methods (FFS vs. T&V) and to include diverse settings. Households were interviewed in 74 rural communities, including 13 where FFS were implemented, 9 where FFS graduates lived but no FFS were held, 26 communities selected randomly where no FFS exists but other IPM extension services were available[15], and 26 communities selected randomly where no IPM extension was present. In each community, households were selected randomly and included clients and non clients of NGOs. The sample distribution includes FFS graduates, farmers participating in other IPM programs, FFS graduates who also attended other IPM programs, and farmers who no prior contact with formal IPM extension.

4.2. The econometric estimation

4.2.1. Potential econometric problems

The main potential econometric problem in this paper is the endogeneity associated with self selection of farmer participation in IPM extension programs and the non-random placement of these programs. Many studies have recognized that failure to correct this problem produces biased estimates of the extension impact, which usually result in an overestimation of their impact (Strauss et al 1991, Owens et al 2003, Feder et al 2003).

In Nicaragua all NGOs participating in the FFS project agreed to implement a group of general rules while organizing each FFS. This group of rules included selecting a place for meetings and experimentation with good access, relying on existing farmers' organizations and farmers' willingness to participate on IPM training. However, most of these rules were related to pre-existing farmer-NGO relationships, which were usually not observed during the data collection process. Farmers with good pre-existing relationships with NGOs could have been more willing to participate in IPM training, whereas farmers with poor NGO relationships could have been less so. It is clear that FFS

[15] Other IPM extension services refers to the training and visit (T&V) approach that was mainly provided by the same NGOs in charge of FFS implementation but usually targeted for NGOs clients who did not participate in FFS.

program availability was not randomly distributed among Nicaraguan farmers and that selectivity bias could be present in the econometric estimations.

This paper evaluates first the convenience of using two stage least square (2SLS) to correct selectivity bias in the econometric estimation, which is the preferred method in linear models with cross sectional data (Wooldridge 2002a). The model for the adoption of IPM practices has a clear non-linear nature and would be more suitable for a trivariate probit or multinomial logit specification, but correcting selectivity bias in non-linear models through the recommended "control function approach"[16] generates big computational problems and can only be applied under normality conditions (Wooldridge 2002a, Wooldridge 2002b, Blundell & Powell 2004). But as Angrist (2001) pointed out, standard instrumental variable estimation can still be applied to non-linear models when the objective is to estimate the causal effect of the endogenous variables. Wooldridge (1997) also showed that 2SLS could still be applied in a random coefficient model with a binary endogenous variable when this variable follows a linear probability model, the linear approximation of models with binary dependent variables as the adoption of IPM practices case. Even recognizing the non-linear nature of the IPM adoption model, this paper will maintain 2SLS as the preferred method to control endogeneity of IPM training participation.

The sample design poses secondary econometric problems of a clustered and stratified sample that can bias the parameter estimates (Wooldridge 2002a). To deal with the clustering problem, this paper adjusts the variance matrix and includes dummy variables for each cluster using survey regression methods (Wooldridge 2003). This

[16] The control function approach adds to the estimation equation an additional variable that controls for part of the correlation between an endogenous variable and the error term (Petrin & Train 2005, Blundell & Powell 2004).

method is suitable given the nature of the sample design that has small clusters (six households per village on average) and a large number of clusters (74 villages). To correct the unbalanced representation of farmers (especially FFS trainees) in the sample, this paper uses a weighting scheme as suggested by Wooldridge (2002a) (see appendix A.3 for details).

4.2.2. The econometric specification

This paper specifies three linear models for pesticide demand, one linear model and three linear probability models for the adoption of IPM practices, and one linear model for the bean net revenue function. All models have the same set of explanatory variables and the general model structure is:

$$X_j = P_K\,\beta_{jP} + T_T\,\beta_{jT} + I_N\,\beta_{jI} + T_{FFS} I_N\,\beta_{jFFSN} + C_H\,\beta_{jCH} + C_C\,\beta_{jCC} + U_j \quad ; \text{For } j=1,\ldots,8$$

The j^{th} dependent variable depends on vectors of K output and input prices (P_K), household participation in the T IPM training program (T_T), the N individual characteristics of the NGO delivering IPM to the household (I_N), the interaction of FFS participation and NGO characteristics ($T_{FFS}I_N$), as well as socioeconomic and other household characteristics (C_H) and community fixed effects (C_C), with disturbances assumed to be independently distributed (U). All variables used in the econometric estimation are described in detail in the following subsections.

This paper uses the predicted probability of each IPM training program participation (FFS and other programs) as generated instruments of the true program participation in all the 2SLS models. Each predicted probability is estimated using a probit specification that has as explanatory variables the original exogenous variables plus some redundant variables that explain the variation of FFS and other IPM program participation (Wooldridge 2002a). The structure of each probit specification uses the same set of explanatory variables as the previous models plus a vector of Z redundant variables that are related to participation in IPM training, but believed to be uncorrelated with the disturbance terms of the IPM adoption, pesticide demand and bean net revenue equations (see first table of Appendix A.9).

4.2.3. The dependent variables

Household input demand for insecticides, herbicides and fungicides is represented by the quantity of pesticide active ingredients used by each household in bean production during the most recent season in 2003 weighted by acute human toxicity. A human toxicity index is calculated for each household i as the sum over all m pesticide active ingredients (ai_{ik} in kg/ha, k=1,...,m) divided by each active ingredient's mammalian toxicity (measured by the minimum dose per gram of body weight that is lethal to 50% of a test rat population or LD50, as reported in USDA, 1998). The human toxicity index, show below, is proportional to the LD50 and is increasing in lethality.

$$HTI_i = \sum_k \frac{ai_{ik}}{LD50_{ik}}$$

The adoption of the three specific IPM practices promoted in FFS is represented by binary variables that indicate whether a household adopted agro-ecological analysis, botanical insecticides and/or yellow insect traps and a variable that measures whether a household adopted one, two or the three IPM practices. As explained before this paper uses a linear approximation for these non-linear models.

Bean net revenues is a continuous expected variable measured in US$/ha and calculated based on farmer self-reported revenues and costs during the most recent bean season in 2003 prior to the household survey in early 2004.

4.3.4. Explanatory variables

Output prices in the regression models are selling prices for beans and maize reported in US$/kg. Input prices include bean seed, metamidophos insecticide, gramoxone (paraquat) herbicide and mancozeb fungicide[17]. The bean net revenue function also included the price of fertilizers[18]. Other prices and price proxies are the transport cost to the nearest market of a sack of beans or maize and the distance between each farm and the municipal capital. Other production variables include the most recent farming season that bean were grown: *primera*, *postrera* or *apante*, the use of disease resistant bean varieties, altitude (proxy for rainfall and temperature) and farmers' observed level of bean pests and diseases (high or not).

IPM training participation is specified for FFS graduates, other IPM training program participants and the interaction of the two[19]. Households without IPM training contact are kept as the control group. Some characteristics of the participating NGOs that usually differ among them are explicitly specified. We use variables that measure NGO size and resource capacity (average number of extensionists per NGO project, average number of NGO extensionists per district), NGO expertise and experience (proportion of

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[17] Metamidophos, paraquat and mancozeb were by far the main active ingredients among insecticides, herbicides and fungicides on the Nicaraguan farms surveyed in 2004

[18] we use the price of the most common combination of nitrogen, phosphorus and potassium (12-30-10)

[19] There were 35 FFS graduates who had previous participation in other IPM training programs

NGO staff with IPM and FFS training, and years of experience of NGO working in the respondent's community), and NGO institutional focus (whether the NGO has a main focus on soil conservation , or agricultural credit, whether the NGO conducted IPM experiments through FFS, Whether farmers observed greater yields in the experimental IPM plot, whether farmers observed greater net revenues in the experimental IPM plot and whether the NGO organized other complementary experiments during FFS implementation). Interactions for FFS participation and individual NGO characteristics were also included as explanatory variables in order to measure whether each individual NGO characteristic affects FFS impacts[20].

Household characteristics are represented by two groups of variables: (1) measures of household assets: farm size, area under irrigation, number of cattle, whether family has electricity at home, and whether the household receives remittances from relatives working in foreign countries; and (2) measures of household composition: gender of household head, age and years of education of household head, percentage of females, and percentage of family members under 14 years old. Other conditioning variables include whether the household relied upon hired labor or family labor for pesticide application and whether household members used protective devices like mask, gloves or special clothing while applying chemicals. Binary (dummy) variables are included for community-level fixed effects with one of them kept as a control. The 73 community dummies are used for the 2SLS estimations, but are substituted by municipality dummy variables (9 out of the 10 municipalities) in the estimation of the predicted probability of FFS and other IPM training participation.

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[20] Therefore interaction for the predicted probability of IPM training participation (instruments) and individual NGO characteristics were also generated for all 2SLS estimations.

Finally, redundant variables are used to control for endogeneity of extension participation. All these variables measure pre-existing linkages between individual NGOs and client farmers, including whether households received previous credits from the NGO, whether they received food assistance or any cash support, and whether they adopted soil conservation practices prior to their IPM training (terraces, contour lines and live fences). As showed in Appendix A.9 many of these redundant variables meet the first condition for a good instrument and significantly explain farmer participation in FFS and other training programs. These variables also meet the second condition for a good instrument in that they were believed to be uncorrelated with other variables that explain the variability of the dependent variables of the household demand models (disturbance terms) but not observed by the researcher. Credits and other NGO support received by farmers prior to the most recent bean season should not influence farmers' decisions about the level of pesticide use or the adoption of IPM practices during this recent bean season. Likewise, prior adoption of soil conservation practices should not condition farmers' decisions about pesticides or non-chemical pest management practices used during the most recent bean season. The adoption of terraces, contour lines and live fences are not related to the level of pest and diseases and therefore the related pest management practices used. The characteristics of these variables make them suitable for specifying robust IV models that will be tested for correcting endogeneity of farmer participation in FFS and other IPM programs.

5. Results

As stated before, FFS in Nicaragua were carried out by NGOs whose diverse institutional characteristics (Table 3.1) generated heterogeneous implementation approaches (Table 3.2). In order to estimate the effect of this institutional and individual FFS diversity on farm outcomes, the econometric analysis uses the institutional variables listed in Table 3.3. It starts by performing Hausman tests in order to evaluate the need for endogeneity correction using 2SLS models (Wooldridge 2002a). As shown in Table 3.4,

Table 3.3. Descriptive statistics of selected variables used in the survey least squares for 436 Nicaraguan bean growers, 2003-04+

Variable description	Average	Std dev
Dependent Variables		
Index of insecticides weighted by toxicity (x 100)	2.9	5.1
Index of herbicides weighted by toxicity (x 100)	0.5	0.7
Index of fungicides weighted by toxicity (x 100)	0.1	0.6
Adopted agro-ecological analysis (%)	28.2	
Adopted botanical insecticides (%)	35.1	
Adopted insect yellow traps (%)	15.8	
Adopted only one IPM practice (%)	19.1	
Adopted two IPM practices (%)	14.9	
Adopted three IPM practices (%)	10.8	
Household net revenue	91.2	124.9
IPM training and NGO characteristics		
FFS participation (%)	20.6	
Other IPM training participation (%)	34.2	
FFS and other IPM participation (%)	8.0	
Number of extension agents / project	1.5	1.4
Number of extension agents / district	1.0	0.8
NGO staff with IPM training (%)	45.9	
NGO staff with FFS training (%)	27.9	
Years of experience NGO	8.1	6.6
NGO emphasis in soil conservation (%)	7.1	
NGO emphasis in credit programs (%)	10.3	
Performed comparative trials (%)	36.0	
Performed complementary trials (%)	28.2	
IPM plot greater yields (%)	15.6	
IPM plot greater net revenues (%)	11.5	

+ Other variables used in econometric analysis are shown in Table A.1.3 (appendix)

the hypothesis that IPM training participation was exogenous is rejected in all models, suggesting that the IV estimates of the pesticide toxicity models (insecticides, herbicides and fungicides), the adoption of IPM models (agro-ecological analysis, botanical insecticides and insect traps), and the net revenue model are more suitable.

Controlling for the endogeneity of FFS participation reveals several OLS results that misleadingly appear to show FFS impacts when in fact they are due to nonrandom selection of participants. FFS participation by itself had no significant impact on the adoption of IPM practices, pesticide use or bean net revenues (Tables 3.5, 3.6 & 3.7). These findings are consistent with similar studies in Indonesia (Feder et al 2004).

Table 3.4. Hausman test and joint significance F-test of specific NGO characteristics interacting with the FFS treatment effect on household pesticide demand, adoption of IPM practices and bean net revenue models for 436 Nicaraguan bean growers, 2003-04.

	Hausman test		FFS aggregate effect	
	F-Statistic	P-value	F-Statistic	P-value
Pesticide demand				
Insecticides	2.05	0.0152	2.42	0.0034
Herbicides	1.80	0.0388	1.90	0.0267
Fungicides	3.65	0.0000	0.92	0.5460
IPM adoption				
Number of IPM practices	3.01	0.0003	5.54	0.0000
Agro-ecosystem Analysis	6.69	0.0000	3.66	0.0000
Botanical Insecticides	1.61	0.0755	4.18	0.0000
Yellow insect trap	5.54	0.0000	4.28	0.0000
Bean net revenue	2.53	0.0022	2.22	0.0077

The participation on other non-FFS IPM training programs performed slightly better in Nicaragua, increasing the likelihood of adopting botanical insecticides by 60% and insect traps by 52% (Table 3.5). Some of these findings can be explained by poor results on the FFS demonstration plots. FFS graduates could observe yield gains from IPM experimental plots in only four of the 12 FFS and net revenue advantages in only two. Most of the FFS graduates observed superior yields and net revenues on the bean plot

Table 3.5 FFS and NGO characteristics effects on adoption of IPM practices. Least squares survey regression results 436 Nicaraguan bean growers, 2003-04[+]

	N. practices	IV N. practices	Scouting[++]	IV Scouting	botanicals	IV botanicals	traps	IV traps
FFS	**0.628****	-1.031	**0.513*****	-0.366	-0.173	0.788	0.280*	-0.766
	(2.24)	(0.35)	(2.91)	(0.22)	(1.40)	(0.40)	(1.86)	(0.38)
Other IPM training	**0.737*****	**1.213*****	**0.149*****	0.160	**0.434*****	**0.597*****	**0.157*****	**0.517****
	(10.72)	(3.29)	(3.38)	(1.07)	(8.32)	(3.13)	(5.21)	(2.35)
Double IPM training	**-0.352****	-0.762	-0.128	-0.100	**-0.196****	-0.474	-0.010	0.125
	(1.99)	(1.24)	(1.20)	(0.39)	2.20)	(1.56)	(0.12)	(0.12
Interactions with FFS								
Extensionists per project	**4.757****	-0.021	**3.084****	1.644	1.513	1.382	1.148	-2.715
	(2.16)	(0.00)	(2.52)	(0.86)	(0.93)	(0.53)	(0.85)	(0.74)
Extensionists per district	**-11.535****	-6.517	**-7.200*****	-3.950	-3.912	-4.823	-2.731	-0.232
	(2.34)	(0.60)	(2.62)	(0.88)	(1.07)	(0.88)	(0.89)	(0.04)
NGO years of experience	-0.032	-0.023	-0.027	-0.028	0.011	-0.029	-0.027	-0.041
	(1.00)	(0.16)	(1.39)	(0.34)	(0.41)	(0.30)	(1.38)	(0.38)
Extensionists with IPM training	**20.060*****	17.619	**12.942*****	**8.065***	5.887	**8.662***	5.203	8.406
	(2.67)	(0.81)	(3.20)	(1.96)	(1.08)	(1.93)	(1.16)	(0.65)
Extensionists with FFS training	-0.140	-1.335	0.245	-0.241	0.221	-0.344	-0.363	-0.462
	(0.15)	(1.12)	(0.56)	(0.36)	(0.46)	(0.68)	(0.87)	(0.63)
Emphasis in soil conservation	0.454	2.287	-0.340	0.013	**1.015****	0.121	-0.285	0.444
	(0.52)	(0.72)	(0.78)	(0.01)	(2.26)	(0.06)	(0.64)	(0.23)
Emphasis in credit programs	**0.858***	**-1.070***	**0.825*****	0.245	0.131	0.192	-0.126	**-1.578***
	(1.88)	(1.69)	(3.65)	(0.40)	(0.66)	(0.24)	(0.45)	(1.66)
Comparative experiments	-1.140	-4.377	**-1.113*****	-0.711	0.226	-0.755	-0.514	-5.411
	(1.06)	(0.60)	(3.26)	(0.40)	(0.72)	(0.46)	(0.81)	(1.05)
Other experiments	**1.799*****	0.011	**1.576*****	**1.019***	0.063	0.702	**0.759****	0.043
	(3.00)	(0.01)	(6.14)	(1.70)	(0.18)	(0.53)	(2.27)	(0.03)
Observed more yields	**10.205*****	**20.894***	**5.683*****	4.041	3.471	**6.145***	2.509	14.687
	(2.61)	(1.88)	(2.84)	(0.62)	(1.25)	(1.98)	(1.15)	(0.84)
Observed more net revenues	**1.621*****	0.569	**0.535*****	**0.249***	0.981	**0.313***	0.916	**0.649*****
	(2.87)	(0.88)	(3.04)	(1.65)	(1.35)	(1.85)	(1.23)	(2.63)
Observed less yields	0.230	2.160	-0.195	0.735	0.199	0.269	0.063	0.826
	(0.53)	(1.59)	(0.72)	(1.02)	(0.69)	(0.29)	(0.23)	(0.92)

Constant	**2.014****	0.944	0.359	0.121	**1.404*****	0.920	0.367	0.135
	(2.12)	(0.65)	(0.72)	(0.15)	(2.82)	(1.28)	(0.69)	(0.19)
Observations	436	436	436	436	436	436	436	436
R-squared	0.63	0.50	0.55	0.50	0.58	0.53	0.40	0.19
Hausman test								
F-Statistic		3.01		6.69		1.61		5.54
P-Value		0.0003		0.0000		0.0755		0.0000

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ Complete regression results are shown in appendix A.9
++ Insect scouting is the main activity of agro-ecological analysis

Table 3.6 FFS and NGO characteristics effect on pesticide demand. Least squares survey regression results for 436 Nicaraguan bean growers, 2003-04[+]

	Insecticides	IV Insecticides	Herbicides	IV Herbicides	Fungicide	IV Fungicides
FFS	**0.059*** **	0.277	**0.009*** **	-0.037	**0.003***	0.001
	(3.94)	(1.27)	(4.62)	(1.28)	(1.89)	(0.06)
Other IPM training	0.009	0.016	0.001	0.003	0.001	-0.001
	(1.57)	(1.28)	(1.06)	(0.88)	(1.15)	(0.63)
Double IPM training	**-0.022***	**-0.070** **	**-0.005** **	**-0.009***	**-0.003** **	-0.003
	(1.88)	(1.99)	(2.04)	(1.67)	(2.01)	(1.20)
Interactions with FFS						
Extensionists per project	0.038	0.345	**-0.036** **	**-0.073** **	-0.005	-0.007
	(0.22)	(1.04)	(2.01)	(2.61)	(0.45)	(0.27)
Extensionists per district	-0.078	-0.595	**0.074***	**0.141** **	0.011	0.024
	(0.22)	(0.94)	(1.85)	(2.35)	(0.43)	(0.50)
NGO years of experience	-0.006	-0.012	-0.000	**-0.003***	-0.000	0.000
	(1.62)	(1.02)	(1.05)	(1.83)	(0.81)	(0.03)
Extensionists with IPM training	0.189	0.863	**-0.106***	**-0.217** **	-0.018	-0.058
	(0.36)	(0.84)	(1.74)	(1.99)	(0.40)	(0.76)
Extensionists with FFS training	-0.033	-0.084	-0.008	-0.003	-0.002	-0.002
	(0.53)	(1.26)	(1.47)	(0.57)	(0.68)	(0.60)
Emphasis in soil conservation	-0.049	-0.178	**-0.015** **	0.030	-0.002	-0.000
	(0.84)	(0.82)	(2.58)	(0.90)	(0.39)	(0.00)
Emphasis in credit programs	0.011	0.107	-0.001	-0.017	0.000	0.002
	(0.31)	(1.16)	(0.29)	(1.44)	(0.17)	(0.26)
Comparative experiments	0.035	0.117	-0.003	0.002	0.003	0.014
	(0.59)	(0.42)	(0.42)	(0.08)	(0.52)	(0.96)
Other experiments	-0.022	0.096	-0.003	**-0.034***	**-0.006***	-0.009
	(0.64)	(0.69)	(0.70)	(1.72)	(1.86)	(0.91)
Observed more yields	-0.020	0.006	-0.046	-0.025	-0.004	-0.037
	(0.08)	(0.01)	(1.55)	(0.26)	(0.18)	(0.79)
Observed more net revenues	**-0.035*** **	**-0.073** **	-0.002	**-0.005***	**-0.005** **	0.000
	(2.62)	(1.99)	(0.56)	(1.66)	(2.45)	(0.45)
Observed less yields	0.148***	0.127*	0.004	0.021*	-0.000	-0.002
	(2.72)	(1.71)	(1.08)	(1.69)	(0.22)	(0.32)

R-squared	0.42	0.35	0.44	0.33	0.43	0.41

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ Complete regression results are shown in appendix A.9

employing conventional pest management (Table 3.2). Table 3.4 also includes results of the F-test indicating rejection of the null hypothesis that specific NGO characteristics do not alter the FFS treatment effect. We fail to reject only the null hypothesis that FFS

Table 3.7. Effects of FFS and NGO characteristics on bean net revenues. Least squares survey regression results for 436 Nicaraguan bean growers, 2003-04[+]

	Bean net revenues	IV bean net revenues
FFS	1,001.366	-492.68
	(1.24)	(0.75)
Other IPM training	**-441.840****	-2.81
	(2.10)	(0.05)
Double IPM training	320.0443	41.17
	(0.44)	(0.54)
Interactions with FFS		
Extensionists per project	**7,125.919***	-233.46
	(1.77)	(0.29)
Extensionists per district	**-15,213.405***	-187.03
	(1.69)	(0.14)
NGO years of experience	18,280.718	359.36
	(1.30)	(0.15)
Extensionists with IPM training	741.935	**179.43***
	(0.35)	(1.68)
Extensionists with FFS training	**-327.830*****	1.71
	(2.96)	(0.05)
Emphasis in soil conservation	-512.618	469.62
	(0.32)	(0.75)
Emphasis in credit programs	**1,266.985****	-178.56
	(2.09)	(0.62)
Comparative experiments	**2,791.729***	-125.28
	(1.69)	(0.16)
Other experiments	1,266.050	-402.67
	(1.11)	(1.01)
Observed higher yields	6,913.019	1672.01
	(0.97)	(0.62)
Observed higher net revenues	-10,161.417	1471.12
	(1.36)	(0.59)
Observed lower net revenues	613.107	46.49
	(1.17)	(0.75)
Observed lower yields	**-1,611.658***	160.71
	(1.81)	(0.59)
Observations	436	436
R-squared	0.50	0.37

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] Complete regression results are shown in appendix A.9

participation and its interactions with NGO characteristics do not jointly influence the use of fungicides.

After controlling for FFS and other IPM training participation, this paper shows that FFS impacts on adoption of IPM practices, pesticide use and bean net revenue are significantly affected by individual characteristics of NGOs in charge of the FFS implementation (Tables 3.5, 3.6 & 3.7).

The adoption of IPM practices among FFS graduates was significantly affected by NGO characteristics related to expertise in IPM and the institutional emphasis given to individual FFS implementation (Table 3.5). NGOs with a greater proportion of extension agents trained in IPM significantly increased their FFS graduates' likelihood of adopting both agro-ecosystem analysis and botanical insecticides by 807% and 866% respectively. Whether most of these extension agents were also trained in FFS methods does not have a significant effect on this adoption decision, which seems to indicate that training in IPM knowledge is more relevant than training in methods for delivering this knowledge.

FFS graduates linked to NGOs that focus on credit programs were less likely to adopt IPM practices in general and especially insect yellow traps, suggesting a deviation from the expected IPM extension focus. They decreased the predicted probability of adopting yellow traps as much as 100% and adopted on average 1.07 fewer IPM practices (Table 3.5). Also farmers working with NGO's that conducted comparative trials finding higher revenues or higher yields in the IPM plot were more likely to adopt all three of the IPM practices (Table 3.5) while farmers working with NGOs that conducted complementary trials like improved seed or fertilization were more likely to adopt agro-ecosystem analysis (scouting) by 102%. These results highlight the importance of FFS field experimentation where graduates have the opportunity to apply directly the IPM knowledge learned. They also show that farmers observing field advantages of IPM are more likely to adopt it.

Pesticide use among FFS graduates was directly affected by how NGOs operated their FFS and we measure the magnitude of the effect in terms of standard deviation of the toxicity-weighted pesticide use. Graduates of FFS run by NGOs that implemented a comparative trial during the FFS experimentation and observed more revenues in the IPM plot decreased slightly the toxicity weighted use of insecticides by 0.01 s.d. and by 0.07 s.d. the use of herbicides (Table 3.6). Likewise, FFS graduates exposed to comparative experimentation that resulted in lower bean yields in the IPM plot significantly increased albeit by low magnitude the use of both types of pesticides, of 0.02 and 0.03 s.d. respectively. When NGOs decided to include other types of field experiments like levels of fertilization or new bean varieties, FFS graduates also reduced the use of toxicity weighted herbicides by 0.55 s.d. (Table 3.6). Field experimentation and especially positive results from IPM treatments seem to be highly relevant for inducing a reduction of pesticide use. Of course, this is entirely consistent with the FFS philosophy of learning by doing. Hence it is not surprising that failure to show FFS graduates tangible advantages of IPM over chemical pest control can result in no incentives for changing the level of pesticide use.

NGO capacity and expertise in IPM also affected FFS graduates' pesticide use. The graduates of FFS managed by NGOs with more extension agents per project reduced considerably their toxicity weighted herbicide use by 0.31 s.d. while another year of experience of an NGO reduced slightly the toxicity weighted of herbicide use by 0.004

s.d. Those from FFS managed by NGOs with a higher ratio of extension agents per district actually increased the toxicity weighted use of herbicides by 0.2 s.d. In Nicaragua, the ratio of agents per project seems to be very relevant for measuring the time that individual extensionists can give to each group of farmers. Graduates of FFS linked to NGOs with more extension agents trained in IPM and with more years of experience working in farmer communities significantly reduced the use of herbicides (Table 3.5). This result suggests that more IPM expertise is needed among extension providers in order to produce impacts on graduates' pesticide use.

Finally, NGO characteristics had much less impact on bean net revenues among FFS graduates from the 2003 season than on their adoption of pest management practices. Only NGOs having more extension agents trained in IPM increased bean net revenues of their FFS graduates by 179 US$ per hectare.

6. CONCLUSIONS

Impact assessment of extension services in developing countries has largely ignored the effect of the diversity in institutional characteristics among extension providers (Raina 2003). We found that these characteristics significantly affect farmers' choices of management practices and, to a lesser extent, farm net revenues. In particular, the institutional focus, expertise in IPM and the capacity of NGOs implementing multi-institutional extension projects significantly affect their clients' input decisions and adoption of agricultural technologies.

The impact of extension programs can be enhanced or diminished by individual characteristics of the institutions delivering agricultural technologies. NGOs with more technical expertise and extension experience tend to enhance the delivery of these agricultural technologies, as many papers have highlighted (Hassan 1993, Carney 1998). By contrast, NGOs with an institutional emphasis different from the main extension program deliver poor extension performance. Depending on the magnitude of these effects, the positive effects generated by desirable NGO characteristics could be offset by negative effects from NGOs with institutional focus irrelevant to the extension focus in question.

The findings presented here highlight how FFS impacts can be erroneously measured in an analysis that fails to correct for endogeneity among explanatory variables. The uncorrected OLS estimates of FFS and other IPM training program effects are upwardly biased, which is likely due to non-random location of the extension programs and farmer self-selection into these training programs. So far, both of the IPM training programs implemented in Nicaragua have had little effect on participating farmers' pesticide use and adoption of IPM practices, two of the main goals of any IPM extension program. However, farmers served by NGOs with a higher proportion of extension agents trained in IPM, with greater expertise in IPM, and longer experience in working with farmer communities tended to improve the delivery of IPM through FFS. More scientific knowledge of IPM turned out to be more important than knowledge of new methods for delivering IPM.

This research provides important insights for policy makers and international donor agencies that wish to broaden the participation of NGOs as extension providers. It is important to improve the selection of NGOs that will deliver agricultural technologies, specifically to choose ones with strong technical capacity whose institutional emphasis matches the main focus of the extension program. An ideal NGO in charge of delivering

IPM should have a large number of extensionists, the extensionists should be soundly trained in the technologies to be delivered, the NGO should have many years of experience working with the targeted communities and it should definitely concentrate its extension efforts on disseminating the targeted technologies and not other institutional activities. Our findings also underscore the major role played by FFS field experimentation in shaping farmer input decisions. Direct exposure to the benefits and limitations of new technologies should always be present in extension programs. However, it is necessary to keep in mind that experimental or demonstration results may not favor a given proposed technology. Institutions charged with improving farmer welfare through technology diffusion should be able to react quickly and incorporate farmers' feedback, even to the point of discarding a specific proposed technology.

This research is a first step toward analyzing how different institutional characteristics among extension providers can affect the impacts of the delivery of agricultural technologies. Future research should seek to obtain better information on the financial situation of participating NGOs. For example, information about amounts of funding, relative weights of individual extension projects within the NGO's budget, and the amounts invested in extensionist training could expand and improve upon this analysis. Such additional information could provide a better idea of the influence of extension provider characteristics on beneficiaries' farm outcomes.

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CONCLUSIONS

Assessing the impact of agricultural extension in developing countries after the major changes suffered by national extension services poses many challenges. Impact studies should carefully examine whether targeted farmers perceive all potential benefits derived from technology adoption, measure all farm household outcomes associated with the adoption process and carefully evaluate the impact of the new generation of non-governmental extension providers. Great care should also be given to the methods for estimating program impacts in order to avoid attributing impacts that do not correspond to the extension program.

This dissertation has explored three major research questions related to the delivery of integrated pest management (IPM) through the farmer field schools (FFS), the preferred means of many development agencies for disseminating IPM. These questions are analyzed in three separate but related essays. The first essay evaluates whether awareness and/or experience of environmental and health (E&H) effects influence farmers' decisions on pest management. The second essay analyzes whether the implementation of FFS has produced farm, environmental and health impacts among participants in this extension program. Finally the third essay explores whether diverse institutional characteristics of extension providers affect the impacts that extension programs have on farmer clients.

Prior experience with the E&H effects of pesticides was found to affect household decisions about pesticide use and the adoption of non-chemical pest control practices. Perceived E&H hazards are only important enough to influence farmer practices when farmers are using toxic or highly toxic pesticides. Below that level Nicaraguan bean growers ignore potential E&H risks. Also when farmers face high health risks, farmers tend to use protective strategies in order to avoid direct exposure. These findings partially support the assumption by many IPM training programs that awareness of the E&H risks of pesticide use will encourage a great IPM adoption. Few previous studies had tested formally whether farmer perceptions of E&H risks influence their input decisions. IPM training programs need to improve their educational component and stress the importance of the E & H effects of pesticide use. Secondary effects that are not perceived directly by farmers making decisions about pesticide use should also be incorporated in the IPM training curricula.

Regarding the impact of FFS for IPM training, this dissertation finds that failing to correct for endogeneity effects associated with IPM training participation can exaggerate the apparent impacts of FFS. Like a previous study-about FFS impacts, this dissertation finds FFS performance to be inferior to other IPM training programs in Nicaragua and to have created no diffusion effect among the neighbors of FFS graduates. Also FFS did not produce the expected E&H benefits associated with the delivery of IPM. These results are partly explained by the poor agricultural resources (especially poor soils and high pest infestation levels) in the hands of small farmers in developing countries, the main target of FFS. However, the dissertation also finds that longer IPM training programs achieve better outcomes. These findings highlight the importance of using appropriate econometric methods to correct for potential endogenity of extension program participation. There is also a need to expand traditional impact studies to include the E & H effects associated with IPM adoption. Given the high cost of delivering IPM through FFS and the limited impact achieved so far, it is important to adjust the FFS approach. Cost savings can be achieved by prioritizing and trimming activities the current FFS curricula. If these savings are invested in designing longer periods of IPM dissemination to maintain and improve farmers' feedback, FFS could improve their outcomes.

Finally, in the search for explanations of the disappointing profitability and pesticide risk outcomes of FFS in Nicaragua, this dissertation explores the influence of institutional characteristics among the NGOs in charge of implementing FFS. It finds that NGO characteristics significantly affect bean farmers' choices of pest management practices and to a lesser extent, their farm net revenues. In particular, the institutional focus, expertise in IPM and the capacity of NGOs implementing multi-institutional extension projects significantly affect their clients' input choices and adoption of agricultural technologies. Previous impact studies have usually ignored the institutional environment that could have hided the influence of individual institutions in the aggregate treatment effect of extension programs. As the impact of extension programs can be enhanced or limited by the individual characteristics of extension providers, there is a need to improve selection of the institutions that deliver agricultural technologies, focusing on strong technical capacity and an institutional emphasis that matches the main focus of the extension program.

APPENDIX A.1

Household Survey

Encuesta sobre el uso de agroquímicos y métodos alternativos para el control de plagas entre productores de fríjol de Nicaragua.
Encuesta número: ________ Fecha: ____________ ______________

I. Información general

Nombre del jefe de hogar:

Ubicación de la finca:		Comunidad:
Municipio:		Departamento:
Código de GPS:		Punto No:
Lat:	Long:	Altura:

Nombre del encuestador:

II. Características del hogar.

(Un hogar es definido por todos los miembros de familia que viven/trabajan permanentemente en la casa/finca durante los siguientes ciclos agrícolas.)

2.1 Composición del hogar.

	Total	Menores de 14 años.	Cuantos van a la escuela
Varones			
Mujeres			

2.2 Información del jefe de hogar.

2.2.1 Género (M=0, F=1) ______________
2.2.2 Edad ________________________
2.2.3 Años de educación________________
2.2.4 Edad del cónyuge _________________
2.2.5 Años de educación del cónyuge______

2.3 Años de educación de los padres del jefe de hogar

2.3.1 Padre_______
2.3.2 Madre_______

2.4 Familiares que trabajan en el extranjero, marcar con una X.

2.4.1 Padres____________
2.4.2 Hermano/a________
2.4.3 Cónyuge__________
2.4.4 Hijo/a_____________
2.4.5 Otro: ______________

2.4.6 Ninguno_______
Donde? _____________

III. Activos del hogar y características de la finca.

3.1 Cuantas manzanas tiene su finca.

3.1.1 Total	3.1.2 Propia	3.1.3 Alquilada	3.1.4 Compartida	3.1.5 Otra

3.1.6 Cuántas manzanas son para producción agrícola ___________________

3.1.7 Cuántas manzanas tiene con sistema de riego _____________

3.1.8 Tipo de riego._________________

3.2 Adquisición de tierras (en manzanas).

3.2.1 Herencia	3.2.2 Comprada	3.2.3 Transferida	3.2.4 Invadida	3.2.5Otro

3.3 Distribución del área de cultivo y producción durante el última ciclo agrícola (en manzanas, kilos y córdobas)

Cultivo	**Ciclo agrícola**	*Área*	**Producción**	**Cantidad vendida**	**Precio unitario**
Maíz					
Fríjol					
Maicillo					

3.4 ¿A qué distancia se encuentra el lugar de venta de su producción.

3.4.1Kilometros__________

3.4.2 Minutos__________

3.5 ¿Cuánto le cuesta transportar el quintal de fríjol al mercado? ______________

3.6 ¿Cuánto tiene de cada uno de los siguientes animales?

3.6.1 Vacunos	3.6.2 equinos	3.6.3 Cerdos	3.6.4 Aves (aproximadam.)	3.6.5 Otros

3.7 Tiene electricidad? SI ( ) NO ( )

3.8 ¿Cuáles cosas de la siguiente lista tiene?

3.8.1 Carro____

3.8.2 Motocicleta_____

3.8.3 Televisor _______

3.8.4 Refrigerador _____

3.8.5 Moto bomba_____

3.8.6 Motor de riego___

3.8.7 Tractor_____

3.8.8 Otro_____________

3.9 Trabajo por temporadas fuera de la finca.

Miembro de la finca	Actividad	Días	Salario / día	Distancia al lugar Kms	Minutos
Padre					
Madre					
Hijos					

Nota: si no contestó el valor del salario preguntar :__________________

3.10 Comparado al salario que paga en su finca, el salario fuera de ella es:

1. Mayor______ 2. Igual______ 3.Menor______

IV-Manejo del fríjol

4.1 Actividades y mano de obra, usadas en la parcela del último ciclo de fríjol.

Actividad	Insumo1	Cant.	Precio C$	Costo	Insumo 2	Cant.	Precio C$	Costo C$	Cantidad de mano de Obra Días / Hombres			Pago C$			Costo Total Mano de Obra
									Familiar	Contrata	Otro	Sin comida	Con comida	Otro	
Chapia y desbasurado															
Prep.deterreno .Bueyes															
Siembra (semilla)															
Fertilización															
Aplicación de Herbicida															
Deshierbe y aporque															
Aplicación de insecticida 1															
Aplicación de insecticida 2															
Arranca															
Aporreo y traslada															
Despolvorear y secado.															

Ahora me gustaría hablar un poco más en detalle del uso de plaguicidas.

4.2 Uso de plaguicidas. (Fríjol)

Producto	Número de aplicaciones	Frecuencia de aplic.	Capacidad de la bomba.	Dosis aplicada.

4.3 ¿Cuáles son las principales plagas que usted tiene normalmente en los fríjoles? Y ¿Qué plaguicidas específicos usa normalmente para controlarlos

Ciclo agrícola Primera				**Ciclo agrícola Postrera**			
4.3.1 Plaga	**Cod**	**4.3.2 Plaguicida**	**Cod**	**4.3.3 Plaga**	**Cod**	**4.3.4 Plaguicida**	**Cod**

4.4- Evaluación del nivel plagas y productos usados.

Respecto a un año promedio.

Plaga	**El Nivel plaga fue:**	**Plaguicida**	**El Nivel plaguicida fue:**	Uso de plaguicidas		
				Desde cuando	Plag. Usados anteriormente	cod

Niveles: 1-menor; 2-mismo; 3-Mayor; 9- No Sabe

4.5 Qué métodos de control de plagas que no requieran químicos conoce?	4.5.1 Marcar con una X lo que usa.

4.6 Quién es responsable de aplicar los plaguicidas en su finca?

4.6.1 Jornal contratado______
4.6.2 Hijos_______________
4.6.3 Padre_______________
4.6.4 Madre______________
4.6.5 Otros_______________

V. Efectos en la salud por el uso de plaguicidas en fríjol

Con relación a los agroquímicos de los que estuvimos hablando recientemente, me gustaría preguntarle sobre las plagas que estos controlan y sobre los efectos posibles que podría producir su uso en la salud humana. Me gustaría saber su propia experiencia con estos agroquímicos y otras formas de controlar plagas.

5.1 Conoce usted efectos que pueda producir el uso de plaguicidas en la salud?
Si ( ) No ( )

5.2 ¿Usted o su familia ha sufrido algún problema en la salud a causa de los plaguicidas.

5.2.1 Si ( ) ó No ( )

5.2.2 Cuantas veces____________

5.2.3 Ha habido casos de intoxicación intencional Si ( ) o No ( )

En otras áreas similares a esta región, ha habido reportes que muestran que el uso de pesticidas puede causar efectos sobre la salud humana y sobre el medio ambiente. Nos gustaría hablar sobre los efectos que usted y su familia ha experimentado por haber estado expuestos directamente a los plaguicidas mientras cultivaban fríjol.

5.3 ¿Cuáles de los siguientes síntomas de intoxicaciones agudas han experimentado los miembros de su familia? y ¿Cuántas veces? (Marcar si experimentó en última campaña

	Veces	número de miembros
5.3.1 Irritación de los ojos	______	_____
5.3.2 Escaldadura de la piel	______	_____
5.3.3 Nausea y vómito	______	_____
5.3.4 Dolor de cabeza	______	_____
5.3.5 Mareo	______	_____
5.3.6 Visión nublada	______	_____
5.3.7 Molestias estomacales	______	_____
5.3.8 Dolores musculares	______	_____
5.3.9 Dificultades para respirar	______	_____
5.3.10 Diarrea	______	_____
5.3.11 Otro	______	_____

5.4 ¿Qué hicieron para solucionar las intoxicaciones agudas en la salud que experimento su familia? (Marcar la celda correspondiente).

SINTOMAS	Doctor local	Clínica/ en la ciudad	Curandero	Auto-prescripción	Nada	Otro
Irritación de los ojos						
Escaldadura de la piel						
Nausea y vómito						
Dolor de cabeza						
Mareo						
Visión nublada						
Molestias estomacales						
Dolores musculares						
Dificultades respiratoria.						
Diarrea						

5.5 Nos gustaría tener un estimado de los costos de salud y otros costos escondidos que están relacionados con la intoxicación de pesticidas. ¿Usted recuerda cuánto gasto la última vez que un miembro de su familia se intoxicó con plaguicidas? (En moneda local).

Intoxicación	**Servicios médicos**	**Medicina**	**Días de trabajo perdidos**	**Otros**	**Año de la intox**
Gasto de recuperación					

5.6 Qué tipo de medicinas necesita para curar una intoxicación?
____
____
____

5.7¿Dónde almacenan los plaguicidas?
____
____

5.8 Usa de nuevo los envases de los plaguicidas? Si ( ) No ( )

5.9¿Para qué?
____
____.

5.10 ¿Cuáles de los siguientes implementos usa normalmente para protegerse contra la intoxicación de plaguicidas? (Antes y después).

	Siempre	**Esporádicamente**	**Nunca**	**Costo (Córd)**	**Año de compra**	**Usó último ciclo agrícola**
Mascara						
Guantes						
Ropa protectora						
Primeros auxilios						
Lavarse las manos.						
Bañarse						
Tomar leche						
Tomar agua con tierra						

VI. Efectos del uso de pesticidas en insectos benéficos en fríjol.

Una de las formas más importantes para controlar plagas es el uso de insectos benéficos. Me gustaría hablar sobre el uso potencial de ellos en su finca.

6.1 Sabía usted que algunos insectos son enemigos naturales de las plagas del fríjol y pueden ayudar a controlar estas plagas? Si ( ) o No ( )

6.2 Si 6.1 no, Cree que algunos insectos puedan controlar naturalmente otros insectos?
____

6.3¿Qué insectos benéficos conoce y qué sabe de ellos?* (si responde NO pasar a la 7.1)

	Insectos	Cod	Insectos que controla	Cod	Plantas refugio	Cod	Son susceptibles a plaguicidas?
1.							
2.							
3.							
4.							

6.3 ¿En un año normal son suficientes los insectos benéficos que hay en su finca para controlar las plagas que mencionó? Si ( ) o No ( ).

6.5 Si 6.4 es no. La presencia de estos benéficos reduce el requerimiento de plaguicidas en la parcela. Si ( ) o No ( ).

6.6 Usted ha visto cuantos plagas puede controlar.

El insecto1________
El insecto 2________
El insecto3_________
El insecto 4________

6.7 Que hacen para conservar y atraer los insectos benéficos.

____
____
____

6.8 En el ultimo ciclo agrícola el nivel de insectos benéficos en el fríjol fue.

6.8.1 Mayor________ 6.8.2 Menor__________ 6.8.3 Igual________

6.9 Dada la presencia de insectos benéficos en el ultimo ciclo del fríjol, el uso de plaguicidas fue;

6.9.1 Mayor________ 6.9.2 Menor__________ 6.9.3 Igual________

VII. Conocimiento y adopción de MIP y ECAs

7.1 Conoce el programa de Escuelas de Campo para Agricultores. Sí ( ) no ( ).
7.1.1 ¿Participa en una de ellas? ______
7.1.2 Conoce alguien que participó. Sí ( ) no ( ).
7.1.3 Escuchó hablar de ellas____________________
7.1.4 En qué año tuvo su primer contacto?_______
7.1.5 No conoce____

7.2 Si conoce.
7.2.1 En qué cultivo de la ECA
7.2.2 En qué año tuvo su primer contacto.

7.3 Conoce el MIC Si ( ) y NO ( ) ___________

7.4 Conoce el MIP Si ( ) y NO ( ) ___________

7.5 Qué actividades de MIP / MIC está implementando en su finca?

MIP	Área	MIC	Área
7.5.1 Análisis de agroeco-ecosistema.		**7.5.11 Incorporación de rastrojos**	
7.5.2 Recuento de plagas/enferm		**7.5.12 Arado en seco**	
7.5.3 Trampas		**7.5.13 Abono verde**	
7.5.4 Conservación de insectos benéficos.		**7.5.14 Acequias**	
7.5.5 Plaguicidas botánicos.		**7.5.15 Agroforestería**	
7.5.6 Plaguicidas biológicos		**7.5.16 Barreras vivas**	
7.5.7 Protección de semillero.		**7.5.17 Barreras muertas.**	
7.5.8 Agua caliente		**7.5.18 Terrazas.**	
7.5.9 Cal + ceniza		**7.5.19 Curvas a Nivel**	
7.5.10 Control de malezas hospederas		**7.5.20 Prueba de germinación**	
		7.5.21 Abono orgánico/ biofertilizante	

7.6 Qué cambios Experimentó en su finca después de implementar MIP?
____
____
____

7.7 ¿Cómo cambio el uso de plaguicidas en fríjol la adopción de MIP?

	Incrementó (litros)	Decreció (litros)
Plaguicida1		
Plaguicida2		
Plaguicida3		
Plaguicida4		

7.8 ¿Cómo cambiaron sus rendimientos de fríjol con la adopción de MIP? (Quintales).

7.8.1 Se incrementó en_________
7.8.2 Decreció en ________

7.9 Cómo cambiaron los requerimientos de mano de obra con la adopción de MIP?

7.9.1 Se incrementó en ______ jornales
7.9.2 Decrecieron en ______ jornales

7.10 ¿Cómo cambio el uso de otros insumos en su producción de fríjol con la adopción de MIP?

Insumo	Nunca uso	Incrementó (%)	Decreció (%)
1.			
2.			
3.			
4.			

7.11 Mejoró su conocimiento sobre la dinámica de insectos?

7.11.1 Tengo el mismo nivel_______
7.11.2 Mejoré mi conocimiento______
7.11.3 conoce menos ______
7.11.4 No sé______

7.12 Trabaja con alguna de las siguientes instituciones?

7.12.1 PROMIPAC_____
7.12.2 INTA_____
7.12.3 CARITAS_____
7.12.4 FIDER _______
7.12.5 ESETECA
7.12.6 CECOTROPIC_____
7.12.7 UNICAM___
7.12.8 CARE______
7.12.9 UNAG______
7.12.10 ODESAR___
7.12.11ADAAC_____
7.12.12 Otros______

7.13 Que tipo de apoyo recibe de éstas instituciones?

Medios	**Fines**
7.13.1 Asistencia técnica ___	7.13.6 Conservación de suelos _____
7.13.2 Capacitación __	7.13.7Reforestación______
7.13.3 Crédito ___	7.13.8 Salud _____
7.13.4 Alimentación ____	7.13.9 Enfoque de género____
7.13.5 Pago directo / incentivos__	7.13.10 Organización____
	7.13.11 Mejoramiento de ganado___

7.14 Tiene usted acceso a crédito a partir de:

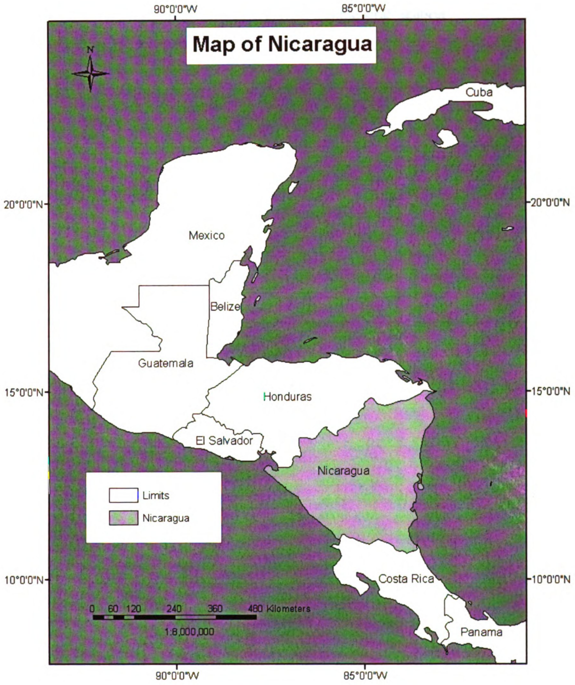
7.14.1 Familia_______
7.14.2 Amigos_______
7.14.3 Proveedor_____
7.14.4 Proyecto______
7.14.5 Banco_________
7.14.6 No tiene crédito__

7.15 OBSERVACIONES.

____
____
____
____

APPENDIX A.2

Map of Nicaragua


90°0'0"W
85°0'0"W
Map of Nicaragua
N
Cuba
20°0'0"N
20°0'0"N
Mexico
Belize
Guatemala
Honduras
15°0'0"N
15°0'0"N
El Salvador
Nicaragua
Limits
Nicaragua
Costa Rica
10°0'0"N
10°0'0"N
0 60 120 240 360 480 Kilometers
1:8,000,000
Panama
90°0'0"W
85°0'0"W

APPENDIX A. 3

Weighting scheme to correct sample stratification

Weighting scheme

We define $Q_j = Pr(\Omega \in W_j)$ as the population frequency for stratum j (probability that each observation belongs to stratum j) and $Hj = N_j/N$ as the current proportion of each stratum within the sample. Then the weight for the stratum j can be defined as Q_j/H_j. This weighting scheme is incorporated in the survey regression methods

APPENDIX A.4

Potential measurement error in Essay 1's environmental and health variables

Potential measurement errors in environmental and health variables

It is possible that respondents misreported the true acute health symptoms suffered by household members or over reported the true level of observed beneficial insect population, in order to obtain additional benefits after participating in IPM training. We can represent these variables as follows:

$$H_O = H_R + \mu_H$$

$$B_O = B_R + \mu_H$$

Where the observed health and beneficial variables equals the real health and beneficial variables plus the measurement error (μ) in each case. The circumstances under which measurement error can produce biased estimates depend on the assumption about correlation between the measurement error and the observed and real explanatory variables. If we assume that the measurement error is uncorrelated with the real variable ($Cov[X_O,\mu_i]=0$), we are assuming that it is correlated with the observed variable, because $\mu_i=X_O-X_R$ (Wooldridge 2002). As we will estimate a model including the observed variables, this assumption would create an endogeneity bias in our estimation and instrumental variable estimation would be necessary to correct the problem. If we assume that the measurement error is uncorrelated with the observed variables ($Cov[X_R,\mu_i]=0$), we are assuming that it is correlated with the real variable. In our case the second assumption seems to be more plausible. It is very likely that households that did not suffer from acute health effects or that observed no beneficial insects will report zero incidence, and therefore the measurement error for them is zero. But households that have suffered acute symptoms are likely to overreport these symptoms in order to give the researcher the impression that they need extra help from externally funded projects, and households that have observed beneficial insects are also likely to overreport their levels in order to give the impression that they benefit from previous training and are available for collaboration. This implies that the measurement error is correlated with the true variables. In this case we can still produce consistent estimates but error variance will be increased

APPENDIX A.5

Production and Socioeconomic Variables used in all regression models

Production and socioeconomic variables used in econometric analysis

Variables	Variable codes	Mean	Std Dev.
Production Variables			
Price of beans (US$ per kilo)	BEANPR	0.3	0.1
Price of maize (US$ per kilo)	MAIZEPR	0.1	0.0
Price of bean seed (US$ per kilo)	SEEDPR	0.5	0.3
Price of metamidophos (US$ per liter)	INSECPR	4.6	0.8
Price of gramoxone (US$ per liter)	HERBPR	5.7	0.7
Price of mancozeb (US$ per kilo)	FUNGPR	4.2	0.6
Price of fertilizer (US$ per sack of 100lb)	FERTPR	12.2	2.5
Price of oxes (US$ per day)	OXESPR	12.7	4.3
Wage for spraying chemicals (US$ per man-day)	WAGE	1.8	0.4
Transport cost (US$ per sack of 100 lbs)	TRANSP	0.6	0.3
Distance to municipal capital (Kms)	MUNDIST	11.3	7.9
Farm altitude (meters above sea level)	ALTITUDE	762.9	232.2
Postrera farming season (%)	POSTRERA	84.0	
Primera farming season (%)	PRIMERA	10.0	
Apante farming season (%)	APANTE	6.0	
Households that observed high level of insect pest (%)	HIGHPEST	8.0	
Households that observed high level of diseases (%)	HIGHDIS	8.0	
Households that observed high level of slugs (%)	HIGHLUGS	9.0	
Households with IPM training (%)	IPMTRAIN	62.8	
Household characteristics			
Households with female head (%)	FEMHEAD	15.0	
Age of household head (years)	AGEHEAD	45.0	13.8
Education of household head (years)	YEAREDU	3.2	3.2
Proportion of female (%)	FEMPERC	49.0	
Number of children	NCHILD	2.2	1.7
Total area of land (hectares)	TOLAND	8.4	12.5
Households with electricity at home (%)	ELECTRIC	44.5	
Number of cattle heads	CATTLE	3.6	6.7
Household receive remittances from relatives (%)	REMITTA	21.0	

APPENDIX A.6

Acute health symptom frequencies used in Essay 1

Frequency of acute health symptoms (in percentage) for 436 Nicaraguan bean growers, 2003-04

	Never	Rarely	Sometimes	Frequently
Headache	51.8	17.2	12.2	18.8
Eye irritation	56.9	14.2	12.6	16.3
Stomachache	76.6	9.4	6.0	8.0
Skin rash	71.0	12.9	8.3	7.8
Blurred vision	72.4	11.7	7.4	8.5
Muscle pain	73.8	9.7	8.7	7.8
Respiratory difficulties	88.8	3.9	3.2	4.1
Diarrhea	96.8	0.7	1.8	0.7

APPENDIX A.7

Complete regression results in Essay 1

Complete regression results for the pesticide demand[+] survey least squares regression for 436 Nicaraguan bean growers, 2003-04

	Insecticide	Herbicide	Fungicide	Molluscicide
Bean Price	-0.000	-0.001	**0.001***	-0.000
	(0.59)	(1.05)	(1.93)	(0.45)
Seed Price	-0.012	-0.007	-0.012	-0.012
	(0.89)	(0.48)	(0.96)	(0.43)
Insecticide Price	**-0.013*****		0.002	0.005
	(3.00)		(0.73)	(1.15)
Herbicide Price		**-0.043*****		
		(5.00)		
Transport cost	-0.001	-0.010	0.006	0.003
	(0.05)	(0.90)	(0.90)	(0.36)
Wage	-0.004	0.003	0.000	0.001
	(0.48)	(0.37)	(0.07)	(0.10)
Altitude	0.000	0.001	-0.002	0.000
	(0.28)	(1.23)	(1.09)	(0.49)
High pest level	-0.059			
	(0.40)			
high level of diseases			**0.442*****	
			(3.47)	
high level of slugs				**1.027*****
				(3.06)
Municipal distance	-0.000	**-0.256****	-0.120	-0.088
	(0.00)	(2.09)	(1.40)	(1.18)
Adopted AAE[++]	-0.093		-0.007	-0.007
	(0.63)		(0.07)	(0.08)
AAE & more beneficials	-0.171		0.337	-0.050
	(1.16)		(1.32)	(0.25)
Adopted botanicals insect.	-0.269		**0.154****	-0.135
	(1.59)		(2.08)	(0.89)
Adopted yellow traps	0.008			
	(0.05)			
IPM trained	**0.339*****	**0.151***	0.060	0.070
	(2.96)	(1.66)	(0.78)	(0.65)
IPM & beneficial awareness	**-0.336***		-0.059	0.007
Number of symptoms	0.012	0.070	-0.003	-0.010
	(0.37)	(1.37)	(0.14)	(0.39)
Freq. eye irritation	-0.009	-0.027	0.002	0.002
	(0.15)	(0.47)	(0.04)	(0.04)
Freq. diarrhea	**-0.398***	-0.048	0.013	-0.118
	(1.74)	(0.47)	(0.13)	(1.01)
Freq. respiratory difficulty	0.084	0.012	-0.020	-0.055
	(0.86)	(0.14)	(0.35)	(0.62)
Freq skin rash	**-0.106***	-0.028	-0.017	0.013
	(1.65)	(0.52)	(0.42)	(0.28)
Freq. Stomach ache	0.039	0.035	-0.067	-0.048
	(0.54)	(0.33)	(1.58)	(0.62)
Freq head ache	**0.177****	0.002	-0.050	-0.029
	(2.26)	(0.03)	(1.41)	(0.60)
Freq muscle pain	0.052	-0.012	0.088	-0.040
	(0.87)	(0.21)	(1.47)	(0.74)
Freq blurred vision	-0.017	**-0.137***	-0.029	0.060

	(0.16)	(1.98)	(0.56)	(0.61)
Lost workdays	**-0.233***	-0.033	-0.000	-0.040
	(1.65)	(0.30)	(0.00)	(0.43)
Visited city doctor	-0.022	0.078	0.051	-0.031
	(0.13)	(0.54)	(0.39)	(0.26)
Hospitalized	-0.128	0.241	0.068	-0.053
	(0.52)	(1.53)	(0.40)	(0.39)
Purchased protective devices	**0.212*****	-0.046	0.028	-0.003
	(3.57)	(0.85)	(0.78)	(0.08)
Homemade protective devices	**-0.178***	-0.146	0.039	-0.034
	(1.73)	(1.49)	(0.45)	(0.41)
Hired applicator	**0.189***	**0.222***	0.082	0.104
	(1.89)	(1.72)	(1.06)	(1.08)
Apante season	-0.034	-0.292	0.172	0.101
	(0.11)	(1.00)	(1.11)	(0.30)
Postrera season	-0.083	0.049	-0.007	-0.042
	(0.50)	(0.26)	(0.07)	(0.14)
Female head	0.136	-0.239	**0.208***	-0.138
	(1.02)	(1.63)	(1.85)	(1.55)
Years of education	0.018	**0.024***	0.011	0.019
	(1.16)	(1.68)	(0.90)	(0.96)
Remittances	0.010	0.026	0.110	**0.326****
	(0.09)	(0.22)	(1.24)	(2.01)
Total land	**-0.001*****	**0.001*****	0.000	-0.000
	(3.61)	(3.08)	(1.41)	(0.82)
Number children	**-0.062****	-0.018	**0.050*****	-0.011
	(2.26)	(0.63)	(2.96)	(0.42)
Female percentage	-0.378	**0.550***	**-0.428*****	-0.180
	(1.37)	(1.94)	(2.68)	(0.81)
Has electricity	0.059	0.135	0.039	-0.217
	(0.50)	(1.04)	(0.34)	(1.35)
Cattle heads	0.005	-0.012	-0.001	0.003
	(0.66)	(1.10)	(0.10)	(0.39)
Constant	1.714	**6.450*****	2.553	0.451
	(1.22)	(3.41)	(1.12)	(0.41)
Resistant variety			0.147	
			(1.38)	
Observations	436	436	436	436
R-squared	0.46	0.52	0.37	0.39

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
$^{+}$ 73 community dummy variables are not reported in this table due to space limitation
$^{++}$ Agro-ecosystem analysis

Complete regression results for the IPM adoption+ survey multinomial logit regression for 436 Nicaraguan bean growers, 2003-04

	Agro-ecol Analysis	Botanical Insecticides	Insect traps	Two IPM practices	Three practices
Seed Price	-0.083	-0.194	4.088	**0.141***	-0.048
	(0.47)	(1.34)	(0.91)	(1.67)	(0.32)
Bean Price	-0.007	0.001	0.199	-0.006	-0.003
	(0.98)	(0.30)	(1.17)	(1.59)	(0.41)
Maize Price	-0.011	**0.026*****	0.731	**0.028****	0.011
	(0.64)	(3.42)	(1.22)	(2.51)	(0.82)
Insecticide Price	**0.045***	-0.005	0.758	-0.049	0.013
	(1.85)	(0.23)	(1.12)	(1.51)	(0.47)
Herbicide Price	-0.058	-0.022	-0.500	0.017	**0.065****
	(1.41)	(0.76)	(1.03)	(0.65)	(2.55)
Transport cost	0.055	0.055	3.029	**0.078****	**-0.327*****
	(0.87)	(1.37)	(1.07)	(2.01)	(3.42)
Wage	**0.161****	-0.019	1.084	**0.114***	-0.015
	(2.24)	(0.31)	(1.08)	(1.85)	(0.17)
Altitude	0.002	0.000	-0.019	**0.004****	0.001
	(1.09)	(0.19)	(1.23)	(2.29)	(0.58)
Municipal distance	**-0.412****	0.038	-4.710	0.029	0.078
	(2.22)	(1.11)	(1.15)	(0.73)	(1.38)
IPM trained	**4.793*****	**5.661*****	24.656	**8.624*****	**89.649*****
	(4.10)	(7.55)	(1.61)	(3.89)	(14.03)
Number of symptoms	**0.569*****	**0.768*****	5.127	0.179	0.053
	(2.77)	(3.56)	(1.44)	(0.75)	(0.20)
Freq. eye irritation	0.268	**-0.757****	-6.854	-0.058	0.467
	(0.54)	(2.19)	(1.10)	(0.22)	(1.54)
Freq dizziness	-0.243	**-1.880*****	19.919	**-0.640***	-0.566
	(0.53)	(3.67)	(1.16)	(1.78)	(1.28)
Freq. respirat. difficulty	0.021	0.891	-18.574	**1.995*****	1.347
	(0.03)	(1.57)	(1.29)	(3.20)	(1.52)
Freq skin rash	**0.894***	0.032	11.439	0.162	**1.027*****
	(1.75)	(0.09)	(1.10)	(0.36)	(3.08)
Freq. Stomach ache	0.449	-0.314	12.612	0.007	0.182
	(1.18)	(0.81)	(1.07)	(0.02)	(0.39)
Freq head ache	-0.290	**0.630****	4.179	0.420	**0.817****
	(0.67)	(2.41)	(1.06)	(1.45)	(2.58)
Freq muscle pain	0.304	-0.553	12.274	-0.681	-0.302
	(0.44)	(1.41)	(1.12)	(1.55)	(0.75)
Freq blurred vision	-0.900	**-1.100****	-10.756	-0.845	**-1.651****
	(1.50)	(2.22)	(1.14)	(1.59)	(2.59)
Lost workdays	**-4.032****	-0.405	-33.518	-0.810	-0.290
	(1.99)	(0.57)	(1.28)	(0.88)	(0.36)
Visited city doctor	3.377	-1.105	-8.263	-2.079	**-5.862*****
	(1.63)	(0.84)	(1.05)	(1.42)	(3.01)
Hospitalized	**47.373*****	0.767	8.726	-0.861	**42.351*****
	(15.34)	(0.66)	(0.86)	(0.64)	(19.94)
Purchased protective devices	**0.785***	0.197	18.881	0.295	0.244
	(1.95)	(0.74)	(1.23)	(1.20)	(0.58)
Homemade protective devices	1.699	0.551	14.538	0.554	**1.553****
	(1.53)	(1.16)	(1.31)	(1.00)	(2.29)
Hired applicator	-0.421	**1.237****	-52.568	-0.827	-0.882

	(0.33)	(2.00)	(1.27)	(1.16)	(0.91)
Apante season	23.663	-2.084	345.235	-3.131	1.880
	(0.65)	(0.82)	(1.03)	(1.38)	(0.80)
Postrera season	0.503	-1.000	119.253	0.868	0.840
	(0.57)	(1.03)	(0.53)	(0.85)	(0.65)
Female head	-0.203	**-1.431***	**-44.225*****	-0.753	0.101
	(0.14)	(1.92)	(4.99)	(0.87)	(0.10)
Years education	-0.062	0.104	-3.058	**0.200****	**0.420*****
	(0.58)	(1.30)	(1.08)	(2.31)	(4.88)
Remittances	**-2.217***	-0.171	19.782	0.605	0.976
	(1.84)	(0.28)	(1.11)	(1.06)	(1.27)
Total land	**-0.104****	-0.010	-1.671	0.003	**0.048****
	(2.16)	(0.67)	(1.15)	(1.06)	(2.11)
Number of children	-0.320	**-0.309***	9.016	-0.236	-0.303
	(1.26)	(1.88)	(1.25)	(1.52)	(1.09)
Female percentage	0.404	1.005	-24.828	**3.173***	2.386
	(0.33)	(0.79)	(0.89)	(1.74)	(1.40)
Has electricity	0.344	-1.091	57.058	-0.850	-0.497
	(0.48)	(1.45)	(1.23)	(1.17)	(0.60)
Cattle heads	0.023	0.098	6.028	**0.101***	0.119
	(0.28)	(1.60)	(1.22)	(1.66)	(1.24)
San Isidro municipal.+	**7.081*****	-0.688	**-70.505****	-0.703	-1.424
	(2.86)	(0.53)	(2.34)	(0.35)	(0.61)
Wiwili municipal.	**-18.245*****	1.682	-202.242	**6.086****	0.563
	(10.20)	(0.60)	(0.99)	(2.43)	(0.24)
Pueblo nuevo municipal.	1.765	**3.083*****	-43.822	**2.907****	2.353
	(0.92)	(2.67)	(1.19)	(2.17)	(1.60)
San Nicolás municipal.	1.766	-0.041	1.015	-0.374	-2.567
	(0.89)	(0.04)	(0.20)	(0.39)	(1.44)
San Marcos municipal.	0.945	1.037	**-122.748***	0.203	1.121
	(0.43)	(0.76)	(1.78)	(0.12)	(0.66)
Condega municipal.	**4.067****	1.094	**-7.892****	1.838	2.561
	(2.56)	(1.07)	(2.02)	(1.30)	(1.65)
Placaguina municipal.	1.436	1.003	**-105.794***	-1.253	0.933
	(0.64)	(0.56)	(1.84)	(0.67)	(0.47)
Niquinohomo municipal.	2.737	-0.104	-72.562	2.560	0.967
	(1.28)	(0.06)	(1.20)	(1.54)	(0.52)
La Trinidad municipal.	1.522	-0.914	**-10.110****	**-44.741*****	**-10.210*****
	(0.71)	(0.76)	(2.35)	(20.04)	(2.76)
Constant	**-8.499***	**-6.637***	-392.582	**-18.984*****	-102.160
	(1.69)	(1.78)	(1.01)	(2.97)	(0.97)
Observations	436	436	436	436	436

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ The municipality of Estelí is used as the control group

Complete regression results for the labor demand+ survey least squares regression for 436 Nicaraguan bean growers, 2003-04

	Family labor	Hired labor	Total labor
Log Seed Price	-0.769	0.787	-0.467
	(1.34)	(1.23)	(0.83)
Log Bean Price	1.165	-1.141	0.496
	(1.58)	(1.08)	(0.79)
Log Insecticide Price	**2.424***	-0.260	0.976
	(1.90)	(0.12)	(0.85)
Log Herbicide Price	**-3.554***	-1.706	**-4.697****
	(1.74)	(0.86)	(2.42)
Log Wage	1.084	-0.261	0.944
	(0.97)	(0.18)	(0.95)
Altitude	-0.001	0.004	-0.001
	(0.54)	(1.10)	(0.27)
Municipal distance	0.119	-0.016	0.228
	(0.24)	(0.02)	(0.57)
Adopted AEA	0.432	-0.060	-0.118
	(0.68)	(0.08)	(0.23)
AEA & more beneficials	**-1.872****	-0.269	**-1.636****
	(2.36)	(0.20)	(2.12)
Adopted botanical insecticides	-0.959	0.615	-0.751
	(1.63)	(0.81)	(1.49)
Adopted yellow traps	0.594	**-2.422*****	0.217
	(0.91)	(2.77)	(0.39)
IPM trained	**0.910****	0.031	0.638
	(2.17)	(0.04)	(1.51)
IPM trained & beneficial awareness	**-1.856*****	0.778	-0.894
	(2.87)	(1.12)	(1.63)
Number of symptoms	-0.078	0.253	0.015
	(0.59)	(1.32)	(0.15)
Freq. eye irritation	-0.277	**0.640****	-0.180
	(1.20)	(2.02)	(0.96)
Freq. diarrhea	-0.431	1.032	**-0.886***
	(0.58)	(1.33)	(1.67)
Freq. respiratory difficulty	0.095	0.548	-0.163
	(0.28)	(1.22)	(0.52)
Freq skin rash	-0.169	**-0.689***	-0.371
	(0.64)	(1.86)	(1.52)
Freq. Stomach ache	0.158	-0.496	0.113
	(0.54)	(1.11)	(0.45)
Freq head ache	0.163	-0.537	0.046
	(0.77)	(1.60)	(0.26)
Freq muscle pain	0.346	-0.163	0.245
	(1.64)	(0.41)	(1.33)
Freq blurred vision	**-0.620*****	-0.248	-0.259
	(2.67)	(0.48)	(1.46)
Lost workdays	-0.542	-0.766	-0.543
	(0.80)	(1.06)	(1.00)
Visited city doctor	-0.981	-0.144	-0.813
	(1.02)	(0.16)	(0.97)
Hospitalized	0.515	-1.149	0.224
	(0.65)	(0.84)	(0.32)
Purchased protective devices	**0.426***	-0.287	0.099
	(1.70)	(1.02)	(0.43)

Homemade protective devices	-0.712	-0.316	**-0.765***
	(1.56)	(0.61)	(1.81)
Apante season	**-3.066*****	0.734	-0.956
	(2.73)	(0.29)	(0.62)
Postrera season	0.814	0.725	0.856
	(1.40)	(0.77)	(1.53)
Female head	**-1.398****	1.047	-0.449
	(2.54)	(1.21)	(1.09)
Years of education	0.090	**0.279*****	**0.154*****
	(1.21)	(3.79)	(2.89)
Remittances	0.052	0.604	0.408
	(0.10)	(0.87)	(0.91)
Log Total land	-0.022	**0.736****	0.119
	(0.09)	(2.54)	(0.59)
Number children	-0.025	-0.073	-0.048
	(0.19)	(0.45)	(0.43)
Female percentage	-0.347	-0.637	0.349
	(0.35)	(0.34)	(0.36)
Has electricity	-0.863	0.413	-0.100
	(1.19)	(0.54)	(0.15)
Cattle heads	**-0.084****	0.063	-0.007
	(2.06)	(1.11)	(0.34)
Constant	2.984	-5.682	12.156
	(0.22)	(0.35)	(0.98)
Observations	436	436	436
R-squared	0.43	0.37	0.46

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ 73 community dummy variables are not reported in this table due to space limitation.

APPENDIX A.8

Complete regression results in Essay 2

Hausman test for the linear approximation of health function models

	F-statistic	P-value
Respiratory difficulties	0.77	0.5471
Eye irritation	0.90	0.4687
Stomachache	1.73	0.1479
Blurred vision	0.46	0.7628

Predicted probability of FFS and other IPM training participation used as instruments in the 2SLS estimations, survey probit regression for 436 Nicaraguan bean growers, 2003-04⁺

	FFS	Other IPM program
Original explanatory variables		
Bean price	0.000	-0.004**
	(0.05)	(2.07)
Insecticide price	0.001	0.000
	(0.12)	(0.03)
Herbicide price	-0.001	0.012
	(0.07)	(1.13)
Fertilizer price	0.000	-0.009***
	(0.05)	(3.14)
Seed price	0.043	0.031
	(1.39)	(0.97)
Transport cost	-0.025	0.022
	(0.77)	(0.89)
Wage	-0.035**	-0.014
	(2.22)	(0.91)
Altitude	0.002**	-0.002**
	(2.04)	(2.52)
High pest level	-0.551*	0.614*
	(1.75)	(1.76)
High disease level	0.136	-0.883**
	(0.33)	(2.47)
High slug level	-0.246	
	(1.00)	
Municipal distance	-0.055	0.039
	(1.49)	(1.34)
Visit city doctor	-0.891**	0.404
	(2.08)	(1.04)
Protective devices	0.240**	-0.068
	(2.05)	(0.60)
Hired applicator	-0.315	0.055
	(1.30)	(0.19)
Apante season	-1.391*	1.631*
	(1.82)	(1.93)
Postrera season	0.086	1.213***
	(0.28)	(3.46)
Female head	1.106***	-1.209***
	(4.15)	(3.44)
Years of education	-0.018	-0.010
	(0.67)	(0.30)
Remittances	-0.048	0.256
	(0.18)	(1.30)
Total land	0.008	-0.004
	(0.88)	(0.30)
Number of children	0.062	0.047
	(1.17)	(0.82)
Female percentage	-2.020***	0.747
	(3.25)	(1.41)
Has electricity	0.710**	-0.339
	(2.50)	(1.25)
Heads of cattle	-0.032	0.023

	(1.33)	(1.32)
Redundant variables		
Number of soil practices	0.007	0.016
	(0.07)	(0.14)
Adopted terraces	0.121	0.601**
	(0.49)	(2.24)
Adopted countour	-0.360	-0.291
	(1.38)	(1.02)
Adopted fences	0.529*	0.178
	(1.85)	(0.61)
Adopted other soil practices	0.231	-0.228
	(1.01)	(0.80)
Received food from NGO	0.505**	-0.343
	(2.51)	(1.20)
Received training from NGO	0.173	0.258
	(0.75)	(1.09)
Received credit from NGO	0.447**	-0.604***
	(2.23)	(2.73)
Constant	-2.963*	-63.029**
	(1.82)	(2.05)
Observations	436	436

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ Community dummy variables not reported due to space limitations

Complete regression results for pesticide demand[+] survey least squares regression for 436 Nicaraguan bean growers, 2003-04

	Insecticide	IV insecticides	Herbicides	IV Herbicides	Fungicide	IV Fungicides
Bean price	-0.000	-0.000	-0.000	-0.000	0.000	0.000*
	(1.26)	(1.08)	(0.49)	(0.72)	(1.62)	(1.83)
Insecticide price	-0.001**	-0.000				
	(2.44)	(1.10)				
Herbicide price			-0.000***	-0.000***		
			(4.83)	(4.13)		
Fungicide price					-0.000*	-0.000*
					(1.81)	(1.65)
Seed price	0.000	-0.001	-0.001*	-0.001**	0.000	0.000
	(0.07)	(0.47)	(1.66)	(2.04)	(0.56)	(0.57)
Transport cost	0.000	0.000	0.000	0.000	0.000	0.000
	(0.59)	(0.14)	(0.21)	(0.05)	(1.14)	(1.16)
Wage	-0.000	0.000	0.000	0.000	0.000	0.000
	(0.03)	(0.15)	(0.95)	(1.00)	(0.96)	(0.91)
Altitude	-0.000	-0.000	0.000	0.000	0.000	0.000
	(1.15)	(0.01)	(0.68)	(0.97)	(0.34)	(0.55)
High pest level	-0.004	0.002				
	(0.61)	(0.25)				
Municipal distance	-0.007**	-0.005	-0.002***	-0.001	0.001	0.001*
	(2.10)	(0.59)	(2.69)	(0.90)	(1.16)	(1.73)
FFS	-0.027**	-0.106	0.003	-0.007	0.001	0.001
	(2.38)	(0.90)	(1.42)	(0.65)	(0.75)	(0.29)
Other IPM training	0.004	-0.002	0.001	0.001	0.000	0.002
	(0.53)	(0.09)	(1.47)	(0.84)	(0.58)	(1.20)
FFS & other IPM	0.007	-0.156	-0.007*	-0.026*	-0.001	-0.001
	(0.54)	(1.04)	(1.94)	(1.66)	(0.80)	(0.17)
Years after graduation	0.007	0.042	-0.002*	0.003	-0.000	0.000
	(1.12)	(0.93)	(1.86)	(0.77)	(0.32)	(0.25)
Influenced	0.003	-0.017	0.001	-0.001	-0.001	-0.000
	(0.53)	(0.83)	(0.94)	(0.33)	(0.90)	(0.06)
Purchased protective devices	0.005	0.005	0.001	0.001	0.000	0.000
	(1.20)	(0.97)	(1.03)	(0.92)	(0.48)	(0.19)
Homemade protective devices	-0.006	0.008	-0.001*	0.000	0.000	-0.000
	(1.41)	(0.65)	(1.86)	(0.10)	(0.13)	(0.06)
Hired applicator	-0.005	-0.008	-0.000	-0.001	-0.001	-0.000

	(1.16)	(1.13)	(0.29)	(0.38)	(1.03)	(0.88)
Apante season	-0.037**	-0.043	-0.001	-0.002	0.002	0.002
	(2.24)	(1.05)	(0.25)	(0.40)	(1.08)	(0.87)
Postrera season	-0.023	-0.022	0.000	0.000	0.002	0.002
	(1.63)	(1.32)	(0.21)	(0.20)	(1.46)	(1.43)
Female head	0.010	0.001	-0.002	-0.003*	0.001	0.001
	(1.50)	(0.12)	(1.65)	(1.92)	(1.26)	(1.29)
Years of education	0.000	0.001	0.000	0.000	0.000	0.000
	(0.28)	(1.12)	(0.42)	(0.96)	(1.59)	(1.39)
Remittances	-0.002	-0.005	0.000	-0.000	0.000	0.000
	(0.30)	(0.39)	(0.15)	(0.34)	(0.46)	(0.21)
Total land	0.000***	0.000**	0.000***	0.000**	0.000	0.000
	(4.51)	(2.48)	(2.68)	(2.54)	(0.61)	(0.95)
Number of children	-0.001	-0.001	-0.000	-0.000	0.000	0.000
	(0.38)	(0.47)	(0.65)	(0.92)	(0.90)	(0.81)
Percentage of female	-0.000	0.010	0.007	0.008*	0.000	0.000
	(0.00)	(0.42)	(1.61)	(1.71)	(0.25)	(0.24)
Has electricity	0.002	0.007	0.000	0.000	-0.002	-0.002
	(0.33)	(0.62)	(0.05)	(0.29)	(0.86)	(0.92)
Heads of cattle	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.83)	(0.42)	(0.50)	(0.55)	(0.73)	(0.97)
Resistant variety					0.002	0.002
					(1.09)	(1.09)
High disease level					0.000	0.000
					(0.17)	(0.20)
Constant	0.191***	0.129	0.048***	0.030	-0.013	-0.019
	(3.69)	(1.07)	(3.59)	(1.58)	(1.26)	(1.59)
Observat.	436	436	436	436	436	436
R-squared	0.30	0.12	0.42	0.15	0.40	0.39

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] 73 community dummy variables are not reported in this table due to space limitation

Complete regression results for IPM adoption[+] survey least squares regression for 436 Nicaraguan bean growers, 2003-04

	N.pract.	IV N.pra	AAE	IV AAE	Botan.	IV bot.	Traps	IV traps
Bean price	-0.001**	-0.001	-0.001**	-0.000	-0.001*	-0.000	-0.000	-0.000
	(2.11)	(1.22)	(2.17)	(1.34)	(1.87)	(1.08)	(0.44)	(0.29)
Insecticide price	0.002	-0.001	0.002	0.001	-0.002	-0.003	0.002	0.001
	(0.51)	(0.15)	(0.92)	(0.34)	(1.14)	(1.26)	(1.10)	(0.82)
Seed price	0.008	0.018	0.004	0.008	-0.001	0.004	0.004	0.005
	(0.44)	(0.77)	(0.52)	(0.82)	(0.16)	(0.32)	(0.59)	(0.73)
Transport cost	0.005	0.002	0.001	-0.000	0.010**	0.008	-0.004	-0.004
	(0.74)	(0.20)	(0.29)	(0.10)	(2.04)	(1.25)	(1.38)	(1.40)
Wage	0.002	-0.001	0.004*	0.002	-0.002	-0.004	0.000	-0.000
	(0.38)	(0.25)	(1.66)	(0.73)	(1.07)	(1.19)	(0.07)	(0.05)
Altitude	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.35)	(0.47)	(0.12)	(0.04)	(0.24)	(0.65)	(0.33)	(0.32)
High pest	0.095	-0.067	0.029	-0.038	0.071	-0.002	-0.005	-0.029
	(0.82)	(0.43)	(0.50)	(0.57)	(0.90)	(0.02)	(0.08)	(0.48)
High disease	-0.114	-0.167	-0.071	-0.072	0.045	-0.011	-0.096**	-0.101*
	(0.98)	(1.05)	(1.13)	(0.81)	(0.59)	(0.11)	(2.19)	(1.72)
Municipal distance	-0.053	-0.161	-0.021	-0.064	-0.040	-0.111*	0.022	0.016
	(0.54)	(1.31)	(0.50)	(0.99)	(0.68)	(1.78)	(0.84)	(0.33)
FFS	1.188***	0.907	0.665***	0.139	0.372**	0.534	0.166	0.180
	(3.80)	(0.82)	(3.96)	(0.24)	(2.04)	(0.85)	(1.39)	(0.44)
Other IPM	0.692***	1.286***	0.155***	0.381**	0.398***	0.647***	0.141***	0.249**
	(9.70)	(3.71)	(3.35)	(2.15)	(7.43)	(3.48)	(5.03)	(2.01)
FFS and other IPM	-0.118	1.463	-0.240	0.591	0.002	0.713	0.518	0.291
	(0.37)	(1.11)	(1.31)	(0.95)	(0.01)	(0.93)	(0.87)	(0.65)
Influenced	-0.172*	0.025	-0.037	0.003	-0.067	0.032	-0.065*	-0.018
	(1.67)	(0.12)	(0.91)	(0.03)	(0.83)	(0.25)	(1.79)	(0.26)
Years after graduation	0.066	-0.175	-0.060	0.020	0.090	-0.178	0.044	-0.000
	(0.43)	(0.36)	(0.69)	(0.08)	(1.11)	(0.63)	(0.74)	(0.00)
Hired applicator	0.013	0.019	-0.051	-0.045	0.145***	0.144***	-0.084**	-0.083**
	(0.14)	(0.17)	(0.94)	(0.76)	(3.05)	(2.78)	(2.27)	(2.11)
Apante season	-0.323	-0.509	-0.207	-0.358*	-0.110	-0.146	-0.016	-0.034
	(0.98)	(1.37)	(1.35)	(1.72)	(0.51)	(0.50)	(0.07)	(0.15)
Postrera season	-0.001	-0.049	0.031	0.021	-0.052	-0.077	0.028	0.018

	(0.00)	(0.22)	(0.34)	(0.19)	(0.78)	(0.90)	(0.49)	(0.26)
Female head	-0.282*	-0.015	-0.118*	-0.020	-0.062	0.076	-0.058	-0.020
	(1.91)	(0.09)	(1.95)	(0.29)	(0.90)	(0.93)	(1.22)	(0.34)
Years of education	0.037**	0.023	0.013	0.009	0.008	0.001	0.016**	0.013*
	(2.18)	(1.29)	(1.57)	(1.09)	(1.37)	(0.13)	(2.09)	(1.80)
Remittances	0.137	0.118	0.007	0.000	0.047	0.042	0.076	0.071
	(1.59)	(0.98)	(0.17)	(0.00)	(0.76)	(0.66)	(1.41)	(1.19)
Total land	-0.001**	0.000	-0.000	0.000	-0.000**	-0.000	-0.000	-0.000
	(2.60)	(0.07)	(0.05)	(1.22)	(2.38)	(0.38)	(1.61)	(0.52)
Number of children	-0.043**	-0.041*	-0.018	-0.017	-0.014	-0.014	-0.014	-0.014
	(1.99)	(1.73)	(1.64)	(1.39)	(1.27)	(1.07)	(1.49)	(1.56)
Percentage of female	0.390**	0.147	0.206**	0.107	0.059	-0.061	0.154*	0.121
	(2.06)	(0.56)	(2.08)	(0.89)	(0.50)	(0.41)	(1.72)	(1.22)
Has electricity	0.151	0.123	0.089	0.065	-0.017	-0.021	0.076	0.072
	(1.45)	(0.74)	(1.65)	(0.81)	(0.27)	(0.26)	(1.49)	(1.23)
Heads of cattle	0.013**	0.004	0.002	-0.001	0.002	-0.001	0.008***	0.006*
	(2.24)	(0.43)	(0.78)	(0.29)	(0.67)	(0.22)	(2.68)	(1.90)
Constant	0.815	2.647	0.149	0.835	0.769	1.948**	-0.239	-0.099
	(0.65)	(1.49)	(0.24)	(0.82)	(1.01)	(2.05)	(0.54)	(0.13)
Observations	436	436	436	436	436	436	436	436
R-squared	0.59	0.29	0.47	0.26	0.55	0.19	0.37	0.32

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ 73 community dummy variables are not reported in this table due to space limitation

Complete regression results for bean yields and net revenues+ survey least squares regression for 436 Nicaraguan bean growers, 2003-04

	Yields	IV Yields	Net revenues	IV Net revenues
Bean price	0.003	0.005	10.165***	0.6777***
	(0.69)	(0.86)	(8.06)	(7.27)
Insecticide price	-0.087**	-0.098**	-24.090***	-1.8012**
	(2.46)	(2.17)	(2.78)	(2.56)
Herbicide price	-0.043	-0.029	-1.699	-0.2614
	(0.81)	(0.44)	(0.14)	(0.30)
Seed price	0.007	-0.093	-66.985**	-5.3448
	(0.04)	(0.44)	(2.31)	(2.07)
Fertilizar price	-0.052***	-0.056***	-12.914***	-0.7954***
	(4.20)	(3.95)	(3.86)	(3.35)
Oxes price	-0.028***	-0.034**	-2.868	-0.3555
	(2.78)	(2.20)	(1.12)	(1.48)
Transport cost	0.101	0.091	12.417	0.8754
	(1.22)	(1.01)	(0.55)	(0.63)
Wage	0.053	0.037	-0.888	-0.4314
	(0.79)	(0.47)	(0.05)	(0.33)
Altitude	0.011*	0.016**	2.145*	0.2293**
	(1.96)	(2.23)	(1.81)	(2.34)
High pest level	-3.262***	-2.965***	-556.864*	-38.127**
	(3.21)	(2.64)	(1.96)	(2.14)
High disease level	2.469	4.223**	863.120**	89.1173***
	(1.41)	(2.01)	(2.24)	(3.28)
High slug level	-3.112***	-1.917	-778.867***	-35.065
	(2.64)	(1.17)	(2.66)	(1.35)
Municipal distance	1.232*	2.408*	597.151***	59.70425***
	(1.74)	(1.91)	(3.05)	(2.79)
FFS	-0.439	-19.670	264.924	-276.0538
	(0.19)	(1.25)	(0.43)	(0.99)
Other IPM	-0.577	-2.650	-191.449	21.22
	(0.56)	(0.74)	(0.70)	(0.36)
FFS & other IPM	0.218	-21.606**	50.015	-233.6391
	(0.12)	(2.35)	(0.12)	(1.65)
Influenced	2.068	0.980	627.566	42.602
	(1.01)	(0.32)	(1.17)	(0.87)
Years after graduation	0.114	8.983	-114.307	136.4294
	(0.11)	(1.44)	(0.41)	(1.25)
Adopted AAE	0.825	2.464	29.519	28.6494
	(0.81)	(1.35)	(0.12)	(0.96)
Adopted botanicals	-0.104	1.861	-166.807	-7.224
	(0.11)	(1.08)	(0.69)	(0.25)
Adopted traps	1.145	2.434*	215.535	19.9775
	(1.05)	(1.68)	(0.74)	(0.95)
Observed more beneficials	-2.308*	-0.382	-254.715	3.4447
	(1.88)	(0.21)	(0.89)	(0.14)
Apante season	-3.150	-5.709	-1,308.192*	-130.3656*
	(1.27)	(1.27)	(1.85)	(1.71)
Postrera season	-1.228	-1.023	-308.223	-21.8674
	(1.01)	(0.61)	(1.35)	(1.10)
Female head	-1.642	-2.169*	-469.010	-32.3588
	(1.49)	(1.83)	(1.47)	(1.32)
Years of education	0.175	0.175	-0.558	-0.2474

	(1.28)	(1.08)	(0.02)	(0.13)
Remittances	-2.100**	-2.012*	-429.778**	-29.30881*
	(2.36)	(1.84)	(2.00)	(1.84)
Total land	-0.005	-0.004	-1.968**	-0.0751
	(1.37)	(0.92)	(2.23)	(1.13)
Number of children	-0.404	-0.317	-120.343*	-7.1267
	(1.46)	(1.01)	(1.86)	(1.50)
Percentage of female	0.434	0.233	481.903	23.6549
	(0.20)	(0.10)	(0.91)	(0.61)
Has electricity	0.811	0.127	-45.536	-12.5814
	(0.57)	(0.07)	(0.19)	(0.61)
Heads of cattle	0.045	0.037	11.377	0.1428
	(0.65)	(0.47)	(0.66)	(0.11)
Constant	4.399	-14.383	-4,538.337*	-606.619**
	(0.42)	(0.84)	(1.70)	(2.21)
Observations	436	436	436	436
R-squared	0.41	0.10	0.47	0.24

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] 73 community dummy variables are not reported in this table due to space limitation.

Complete regression results for the incidence of acute health symptoms+ survey ordered probit regression for 436 Nicaraguan bean growers, 2003-04

	Respiratory difficulty	Eye irritation	Stomach ache	Blurred vision
Bean price	-0.001	-0.002*	0.001	-0.001
	(0.65)	(1.81)	(0.41)	(0.87)
Insecticide price	0.013*	-0.003	0.013*	0.007
	(1.78)	(0.33)	(1.85)	(0.89)
Herbicide price	0.005	-0.007	0.007	-0.000
	(0.38)	(0.94)	(0.72)	(0.07)
Seed price	0.068	0.009	0.097***	0.068***
	(1.61)	(0.26)	(2.88)	(3.11)
Fertilizer price	-0.003	0.002	-0.004*	-0.002
	(1.11)	(0.94)	(1.76)	(0.71)
Transport cost	0.019	0.038**	-0.040**	0.011
	(0.90)	(2.29)	(2.54)	(0.61)
Wage	0.028**	0.005	0.008	0.020*
	(2.39)	(0.33)	(0.50)	(1.82)
Altitude	-0.000	-0.000	0.000	-0.000
	(0.17)	(0.80)	(0.39)	(0.63)
Municipal distance	-0.007	0.020	-0.041***	0.013
	(0.40)	(1.32)	(2.68)	(0.88)
FFS	1.137**	1.002*	0.156	-0.021
	(2.18)	(1.89)	(0.28)	(0.04)
Other IPM	0.009	0.218	-0.092	0.155
	(0.03)	(1.15)	(0.42)	(0.75)
FFS & other IPM	0.196	0.017	-0.019	0.255
	(0.57)	(0.05)	(0.05)	(0.96)
Years after graduation	-0.452*	-0.156	-0.185	0.230
	(1.69)	(0.64)	(0.70)	(0.95)
Influenced	-0.341	0.636**	-0.276	-0.332
	(0.84)	(2.30)	(0.83)	(1.17)
Protective devices	-0.354***	-0.078	-0.236*	-0.188*
	(2.79)	(0.69)	(1.81)	(1.95)
Homemade devices	0.604***	0.234	0.267	0.101
	(2.80)	(1.14)	(0.94)	(0.63)
Hired applicator	-0.017	-0.422*	0.184	-0.204
	(0.06)	(1.96)	(0.75)	(0.94)
Apante season	1.060	-0.091	-1.203*	-0.260
	(1.58)	(0.13)	(1.92)	(0.40)
Postrera season	0.377	-0.328	-0.499*	-0.184
	(1.25)	(1.08)	(1.93)	(0.68)
Female head	0.132	0.290	-0.075	-0.222
	(0.66)	(1.18)	(0.27)	(0.89)
Years of education	0.051	0.000	-0.016	0.008
	(1.44)	(0.02)	(0.57)	(0.28)
Remittances	-0.179	-0.035	-0.532**	0.310
	(0.65)	(0.17)	(2.47)	(1.54)
Total land	-0.001	-0.001	0.000	0.000
	(0.85)	(0.89)	(0.81)	(0.08)
Number of children	0.074	-0.088*	0.031	0.050
	(1.43)	(1.67)	(0.63)	(1.15)
Percentage of female	0.538	0.849**	-0.578	-0.076
	(0.91)	(2.02)	(1.15)	(0.16)

Has electricity	-0.187	0.261	-0.150	0.063
	(0.66)	(1.34)	(0.73)	(0.38)
Heads of cattle	-0.006	0.027**	0.001	0.004
	(0.51)	(2.13)	(0.11)	(0.33)
Observations	436	436	436	436

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] 73 community dummy variables are not reported in this table due to space limitation.

Complete regression results for observed levels of beneficial insect populations⁺ survey probit and ordered probit regressions for 436 Nicaraguan bean growers, 2003-04

	Adequate level of beneficials	Level of beneficial insects
Bean price	0.001	0.000
	(0.47)	(0.09)
Insecticide price	-0.014	0.012
	(1.03)	(1.03)
Herbicide price	0.031	0.023
	(1.64)	(1.44)
Seed price	-0.056	0.126
	(0.50)	(1.44)
Fertilizer price	-0.008**	0.004
	(2.21)	(1.00)
Transport cost	0.029	0.014
	(1.26)	(0.47)
Wage	0.048	0.047*
	(1.42)	(1.72)
Altitude	-0.001	-0.000
	(1.33)	(0.11)
Municipal distance	-0.044**	0.018
	(2.18)	(0.80)
FFS	0.747	-0.187
	(0.98)	(0.23)
Other IPM	0.873**	1.864***
	(2.35)	(4.91)
FFS & other IPM	0.820	-0.281
	(0.99)	(0.36)
Years after graduation	0.464	0.492
	(1.35)	(1.35)
Purchased protective devices	-0.255	-0.066
	(1.65)	(0.45)
Homemade protective devices	0.073	0.713**
	(0.25)	(2.54)
Hired applicator	0.314	-0.431
	(0.86)	(1.06)
Apante season	0.987	-0.258
	(0.93)	(0.24)
Postrera season	-0.182	0.481
	(0.37)	(0.90)
Female head	0.268	0.077
	(0.77)	(0.23)
Years of education	0.139***	0.092**
	(3.09)	(2.47)
Remittances	0.282	-0.220
	(0.93)	(0.71)
Total land	0.004	0.013
	(0.66)	(1.57)
Number of children	-0.024	-0.005
	(0.26)	(0.06)
Percentage of female	-0.531	-0.323
	(0.64)	(0.39)
Has electricity	-0.668	-0.312
	(1.55)	(0.93)
Heads of cattle	-0.000	-0.016

	(0.01)	(0.66)
Constant	-5.558**	
	(2.02)	
Observations	212	144

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ 73 community dummy variables are not reported in this table due to space limitation.

APPENDIX A.9

Complete regression results in Essay 3

Predicted probability of FFS and other IPM training participation, used as instruments in the 2SLS estimation. Probit survey regression results for 436 Nicaraguan bean growers, 2003-04[+]

	FFS	Other IPM training
Original explanatory variables		
Bean price	0.002	-0.002
	(1.04)	(1.07)
Insecticide price	-0.024***	0.001
	(3.03)	(0.12)
Herbicide price	-0.004	0.026**
	(0.41)	(2.19)
Fertilizer price		-0.007***
		(2.62)
Oxes price	0.015*	0.013***
	(1.80)	(2.83)
Seed price	-0.041	0.031
	(1.05)	(1.06)
Transport cost	-0.010	-0.004
	(0.30)	(0.19)
Wage	-0.001	-0.010
	(0.07)	(0.71)
Altitude	0.001	-0.002***
	(1.08)	(3.14)
High pest	-1.450***	0.306
	(2.76)	(1.10)
High disease	0.904**	-1.125***
	(2.33)	(3.01)
Municipal distance	-0.002	0.005
	(0.07)	(0.27)
Extensionist trained in IPM	2.421	3.934
	(0.95)	(1.61)
Extesnionist trained in FFS	6.255***	0.368
	(5.26)	(0.41)
Extensionist per project	-1.350	0.635
	(1.38)	(0.85)
Working years of NGO	0.022	-0.016
	(0.30)	(0.32)
Extensionist per district	4.130*	-3.260*
	(1.85)	(1.97)
Conducted comparat. experiment	-4.106**	0.710
	(2.18)	(0.62)
Conducted other experiments	-3.133	-1.894**
	(1.37)	(2.09)
Observed more yields	5.546*	4.566*
	(1.90)	(1.81)
Observed more revenues	-0.793	-3.042
	(0.51)	(1.29)
Observed less revenues	3.225***	
	(6.18)	
Observed les yields	2.624***	-2.121***
	(3.31)	(3.27)
Soil emphasis	3.060	1.785
	(0.75)	(1.34)

Credit emphasis	-4.801***	-0.073
	(5.24)	(0.18)
Protective devices	0.558***	0.130
	(3.28)	(1.06)
Hired applicator	-0.360	0.036
	(1.48)	(0.15)
Apante season	-1.566	0.452
	(1.63)	(0.58)
Postrera season	-0.566	1.106***
	(1.21)	(3.20)
Female head	1.704***	-0.538**
	(4.34)	(2.05)
Years of education	-0.064**	-0.008
	(2.08)	(0.26)
Remittances	-0.337	0.420**
	(1.17)	(2.13)
Total land	-0.006	-0.004
	(0.79)	(1.52)
Number of children	-0.027	0.016
	(0.32)	(0.28)
Female percentage	-1.703***	0.602
	(2.90)	(1.29)
Has electricity	0.405	0.095
	(1.22)	(0.41)
Heads of cattle	0.018	0.036**
	(0.57)	(2.17)
Redundant variables		
Adopted terraces	0.098	0.684***
	(0.31)	(3.16)
Adopted contour	-0.805*	-0.110
	(1.97)	(0.44)
Adopted live fences	0.755***	-0.440**
	(2.84)	(2.33)
Received food from NGO	0.747***	-0.322
	(2.94)	(1.05)
Received credit from NGO	0.191*	0.391*
	(1.68)	(1.65)
Received trained	0.308	0.177
	(0.94)	(0.72)
Constant	-8.442**	-1.262
	(2.26)	(0.77)
Observations	436	436

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ Community dummy variables not reported due to space limitations

Complete regression results for pesticide demand[+] survey least squares regression for 436 Nicaraguan bean growers, 2003-04

	Insecticide	IV Insecticide	Herbicide	IV Herbicide	Fungicide	IV Fungicide
Bean price	-0.000	-0.000	-0.000	0.000	0.000*	0.000
	(1.16)	(1.57)	(0.56)	(0.26)	(1.95)	(1.37)
Insecticide price	-0.000**	-0.000**				
	(2.29)	(2.02)				
Herbicide price			-0.000***	-0.000***		
			(4.78)	(4.19)		
Fungicide price					-0.000**	-0.000**
					(2.07)	(2.11)
Seed price	0.001	0.002	-0.001*	-0.001*	0.000	0.000
	(1.15)	(1.47)	(1.71)	(1.92)	(0.71)	(0.52)
Transport cost	0.001	0.001	0.000	0.000	0.000*	0.000
	(1.02)	(1.30)	(0.05)	(0.34)	(1.77)	(1.29)
Wage	0.000	0.000	0.000	0.000	0.000	0.000
	(0.60)	(0.80)	(1.45)	(1.27)	(1.09)	(1.14)
Altitude	-0.000	-0.000	0.000	0.000	0.000	0.000
	(1.42)	(0.87)	(0.51)	(0.70)	(0.51)	(0.51)
High pest level	-0.006	-0.009				
	(0.93)	(1.10)				
High disease level					0.000	-0.000
					(0.18)	(0.12)
Municipal distance	-0.005**	-0.005	-0.002**	-0.002	0.000	-0.000
	(2.02)	(0.95)	(2.38)	(1.18)	(0.57)	(0.64)
FFS	0.059***	0.277	0.009***	-0.037	0.003*	0.001
	(3.94)	(1.27)	(4.62)	(1.28)	(1.89)	(0.06)
Other IPM	0.009	0.016	0.001	0.003	0.001	-0.001
	(1.57)	(1.28)	(1.06)	(0.88)	(1.15)	(0.63)
FFS & other IPM	**-0.022***	**-0.070****	**-0.005****	**-0.009***	**-0.003****	-0.003
	(1.88)	(1.99)	(2.04)	(1.67)	(2.01)	(1.20)
Estensionists with IPM training	-0.053	0.374	-0.000	-0.044	-0.008	0.013
	(0.67)	(0.54)	(0.01)	(0.60)	(0.94)	(0.34)
Estensionists with FFS training	0.026	0.013	0.002	0.001	-0.001	-0.002
	(0.48)	(0.26)	(0.78)	(0.32)	(0.36)	(0.44)
Extensionist per project	0.049	0.045	0.006	0.010*	-0.001	-0.002
	(1.40)	(0.91)	(1.59)	(1.81)	(0.75)	(0.53)
NGO years of experience	-0.001	-0.002	-0.000*	-0.000*	0.000	0.000

	(0.36)	(0.88)	(1.65)	(1.66)	(0.29)	(0.02)
Extensionists per district	-0.093	-0.270	-0.008	0.007	0.006	-0.003
	(1.31)	(1.04)	(0.98)	(0.24)	(1.14)	(0.18)
Comparative experiments	0.070*	-0.053	0.007	0.025	-0.002	-0.007
	(1.95)	(0.21)	(1.27)	(0.96)	(0.48)	(0.60)
Other experiments	-0.070	-0.083	-0.001	0.000	0.002	0.002
	(0.92)	(1.30)	(0.16)	(0.05)	(0.89)	(0.47)
Higher yields	-0.223***	-0.275***	-0.003*	-0.001	-0.002*	-0.000
	(5.10)	(5.14)	(1.79)	(0.09)	(1.75)	(0.04)
Higher revenues	0.008	-0.461	0.013*	0.075	0.008	-0.017
	(0.09)	(0.53)	(1.90)	(0.82)	(1.08)	(0.37)
Lower yields	0.081	0.582	-0.014*	-0.081	-0.006	0.020
	(0.72)	(0.64)	(1.97)	(0.83)	(0.81)	(0.42)
Soil emphasis	0.119	0.158**	0.000	-0.002	-0.001	0.000
	(1.49)	(2.22)	(0.08)	(0.27)	(0.32)	(0.06)
Credit emphasis	0.030	0.025	0.001	0.002	0.004**	0.003*
	(1.31)	(0.98)	(0.52)	(0.79)	(2.08)	(1.65)
FFS & extensionists with IPM training	0.189	0.863	-0.106*	-0.217**	-0.018	-0.058
	(0.36)	(0.84)	(1.74)	(1.99)	(0.40)	(0.76)
FFS & extensionists with FFS training	-0.033	-0.084	-0.008	-0.003	-0.002	-0.002
	(0.53)	(1.26)	(1.47)	(0.57)	(0.68)	(0.60)
FFS & NGO years of experience	-0.006	-0.012	-0.000	-0.003*	-0.000	0.000
	(1.62)	(1.02)	(1.05)	(1.83)	(0.81)	(0.03)
FFS & extensionists per project	0.038	0.345	-0.036**	-0.073**	-0.005	-0.007
	(0.22)	(1.04)	(2.01)	(2.61)	(0.45)	(0.27)
FFS & extensionists per district	-0.078	-0.595	0.074*	0.141**	0.011	0.024
	(0.22)	(0.94)	(1.85)	(2.35)	(0.43)	(0.50)
FFS & comparative experiments	0.035	0.117	-0.003	0.002	0.003	0.014
	(0.59)	(0.42)	(0.42)	(0.08)	(0.52)	(0.96)
FFS & other experiments	-0.022	0.096	-0.003	-0.034*	-0.006*	-0.009
	(0.64)	(0.69)	(0.70)	(1.72)	(1.86)	(0.91)
FFS & higher yields	-0.020	0.006	-0.046	-0.025	-0.004	-0.037
	(0.08)	(0.01)	(1.55)	(0.26)	(0.18)	(0.79)
FFS & lower yields	-0.063	-0.189	0.045	0.045	-0.000	0.031
	(0.23)	(0.24)	(1.44)	(0.51)	(0.01)	(0.68)
FFS & higher revenues	-0.035***	-0.073**	-0.002	-0.005*	-0.005**	0.000
	(2.62)	(1.99)	(0.56)	(1.66)	(2.45)	(0.45)

FFS & lower yields	0.148***	0.127*	0.004	0.021*	-0.000	-0.002
	(2.72)	(1.71)	(1.08)	(1.69)	(0.22)	(0.32)
FFS & soil emphasis	-0.049	-0.178	-0.015**	0.030	-0.002	-0.000
	(0.84)	(0.82)	(2.58)	(0.90)	(0.39)	(0.00)
FFS & credit emphasis	0.011	0.107	-0.001	-0.017	0.000	0.002
	(0.31)	(1.16)	(0.29)	(1.44)	(0.17)	(0.26)
Hired applicator	-0.005	-0.006	-0.000	-0.000	-0.000	-0.001
	(1.14)	(1.18)	(0.18)	(0.45)	(0.44)	(1.15)
Apante season	-0.011	-0.001	0.000	-0.001	0.002	0.001
	(0.78)	(0.06)	(0.02)	(0.32)	(1.18)	(0.60)
Postrera season	0.002	0.010	0.002	0.000	0.002	0.002
	(0.21)	(0.83)	(1.04)	(0.06)	(1.63)	(1.35)
Female head	0.012*	0.011	-0.002**	-0.003**	0.001	0.001
	(1.95)	(1.60)	(2.03)	(2.01)	(1.00)	(0.94)
Years of education	0.000	0.000	0.000	-0.000	0.000	0.000
	(0.46)	(0.39)	(0.11)	(0.03)	(1.41)	(1.63)
Remittances	-0.007	-0.008	-0.000	-0.001	-0.000	-0.000
	(1.16)	(1.33)	(0.28)	(0.64)	(0.55)	(0.35)
Total land	0.000***	0.000***	0.000***	0.000***	0.000	-0.000
	(4.78)	(4.88)	(2.67)	(3.64)	(0.66)	(0.84)
Number of children	-0.002	-0.002	-0.000	-0.000	0.000	0.000
	(1.13)	(1.23)	(1.04)	(1.03)	(1.17)	(1.33)
Female percentage	0.001	0.004	0.008*	0.009*	0.000	0.001
	(0.10)	(0.20)	(1.71)	(1.79)	(0.24)	(0.39)
Has electricity	-0.000	0.001	-0.000	0.000	-0.002	-0.002
	(0.05)	(0.23)	(0.05)	(0.03)	(0.87)	(0.73)
Constant	0.153***	0.111*	0.042***	0.038**	-0.010	-0.005
	(3.03)	(1.96)	(3.23)	(2.00)	(1.07)	(0.55)
R-squared	0.42	0.35	0.44	0.33	0.43	0.41

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ 73 community dummy variables are not reported in this table due to space limitation

Complete regression results for the adoption of IPM⁺ survey least squares regression results for 436 Nicaraguan bean growers, 2003-04

	Number Practices	IV Num. Practices	AAE	IV AAE	Botan.	IV botan	traps	IV traps
Bean price	-0.001*	-0.001	-0.001*	-0.000	-0.000*	-0.000	-0.000	0.000
	(1.77)	(0.80)	(1.90)	(1.65)	(1.74)	(1.35)	(0.55)	(0.48)
Insecticide price	0.001	0.000	0.002	0.001	-0.002	-0.002	0.001	0.001
	(0.21)	(0.01)	(0.79)	(0.58)	(1.14)	(0.89)	(0.83)	(0.47)
Herbicide price	0.004	0.002	0.001	0.001	0.002	0.001	-0.001	-0.003
	(1.21)	(0.45)	(0.61)	(0.51)	(1.08)	(0.54)	(0.43)	(1.20)
Seed price	0.004	-0.007	0.003	-0.002	-0.002	-0.004	0.000	-0.005
	(0.26)	(0.38)	(0.43)	(0.23)	(0.30)	(0.39)	(0.08)	(0.53)
Transport cost	0.005	0.002	0.001	-0.000	0.009*	0.007	-0.003	-0.006
	(0.67)	(0.26)	(0.15)	(0.10)	(1.73)	(1.22)	(1.11)	(1.18)
Wage	0.004	0.003	0.005**	0.004*	-0.002	-0.002	0.000	-0.001
	(0.74)	(0.50)	(2.03)	(1.85)	(0.92)	(0.68)	(0.06)	(0.27)
Altitude	-0.000	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.98)	(1.22)	(0.41)	(0.84)	(0.87)	(0.99)	(0.42)	(0.61)
High pest level	0.079	-0.027	0.024	0.023	0.077	0.018	-0.026	-0.113
	(0.69)	(0.17)	(0.40)	(0.31)	(1.09)	(0.20)	(0.44)	(1.49)
Municipal distance	-0.136**	0.034	-0.044	0.001	-0.091***	-0.031	0.005	0.076
	(2.06)	(0.27)	(1.31)	(0.02)	(2.78)	(0.45)	(0.14)	(1.33)
FFS	0.628**	-1.031	0.513***	-0.366	-0.173	0.788	0.280*	-0.766
	(2.24)	(0.35)	(2.91)	(0.22)	(1.40)	(0.40)	(1.86)	(0.38)
Other IPM	0.737***	1.213***	0.149***	0.160	0.434***	0.597***	0.157***	0.517**
	(10.72)	(3.29)	(3.38)	(1.07)	(8.32)	(3.13)	(5.21)	(2.35)
FFS & other IPM	-0.352**	-0.762	-0.128	-0.100	-0.196**	-0.474	-0.010	0.125
	(1.99)	(1.24)	(1.20)	(0.39)	2.20)	(1.56)	(0.12)	(0.12
Extens. with IPM training	-0.985	-14.794	0.138	-0.845	-0.687	-2.970	-0.363	-14.115
	(0.91)	(0.74)	(0.30)	(0.21)	(0.77)	(0.64)	(0.90)	(0.89)
Extens. with FFS training	0.793	1.658*	0.479**	0.806**	0.012	0.254	0.301	0.758
	(1.32)	(1.79)	(2.21)	(2.37)	(0.04)	(0.78)	(1.12)	(1.32)
Extens. Per project	0.633*	0.532	0.362**	0.102	0.146	0.089	0.109	0.339
	(1.95)	(0.68)	(2.05)	(0.37)	(0.60)	(0.30)	(0.78)	(0.50)
NGO years of experience	-0.037	0.012	-0.016	0.005	-0.020	-0.011	-0.000	0.032

	(1.58)	(0.25)	(1.30)	(0.23)	(0.96)	(0.52)	(0.01)	(0.99)
Estén. Per district	-0.527	5.468	-0.712*	-0.014	0.299	1.370	-0.132	5.419
	(0.66)	(0.71)	(1.87)	(0.01)	(0.53)	(0.74)	(0.44)	(0.90)
Comparative experiement	1.101***	4.359	0.500**	0.270	0.300	0.697	0.257	4.223
	(3.08)	(0.67)	(2.60)	(0.20)	(1.21)	(0.46)	(1.56)	(0.78)
Other experiments	-1.098**	-0.673	-0.462***	-0.584	-0.248	-0.221	-0.366*	-0.072
	(2.32)	(0.58)	(2.86)	(1.28)	(1.33)	(0.66)	(1.93)	(0.07)
Higher yields	-0.719	-18.292	0.432	-0.381	-0.715	-3.582	-0.334	-17.802
	(0.73)	(0.71)	(1.23)	(0.07)	(0.99)	(0.60)	(0.86)	(0.89)
Higher yields	0.313	0.000	0.213*	0.000	0.110	0.000	0.263*	0.000
	(1.27)	(0.42)	(1.67)	(1.01)	(1.09)	(0.58)	(1.82)	(0.80)
Lower yields	-0.785***	-0.894	-0.301**	-0.603*	-0.334*	-0.420*	-0.155	0.086
	(2.90)	(0.86)	(2.52)	(1.74)	(1.93)	(1.67)	(1.61)	(0.12)
Soil emphasis	0.737	-0.594	0.366	0.382	0.165	-0.064	0.177	-0.931
	(1.29)	(0.32)	(1.50)	(0.58)	(0.63)	(0.12)	(0.78)	(0.77)
Credit emphasis	-0.074	0.247	-0.014	0.014	-0.014	0.003	-0.041	0.270
	(0.40)	(0.54)	(0.15)	(0.11)	(0.11)	(0.02)	(0.51)	(0.75)
FFS&EXTIPM	20.060***	17.619	12.942***	8.065*	5.887	8.662*	5.203	8.406
	(2.67)	(0.81)	(3.20)	(1.96)	(1.08)	(1.93)	(1.16)	(0.65)
FFS&FFS/IPM	-0.140	-1.335	0.245	-0.241	0.221	-0.344	-0.363	-0.462
	(0.15)	(1.12)	(0.56)	(0.36)	(0.46)	(0.68)	(0.87)	(0.63)
FFS&YearNGO	-0.032	-0.023	-0.027	-0.028	0.011	-0.029	-0.027	-0.041
	(1.00)	(0.16)	(1.39)	(0.34)	(0.41)	(0.30)	(1.38)	(0.38)
FFS&ExtPROJ	4.757**	-0.021	3.084**	1.644	1.513	1.382	1.148	-2.715
	(2.16)	(0.00)	(2.52)	(0.86)	(0.93)	(0.53)	(0.85)	(0.74)
FFS&EXTDIST	-11.535**	-6.517	-7.200***	-3.950	-3.912	-4.823	-2.731	-0.232
	(2.34)	(0.60)	(2.62)	(0.88)	(1.07)	(0.88)	(0.89)	(0.04)
FFS&CompExp	-1.140	-4.377	-1.113***	-0.711	0.226	-0.755	-0.514	-5.411
	(1.06)	(0.60)	(3.26)	(0.40)	(0.72)	(0.46)	(0.81)	(1.05)
FFS&OtherExp	1.799***	0.011	1.576***	1.019*	0.063	0.702	0.759**	0.043
	(3.00)	(0.01)	(6.14)	(1.70)	(0.18)	(0.53)	(2.27)	(0.03)
FFS & higher yields	10.205***	20.894*	5.683***	4.041	3.471	6.145*	2.509	14.687
	(2.61)	(1.88)	(2.84)	(0.62)	(1.25)	(1.98)	(1.15)	(0.84)
FFS & higher revenues	1.621***	0.569	0.535***	0.249*	0.981	0.313*	0.916	0.649***
	(2.87)	(0.88)	(3.04)	(1.65)	(1.35)	(1.85)	(1.23)	(2.63)
FFS & Lower yields	0.230	2.160	-0.195	0.735	0.199	0.269	0.063	0.826

	(0.53)	(1.59)	(0.72)	(1.02)	(0.69)	(0.29)	(0.23)	(0.92)
FFS &Soil emphasis	0.454	2.287	-0.340	0.013	1.015**	0.121	-0.285	0.444
	(0.52)	(0.72)	(0.78)	(0.01)	(2.26)	(0.06)	(0.64)	(0.23)
FFS &Credit emphasis	0.858*	-1.070*	0.825***	0.245	0.131	0.192	-0.126	-1.578*
	(1.88)	(1.69)	(3.65)	(0.40)	(0.66)	(0.24)	(0.45)	(1.66)
Hired labor	-0.014	0.037	-0.063	-0.057	0.141***	0.142***	-0.097**	-0.049
	(0.14)	(0.34)	(1.22)	(1.04)	(2.89)	(2.94)	(2.51)	(0.80)
Apante season	-0.202	-0.180	-0.147	-0.148	-0.044	-0.008	-0.049	-0.074
	(0.73)	(0.54)	(1.00)	(0.88)	(0.26)	(0.04)	(0.23)	(0.35)
Postrera season	0.025	-0.123	0.047	0.037	-0.062	-0.086	0.026	-0.090
	(0.19)	(0.58)	(0.57)	(0.32)	(0.90)	(0.77)	(0.47)	(0.78)
Female head	-0.227	-0.261*	-0.097	-0.096	-0.047	-0.055	-0.035	-0.041
	(1.57)	(1.84)	(1.60)	(1.55)	(0.68)	(0.82)	(0.75)	(0.72)
Years of education	0.038**	0.032*	0.013	0.014	0.009	0.008	0.016**	0.011
	(2.27)	(1.89)	(1.65)	(1.64)	(1.46)	(1.32)	(2.14)	(1.21)
Remittances	0.092	0.046	-0.013	-0.011	0.031	0.015	0.066	0.030
	(1.03)	(0.41)	(0.30)	(0.22)	(0.51)	(0.20)	(1.29)	(0.51)
Total land	-0.001**	0.000	-0.000	0.000	-0.000**	-0.000	-0.000	0.000**
	(2.39)	(0.44)	(0.29)	(0.85)	(2.39)	(1.34)	(1.05)	(2.55)
Number of children	-0.046**	-0.059**	-0.019*	-0.022**	-0.016	-0.021	-0.014	-0.021*
	(2.12)	(2.48)	(1.86)	(2.07)	(1.43)	(1.65)	(1.56)	(1.74)
Female percentage	0.298	0.236	0.151	0.157	0.049	0.010	0.119	0.015
	(1.57)	(0.95)	(1.45)	(1.37)	(0.41)	(0.09)	(1.43)	(0.11)
Has electricity	0.132	0.023	0.078	0.067	-0.019	-0.040	0.073	-0.038
	(1.25)	(0.12)	(1.44)	(0.94)	(0.29)	(0.53)	(1.45)	(0.34)
Constant	2.014**	0.944	0.359	0.121	1.404***	0.920	0.367	0.135
	(2.12)	(0.65)	(0.72)	(0.15)	(2.82)	(1.28)	(0.69)	(0.19)
Observations	436	436	436	436	436	436	436	436
R-squared	0.63	0.50	0.55	0.50	0.58	0.53	0.40	0.19

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
[+] 73 community dummy variables are not reported in this table due to space limitation

Complete regression results for net revenue function+ survey least squares regression results for 436 Nicaraguan bean growers, 2003-04

	Insecticide	IV insecticides
Bean price	10.245***	11.288***
	(7.84)	(5.02)
Insecticide price	-28.534***	-31.117***
	(2.86)	(2.80)
Herbicide price	-4.471	-2.133
	(0.34)	(0.17)
Seed price	-87.589***	-102.937**
	(3.12)	(2.52)
Fertilizar price	-14.514***	-15.664***
	(4.19)	(3.80)
Oxes price	-3.191	-4.752
	(1.22)	(1.07)
Transport cost	5.826	2.868
	(0.24)	(0.11)
Wage	-5.394	-6.596
	(0.30)	(0.36)
Altitude	1.958*	1.275
	(1.66)	(1.01)
High pest level	-537.381*	-535.607
	(1.97)	(1.54)
High disease level	920.427**	1,298.593**
	(2.34)	(2.20)
Municipal distance	438.153**	673.228**
	(2.00)	(2.05)
FFS	1,001.366	-7,903.323
	(1.24)	(0.75)
Other IPM	-441.840**	-44.884
	(2.10)	(0.05)
FFS & other IPM	320.0443	658.789
	(0.44)	(0.54)
Extens. with IPM training	-5,552.444*	-33,326.700
	(1.77)	(0.83)
Extens. With FFS training	1,581.089*	1,757.835*
	(1.81)	(1.69)
Extensionists per project	-1,232.401	-246.359
	(1.42)	(0.11)
NGO years of experience	185.125**	211.698**
	(2.20)	(2.01)
Extensionists per district	2,164.973	12,951.043
	(1.11)	(0.85)
Comparative experiments	823.772	9,791.349
	(0.78)	(0.69)
Other experiments	-1,984.577*	-186.822
	(1.84)	(0.07)
Higher yields	-372.733	-36,401.585
	(0.15)	(0.70)
Higher revenues	1,693.727	34,597.145
	(0.78)	(0.69)
Lower yields	-122.859	-567.876
	(0.30)	(0.31)
Soil emphasis	1,011.601	-1,619.692
	(0.70)	(0.48)

Credit emphasis	-3.493	630.570
	(0.01)	(0.82)
FFS & Extens. with IPM	18,280.718	5,749.751
	(1.30)	(0.15)
FFS & Extens. with FFS	741.935	2,870.838*
	(0.35)	(1.68)
FFS & NGO years of experience	-327.830***	27.346
	(2.96)	(0.05)
FFS & Extens. per project	7,125.919*	-3,735.391
	(1.77)	(0.29)
FFS & Extens. per district	-15,213.405*	-2,992.549
	(1.69)	(0.14)
FFS & Comparative experiments	2,791.729*	-2,004.619
	(1.69)	(0.16)
FFS & Other experiments	1,266.050	-6,442.738
	(1.11)	(1.01)
FFS & Higher yields	6,913.019	26,752.112
	(0.97)	(0.62)
FFS & Higher revenues	-10,161.417	-23,537.954
	(1.36)	(0.59)
FFS & Less revenues	613.107	743.859
	(1.17)	(0.75)
FFS & Less yields	-1,611.658*	2,571.371
	(1.81)	(0.59)
FFS & Soil emphasis	-512.618	7,513.954
	(0.32)	(0.75)
FFS & Credit emphasis	1,266.985**	-2,856.929
	(2.09)	(0.62)
Apante season	-1,274.282*	-1,257.783
	(1.81)	(1.49)
Postrera season	-361.551	-710.473
	(1.44)	(1.44)
Female head	-220.091	-269.071
	(0.76)	(0.83)
Years of education	-6.095	-10.098
	(0.22)	(0.34)
Remittances	-295.548	-356.240
	(1.14)	(1.25)
Total land	-2.163***	-1.395***
	(2.88)	(2.72)
Number of children	-109.392*	-122.987*
	(1.76)	(1.82)
Female percentage	344.629	356.044
	(0.65)	(0.57)
Has electricity	-58.374	-242.629
	(0.28)	(0.80)
Constant	-675.639	-1,796.173
	(0.24)	(0.45)
Observations	436	436
R-squared	0.50	0.37

* Significant at 10%; ** significant at 5%; *** significant at 1%
Absolute value of t statistics in parentheses
+ 73 community dummy variables are not reported in this table due to space limitation