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THE ECONOMIC IMPACT OF IMPROVED BEAN VARIETIES
IN NORTHERN ECUADOR

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THE ECONOMIC IMPACT OF DISEASE-RESISTANT BEAN BREEDING RESEARCH IN NORTHERN ECUADOR

By

Daniel F. Mooney

A THESIS

Submitted to
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ABSTRACT

THE ECONOMIC IMPACT OF DISEASE-RESISTANT BEAN BREEDING RESEARCH IN NORTHERN ECUADOR

By

Daniel F. Mooney

Breeding for disease resistance is one form of productivity-enhancement research that can also potentially contribute to poverty alleviation and sustainability goals. As agricultural research funds become increasingly scarce and investment alternatives multiply, knowledge about the economic impact of such research becomes useful in resource allocation decision making. This thesis evaluates the economic impact of disease-resistant bean varieties (RVs) in northern Ecuador using farm-level survey data from 2006. Regression analysis of the farm-level benefits associated with red mottled RVs reveals that, when high levels of disease pressure are present, adopters enjoy 40% higher yields and 20% lower per-unit production costs than do non-adopters. When high levels of disease pressure are absent, resistant and local varieties perform similarly but RV adopters apply 43-74% less chemical inputs than do non-adopters. Economic impact assessment results under a baseline scenario indicate that red mottled RVs have an *ex post* internal rate of return (IRR) of 29% and a net present value (NPV) of $1.29 million USD from 1982 to 2006. Likewise, recently released purple mottled RVs have an estimated *ex ante* IRR of 34% and a NPV of $536,000 USD from 2004 to 2024.

Dedicated to Ignacia, Sebastian, and Marianela

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Thanks are also given to the Bean/Cowpea Collaborative Research Support Project (CRSP) and the Department of Agricultural Economics for providing research and assistantship funding. Related to the CRSP, I'd like to thank both Dr. Irv Widders and former research assistant Ricardo Labarta, in particular, for their advice and research enthusiasm.

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LIST OF ACRONYMS

3SLS	Three Stage Least Squares
AI	Active Ingredient
B/C CRSP	Bean/Cowpea Collaborative Research Support Program
CGIAR	Consultive Group on International Agricultural Research
CIAL	Comité de Investigación Agrícola Local
CIAT	Centro Internacional de Agricultura Tropical
CIMMYT	Internacional Maize and Wheat Improvement Center
GPS	Global Positioning System
INIAP	El Instituto Nacional Autónomo de Investigaciones Agropecuarias
INEC	El Instituto Nacional de Estadística y Censos
IRR	Internal Rate of Return
m.a.s.l	Meters above sea level
MSU	Michigan State University
MWD	MacKinnon, White, and Davidson
NPV	Net Present Value
OLS	Ordinary Least Squares
PESAE	El Programa Especial de Seguridad Alimentaria en el Ecuador
PPB	Participatory plant breeding
PRONALEG-GA	Programa Nacional de Leguminosas y Granos Andinos,
PVS	Participatory Varietal Selection
RUM	Random Utility Model
RV	Resistant Variety
SICA	Servicio de Información y Censo Agropecuario
SUREG	Seemingly Unrelated Regression
TEM	Treatment Effect Model
UBN	Unsatisfied Basic Need
USAID	United States Agency for International Development
USD	United States Dollar
UVC	Unit Variable Costs
VIF	Variance Inflation Factor

CHAPTER ONE:

INTRODUCTION

1.1 The Economic Impact of Breeding for Disease-Resistance

Post-green revolution research agendas of national and international agricultural research organizations have diversified away from their original focus on enhancing crop productivity to encompass a set of objectives that includes topics such as sustainability and poverty reduction (World Bank 2003; Pingali 2001). As agricultural research funding becomes increasingly scarce and the number of alternative investment possibilities multiplies, national governments and international donor organizations must carefully decide which projects to invest in.

Economic impact assessments provide a useful tool for understanding the relative merits of alternative investment opportunities by serving as a yardstick that is comparable across disparate technologies. The most common scholarly approach to economic impact assessment relies on the economic surplus model, which measures the change in consumer and producer surplus associated with the adoption of a new technology adoption and the subsequent research-induced supply shift. By comparing with and without-research scenarios, incremental net benefits derived from the new technology may be determined and then combined with research costs so as to obtain summary statistics such as net present value (NPV) and the internal rate of return (IRR) that are useful in priority setting and resource allocation decision making. Methodology for this class of economic impact assessment is well established in the literature (Alston et al. 1998, Masters et al. 1996). In addition, a set of best practices for impact assessment implementation and data collection also exist (Morris and Heisey 2003, Maredia et al. 2000). Finally, numerous studies highlight the high returns—well over 50% in many cases—to investments in plant breeding over the past half century (Alston et al. 2000, Evenson 2001, Evenson and Gollin 2003).

Frequently overlooked, however, is the impact that plant breeding research itself can have on non-productivity objectives such as sustainability (be it economic or environmental) or poverty reduction. This is particularly true when the targeted crops are produced by poor households and production systems depend heavily on the use of purchased and potentially hazardous agricultural chemicals. For example new crop varieties endowed with disease resistance (RVs, for *resistant varieties*) can increase productivity while simultaneously reducing the need for costly and potentially hazardous fungicide inputs. Furthermore, inclusion of small-scale farmers in the research phase of the crop improvement process using participatory techniques may increase RV adoption rates and yield gains among the poor or similarly marginalized groups, many of whom did not benefit from the first generation of green revolution technologies. The appeal of embedding genetic improvements directly into the seed is that additional inputs or changes in management practices are typically not required—farmers already know how to plant and use existing seeds, and seed distribution systems are widespread.

Impact analysis methodologies for such RVs differ from those for traditional high yielding varieties without disease resistance characteristics. First, RVs provide two distinct avenues to achieving productivity increases (Smale et al. 1998; Morris and Heisey 2003). One avenue is through productivity maintenance, where research benefits are not derived from yield gains per se but rather from the avoidance of yield losses associated with disease pressure. The other avenue is through traditional yield gains that RVs may exhibit over currently planted varieties in instances where disease pressure is absent. Second, the embedded resistance traits provide damage abatement services that can substitute for pesticide inputs (Lichtenberg and Zilberman 1986). Mather (2005) showed this to be true for disease-resistant bean varieties in Honduras. This potentially leads to a reduction in both production costs and in the quantity of pesticide active ingredient released into the environment.

Given these distinctions, breeding for disease resistance is described in this thesis as a type of *productivity-enhancing* research rather than *yield-enhancing* or *productivity-maintenance* research, both of which are commonly used in the economic impact assessment literature. The term productivity-maintenance is reserved strictly for genetic research that is conducted to keep a previously-bred trait (e.g. disease resistance) viable in the face of genetic adaptation by diseases and their vectors. Similarly, the term yield-enhancing is reserved strictly for genetic research aimed at increasing yields without consideration to resistance characteristics. So defined, the term productivity-enhancing research is thus preferred as it encompasses both other types of research as special cases and therefore does not limit *a priori* the possibility of either as a source of productivity gain.

Few economic impact assessments are devoted to disease resistance research. Those that do exist indicate high rates of return. Morris et al. (1994) found an *ex post* IRR of 80% for Nepal's national wheat RV research program during a 30-year period from 1960-1990. This same study also estimated an *ex ante* IRR of 49% for the period 1990-2020. Smale et al. (1998) assessed research on breeding for disease resistance in Mexican wheat varieties developed by the International Maize and Wheat Improvement Center (CIMMYT) for a 20-year period from 1970-1990 and estimated the IRR to lie between 13% and 40%. In a multiple-country impact assessment of CIMMYT's disease-resistant genetic research in wheat, Marasas et al. (2003) found an IRR of 41% with an NPV of $5.36 billion USD over the period 1973-1990. Mather et al. (2003) found a rate of return to disease-resistant genetic bean research in Honduras close to 40% for a 16-year period from 1984 to 2000. In each case, the returns to disease-resistant genetic research remained well above the assumed opportunity cost of capital (between 5-10% in each study) which suggests that similar research should be considered by national governments and international donors as an attractive funding possibility.

1.2 Research Motivation

The economic impact of similar disease-resistant research in northern Ecuador is largely unknown. Since 1982, Ecuador's national agricultural research institution *El Instituto Nacional Autónomo de Investigaciones Agropecuarias* (INIAP) has developed and released a series of disease-resistant bush bean (*Phaseolous vulgaris* L.) varieties in the northern *sierra* provinces of Imbabura and Carchí. The release of these RVs was supported in part by external funding from both the *Centro Internacional de Agricultura Tropical* (CIAT) and the Bean/Cowpea Collaborative Research Support Program (B/C CRSP).

The motivation behind this bean improvement effort stems from the central role of bean production within the area. First, beans represent one of the principal crops in the region in terms of total area planted and number of farmers. Second, bean production provides farm households with a source of both income and household nutrition through sales and consumption, respectively. Finally, the northern Andean region serves as a source of bean genetic biodiversity whose values extend beyond national borders.

Since INIAP's release of the first RVs, descriptive statistics obtained from a series of household surveys within the region indicate increasing trends in average yields and in the land area planted to beans (Arévalo 1985, Peralta et al. 1991, Lépiz et al. 1995, and Peralta et al. 2001). In addition, high indices of poverty and the significant health risks posed by agricultural chemicals are well documented throughout the region (SIISE 2001, Crissman et al. 1998). Nevertheless, no research has been conducted on the farm-level impacts of RV bean adoption or on the estimated return to bean research expenditures.

In 2005, this knowledge gap lead INIAP to a request an economic impact assessment of the disease-resistant bean breeding research program during a joint meeting between INIAP and B/C CRSP researchers. The research presented here serves the dual purpose of fulfilling this request while also expanding the economic impact assessment literature, with the principal contribution being the use of treatment effect regression models to determine the farm-level benefits associated with RV adoption and then incorporating these findings into the traditional economic impact assessment methodology.

1.3 Research Goal and Objectives

The goal of this thesis is to evaluate the economic impact of disease-resistant bean breeding research and outreach in Northern Ecuador. While RVs from various bean market classes exist, this analysis will focus on RVs developed for the red mottled and purple mottled market classes, which represent over 80% of the total land area cultivated to beans in northern Ecuador. To accomplish this, three specific objectives are identified. They are:

1. Determine the rate of diffusion of red mottled and purple mottled RVs across time, and identify factors that influence farmers' adoption decisions (Chapter 4).
2. Statistically estimate the farm-level benefits associated with the adoption of RV red mottled varieties, including impacts on yield, input use and the unit cost of production using a set of treatment effect regression models (Chapter 5).
3. Calculate estimates of a) the *ex post* economic impact of bean breeding research on red mottled varieties from 1982 to 2006, and b) the *ex ante* economic impact of bean breeding research on purple mottled varieties from 2000 to 2024, along with appropriate sensitivity analyses on key parameters (Chapter 6).

Before discussing each of these objectives in turn, however, the subsequent two chapters provide needed background information on bean production in Ecuador (Chapter 2) and on the field survey methodology used in data collection (Chapter 3).

CHAPTER TWO:

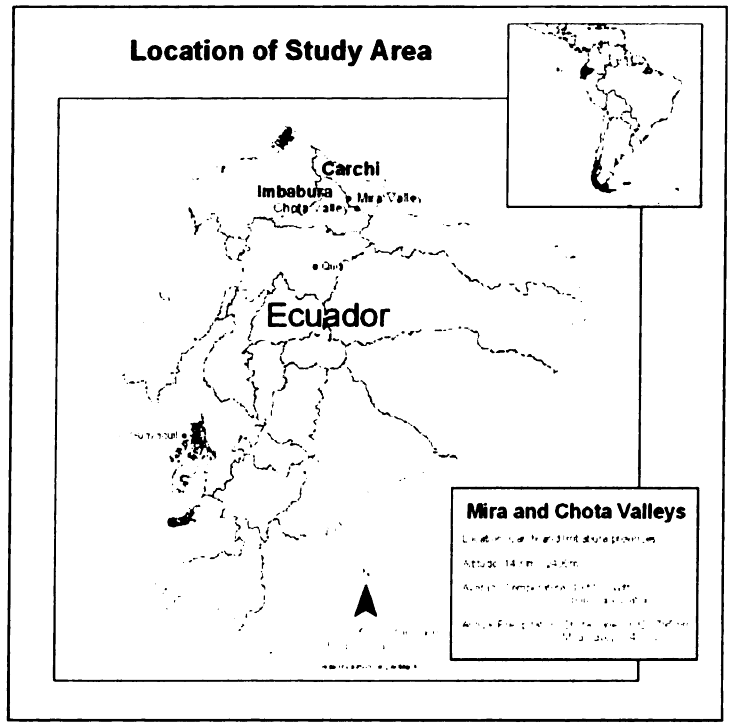
BEAN PRODUCTION IN NORTHERN ECUADOR

2.1 Introduction

The common bush bean (*Phaseolus vulgaris* L.) represents one of Ecuador's principal agricultural crops. In particular, the Mira and Chota river valleys—located along the shared border of Ecuador's two northern *sierra* provinces of Imbabura and Carchi—stand out as the focal point of production (Figure 2.1). This chapter provides an overview of production trends, crop management practices, principal insect pests and plant diseases, and local breeding efforts that surround the bush bean.

The information presented here was obtained in collaboration with bean breeders from Ecuador's national program on food legumes and Andean grains, *El Programa Nacional de Leguminosas y Granos Andinos* (PRONALEG-GA), located at the Santa Catalina Experimental Research Station in Quito, Ecuador. PRONALEG-GA pertains to Ecuador's national agricultural research institute, *El Instituto Nacional Autónomo de Investigaciones Agropecuarias* (INIAP). The information gathering process involved two visits by the thesis author to the Santa Catalina station in Quito and survey site in northern Ecuador. In addition, a number of previous studies on bush bean cultivation in the provinces of Imbabura and Carchí also aided in analyzing changes in production practices over time (Arévalo 1985, Peralta et al. 1991, Lépiz et al. 1995, Peralta et al. 2001, and Subía et al. 2004).

Figure 2.1:



2.2 Bean Production Overview

The majority of bean production in northern Ecuador occurs during two main planting cycles. The first cycle runs from January through April, while the second cycle runs from September through December (Vasquez et al. 1992). Each of these cycles corresponds to a period of increased precipitation. Between cycles, from June to August, the region faces an extended dry season. Precipitation totals vary greatly throughout the region. Communities located near the valley's center receive an annual average precipitation of 480 mm whereas communities located 10 kilometers from the valley's center receive a much higher annual average precipitation of 630-795 mm (Rodriguez-Jaramillo 1994).

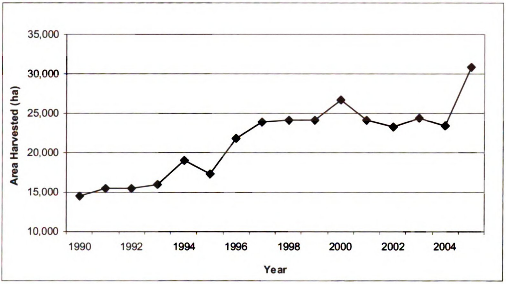
In 2001, the provinces of Carchí and Imbabura together accounted for 40% of all national dry bush bean production (INEC 2001). In Carchí, beans rank as the second most important agricultural crop in terms of both land area cultivated (7,700 hectares) and number of farm households (4,200) after the potato. In Imbabura, beans rank as the second most important crop in terms of land area (4,600 hectares) after maize, and as the third most important crop in terms of number of farms (2,500) after both maize and potatoes.

The total land area dedicated to bean cultivation increased steadily from 1990 to 2000 (Figure 2.2)[1]. The period from 2000 to 2004, however, registered a slight decline. Interestingly, this decline directly follows the period of economic instability and eventual dollarization of the Ecuadorian economy in 1999-2000. The estimated area dedicated to beans in 2005 shows a large upward tick to over 30,000 hectares. In 2005, the total bean harvest in Imbabura and Carchí was approximately 24 thousand metric tons.

Bean market classes are primarily defined by seed coat color, degree of mottling (i.e. spotting), and whether they are harvested dry (*seco*) or as fresh pods (*en tierno*). The size, shape and texture of the beans are also important, but help to define quality rather than market class. The two largest market classes for dry beans in northern Ecuador are the red mottled and purple mottled classes—both of which have a high demand in regional markets due to their popularity in Colombia. Many additional market classes are also

[1] This figure uses estimated yield data from SICA (2007b) and assumes that Carchí and Imbabura together account for 40% of total national dry bean production following INEC (2001).

Figure 2.2: Total Bean Area Harvested, Imbabura and Carchi, Ecuador, 1990-2005



Source: SICA (2007a)

cultivated, but are primarily sold locally or are grown for home consumption. These include white, yellow, solid red, solid black, cream, and pink mottled market classes.

Land preparation is standardized throughout much of the region and generally involves two steps. The first step, called *la rastra*, consists of harrowing of the bean field using either animal traction equipment or a tractor. The second step, called *la surcada*, uses animal traction to form topsoil into furrows that wind throughout the bean field so as to increase the efficiency of gravity-fed irrigation practices. Following *la surcada*, a process called *arreglo de guachos* is often undertaken using manual labor to put the finishing touches on the furrows. Occasionally, the above two steps are preceded by an initial plowing, called *la arada*. The combination of land preparation practices used by a particular farmer depends largely on previously planted crops and/or if the land had been previously fallow. In 2005, Subía et al. (2004) found that 100% of producers prepared their land using the *surcada*, 85% used the *rastra*, and only 40% used the *arada*. These numbers match those presented by Arévalo (1985), suggesting that land preparation practices have changed little over the past two decades.

Typical production inputs consist of seed, pesticides, fertilizers, and manual labor. Seed is obtained either through local markets, from other farmers, or is retained from the previous harvest. INIAP recommends a seed planting density of approximately 90 kg (or 2 *quintales*) per hectare (Vasquez et al. 1992), although a recent survey of 27 bean farmers reported an actual mean of 68 kg ha^{-1} (Subía et al. 2004). Pesticides are traditionally applied on a prophylactic calendar spray basis, without regard to observed infestations. Farmers typically use at least one insecticide and one fungicide in each application (Peralta et al. 1991). It is not uncommon, however, for farmers to mix multiple insecticides and fungicides with different commercial names for use in the same application.

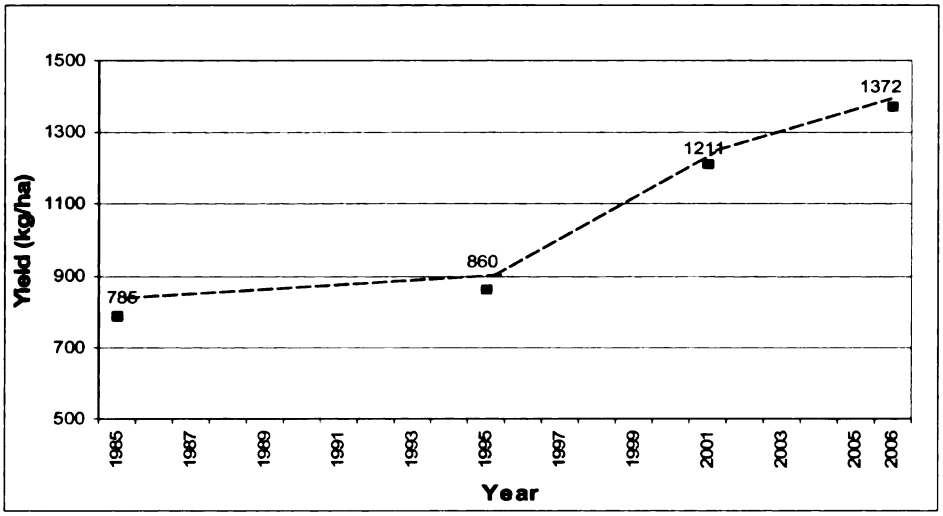
A reduction in farmers' reliance on pesticides over the past two decades is evident. In 1985, 90% of all farmers relied on 3 or more pesticide applications per production cycle (Arévalo 1985). In 1991, 83% of all farmers relied on 3 or more pesticide applications per cycle, with an overall average of 3.2 applications per cycle (Peralta et al. 1991). Survey results from the present study (2006) indicate only 70% of farmers relied on 3 or more pesticide applications, with an overall average of 2.9 applications per cycle. An even larger reduction appears to have occurred in villages receiving INIAP extension services. Subía et al. (2004) reported that only 34% of farmers from a set of 9 villages previously receiving INIAP extension intervention related to bean production used 3 or more pesticide applications per cycle with an overall average of 1.9 applications per cycle.

Fertilizers used in bean production include both foliar fertilizers and soil fertilizers. Foliar fertilizers are frequently included in pesticide applications. Survey results indicate that 84% of all pesticide applications included a foliar fertilizer. Again, it is not uncommon for farmers to include more than one foliar fertilizer in the same application. It is also common for farmers to use a foliar fertilizer that is inappropriate for the stage of plant growth at the time of application. Soil fertilizers, on the other hand, are applied at low rates. Subía et al. (2004) reported only 19% of bean producers apply soil fertilizers, with 18-46-00 NPK being the most common.

Labor input is used primarily for four tasks: weeding, *el aporque* or "mounding" (a cultural practice of covering the plant base with topsoil), irrigation management, and harvesting. Weeding and mounding are often undertaken simultaneously in a process called *la pala* where farmers use shovels to clear soil sediment out of the irrigation furrows while simultaneously managing weed infestations. On rare occasions, herbicides or animal traction are substituted for manual weeding. Irrigation management requires the most labor days, often accounting for the majority of the overall labor requirement (Arévalo, 1985; Subía et al. 2007). In addition, the number of required irrigations per production cycle depends almost exclusively on precipitation levels—and as a result varies greatly from year to year.

Land tenure arrangements commonly found among bean producers vary. Data collected for the present study found just under two-thirds of producers (81 of 132) owned their own land. Exactly one-third (44 of 132) entered a sharecropping agreement

Figure 2.3: Average Annual Farm-Level Bean Yields, All Market Classes, Imbabura and Carchi, Ecuador, 1985-2006



Source: Arévalo (1985), Lépiz et al. (1995), and Peralta et al. (2001), 2006 data is from the present study

where production inputs and harvests are shared between the farmer and land owner. Only a few farmers rented land (5 of 132).

Average per hectare bean yields appear to have almost doubled over the past two decades—from 785 kg ha^{-1} in 1985 to over 1300 kg ha^{-1} in 2006 (Figure 2.3). Yield data is typically reported by farmers as the number of *quintales* harvested per *quintal* of seed input, where one *quintal* is equal to 100 pounds (or, equivalently, 45.4 kilograms). All data reported here, however, is converted into kilograms per hectare. The data presented in Figure 2.3 reflect descriptive statistics obtained from previous farm-level surveys in the Provinces of Imbabura and Carchí. The reported figures utilize different sample sizes and sample selection methods. In general, they include varieties from all market classes and are not representative of the entire area of impact. Data from the present survey (2006) indicate per hectare yields for red mottled varieties to be slightly above average and per hectare yields for purple mottled varieties to be slightly below average.

Table 2.1:
Dry Bean Production Costs, Imbabura and Carchi, Ecuador, 2000 and 2004 (n=19)

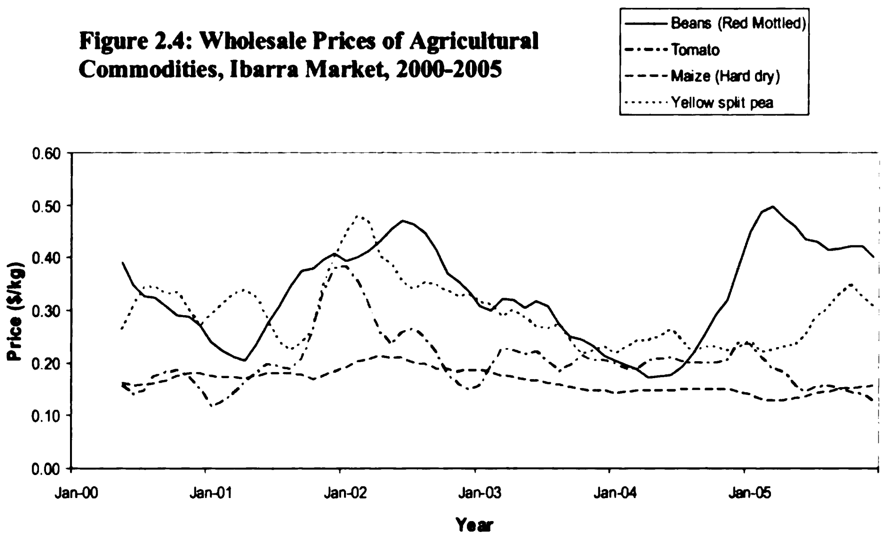
Cost *	2000		2004	
	$/ha	% of total cost	$/ha	% of total cost
Land Preparation	55	12	87	18
Pesticides	117	26	70	15
Other Purchased Inputs	129	28	107	22
Manual labor (hired and household)	157	34	220	45
Total Cost	**458**		**484**	

*Cost data from 2000 was inflated to 2004 prices using the Ecuador producer price index
Source: Subía et al. (2007)

Panel data for a sample of 19 bean farmers collected in 2000 and 2004 reported an increase of 5.5% in variable per hectare production costs from 2000 to 2005 (Table 2.1). Analysis of specific cost categories reveals a decrease in total expenditures on pesticides and other purchased inputs, and an increase in total expenditures on land preparation and labor. Labor costs tend to vary widely from year to year, however, since irrigation practices depend on the quantity of rainfall and are labor-intensive. The increase in land preparation costs is also most likely driven by the labor-intensive nature of land preparation practices.

The majority of beans harvested are sold for cash to market intermediaries, either at the farm gate or in the local markets. Results from the present survey (2006) indicate that the average percentage of bean harvest sold in the market is 87%. A breakdown of percentages sold by province show 91% of the harvest was sold in Imbabura and 84% was sold in Carchi. These finding are higher but proportionally consistent with Lépiz et al. (1996), who found that 89% of total bean production was sold in Carchí and only 65% of in Imbabura. The local markets of Ibarra and Pimampiro generally serve as the first stop for these beans before they are exported to Colombia. In 1998, dry bean

Figure 2.4: Wholesale Prices of Agricultural Commodities, Ibarra Market, 2000-2005



Source: SICA (2007b)

consumption in Colombia exceeded 145,000 metric tons[2], with the cities of Medellín, Bogotá, Cali, and Barranquilla accounting for over 70% total demand. Dry bean imports from Ecuador during the same year totaled 11,500 metric tons, or about 8% of total dry beans consumed (CCI 2000).

Market prices for beans fluctuate greatly from year to year (Figure 2.4). Between 2000 and 2005, two periods of high prices and two periods of low prices are evident—even after adjusting the price series for both seasonal trends and inflation. These fluctuations contrast with the prices of tomatoes, maize, and yellow split peas. Both tomato prices and split pea prices show an abrupt increase and decrease in price in 2002, but otherwise remain relatively constant compared to beans. Maize prices remain very constant throughout the entire 5 year period. The difference in price fluctuations likely reflects the fact that tomatoes, maize, and split peas are oriented towards the domestic market whereas red mottle beans are produced primarily for export.

[2] Total dry bean consumption in Colombia is estimated as total dry bean production plus imports and minus exports.

Table 2.2:
Net Returns to Bean Production, Imbabura and Carchí, Ecuador, 2000 and 2004 (n=19)

Year:	2000	2004
Total Cost ($USD, nominal)	348	484
Yield (kg ha^{-1})	1350	1166
Price ($/kg) (unadjusted)	0.6	0.97
Total Revenue	**810**	**1131**
Net Return / ha	462	647
Benefit-Cost Ratio	1.33	1.34

Source: Subía et al. (2007)

This price fluctuation affects net returns to bean production. Panel data from a small sample of 19 farmers in 2000 and 2004 show average revenues per hectare of $810 in 2000 and $1,131 in 2004 (Table 2.2). While yields were lower in 2004, producers received a much higher price, and average revenues are actually higher. Net returns equaled $462/ha in 2000 and $647/ha in 2004. In both years, the ratio of total revenue to total costs per hectare was approximately 1.33.

2.3 Bean Diseases and Insect Pests

Plant diseases and insect pests represent two important production constraints. In 1995, Lépiz et al. (1996) reported that 55% of all respondents listed insect pests as a principal production constraint and 40% listed plant diseases. Farmers also mentioned inadequate soil and seed, and weed infestation as other production constraints, but none was listed by more than 15% of respondents.

Bean rust and anthracnose are the most widely reported plant diseases. This is expected since bean production in northern Ecuador occurs at altitudes over 1000 meters above sea level (m.a.s.l.) where both diseases be more prevalent. Both Lépiz et al. (1996) and Peralta et al. (1991) report bean rust as the single most prominent disease in northern Ecuador, affecting 70% and 85% of all farmers in each study, respectively. Anthracnose was reported to affect 35% and 25% of all farmers, respectively. Results from the present survey (2006) are consistent with these earlier findings: 70% of farmers reported the presence of bean rust and 62% reported the presence of anthracnose. In addition, 89% of farmers reported at least one of the two diseases and 43% reported both. Other common diseases include powdery mildew, angular leaf spot, bacterial blights, web blights, and root rots (Table 2.3).

Successful disease management requires using proper cultural practices and disease recognition ability. Bean rust, powdery mildew, angular leaf spot, and web blight are transmitted through decaying plant materials left from previous harvests in the same or adjacent fields. Root rot disease spores can remain in the soil for many months after harvest. Crop rotations can help to minimize the recurrence of these diseases. Anthracnose and bacterial blights, on the other hand, are transmitted through bean seed, and farmers confronting these diseases must obtain seed from a secure source. Proper seed management and renovation can help to minimize the recurrence of these diseases. Nevertheless, these cropping practices are not standardized throughout the region. An additional confounding factor confronting plant disease management is farmer inability to properly identify plant diseases. Lépiz et al. (1995) reported that farmers often refer to all plant diseases collectively as "*la lancha*," a local term used by farmers.

Whitefly is the most commonly reported insect pest. Peralta et al. (1991) reported an incidence of whitefly of 95%. Other insect pests of minor importance include cutworms, red spider mites, leaf miners, leaf rollers, leaf hoppers, nematodes, aphids, Chrysomelid beetles,

Table 2.3: Plant diseases affecting bush bean cultivation in Ecuador

Common Name (English)	*Common Name (Spanish)*	*Scientific Name(s)*
Bean rust	Roya	*Uromyces appendiculatus*
Anthracnose	Antracnosis	*Colletotrichum lindemuthiamum*
Powdery mildew	Ceniza/Oidium	*Erysiphe polygoni*
Angular leaf spot	Mancha Angular	*Phaeoisariopsis griseola*
Bacteriosis	Bacteriosis	*Xanthomonas campestris*
Web blight	Mustia	*Thanatephorus cucumeris*
Root rot	Pudrición Radicular	*Rhizoctonia sp.* *Fusarium sp.* *Sclerotium sp.*

Source: Arévalo (1985); Vásquez et al. (1992), Subía et al. (2004)

Table 2.4: Insect pests affecting bush bean cultivation in Ecuador

Common Name (English)	*Common Name (Spanish)*	*Scientific Name(s)*
Whitefly	Mosca blanca	*Trialeurodes vaporariorum*
Leaf Miner	Minadores de la hoja	*Liriomyza huidobrensis* *Hemichalepus* sp. *Phyllonorycter* sp
Cut worm	Trozador/ descortezador	*Phyllophaga obsoleta* *Agrotis ipsilon* *Spodoptera frugiperda.*
Leaf roller	Barrenador/ enrollador	*Epinotia* sp.
Red spider mite	Arañita roja	*Tetranychus* sp.
Nematode	Nemátodo del nudo	*Meloidogine* spp.
Leaf hopper	Lorito verde	*Empoasca kraemeri.*
Aphid	Pulguilla	*Aphis* sp.
Chrysomelid beetle	Pinda	*Cerotoma* sp. *Diabrotica balteata*
Caterpillar	Pega pega	*Omiodes indicata.*
Mole cricket	Grillo topo	*Gryllus* sp.
Thrip	Trips	*Thrips palmi* *Frankliniella* sp.
Bean weevil	Gorgojo	*Acanthoscelides obtectus*

Source: Vásquez et al. (1992) and Arévalo (1985) mole crickets, and thrips (Table 2.4). Cut worm infestations increase susceptibility to plant diseases. Red spider mite infestations increase under dry conditions when planting is delayed (Vásquez et al. 1992). The bean weevil does not affect bean cultivation itself, rather it poses as a pest during storage.

2.4 Bean Breeding Research and Resistant Varieties

A network of national and international organizations leads the bean improvement effort in northern Ecuador. This effort is led primarily by PRONALEG-GA of INIAP, which is the arm of Ecuador's national agricultural research center responsible for the genetic improvement of leguminous crops. International organizations involved in the bean breeding process include the Bean/Cowpea Collaborative Research Support Project (B/C CRSP) funded by the United States Agency for International Development (USAID) and the *Centro Internacional de Agricultura Tropical* (CIAT) in Cali, Colombia, which is a member of the Consultative Group on International Agricultural Research (CGIAR). In addition, two non-governmental organizations, the *Programa Especial de Seguridad Alimentaria en el Ecuador* (PESAE) and the *Corporación Randi-Randi* have also contributed to the bean improvement process through their extension services. The Ecuadorian Ministry of Agriculture does not currently provide agricultural extension services related to bean production within the area of impact targeted by PRONALEG-GA's bean breeding efforts.

PRONALEG-GA began their bean improvement efforts by releasing a set of improved bush bean cultivars in northern Ecuador during the 1980s and 1990s. Between

Table 2.5
Bean Varieties Released by INIAP, 1986-2005

Variety Name	*Year of Release*	*Market Class*	*Resistance to Bean Rust*	*Resistance to Anthracnose*	*Altitudinal Adaptation (meters)*	*Yield (kg ha^{-1})*
Paragachi*	1986	Red Mottle	Susceptible	Susceptible	1800-2500	1200-2000
Cargabello (INIAP-404)	1987	Red Mottle	Susceptible	Tolerant	1600-2500	1500
Imbabello (INIAP-411)	1991	Red Mottle	Intermediate	Susceptible	1500-2200	1500-2900
Je.Ma. (INIAP-418)	1996	Red Mottle	Resistant	Resistant	1800-2500	1200-2300
La Concepción** (INIAP-424)	2004	Purple Mottled	Intermediate	Susceptible	1400-2400	700-1800
Yunguilla (INIAP-414)	1993 2004	Red Mottled	Intermediate	Resistant	1400-2400	500-2000
Canario del Chota (INIAP-420)	2005	Yellow	Intermediate	Susceptible	1400-2400	1200-2200
Blanco Fanesquero (INIAP-425)	2005	White	Intermediate	Resistant	1400-2400	1090-2000

Source: Lépiz (1996); INIAP (1991a, 1991b, 1996a, 1996b, 2004a, 2004b, 2004c, and 2005)
* The variety Paragachi is resistant to root rots
**The variety La Concepcíon was formerly known as the local variety Mil Uno

1987 and 1996, a total of four improved varieties were released, including Cargabello (INIAP-404), Imbabello (INIAP-411), Yunguilla (1993), and Je.Ma. (INIAP-418) (Table 2.5). These varieties all pertain to the red mottled market class and are adapted to production environments between 1500 and 2500 m.a.s.l. They also have varying degrees of resistance to bean rust and anthracnose, with Yunguilla and Je.Ma. resistant or intermediately resistant to both. These cultivars were bred at CIAT, with INIAP's role limited to testing and evaluation and maintenance breeding. The varieties released were selected by plant breeders with little or no input from farmers.

The variety Paragachi, also originally developed by the CIAT, is a cross between varieties of both Andean and Central American descent (INIAP 1996b). It was developed using traditional breeding methods and widely tested by INIAP scientists in northern Ecuador. It is well adapted to the production environment in northern Ecuador and is resistant to root rots. It is also the most widely planted improved cultivar in spite of its susceptibility to both bean rust and anthracnose (Table 2.5). Since its introduction in Ecuador by CIAT, PRONALEG-GA bean breeders have undertaken maintenance breeding on the Paragachi variety.

In 2002, a renewed bean improvement effort began and was led by bean breeders from both PRONALEG-GA and the B/C CRSP at Michigan State University. In contrast to earlier traditional bean breeding and testing efforts, this more recent effort relied on participatory plant breeding (PPB) methods to select varieties to be released. PPB involves the close collaboration between researchers and farmers to bring about plant genetic improvements within a species. Instead of playing a passive role of technology recipients as with traditional breeding programs, in PPB farmers are treated as partners in research (Vernooy 2003).

In Ecuador, the particular PPB method utilized is called participatory varietal selection (PVS), in which farmers select the final variety to be released from a set of fixed-lines chosen by PRONALEG-GA breeders (Ernest 2004). The PVS process generally consists of four steps: i) identification of the farmer's varietal needs, ii) a search for suitable genetic materials, iii) farmer experimentation with potential varieties in their own fields under their own crop management practices, and iv) selection of the preferred varieties based on their own selection criteria (Vernooy 2003).

To implement the PVS process, PRONALEG-GA researchers established four local agricultural research committees, or CIALs to use their Spanish acronym (*Comité* *de Investigación Agricola Local*). As the name implies, CIALs are community-based organizations that implement farmer-run agricultural experiments. CIAL leaders are elected by community members, research topics are collectively identified by the community at large, and each manages a small fund to offset the costs and risks associated with their experiments. Most CIALs are focused on increasing agricultural productivity, however multiple objectives such as agro-biodiversity conservation, increased experimentation, protection of farmer's breeding rights, or increasing the availability of improved seed, or the targeting of marginalized groups such as women, poor, landless, or historically underrepresented ethnic groups, may also be included (CIAT 2001). The CIAL concept originated at CIAT in Colombia.

The four bean-oriented CIALs in northern Ecuador are located in the communities of La Concepción, Santa Lucia, El Tambo, and San Clemente (Table 2.6). Each of these CIALs emphasize PVS processes and are targeted towards communities with high indices of poverty and malnutrition (Mazón and Peralta 2005). PRONALEG-GA breeders carry out three trials together with CIAL members before a final variety is selected for release. First, a test plot is planted with trial varieties without the use of external inputs. Second, a

Table 2.6: Bean-Oriented CIALs in Northern Ecuador

Community	*Valley*	*Name*	*Date Founded*
La Concepción	Mira	Cuenca del Rio Mira	June, 24 2002
Santa Lucía	Mira	Nueva Esperanza	July, 19 2003
El Tambo	Chota	El Progreso del Tambo	January, 27 2004
San Clemente	Chota	La Esperanza de San Clemente	September 8, 2004

confirmation plot is planted with the best performing varieties from the test plot to verify the initial results. Finally, a production plot is planted and managed according to INIAP crop management recommendations.

By 2004, two CIALs had completed the investigative cycle and released INIAP-bred disease resistant varieties. The varieties La Concepción (INIAP-424) and Yunguilla (INIAP-414) were released through the CIAL based in La Concepción. The variety Canario del Chota (INIAP-420) was released through the CIAL in El Tambo. An additional variety, Blanco Fanesquero, was developed using participatory methods but in a non-CIAL affiliated community. The variety La Concepción belongs to the purple mottled market class, Yunguilla to the red mottled market class, Canario del Chota to the yellow market class, and Blanco Fanesquero to the white market class. Farmer-selected criteria used to rank the trial varieties included yield, disease resistance, time to harvest, plant uniformity, and tolerance to drought (Mazón and Peralta 2005). All four of these varieties possess intermediate resistance to bean rust. The varieties Yunguilla and Blanco Fanesquero are also resistant to anthracnose, whereas the varieties Concepción and Canario del Chota are susceptible.

2.5 Chapter Summary

Bean production is of central importance to farmers in Ecuador's northern provinces of Imbabura and Carchi. Over the past two decades, both the total area planted to beans and farm-level bean yields have increased. These increases correspond to the release of disease resistant bean varieties by INIAP. A first set of improved varieties was released during the late 1980's and early 1990's, and included four varieties from the red mottled market class. A second set of improved varieties was released beginning in 2004 and included one variety each from the purple mottled, red mottled, yellow, and white market classes. The adoption of these improved varieties is expected to reduce the unit cost of production through increased yields and reduced fungicide input requirements, with the latter due to in-bred resistance to the major plant diseases bean rust and anthracnose. The remainder of this thesis seeks to determine the economic impact of these improved INIAP varieties.

CHAPTER THREE:

FIELD DATA COLLECTION

3.1 Introduction

This chapter describes the field data collection process—including survey design and implementation, sample selection methodology, survey weighting, and a description of questionnaire contents. The survey design and questionnaire development were developed by an interdisciplinary team of agricultural economists funded by the B/C CRSP at Michigan State University (including the author) and bean breeders from Ecuador's national agricultural research institution, INIAP[3]. Survey planning details were finalized during a week-long joint meeting at INIAP's Santa Catalina experimental field station in Quito in August, 2006[4].

3.2 Survey Design and Implementation

The survey design serves the dual purpose of 1) obtaining regional estimates of varietal adoption by market class, and 2) analyzing the economic impact of improved INIAP varieties. The population of interest is defined as the set of all bean farmers who planted at least one parcel of mono-cropped bush beans (*Phaseolus vulgaris* L.) during the first production cycle of 2006, and whose farmstead is located 1) within the provinces of Imbabura or Carchí, and 2) within the predefined altitudinal range of 1200 to 2400

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[3] More specifically, INIAP's bean breeders belong to INIAP's *Programa Nacional de Leguminosas y Granos Andinos* (PRONALEG-GA).

[4] All discussion occurred in Spanish.

meters above sea level (m.a.s.l.). The majority of this population lives within the Mira and Chota river valleys, which is INIAP's targeted area of impact for bean research.

In total, 132 farmers from 30 communities were interviewed[5]. Data collection occurred from October through December of 2006 (Table 3.1), with over 70% of the interviews being conducted in November. Two questionnaires were used to collect data with one targeting the village-level information and the other targeting household-level information (contents described below). Each questionnaire underwent two rounds of pre-testing—first in the community of Peruche, located outside of the targeted area of influence, and second in the community of La Concepción, which was later included in the survey[6]. All questions pertained to the first production cycle of 2006 (January through March).

A team of INIAP investigators served as enumerators. To prepare for this task, enumerators received a half day of training to review the study's main objectives, research hypotheses, and questionnaire contents. Training also involved sessions on plot measurement and the use of global positioning system (GPS) devices to record latitude, longitude, and altitude coordinates of bean plots. Enumerators generally worked in teams of two, and spent one whole day in each community. In the morning, enumerators conducted the village-level and household interviews. In the afternoon, they recorded plot measurements and obtained confirmation of the variety planted by observing either saved seed or plants in fields planted with saved seed.

[5] Sample selection details are provided in Section 3.3

[6] In the case of La Concepcion, the two farmers who participated in the pre-testing session were excluded as possible survey participants during the actual data collection.

Table 3.1
Number of Households Interviewed by Date

Interview Dates (2006)	*Number of Interviews*	*Percent of Total Interviews (%)*
October 2-7	7	5
October 16-21	12	9
October 23-28	7	5
November 6-11	34	26
November 13-18	29	22
November 20-25	23	17
November 27-30	12	9
December 18-23	8	6
Total	**132**	**100**

Table 3.2
Number of Households Interviewed by Enumerator

Enumerator(s)	*Number of Interviews*	*Percent of Total Interviews (%)*
A	57	43
B	52	39
C	6	5
D	6	5
E	4	2
F	4	3
G	3	3
Total	**132**	**100**

At the initiation of each interview, enumerators presented participants with a declaration of consent which solicited their willingness to participate and guaranteed confidentiality and anonymity to their responses[7]. Village-level questionnaires lasted approximately 20 minutes each while household questionnaires lasted approximately 30 minutes each. The two principal enumerators (denoted A and B) conducted over 80% of all interviews (Table 3.2). The enumerator denoted E consisted of a team of three INIAP

[7] The Declaration of Consent forms used in the survey are included in Appendices 3 and 4 along with questionnaire contents. Approval for involving human subjects in the survey was granted on September 15, 2006 by the Institutional Review Board (IRB) under application number X04-142.

researchers. The thesis author participated as an enumerator for 6 interviews during a one-week visit to Ecuador in November of 2006.

3.3 Sample Selection Methodology

A clustered, double-stratified sample design was implemented following Deaton (1997). Clusters are defined as villages. Village-level clustering provides two important practical advantages over the use of a purely random sample. First, it is cost-effective given the rugged topography of Ecuador's northern Andean region. Travel from village to village saves time and resources as compared to visiting dispersed households selected at random. Second, it facilitates repeat visits to collect absent information or clarify confusing data.

One disadvantage to the clustering method, however, is that it reduces the precision of population parameter estimates. This is because similarities exist among farmers from the same village. For example, they face similar prices, production environments, and other fixed factors such as transportation or infrastructure. As a result, clustered samples are slightly less representative of the overall population than a completely random sample. This weakness is minimized by interviewing a handful of farmers from many villages, as opposed to interviewing many farmers from only a few villages.

Stratification provides the advantage of specifically targeting sub-groups of particular interest that are relatively rare in the population as a whole, such farmers who belong to a CIAL. A first stratification involved the division of village clusters into three groupings based on the level of prior extension intervention by INIAP directly related to bean production. All villages with prior intervention were automatically included in the survey—including 4 communities with a CIAL and 8 additional communities without a CIAL but with previous INIAP intervention related to bean production. An additional 18 villages were randomly selected from an area frame compiled by the survey design team[8]. The second stratification occurred only within the four CIAL villages and involved a division of farmers based on CIAL membership. Use of a straightforward random sample would most likely not include enough CIAL farmers and their inclusion must be guaranteed through other means.

In total, 132 farm households were interviewed from 30 village clusters. In each of the 4 CIAL villages, a total of 7 farmers were interviewed, including three CIAL members and four non-members. In each of the 8 non-CIAL villages with a previous INIAP extension intervention and in each of the 18 villages without a previous INIAP extension intervention 4 farmers were interviewed at random.

To ensure randomness within clusters, enumerators developed a list of bean farmers with community leaders. In cases where this was not possible, separate *barrios* (neighborhoods) were identified within each village and one farmer from each *barrio* was selected who had no relation to either the community leader or other survey participants.

This sample selection process resulted in four stratification levels and the following breakdown in number of interviews:

1) Level 1: 12 CIAL members from CIAL communities
2) Level 2: 16 non-CIAL members from CIAL communities
3) Level 3: 32 non-CIAL members from non-CIAL communities *with* previous INIAP intervention

[8] For details on development of the area frame see Appendix 1.

4) <u>Level 4:</u> 72 non-CIAL members from non-CIAL communities *without* previous INIAP intervention

The process also resulted in a spatial variation of farmers interviewed across both *cantones* (local political divisions) and watersheds. As for *cantones*, the largest number of farmers interviewed lived in Mira (50 total interviews), whereas the smallest number of farmers interviewed lived in Ibarra (23 total interviews) (Table 3.3). As for principal watersheds, the majority of farmers interviewed lived in the Chota watershed (74 total interviews) and Mira watershed (54 total interviews) (Table 3.4). A total of 4 farmers were interviewed who did not live within either the Mira or Chota watersheds.

Table 3.3: Number of Households Interviewed by Cantón

Cantón	*Number of Interviews*	*Percent of Total Interviews*
Ibarra	23	17
Pimampiro	28	21
Bolivar	31	24
Mira	50	38
Total	**132**	**100**

Table 3.4 : Number of Households Interviewed by Watershed

Watershed	*Number of Interviews*	*Percent of Total Interviews*
Mira	54	41
Chota	74	56
Other	4	3
Total	**132**	**100**

3.4 Survey Weights

Since each cluster and stratification level is representative of an unequal number of farm households, the survey design described above results in unequal selection probabilities. In order to estimate descriptive statistics (such as adoption rates) that are representative of the target population and avoid sample bias, each observation must be appropriately weighted.

Two sample weights are calculated: the first corrects for the difference in selection probabilities within clusters, while the second corrects for the difference in selection probabilities within stratification levels. To determine the first sample weight suppose that each stratification level S (where $S = 1$ to 4) represents a separate population, and that the total population within each strata is given by N_s. We can define the probability of sample selection, π_i, for household i from village-level cluster c as,

$$\pi_i = \frac{n_c}{N_{sc}} \tag{3.1}$$

where n_c is the sample size chosen for cluster c and N_{sc} indicates the total population of cluster c within stratification level S (Deaton 1997). Next we define a sample weight w_i for each household that is equal to the inverse of its sample selection probability multiplied by the number of draws into the sample n_c. This is because households with a high probability of sample selection (such as CIAL members) represent only a small fraction of households in the overall population and should receive a lower survey weight—and vice versa for households with a small probability of selection. Each household's survey weight is then given by,

$$w_i = (n_c \pi_i)^{-1} \tag{3.2}$$

and is approximately equal to the number of households in the population that are represented by the sample household i (Deaton 1997)[9]. In addition, the probability weighted mean for each stratification level v_i can be easily estimated as the proportion:

$$v_i = \frac{w_i}{\sum_{k=1}^{n} w_k} \quad (k = w_1, w_2, \dots, w_n), \tag{3.3}$$

where k represents all clusters within the stratification level of interest. Using the above formulas, we obtain descriptive statistics that are representative only within a given stratification level.

To obtain an estimate that is representative of the target population, the second sample weight is used to correct for the difference in selection probabilities within stratification levels. The weighting process here is identical to the process explained above, with the only difference being that the probability of sample selection, π_i, is defined as,

$$\pi_i = \frac{N_s}{N}, \tag{3.4}$$

or the ratio of total households within stratification level, N_s, to the total number of households in the overall population, N[10].

3.5 Questionnaire Contents

Data collection involved the use of two survey instruments—a village-level questionnaire and a household-level questionnaire. The village-level questionnaire was designed to be a formal way of recording similarities and differences between

[9] See Table A.2.1 of Appendix 2 for sample selection and sample weight calculations by cluster.
[10] See Table A.2.2 of Appendix 2 for sample selection and sample weight calculations by stratum.

communities[11]. In total, 30 village-level questionnaires were executed with an exact one-to-one correspondence to the 30 village-level clusters previously discussed. Upon arriving at a selected village for data collection, the enumerator's first task involved seeking out a community leader in order to present the village-level questionnaire and obtain a list of all bean farmers within the community.

Questions focused mainly on demographic data (including the aggregate number of farmsteads producing beans), availability of public services, existing community organizations, and support from outside agencies other than INIAP (either governmental or non-governmental). Specific to bean production, the questionnaire solicited data on factors that are expected to change *between* communities but not necessarily *within* communities—such as wages for agricultural labor, transportation costs to the point of sale, primary input and output markets, and market access.

The household-level survey was designed to obtain economic and agronomic data on bean production for use in estimating both adoption rates by market class and the economic impact of improved varieties bred by INIAP[12]. Whole farm data was collected on the bean varieties planted, land areas, and related yields. More detailed parcel-level production data was also collected with respect to the largest plot of beans planted by the household during the first production cycle of 2006. During each interview, enumerators obtained a surface area measurement of the plot indicated and also received confirmation of the variety planted whenever possible through the inspection of saved seed or a bean field planted with saved seed. Specific production data collected includes varietal choice

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[11] See Appendix 4 for a copy of the village-level questionnaire.
[12] See Appendix 3 for a copy of the household-level questionnaire

and desirable varietal traits, pest and disease pressure, pesticide use and other crop management practices, and harvest, yield and price data.

In addition to bean production data, the household survey also elicited data on farm and household characteristics, such as household size and demographics, primary occupations, age and education of the household head, and poverty levels. Poverty is measured as the number of unsatisfied basic needs (UBNs) for each household[13]. Questions were also included to measure the impact of pesticide use on human health for use in a cost of illness model, however only 7 of 132 survey respondents indicated having suffered an acute pesticide poisoning episode during the first bean production cycle of 2006. This is most likely due to the fact that the toxicity of pesticides used in bean production appears to be low compared to those used in the production of potatoes and horticultural crops[14].

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[13] The UBN index was chosen since it is one official indicator of poverty used by the Ecuadorian government. See Appendix 5 for a description of this index.
[14] Subía et al. (2007) provides background information on pesticides used in the production of bush beans and other rotation crops in the Mira and Chota valleys.

CHAPTER FOUR:
THE DIFFUSION AND ADOPTION OF DISEASE-RESISTANT BEAN VARIETIES IN NORTHERN ECUADOR

4.1 Introduction

The economic impact of agricultural research outputs, such as improved crop varieties, is highly dependent on the total land area on which they are cultivated. The adoption of agricultural research outputs, however, often occurs in some areas or among certain populations, but not in or among others. Consequently, knowledge about the extent of diffusion and what factors impel or constrain a farmer's technology adoption decision is desirable for an economic impact assessment.

The objectives of this chapter are 1) to estimate the rate of diffusion of improved varieties across time, and 2) to determine the factors influencing individual farmers' adoption decisions. For the first objective, both red mottled and purple mottled market classes are considered. For the second, analysis will focus only on red mottled varieties. The terms *adoption* and *diffusion* are frequently used in economic literature, and slight variations in their definitions are common. In this chapter, the term adoption refers to an individual's discrete decision whether to use a given technology at a specific point in time. The term diffusion refers to the level of cumulative adoption across time and space, and is measured as the proportion of total bean land cultivated with the new variety.

4.2 Conceptual Framework

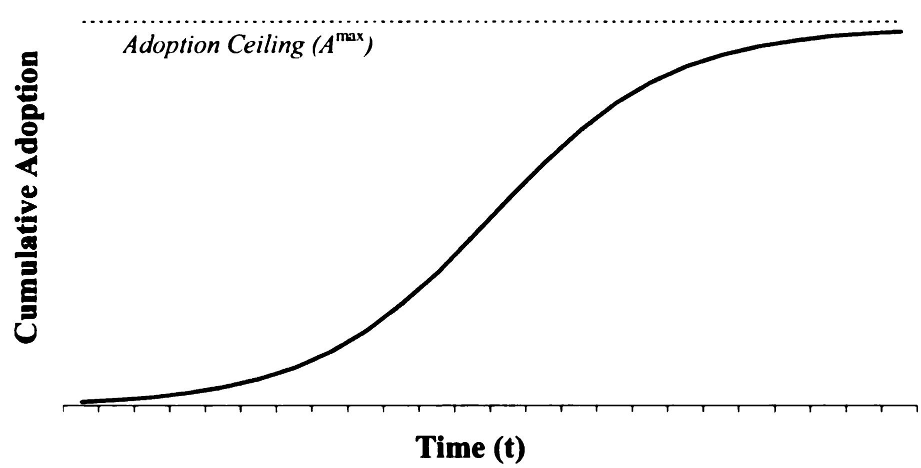
4.2.1 Technology Diffusion

The period of diffusion between when a technology is initially released and when it reaches its maximum cumulative adoption rate typically follows an S-shaped pattern similar to that shown in Figure 4.1. The exact shape of the diffusion curve for particular technologies varies, but each can be characterized by their adoption ceiling and rate of diffusion. The adoption ceiling (A^{max}) expresses the maximum cumulative adoption as a proportion and ranges in value from 0 to 1. The rate of adoption (given by the slope of the diffusion curve) expresses the speed with which diffusion occurs and determines how soon the cumulative adoption rate approaches A^{max}.

The observation of an S-shaped curve was first remarked a half century ago by both sociologists and economists in studies on the diffusion of hybrid corn in the central United States (Rogers 1962, Griliches 1957). Sociological explanations of this pattern generally emphasize the role of both awareness and attitude in influencing the diffusion rates of new technologies. Rogers' (1962) basic observation is that diffusion depends on the flow of information between adopters and potential adopters. These flows are central to generating awareness and allow farmers to formulate their attitudes towards a technology's performance. Information costs, however, typically increase with distance from the center of diffusion and the decision to adopt for many farmers often does not become optimal until later in time.

Economic studies of technology diffusion, on the other hand, typically emphasize the role of incentives and capacity. Incentive is linked to profitability. New technologies

Figure 4.1: The S-Shaped Diffusion Curve



therefore are expected to be adopted at higher rates wherever they are more profitable. Griliches (1957) found that, indeed, both the adoption ceiling and the rate of adoption parameters for hybrid corn varieties were higher in counties where the profit differential between new and old technologies was also higher. Capacity is generally linked to certain characteristics of the farmstead, individual adopters, and economic institutions. For example, farm size, management capacity, risk preferences, wealth, and land tenure have been recognized as crucial to the widespread cumulative adoption of certain technologies (Feder et al. 1985, Sunding and Zilberman 2001). While in some cases these characteristics indicate the capacity for adoption, in others the lack of certain characteristics among non-adopters indicates an adoption constraint.

The S-shaped diffusion curve can be split into three conceptual phases: the early adoption phase, the take-off phase, and the saturation phase (Sunding and Zilberman

2001). Low levels of aggregate adoption and high rates of marginal adoption characterize the early adoption phase. Farmers adopting in this phase are known as innovators, and often have higher levels of educational attainment, financial resources, social status, and willingness to accept risk. Awareness and attitude play their most important role in this early stage. The takeoff phase, which begins just before the inflection point, represents a period of rapid adoption within a short period of time. Many farmers choose to adopt in this phase only after they observe the technology as profitable. They are characterized as less willing to accept risk than early adopters and may face certain adoption constraints. Finally, the saturation phase occurs as the adoption rate slows and the diffusion curve reaches its adoption ceiling.

In the case of Ecuador, the diffusion process for improved bean varieties is assumed to follow a similar S-shaped pattern since the population of bean farmers is relatively large and heterogeneous with respect to their access to information, farm and household characteristics, and production environments. It is also important to note that since the red mottled RVs were released at different points in time, some degree of varietal replacement likely occurred due to farmers switching from older to newer RVs (Maredia et al. 2000). However, the focus of this study is on the cumulative adoption across all red mottled RVs, which as a group are assumed to exhibit a continually increasing rate of diffusion over the period 1986-2006.

4.2.2 Technology Adoption

For individual farmers, the decision whether or not to adopt a new technology poses as an economic dilemma. Economic theory suggests that farmers seek to maximize their utility subject to various production constraints. For discrete cases of technology adoption, we accordingly expect to observe the adoption of a new technology whenever the utility to be received from adoption exceeds that from non- adoption.

The random utility model (RUM) developed by McFadden (1973) provides a useful framework to formalize the discussion of discrete technology adoption decisions. The RUM states that farmers base their adoption decision for a new technology, v, on the unobservable utility function,

$$U_v^* = U_A - U_N, \tag{4.1}$$

where U_v^* represents a latent variable equal to the difference between the utility received with adoption, U_A, and the utility received without adoption, U_N. Assuming that farmers act to maximize utility, we expect adoption to occur whenever U_v^* takes on a positive value, such that

$$\begin{cases} A = 1 & whenever \quad U_v^* \geq 0 \\ A = 0 & whenever \quad U_v^* < 0 \end{cases} \tag{4.2}$$

where A represents a farmer's final technology adoption decision and is equal to 1 if the farmer adopts and is equal to 0 if the farmer does not adopt.

The factors influencing individual adoption decisions can be determined by modeling the probability that U_v^* takes on a positive value as a function of observable explanatory variables, $\boldsymbol{X}$, and an associated vector of parameter coefficients, β, such that

$$P(U_v^* \geq 0) = P(A = 1|\mathbf{X}) = F(\mathbf{X}; \beta). \tag{4.3}$$

For an agricultural production technology, $\boldsymbol{X}$ typically contains those variables associated with an input demand function. In this chapter, the variables to be included in $\boldsymbol{X}$ are organized into three conceptual categories: price variables, farm and household characteristics, and other fixed factors. Specific variables are discussed in Section 4.4.2.

4.3 Quantitative Methods

4.3.1 Logistic Diffusion Curve

Logistic functions are a widely used method of estimating aggregate adoption rates through time, conditional upon the expectation that diffusion of the technology under consideration will follow an S-shaped pattern (Morris and Heisey 2003, Sunding and Zilberman 2001). The logistic function expresses the cumulative adoption rate of a given technology, P_t, as a function of time t, the maximum rate of adoption A^{max}, and two parameters α and β,

$$P_t = \frac{A^{\max}}{1+e^{-(\alpha+\beta t)}}\ , \tag{4.4}$$

where α represents an intercept shifter and β represents a curvature parameter that relates to the rate of adoption. Since the cumulative adoption rate is expressed as a proportion, A^{max} can take on any value from 0 to 1.

One advantage of the logistic function is that diffusion estimates can be obtained for multiple years using as few as two data points and an assumption about A^{max}. This is accomplished by rearranging Equation (4.4) so that the natural log of the ratio of the current adoption level to the amount of remaining adoption is set equal to a linear function of the parameters α and β, and time t,

$$\ln\left(\frac{P_t}{\mathrm{A}^{\max}-P_t}\right)=\alpha+\beta t\,. \tag{4.5}$$

One can calculate the left hand side of Equation (4.5) for each time period and obtain a system of two linear equations with two unknowns[15]. This allows us to derive values for α and β and estimate Equation (4.4). While the logistic function is estimable with two data points, this is the absolute minimum data requirement. Access to three or more data points is preferable since it allows statistical estimation of the logistic function. In the case of Ecuador, however, only two data points are obtainable—one from the 2006 B/C CRSP survey and a second that is generated under the assumption that the adoption rate during the first year of release (1986) is 1% (Alston et al. 1998).

One important weakness of the logistic function, as presented, is that it does not allow for the possibility of disadoption[16]. Farmers may adopt new production technologies with frequency but discontinue their use just as rapidly. While a certain technology may achieve high adoption rates for a number of years, the technology may become unprofitable or a newer technology may come along and replace it. In both cases, the cumulative adoption rate may decrease. As specified, the logistic function is unable to capture such a decrease.

As for the adoption of improved red mottled beans in Ecuador, a strictly rising diffusion curve is suitable for the period of interest (1986-2006), given that the varieties being analyzed were released over ten years ago and that alternative disease-resistant technologies from bean market classes other than red mottled did not become available until 2004.

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[15] Note also that in the special case where $A^{max} = 1$, the left hand side of Equation (4.5) gives the odds ratio for logit regression.
[16] Disadoption is also commonly referred to as *abandonment* in the literature.

4.3.2 Probit Model of Adoption

The probit model provides a means of empirically estimating the influence of particular explanatory variables on individual farmers' adoption decisions in a manner consistent with the random utility model. Assuming the error term follows a normal distribution, the probit model allows the probability of adoption to be computed from the cumulative distribution function (*cdf*) for the standard normal distribution. By using the definition of expected value and allowing the latent utility function to become a random variable, Equation (4.3) can be rewritten as,

$$A = F(X;\beta) + \varepsilon . \tag{4.6}$$

Now, substituting in the *cdf* of the standard normal distribution, Φ, we obtain,

$$A = \Phi(X\beta) + \varepsilon , \tag{4.7}$$

which is the standard probit model. The probit model is advantageous since it restricts the predicted probability outcomes to lie between 0 and 1.

Empirical estimation of the probit model is carried out using a maximum likelihood estimation procedure. The process is as follows. First, the probability of adoption for each observation, i, is expressed as,

$$P(A|X) = \Phi(X;\beta)^{A_i}[1-\Phi(X;\beta)^{(1-A_i)}] , \tag{4.8}$$

where A again represents individual adoption decisions by farmers, and is equal to 1 if a farmer adopts and 0 otherwise. Second, the log likelihood function is obtained by taking the natural log of Equation (4.8) and summing across all i to obtain:

$$\ln L = \sum(A_i \ln[\Phi(X\beta)] + (1-A_i)\ln[1-\Phi(X\beta)]) . \tag{4.9}$$

Probit estimation is then completed by choosing the β so as to maximize the log likelihood function given in Equation (4.9) for the given dataset (Myers 2006).

To facilitate the interpretation of probit regression results, the marginal effects will be reported alongside normal probit coefficients. Marginal effects show the expected change in the probability of adoption given a one unit change in a particular explanatory variable X_j, holding all other explanatory variables fixed. In the case of binary explanatory variables, marginal effect estimates report the expected change in the probability of adoption given that the value changes from 0 to 1. All marginal effect estimates will be reported at the data means.

4.4 Data Description

The data used to estimate both the logistic diffusion curve and the probit model for discrete adoption decisions comes from the 2006 field survey carried out by the Bean/Cowpea Collaborative Research Support Project (B/C CRSP) and INIAP in northern Ecuador (as discussed in Chapter 3).

4.4.1 Diffusion Data

Survey results obtained from the varietal adoption component of the household questionnaire indicate a wide diversity of bean varieties cultivated with respect to both market class and varietal classification (Table 4.1). The red mottled bean market class is the best represented, with 11 different varieties appearing in the sample, including the two most widely observed varieties Paragachi and Injerto. Additional varieties recorded belong to the purple mottled, yellow, solid black, solid red, and pink mottled market classes.

Table 4.1:
Bean Varieties Planted by Plot and Land Area, Imbabura and Carchí, Ecuador, 2006 (n = 187)

Variety Name	*Market Class*	*Variety Grouping*	*Number of Plots (n)*	*Percent of Plots (%)*	*Area Planted (ha)*	*Percent of Area (%)*
Paragachi	Red mottled	RV-1990s	36	19.3	44.3	19.1
Injerto	Red mottled	Local	30	16.0	48.0	20.7
Calima Negro	Purple mottled	Local	21	11.2	29.0	12.5
Selva	Red mottled	Local	14	7.5	24.5	10.6
Canario del Chota	Yellow	RV-2000s	12	6.4	10.9	4.7
Calima Rojo	Red mottled	Local	11	5.9	22.8	9.8
Concepcion	Purple mottled	RV-2000s	11	5.9	10.8	4.7
Negro	Solid black	Local	8	4.3	5.4	2.3
Capulí	Solid red	Local	8	4.3	9.0	3.9
Je.Ma.	Red mottled	RV-1990s	7	3.8	7.3	3.1
Cargabello	Red mottled	RV-1990s	5	2.7	4.8	2.1
Imbabello	Red mottled	RV-1990s	3	1.6	2.8	1.2
Yunguilla	Red mottled	RV-2000s	2	1.1	1.8	< 1.0
Uribe o Magola	Pink mottled	Local	2	1.1	1.3	< 1.0
S35*	Purple mottled	RV-2000s	2	1.1	3.5	1.5
S23*	Red mottled	RV-2000s	2	1.1	1.0	< 1.0
Matahambre	Yellow	Local	2	1.1	1.0	< 1.0
Blanco Fanesquero	White	RV-2000s	2	1.1	1.0	< 1.0
Blanco de Leche	White	Local	2	1.1	< 1.0	< 1.0
Toa	Red mottled	Other	1	0.5	< 1.0	< 1.0
S26*	Yellow	RV-2000s	1	0.5	< 1.0	< 1.0
Rojo	Solid red	Local	1	0.5	< 1.0	< 1.0
Radical	Solid red	Local	1	0.5	< 1.0	< 1.0
Mixturiado	Various	Local	1	0.5	< 1.0	< 1.0
Blanco Belén	White	Local	1	0.5	< 1.0	< 1.0
Algarrobo	Red mottled	Local	1	0.5	< 1.0	< 1.0
Total			**187**	**100.0**	**229.2**	**100.0**

Source: B/C CRSP and INIAP farm-level varietal adoption survey, northern Ecuador, 2006
* - Indicates varieties currently under participatory evaluation

All RVs released by INIAP during the 1990's (grouping "RV-1990s"[17]) are represented in the sample, and all belong to the red mottled market class. The majority of local varieties also belong to the red mottled market class. This will allow for an *ex-post* comparison between INIAP red mottled RVs and local red mottled varieties for the period 1986-2006. All four recently released INIAP purple mottled RVs released through

[17] Exceptions are the variety Paragachi released in 1996 and the variety Cargabello released in 1987.

participatory breeding techniques (grouped as "RV-2000s") are also represented in the sample. Of these, however, only the purple mottled market class provides enough observations of both resistant and local varieties to permit a comparison. Given the recent introduction of the purple mottled RV "La Concepción" in 2004, we predict *ex-ante* diffusion rates for the 21-year period 2004-2024.

Together, the red mottled and purple mottled market classes account for an estimated 80% of all land cultivated to beans in the Imbabura and Carchí provinces (Table 4.2). Of these two classes, the red mottled varieties dominate with an adoption rate

Table 4.2: Estimated Adoption Rates by Market Class in 2006, Imbabura and Carchi, Ecuador

Market Class	*Estimated Land Area* (%)	*Estimated Land Area* (ha)	*Estimated Number of Farm Households*
Red Mottled	68.4%	21,090	2,893
Purple Mottled	12.3%	3,784	519
Yellow	6.0%	1,837	252
Solid Black	5.8%	1,793	246
Solid Red	5.8%	1,790	246
White	< 1.0%	< 300	< 50
Pink Mottled	< 1.0%	< 300	< 50
Other/mixed	< 1.0%	< 300	< 50
Total	100.0%	30,816	4,227

Notes: Estimated land area proportions are calculated using the survey weighting method described in Section 3.4. Estimated land area is from 2005 (SICA 2007); Estimated total number of households is from 2001 (INEC 2001).

Table 4.3: Estimated Adoption Rates of Disease-Resistant Varieties as a Proportion of Land Area Cultivated, Imbabura and Carchí, Ecuador, 2006

Variety	*Market Class*	
Grouping	*Red Mottled*	*Purple Mottled*
Local	54%	84%
RV-1990s	45%	---
RV-2000s	< 1%	10%
Other	< 1%	6%
Total	100%	100%

of 66% and an estimated 21,000 hectares planted. Purple mottled varieties account for just over 12% of all land cultivated and an estimated 3,700 hectares of production. Yellow, solid black, and solid red varieties are also found on over 5% of cultivated land each. White and pink mottled varieties are planted on less than 1% of all land.

RV adoption rates vary for the red mottled and purple mottled market classes (Table 4.3). Within the red mottled market class, 44.9% of all land was cultivated to RVs—which, again, pertain exclusively to the set of INIAP varieties released during the 1990s. Within the purple mottled class, 9.82% of all land was cultivated with an improved variety—which, in this case, refers to the variety "La Concepcion" released by INIAP in 2004 under a participatory varietal selection process. It is important to note that the red mottled RVs are in the saturation phase of their diffusion process, while the purple mottled RV is still in the early adoption phase.

4.4.2 Adoption Data

Specific variables to be included in the adoption analysis of red mottled RVs are shown in Table 4.4. Price variables include the price of bean seed, the market price

Table 4.4: Descriptive Statistics of Variables Included in the Adoption Model for Disease-Resistant Red Mottled Varieties, Imbabura and Carchí, Ecuador, 2006 (n=82)

Variable Description	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*
Dependent Variable				
Adoption of an improved variety (1=Yes)	0.49	0.50	0	1
Price Variables				
Bean Seed Price ($/kg)	0.94	0.30	0.40	1.76
Bean Sale Price ($/kg)	0.64	0.18	0.28	1.10
Cost of transport to market ($/100 lb. sack)	0.39	0.42	0.00	1.50
Family and Household Characteristics				
Age of household head (years)	47.9	13.6	21	76
Education of household head (years)	5.1	2.5	0	16
Number of working household members	2.6	1.7	0	9
Attended a pest management seminar (1=Yes)	0.30	0.46	0	1
Received remittances (1=Yes)	0.20	0.40	0	1
Proportion of Harvest Sold	0.89	0.19	0.00	1.00
Unsatisfied Basic Needs Index (# UBN)	0.7	0.9	0.0	3.0
Farm Characteristics				
Agricultural land owned (ha)	3.18	2.49	0.25	12.00
Agricultural land planted to beans (ha)	1.93	1.79	0.25	10.00
Received credit for bean production (1=Yes)	0.20	0.40	0	1
Sharecropped land (1=Yes)	0.48	0.50	0	1
Fixed Factors				
Altitude (m)	2024	329	1306	2583
Time of transport to market (hours)	0.49	0.60	0	3
Located in the Chota Valley (1=Yes)	0.67	0.47	0	1
Village w/out prior INIAP intervention (1=Yes)	0.57	0.50	0	1

Source: B/C CRSP and INIAP field survey, Ecuador, 2006

received at the time of harvest, and an additional variable measuring the cost to transport to market. This last variable is included to capture the effective prices paid by farmers (Sadoulet and de Janvry 1995). Household characteristics include the age and education of the household head, the number of working adults, a dummy variable indicating whether the household received financial remittances, a dummy variable indicating whether the household head attended a pest management seminar, the proportion of harvest sold, and the unsatisfied basic needs (UBN) index. Age, education, and attendance at a pest management seminar serve to proxy human capital and management ability. The number of working adults is a proxy for labor availability. The remittance variable is used to proxy financial capital. The proportion of harvest sold indicates the degree of subsistence. The UBN poverty index is included as a proxy for wealth[18].

Farm characteristics include the total agricultural land area owned by the household, the total area planted to beans, whether the household received credit for bean production during the 2006 cycle, and whether the household utilizes a sharecropping arrangement. Land serves as an indicator of wealth, total area planted to beans serves as an indicator of specialization in bean production, and access to credit is a proxy for financial capital. Sharecropping is a management practice known to reduce input provision.

Fixed factors include altitude, the time required to travel to market, whether the household is located in the Chota Valley, and the level of extension intervention by INIAP. Altitude serves as a proxy for both disease pressure and precipitation. The required time to travel to market captures access to information, under the assumption that information costs increase with distance. A binary variable for farmers living within the Chota river valley is included so as to control for unobserved differences in bean production between the two zones. Mean difference tests of the summary statistics between farmers living in the Mira and Chota river valleys reveal that, on average, farmers in the Chota valley are younger, have smaller plot sizes, sell a much higher share of total production, had higher costs of transporting their product to the market, and also received higher bean prices. Finally, the dummy variable for farmers living in villages without previous extension intervention by INIAP is included to control for awareness of improved varieties.

[18] See Appendix 5 for details on the construction of the Unsatisfied Basic Needs (UBN) Index.

4.5 Results and Discussion

4.5.1 Estimated Rates of Diffusion

A logistic function is estimated for RV adoption within both the red mottled and purple mottled market classes. In the case of red mottled varieties, an *ex-post* diffusion curve is estimated for the years 1986 through 2006. In the case of purple mottled varieties, an *ex-ante* diffusion curve is estimated for the years 2004 through 2024.

The adoption ceiling, or maximum cumulative adoption rate, for the set of red mottled RVs is 45%, equal to the 2006 adoption rate shown in Table 4.2. Two observations support this assumption. First, the diffusion of red mottled RVs is assumed to be in the saturation phase of adoption. A 10-year window exists between the release of the last of these varieties (Je.Ma. in 1996) and data collection and it is likely that non-adopters are classified as such by choice rather than by a lack of awareness. Second, INIAP began releasing a new set of RVs in 2004. A process of varietal replacement will likely occur and result in a decrease in the cumulative adoption level of red mottled RVs released during the 1990s.

Two data points are used to estimate values for the two logistic function parameters α and β. First, the 2006 adoption rate of 45% for the red mottled market class is used. Second, we assume that in 1986, the first year a red mottled RV was released, the adoption rate was near 1%. Using this data, the estimated parameter values are $\alpha = -795$ and $\beta = 0.398$ and the logistic function is as presented in Figure 4.2.

The adoption ceiling for purple mottled RVs is also assumed to be 45%. In lieu of better data on which to base the estimate, this assumption is made using the history of red mottled RVs. As more data becomes available in the future, it may be necessary to change this assumption. Two data points are also used to estimate values the value of α and β. In 2006, we found an adoption rate for RVs from the purple mottled market class of 10%. Second, we assume that in 2004, the first year of release, the adoption rate was near 1%. Using this data, the estimated parameter values are $\alpha = -25200$ and $\beta = 1.25$ and the diffusion curve is as presented in Figure 4.3.

A comparison of Figures 4.2 and 4.3 shows faster predicted rate of adoption for purple mottled RVs than for red mottled RVs. The method used to estimate the diffusion rate of red mottled varieties, however, most likely overestimates the time needed for the cumulative adoption rate to reach A^{max} in 2006—at the time of the survey. Thus, this assumption provides an underestimate of the cumulative adoption rate in previous years and Figure 4.2 then provides a lower bound estimate of diffusion rates for the red mottled varieties.

It may not be the case however that the cumulative adoption of red mottled varieties reached A^{max} as quickly as predicted for the purple mottled varieties. The diffusion of purple mottled varieties may enjoy a faster rate of adoption and possibly even a higher adoption ceiling than red mottled varieties. First, the popularity of red mottled RVs may lead to faster adoption of newer generations of RVs. Second, the participatory nature of INIAP's bean improvement program and/or improved communication networks and other similar factors may accelerate awareness compared to two decades ago when the previous RVs were released.

Figure 4.2: Estimated Diffusion of Improved Red Mottled Beans, Provinces of Imbabura and Carchi, Ecuador, 1986-2006

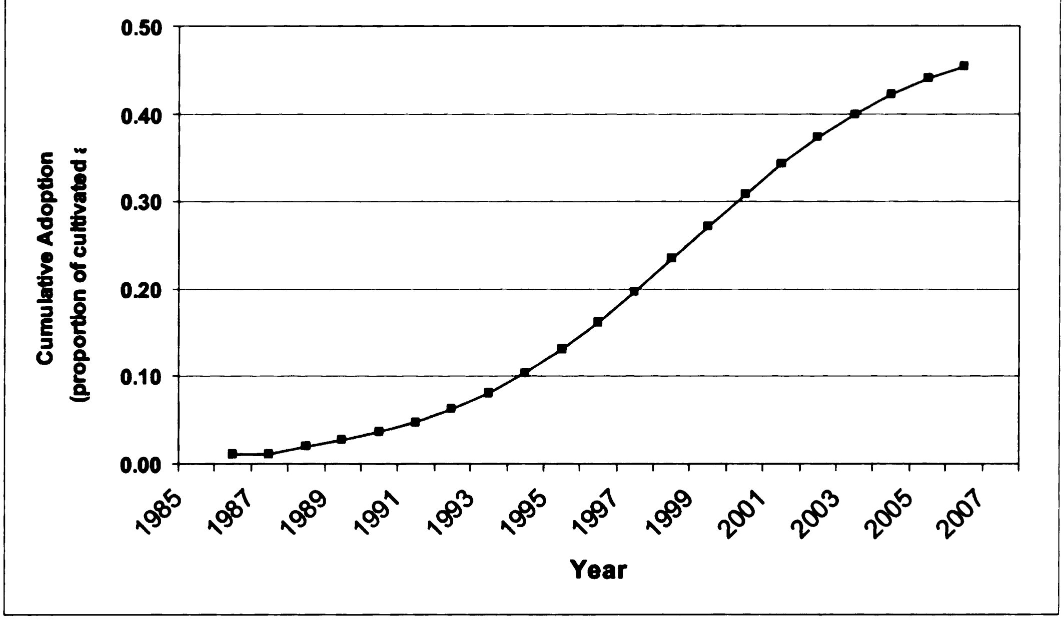
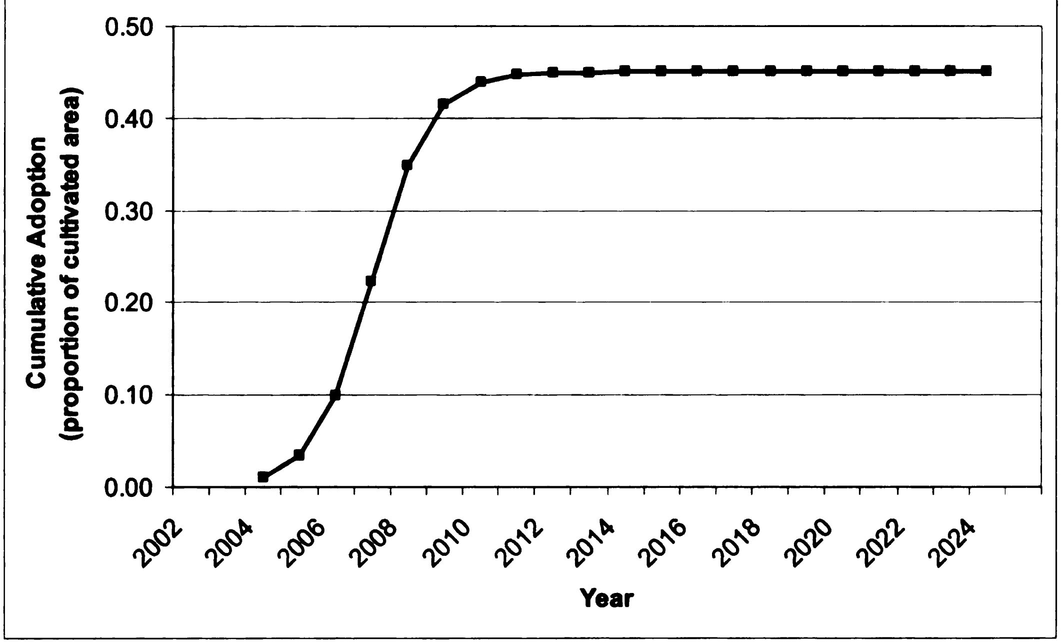


Figure 4.3: Expected Diffusion of Improved Purple Mottle Beans, Imbabura and Carchi, Ecuador, 2004-2024



4.5.2 Factors Influencing Individual Adoption Decisions

Moving from analysis of cumulative adoption rates to analysis of individual adoption decisions, probit results of the factors influencing adoption decisions for red mottled RVs indicates a high percentage (71%) of correctly predicted observed adoption decisions (Table 4.5). Across variable categories, price variables and fixed factor variables play the most significant role in influencing farmers' RV adoption decisions.

Statistically significant price variables include the price of bean seed (significant at a .01 level) and the cost of transport to market (significant at a .05 level). Other things equal, an increase in the price of bean seed by one dollar per kilogram reduces the probability of adoption by 77%. Similarly, an increase in the cost of transportation of a 100 pound sack of beans by one dollar decreases the probability of adoption by 63%. While these marginal effects appear large, a one-dollar per kilogram increase is also large relative to the sample means of bean seed price and transport costs of $0.94/kg and $0.39/kg, respectively.

Statistically significant fixed factor variables include the dummy variable for farmers living in the Chota watershed (significant at a .01 level), altitude (significant at a .05 level), and the time of transport to market (also significant at a .05 level). A farmer living in the Chota watershed is 58% more likely to adopt a red mottled RV than a farmer living in the Mira watershed. An increase in the altitude by 100 meters reduces the probability of adoption by 6%. Contrary to expectations, an increase in travel time by one hour *increases* the probability of adoption by 41%. Finally, the household characteristic dummy variable indicating that a family received remittances is negative and significant at a .10 level. This implies that, other things equal, a family receiving remittances is 29% less likely to adopt RVs.

The coefficients on the price variables and altitude have the expected sign. The negative sign on the remittances variable indicates that households with access to financial capital are less likely to adopt RVs. This may indicate that wealthier households

Table 4.5: Probit Model Results for Factors Influencing the Adoption of Disease-Resistant Red Mottled Varieties, Imbabura and Carchí, Ecuador, 2006 (N=82)

Explanatory Variables	Probit Coefficient	Marginal Effect	P-Value
Price of seed ($/kg)	-1.9473	-0.7698	***0.010
Price of beans ($/kg)	-0.0961	-0.0380	0.924
Cost of transport to market ($/qq)	-1.5848	-0.6264	**0.031
Age (years)	0.0008	0.0003	0.954
Education (years)	-0.0816	-0.0322	0.268
Pest management seminar (1=Yes)	0.0319	0.0126	0.941
Number of working adults	-0.0308	-0.0122	0.764
Received remittances (1=Yes)	-0.8057	-0.2921	*0.086
Percent of harvest sold	-1.1344	-0.4484	0.314
Poverty measure (# of UBN)	-0.1703	-0.0673	0.445
Agricultural land (ha)	0.2053	0.0811	0.179
Land planted to bean (ha)	-0.2118	-0.0837	0.311
Received credit (1=Yes)	0.1677	0.0666	0.759
Partidario (1=Yes)	0.4273	0.1679	0.326
Altitude (100 meters)	-0.0015	-0.0601	**0.028
Time of transport to market (hours)	1.0258	0.4055	**0.025
Chota valley (1=Yes)	1.7596	0.5773	***0.002
Village w/out prior INIAP intervention	0.2326	0.0915	0.564
Log likelihood	-39.26		
LR Chi2	35.10		
Prob > chi2	0.00		
% Correctly Predicted	71%		

*** = Significant at α=0.01
** = Significant at α=0.05
* = Significant at α=0.10

invest in areas other than bean production, or that receipt of remittances indicates households with limited production resources. The negative sign on travel time, however, is contrary to expectations. Since the cost of transport to market is also included in this analysis, the positive sign may indicate that better transportation infrastructure leads to increased adoption. The reasoning here is that a longer trip along a route with improved infrastructure would cost the same as a short trip along a route with unimproved infrastructure. Since improved infrastructure lowers communications costs, the negative sign may indeed be in accordance with diffusion theories.

4.6 Chapter Summary

The diffusion analysis provides data on the estimated cumulative adoption rate of red mottled RVs from 1986-2006 and predicted cumulative adoption rates for recently release purple mottled RVs for the period 2004-2024. Comparison of the diffusion rates between the red mottled and purple mottled RVs shows a faster rate of adoption for purple mottled varieties. This finding is partially by construction, because red mottled estimates represent a lower bound on estimates for purple mottled varieties. The diffusion data presented here will be used as key parameters in the economic surplus analysis in Chapter 6.

The adoption analysis indicated that price variables and fixed factor variables influence RV adoption decisions the most. For the most part, results followed expectations. Low seed prices and low transportation costs (which reflect market access) acted as incentives to adoption. As for the fixed factors, altitude (which is correlated with rainfall and disease pressure) acted as a constraint to adoption, while unobserved factors present among producers located in the Chota valley increased the probability of adoption.

CHAPTER FIVE:

ECONOMETRIC MEASUREMENT OF INCREMENTAL FARM-LEVEL BENEFITS

5.1 Introduction

Disease-resistant varieties (RVs) have the potential to provide an array of farm-level benefits to adopters such as higher yields and lower input requirements, which can jointly reduce unit costs of production[19]. Ecuador's national agricultural research institute, the *Instituto Nacional Autónomo de Investigaciones Agropecuarios* (INIAP) began releasing a series of improved red mottled bean varieties during the 1980's in the two northern provinces of Imbabura and Carchi as part of it bean improvement program. Each of these varieties is resistant to a specific plant disease that is prevalent in the area as reported in Table 2.5.

The objective of this chapter is to estimate the farm-level impact of RV adoption on bean yield, pesticide use, and the unit cost of production. Empirical measures of these impacts are obtained using multiple regression treatment effect models. This knowledge is important for agricultural researchers within Ecuador, as well as to other decision makers who are seeking information about estimating the economic impact of disease-resistant varietal technologies. In addition, these measures can be used as parameters in an overall economic impact assessment of INIAP's efforts to breed for disease resistance.

5.2 Research Objectives

Breeding for disease-resistance seeks to enhance productivity through strict yield-gains, yield-losses avoided (Morris and Heisey, 2003), or by embedding damage

[19] In this chapter, unit cost is defined as the cost per unit of output (i.e. $/kg).

abatement services into improved seed which can then substitute for chemical fungicide inputs (Lichtenberg and Zilberman 1986). In this chapter, three hypotheses concerning RV adoption are tested using multiple regression techniques:

- H_1: Farmers who plant RVs have *higher yields per hectare* compared to farmers who plant local varieties when faced with disease pressure.
- H_2: Farmers who plant RVs apply *less pesticide active ingredients per hectare* compared to farmers who plant local varieties. This hypothesis is tested for both fungicides and insecticides.
- H_3: Farmers who plant RVs have a *lower unit variable cost of production* than do farmers who plant local varieties[20].

5.3 Conceptual Framework

The empirical estimation of these hypotheses requires the appropriate identification of the with- and without-research scenarios, also known as the *counterfactual* (Morris and Heisey 2003). However, we are only able to observe one of these outcomes for each farmer. For adopters, the challenge lies in determining what their production outcomes would have been *without* RVs. For non-adopters, we face the opposite challenge of determining what their outcomes would have been *with* RVs.

In practice, a number of approaches to formulating the counterfactual are possible. One possibility is to compare production outcomes for the same farmers both before and after adoption. This requires that panel data, but most adoption surveys (including this one) collect data for a single year and thereby exclude this possibility. In

[20] Unit *variable* cost (UVC) is defined as those costs expected to vary upon the adoption of a resistant variety. A more formal definition is provided in Section 5.5.

addition, the before-and-after approach assumes that the counterfactual scenario remains constant, which is rarely the case.

A second possible approach is to compare the production outcomes of adopters to those of non-adopters. This approach is common within the growing body of literature on the economic impact of input-saving biotechnologies. A number of studies compare the yield and input-saving impacts using only a simple mean comparison approach (Bennett et al. 2004, Brookes 2005, Qaim and Traxler 2005). This may lead to biased conclusions, however, since the observed differences in production outcomes between adopters and non-adopters is generally not a result of the improved variety alone. Many secondary factors such as plot characteristics, crop management techniques, and even certain household characteristics (such as management ability) are also often correlated with observed crop yields, input use, and unit costs. The failure to control for these factors leaves open the possibility of attributing observed differences in farm-level benefits to the improved technology rather than its true source.

To avoid these criticisms, this paper employs the use of multiple regression *treatment effect models* (TEMs), which allow for production outcomes between adopters and non-adopters to be compared conditional upon a set of explanatory covariates (Wooldridge 2002). This methodology draws from the literature on program evaluation whose focus is on identifying the impact of economic or social programs, called *treatments*, on program participants, called the *treated*. In our case, the treatment of interest is the adoption of an INIAP RV and the impacts of interest are the effect of this RV adoption on yield, input-savings, and the unit cost of production. An empirical measure of each impact is given by the *treatment effect*, which is the partial effect of the binary treatment variable on a dependent variable.

Treatment effect models provide unbiased results provided that two assumptions hold (Wooldridge 2002). The first is called the *stable unit treatment value assumption*. It states that the treatment of one observation does not affect another's outcome. Given that the technology of interest is embedded in self-pollinating bean seed, this assumption clearly holds[21]. The second is called the *ignorability of treatment*. It implies that selection of those who receive treatment does not occur based on a set of observable characteristics. In cases where selection on observables does occur, it can be controlled for by including those characteristics that partially determine selection into the regression analysis as covariates[22].

Applications of TEMs to agriculture are limited. Godtland et al. (2004) uses a TEM to isolate the impact of participation in farmer field schools on farmer knowledge about integrated pest management practices. More specific to input-saving agricultural technology, Fernandez-Cornejo et al. (2002) used a TEM in their study of on-farm impacts of herbicide-tolerant soybean varieties on yield and herbicide demand. Qaim and de Janvry (2005) use a treatment effect model (although not stated as such) to estimate the farm-level economic impact of Bt cotton adoption yield and pesticide use. More recently, Gardner and Nelson (2007) use a TEM to estimate labor savings in U.S. agriculture that have resulted from the adoption of genetically modified crops.

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[21] An example of when this assumption may not hold is with knowledge-intensive technologies, such as integrated pest management, where diffusion is likely to occur between the treated and un-treated.

[22] The selection on observables can be examined using a mean comparison test of descriptive statistics between the treated and un-treated (Godtland et al. 2004). In this case, differences between adopters and non-adopters are explored in Section 5.5.

A further issue in using treatment effect models to compare production outcomes is an assumption that no self-selection occurs among farmers. Previous economic impact assessments of disease-resistant bean breeding did control for this possibility (Mather 2005). This correction was necessary given that the farm-level survey included areas both with and without disease pressure. Given individual farmers' knowledge of disease infestation probabilities in their own fields, adoption occurred only in areas with high disease-pressure. Thus, a comparison of adopters to non-adopters would not provide a good estimate of what the production outcome of adopters would have been in absence of the RVs. Data from the B/C CRSP household survey in Ecuador however includes only farmers living in disease-prone areas and will not result in a self-selection process similar to that described in by Mather (2005).

5.4 Conceptual Models

Before presenting empirical tests for each of the three stated hypotheses, this section introduces the three conceptual models to be used in evaluating the farm-level impact of improved varieties: a crop yield model, a pesticide demand model, and a unit cost model. For the pesticide demand model, two separate functions are specified, one for fungicides and the other for insecticides.

5.4.1 Crop Yield Model

In order to form *a priori* expectations about the farm-level impact of resistant varieties on crop yields, it is important to understand the economic motivation behind their development. The breeding of crop varieties for disease resistance is generally undertaken in order to maintain current yield levels in the face of disease pressure (Smale et al. 1998; Morris et al. 1994). Thus, our expectation regarding the impact of RV adoption on yield is positive when compared to susceptible varieties in the presence of disease pressure. When disease pressure is absent, we expect there to be no yield differential between the resistant and susceptible varieties.

A crop yield model is used to test this hypothesis. The crop yield model is stated as a production function where *Y* represents the maximum obtainable yield for a set of fixed inputs, *X*, that is conditioned by certain covariates such that,

$$Y = f(X \mid A, D, L, F, Z) \tag{5.1}$$

where *A* represents the RV adoption decision, *D* represents pest and disease pressure, *L* plot characteristics, *F* farm household characteristics, and *Z* represents community-level fixed factors. The *Z* variables are included to control for unobserved variables that differ between communities but remain constant within communities.

5.4.2 Input Demand Functions

In addition to yield gains, the disease resistance embodied in the improved seed provides damage abatement services that can be substituted for fungicide inputs in a biological production function (Lichtenberg and Zilberman 1986, Mather 2005). This suggests that RV adoption should reduce the quantity of fungicides used. Since farmers in northern Ecuador typically apply fungicides and insecticides jointly in a single application, there may also be an indirect impact of RV adoption on insecticide use.

Two input demand functions are developed to test these hypotheses, one for fungicides and the other for insecticides. These models state the quantity of pesticide active ingredient (AI) demanded, X, as a function of price variables, P, and conditioned by a set of covariates such that,

$$X = f(P|A, D, L, F, Z) \tag{5.2}$$

where A, D, L, F, and Z are identical to those described in the yield model.

5.4.3 Unit Cost Function

An economic measure of the farm-level impact of improved varieties can be obtained using a unit cost function (Alston et al. 1998). This approach is advantageous, since it reflects the economic benefits of both yield-enhancing and input-saving components of a new technology. While the yield and pesticide demand functions measure changes in the agronomic quantities of yield, seed, and pesticides associated with the adoption, they do not reflect differences in the prices paid for these products between adopters and non-adopters. A farmer may obtain a higher yield upon adopting an improved variety, but if his or her variable production costs also increase then the final economic benefits realized through adoption may not be as large as expected.

Assuming farmers act to maximize profits, the unit cost function describes the average cost of producing one unit of product (C) for a given set of input prices (W) and level of output (Q) and covariates such that,

$$C = f(W, Q|A, D, L, F, Z) \tag{5.3}$$

where A, D, L, F, and Z are as previously defined.

5.5 Data Description

Data comes from the 2006 B/C CRSP and INIAP field survey conducted in the provinces of Imbabura and Carchí in northern Ecuador in 2006 (see chapter 3). A total of 132 farmers from 30 communities were surveyed, with results indicating that 82 farmers planted a red mottled variety on their largest bean plot whereas 23 planted a purple mottled variety. The other 27 farmers planted varieties from either the yellow, white, solid red, solid black, or pink mottled market class. In addition, 12 farmers planting a red mottled variety could not provide complete information on specific pesticides used. For the purposes of the regression analysis to follow, only those using a red mottled variety with complete data on all pesticide applications are considered.

A description of variables to be included in the regression analysis and their units of measurement, along with descriptive statistics are provided in Table 5.1. Bean yield (*Y*) is measured in terms of kilograms of beans produced per hectare and serves as the dependent variable for the yield impact model. The per-hectare yields reported here appear much higher than that presented in Figure 2.3. This is due to the restriction of analysis to red mottled varieties[23]. Production inputs (*X*) include the quantity of insecticide, fungicide and foliar fertilizer active ingredient (AI) used per hectare and seed input. The same insecticide and fungicide values serve as dependent variables in the two input demand functions[24].

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[23] It is important to note that two of the top three observations with respect to per-hectare yields (i.e. > 3000 kg/ha) pertain to farmers who planted relatively small plots (i.e. <0.25 ha). The conversion of these figures to ones representative of a per-hectare basis results in higher per hectare yield values than might be normally expected. This helps explain the egregiously large maximum values for per hectare yields.

[24] Fungicides, insecticides and foliar fertilizers used in northern Ecuador come in liquid and powder forms resulting in various units of measurement. A conversion to kilograms of AI assumes 1 cc = 1 ml = 1g.

Table 5.1: Summary Statistics of Variables to be Included in the Regression Analysis for Red Mottled Varieties, Imbabura and Carchi, Ecuador, 2006 (n=73)

Variable Category:	*Mean*	*Std Dev*	*Min*	*Max*
Dependent Variables:				
Yield (kg/ha)	1526	906	239	4915
Fungicide AI (kg/ha)	15.8	34.0	0.1	187.5
Insecticida AI (kg/ha)	6.1	14.0	0.1	96.1
Unit variable cost ($/kg)	0.16	0.13	0.03	0.86
Treatment Effect Variables:				
Adopted improved variety (1=yes)	0.60	0.49	0	1
High disease pressure (1=yes)	0.29	0.46	0	1
High pest pressure (1=yes)	0.23	0.43	0	1
Production Inputs:				
Fungicide AI (kg/ha)	15.8	34.0	0.1	187.5
Insecticida AI (kg/ha)	6.1	14.0	0.1	96.1
Foliar fertilizer AI (kg/ha)	12.2	25.4	0	153.39
Seed (kg/ha)	112.8	44.7	53.1	294.9
Plot Characteristics:				
Plot size (ha)	1.04	1.00	0.23	7.00
Altitude (m.a.s.l.)	2034	323	1306	2583
Loam soil (1=yes)	0.42	0.50	0	1
Irrigated plot (1=yes)	0.95	0.23	0	1
Plot prev. cropped w/ beans (1=yes)	0.30	0.46	0	1
Sharecropped plot (1=yes)	0.40	0.49	0	1
Rented plot (1=yes)	0.08	0.28	0	1
Household Variables:				
Age (years)	46.4	13.8	21	76
Attended pest man. seminar (1=yes)	0.33	0.47	0	1
Symptom-based pest man. (1=yes)	0.16	0.37	0	1
Poor household (1 or more UBN) (1=yes)	0.42	0.50	0	1
Price Variables:				
Market price for beans ($/kg)	0.64	0.18	0.28	1.10
Cost of transport to point of sale ($/qq)	0.34	0.36	0.00	1.00
Avg. price of fungicide ($/kg AI)	0.75	0.37	0.30	2.00
Avg. price of insecticide ($/kg AI)	1.35	0.37	0.80	3.40
Seed price ($/kg)	0.89	0.27	0.40	1.76
Community-Level Variables:				
Chota valley (1=yes)	0.62	0.49	0	1
Prev. extension intervention (1=yes)	0.45	0.50	0	1

Source: 2006 B/C CRSP and INIAP field survey

Table 5.2: Sample Means of Explanatory Variables by Adoption Status, Red Mottled Varieties, Imbabura and Carchi, Ecuador, 2006 (n=73)

Variable Category:	*Adopters (n=42)*		*Non-Adopter (n=31)*		*P-Value*
	Mean	*Std Dev*	*Mean*	*Std Dev*	a/
Dependent Variables:					
Yield (kg/ha)	1554	776	1372	1060	0.36
Fungicide AI (kg/ha)	11.3	16.0	17.9	46.1	0.16
Insecticide AI (kg/ha)	3.60	3.79	7.61	19.91	0.34
Unit variable cost ($/kg)	0.15	0.13	0.17	0.12	0.53
Treatment Effect Variables:					
High disease pressure (1=yes)	0.26	0.44	0.40	0.50	0.17
High pest pressure (1=yes)	0.24	0.43	0.20	0.41	0.66
Production Inputs:					
Fungicide AI (kg/ha)	11.3	16.0	17.9	46.1	0.35
Insecticide AI (kg/ha)	3.60	3.79	7.61	19.91	0.16
Foliar fertilizer AI (kg/ha)	0.08	0.11	0.08	0.14	0.34
Seed (kg/ha)	112.09	26.95	114.67	63.41	0.80
Plot Characteristics:					
Plot size (ha)	1.00	1.16	1.05	0.74	0.81
Altitude (m.a.s.l.)	1986	307	2091	351	0.15
Loam soil (1=yes)	0.36	0.48	0.63	0.49	***0.01
Irrigated plot (1=yes)	0.94	0.24	0.91	0.28	0.65
Plot prev. cropped w/ beans (1=yes)	0.34	0.48	0.23	0.43	0.27
Sharecropped plot (1=yes)	0.40	0.49	0.34	0.48	0.60
Rented plot (1=yes)	0.57	0.53	0.58	0.49	0.93
Household Variables:					
Age (years)	45.0	12.8	50.0	14.1	*0.10
Attended pest man. seminar (1=yes)	0.34	0.48	0.32	0.47	0.80
Symptom-based pest management (1=yes)	0.12	0.33	0.26	0.44	0.11
Poor household (at least 1 UBN) (1=yes)	0.44	0.50	0.43	0.50	0.92
Price Variables:					
Market price for beans ($/kg)	0.66	0.19	0.59	0.13	**0.05
Cost of transport to point of sale ($/qq)	0.38	0.36	0.34	0.42	0.60
Avg. price of fungicide ($/kg AI)	0.69	0.30	1.00	1.04	*0.07
Avg. price of insecticide ($/kg AI)	1.37	0.43	1.31	0.27	0.54
Seed price ($/kg)	0.84	0.22	1.06	0.35	***0.00
Community-Level Variables:					
Chota valley (1=yes)	0.76	0.43	0.40	0.50	***0.00
Prev. extension intervention (1=yes)	0.40	0.49	0.51	0.51	0.30

a/ P-value is for a mean-difference t-test between adopters and non-adopters assuming equal variances
*** = significant at a 1% level; ** = significant at a 5% level; * = significant at a 10% level
Source: 2006 B/C CRSP and INIAP field survey

Variables used to measure the treatment effect of improved varieties include binary indicators representing the RV adoption decision (A) and disease and pest pressure (D). For each model, $A=1$ indicates adoption occurred and $A=0$ indicates non-adoption. Survey results indicate that 44 of 73 (60%) farmers planting a red mottled variety had adopted an RV. To corroborate that farmer's correctly identified the variety planted, enumerators obtained confirmation through either viewing saved seed or visiting a bean plot planted from saved seed.

To measure *D*, two binary indicators are used to compare plot-level pest and disease pressure experienced by farmers when compared to an average year. In both cases, $D=1$ indicates higher than average disease (pest) pressure and $D=0$ indicates either normal or lower levels of disease (pest) pressure. Data collection for the construction of D included a question in the survey that asked farmers to relate the pest pressure they observed in the first production cycle in 2006 to the average level of pest pressure observed in previous years.

Explanatory variables included as physical plot characteristics (*L*) include plot size, altitude, binary indicators for a loam soil texture and access to irrigation, and another two binary variables indicating whether the plot was either sharecropped or rented versus the base case of ownership, and finally, whether the plot was previously cropped to beans (bean diseases often survive in the soil and thus affect yields). To analyze potential violations of the selection on observables assumption, Table 5.2 presents p-values for an equality of mean t-test between adopters and non-adopters. For plot characteristics, results indicate the only significant difference between adopters and non-adopters is that a greater proportion of non-adopters who have plots with a loam soil texture versus either clay or sandy soils.

Price variables (P) include the market price of beans, the cost of transport to market, the average price of fungicides and insecticide, and the price of bean seed. The cost of transport to point of sale helps capture the effective price received by producers (Sadoulet and de Janvry 1995). T-test results indicate a difference in the mean prices received by adopters and non-adopters both in the market price and seed price. Adopters received higher market prices and paid lower seed prices. A similar difference was found for the price of fungicide inputs, with non-adopters paying higher prices (Table 5.2).

Household characteristics (*F*) include the age of the household head, whether the household head had previously attended a pest management seminar, whether the household follows a symptom-based pest management strategy compared to the base case scenarios of relying on a calendar-spray pest management strategy, and whether the household is categorized as poor, according to the UBN index[25]. The UBN poverty index is used to proxy wealth, with "poor" households categorized as such if they have one or more UBN. Finally, community-level variables (*Z*) include two binary variables indicating, first, whether the community is located in the Chota Valley versus the base case of living in the Mira Valley, and second, whether the community received previous extension intervention by INIAP related to bean production versus having received no previous extension intervention. Of all the household characteristics, t-test results indicate a difference between adopters and non-adopters only for the mean age of farmers, with adopters being significantly younger than non-adopters (Table 5.2).

[25] UBN index is discussed in Chapter 2 and in Appendix 5.

For the unit cost model, the dependent variable is defined as total production costs that are expected to vary upon adoption of an improved variety divided by total output. For each individual farmer, *i*, unit cost values are constructed using the following formula,

$$UVC_i = \frac{\sum w_{ji} x_{ji}}{Y_i^t} \tag{5.4}$$

where *x* represents the set of production inputs *j* that are expected to vary between adopters and non-adopters, *w* represents input prices, and Y^t represents total output. In this case, three production inputs are expected to vary depending on a farmer's choice of varietal technology: seed inputs, fungicide use, and insecticide use. Production inputs that are *not* expected to vary between adopters and non-adopters, such as land preparation, fertilizers, and labor inputs[26], are assumed to be fixed. This definition of unit variable cost (UVC) is used for the remainder of this paper.

5.6 Empirical Models and Testable Hypotheses

Empirical treatment effect models define two possible outcomes for each observation: the outcome *without* treatment, y_0, and the outcome *with* treatment, y_1. Together with the farmers' adoption decision, *A*, the observed outcome for each observation is,

$$y = (1 - A)y_0 + A(y_1) \tag{5.5}$$

[26] While RV adoption may impact labor costs for pesticide applications, a mean difference test did not reveal a statistically significant difference in the number of applications between adopters and non-adopters (p=0.42). Thus, this model accounts for changes in the quantity of pesticide active ingredient applied but not for a reduction in the number of total applications.

Allowing y_o and y_I to become random variables and assuming error terms have a mean of zero, the outcome can be modeled as a function of treatment status and set of covariates, $\mathbf{X}$, such that,

$$E(y|A,\mathbf{X}) = \alpha_0 + \alpha_1 A + \mathbf{X\beta} \tag{5.6}$$

where α_1 is the treatment effect of adoption on the outcome y. In the cases where the impact of adoption on a production outcome is assumed to also be dependent on disease pressure, the appropriate covariate and interaction term with adoption can be included.

5.6.1 Crop Yield Model

The yield model is specified empirically as a quadratic function, following Qaim and de Janvry (2005) and Fernandez-Cornejo et al. (2002), as well as a log-log function, based on a model specification test[27]. Using the notation provided in the data description above, it follows that,

[27] The quadratic specification was selected based on a review of economic literature on farm-level impact analyses of varietal technologies with input-saving characteristics. However, a MacKinnon, White, and Davidson (MWD) test (Gujarati 2003, p. 280) rejected the null hypothesis of a linear model (p=0.04) but failed to reject the alternative hypothesis of a log-log model (p=0.38). Empirical results for both models will be presented in Section 5.7.1.

$$Y = \alpha_o + \alpha_1 A + \alpha_2 D_1 + \alpha_3 A * D_1 + \alpha_4 D_2 + \cdots$$
$$\cdots + X\beta_1 + X^2 \beta_2 + L\gamma + F\phi + Z\theta + \varepsilon \quad (5.7)$$

where,

Y	= Per hectare bean yield,
A	= Adoption of improved crop variety (binary; 1=Yes),
D_1	= Above average disease pressure (binary; 1=Yes),
D_2	= Above average pest pressure (binary; 1=Yes),
$A{*}D_1$	= Interaction term between A and D_1 (binary; A=1, D_1=1),
α	= Parameter coefficients on the intercept, adoption, and disease pressure variables,
X, L, F, and Z	= Matrices of regression covariates as previously defined,
β, γ, ϕ, *and* θ	= Vectors of coefficients on X, L, M, F, and Z, and
ε	= A normally distributed error term

The treatment effect of adoption on bean yield can now be elicited through interpretation of the appropriate parameter coefficients. The parameter coefficients on the binary variables representing RV adoption, disease pressure, and pest pressure serve as differential intercept coefficients such that,

α_1 = differential intercept effect of adoption on average bean yield without disease pressure

α_2 = differential intercept effect of disease pressure on average bean yield without adoption

$\alpha_1 + \alpha_2 + \alpha_3$ = differential intercept effect of adoption on average bean yield when disease pressure is present, and

α_4 = differential intercept effect of insect pest pressure on average bean yield without adoption.

The hypothesis (H_1) that farmers planting an RV obtain superior yields to those planting susceptible varieties when disease pressure is present can be tested as,

$$\begin{aligned} H_{1o} &: \alpha_1 + \alpha_2 + \alpha_3 \leq 0 \\ H_{1a} &: \alpha_1 + \alpha_2 + \alpha_3 > 0 \end{aligned} \tag{5.8}$$

Rejection of the null hypothesis (H_{1o}) in favor of the alternative (H_{1a}) will confirm a positive RV yield impact in the presence of disease pressure. That is, the productivity-maintenance aspect would be confirmed. Conversely, a failure to reject H_{1o} would suggest that no yield differential exists between resistant and local varieties. Empirically, this hypothesis is tested by evaluating the sum of those coefficients in H_{1o} deemed significant at conventional levels. In the case that only α_1 is significant and positive, then there would be evidence suggesting that RV varities provide a yield-enhancing advantage over susceptible varieties.

5.6.2 Input Demand Functions

The two input demand functions, one for fungicides and the other for insecticides, are specified using a linear functional form as follows[28],

$$\begin{aligned} X_j = \delta_o + \delta_1 A + \delta_2 D + \delta_3 A * D + & \cdots \\ \cdots + P\omega + L\gamma + F\phi + Z\theta + \varepsilon; & \quad (j = 1,2) \end{aligned} \tag{5.9}$$

where,

[28] Similar to the yield equation, a linear input demand specification was selected based on a literature review of impact analyses of varietal technologies. However a MacKinnon, White, and Davidson (MWD) test also rejected the null hypothesis of a linear model for both the insecticides (p=0.01) and fungicides (p=0.00) but failed to reject the alternative hypothesis of a log-log model for both insecticides (p=0.54) and fungicides (p=0.70). Empirical results for both models will be presented in Section 5.7.1.

X_j = Denotes either fungicides (j=1) or insecticides (j=2),
D = Denotes either disease pressure (when j=1) or pest pressure (when j=2),
δ = Parameter coefficient for the intercept and binary variables representing adoption and disease/pest pressure,
P = Vector of input and output prices,
ω = Vector of parameter coefficients associated with P,

and all other variables are as previously defined. The input demand function for fungicides includes a binary variable for disease pressure and an interaction term between D_1 and adoption. The demand function for insecticides, however, includes only a binary variable for pest pressure.

Similar to the yield model, the treatment effect of RV adoption on input use is analyzed using the appropriate parameter coefficients. The parameter coefficients δ_1 and δ_2 represent differential intercept coefficients for RV adoption and disease (or pest) pressure. The parameter coefficient on δ_3 is the differential intercept with both adoption and disease pressure. The hypothesis (H_2) that farmers who plant RVs reduce the quantity of pesticides applied versus those who plant susceptible varieties can be tested as,

$$\begin{aligned} &H_{2o}^{j}: \delta_1 + \delta_2 + \delta_3 \geq 0 \\ &H_{2a}^{j}: \delta_1 + \delta_2 + \delta_3 < 0 \end{aligned} \quad . \tag{5.10}$$

As stated, rejection of the null hypothesis (H_{2o}^{j}) in favor of the alternative (H_{2o}^{j}) will confirm that RV adoption leads to a decrease in the quantity of fungicides (for j=1) or insecticides (for j=2) applied when disease (pest) pressure is present. Note that if only δ_1 is significant and negative, then RV adoption leads to a decrease in pesticide use regardless of disease pressure levels. Alternatively, a failure to reject H_{2o} suggests that the adoption of an improved variety does not result in significant input-savings.

Empirically, this hypothesis is tested by evaluating the coefficient δ_1 at conventional levels of significance using a one-tailed t-test.

5.6.3 Unit Cost Function

The unit cost function is specified using a log-log functional form[29]. Following the notation previously provided, the unit cost function can be stated empirically as,

$$\begin{aligned}\ln(UVC) = \eta_o + \eta_1 A + \eta_2 D_1 + \eta_3 A * D_1 + \eta_4 D_2 + \cdots \\ \cdots + \ln(W)\lambda + \ln(Y)\pi + \ln(L)\gamma + \ln(F)\phi + \ln(Z)\theta + \varepsilon\end{aligned} \tag{5.11}$$

where,

η	= Parameter coefficients on the intercept term and binary variables, representing adoption and disease/pest pressure,
W	= Vector of input prices,
λ	= Vector of parameter coefficients on W,
Y	= Bean yield (level of output variable),
π	= Parameter coefficient on the yield (output) variable,

and all other characters are as previously defined.

As in the yield model, η_1, η_2, and η_4, represent differential intercept terms on RV adoption, disease pressure, and pest pressure, respectively. The coefficient on the interaction term between adoption and disease pressure, η_3, is the differential intercept term for the unit cost of bean production with adoption in the presence of disease pressure.

Hypothesis three concerns the treatment effect of RV adoption on unit variable costs (UVC). The null hypothesis (H_3) that farmers who plant RVs varieties have lower

[29] The log-log specification was selected based on a MacKinnon, White, and Davidson (MWD) test of the unit cost function (Gujarati 2003, p. 280). The MWD test rejected the null hypothesis of a linear model (p=0.00) but failed to reject the alternative hypothesis of a log-log functional form (p=0.62).

unit costs than those who plant susceptible varieties can be tested for both the fungicide and insecticide models as,

$$
\begin{aligned}
H_{3o} &: \eta_1 + \eta_2 + \eta_3 \geq 0 \\
H_{3a} &: \eta_1 + \eta_2 + \eta_3 < 0
\end{aligned}
\qquad (5.12)
$$

Rejection of the null hypothesis (H_{3o}) in favor of the alternative (H_{3a}) will confirm that RV adoption leads to a decrease in UVC when disease pressure is present. Alternatively, a failure to reject H_{3o} would suggest that the RV adoption does not significantly reduce UVC. Empirically, this hypothesis is tested by evaluating statistically significant coefficients in H_3 with a one-tailed t-test. Finally, it is important to note that if the coefficient on η_1 alone is statistically significant and negative, then RV adoption is expected to reduce unit variable costs regardless of the presence of disease pressure.

5.7 Results and Discussion

This section reports information on model specification, empirical results, and regression diagnostics for the crop yield, input demand, and unit cost equations. A discussion of key findings is also included.

5.7.1 Yield and Input Demand Equations

The yield and input demand equations are estimated as a system using seemingly unrelated regression (SUREG)[30]. Given that the system estimates two demand functions for similar products, correlation among the errors terms is expected and this approach

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[30] Fernandez-Cornejo et al. (2002) also estimated yield and input demand treatment effect models as a SUREG system but with a profit function. In this case, however, a unit cost function is estimated separately as opposed to a profit function so as to obtain an empirical measure of the farm-level economic impact that is consistent with the economic surplus framework used in economic impact analyses of agricultural technologies (i.e. the reduction in variable cost per unit of output).

provides efficient and unbiased standard errors compared to OLS[31]. The crop yield model is specified as quadratic production function and the two input demand functions are linear. All three models are regressed through the origin to preserve a maintained hypothesis of non-negative yields and input demands. Each model also shows a high degree of overall statistical significance (Chi^2 statistics significant at $p< 0.00$ for all models) and statistical fit (R^2 of 0.79 or higher for all models). Coefficients on continuous explanatory variables are interpreted as the expected marginal change in the dependent variable for a one unit increase in a given explanatory variable. The coefficients on binary explanatory variables are interpreted as the expected change in the dependent variable for a change in the binary variable from 0 to 1.

The null hypothesis for the yield model ($H1_o$) is rejected, as shown by the magnitudes and significance levels of the adoption and disease pressure treatment effect variables (Table 5.3). The high disease pressure variable and the interaction term between RV adoption and high disease pressure are significant at the 10% and 1% levels, respectively. Other things equal, higher than average disease pressure *decreases* yields by 486 kg ha^{-1}, while the use of an RV in the presence of disease pressure *increases* yields by 1350 kg ha^{-1}. The RV adoption variable alone is not significantly different from zero at conventional levels, and is thus treated as zero in testing *H1*. Together, these coefficients sum to 658 kg ha^{-1}, suggesting a positive impact of resistant varieties on bean

[31] The same yield and input models were also estimated using two alternative estimation procedures: first using ordinary least squares (OLS) with heteroskedasticity-robust standard errors, and second using three-stage least squares (3SLS). Both SUREG and 3SLS proved superior to OLS in terms of efficiency. The potential advantage of 3SLS is that it controls for the endogeneity of fungicide and insecticide inputs. However, SUREG and 3SLS estimates reported identical significance levels and magnitudes for all treatment effect variables. Thus, SUREG was chosen for presentation here since the additional benefit to be gained by using 3SLS appears minimal and doesn't justify the additional computational complexity required by 3SLS. See Tables A.6.1 and A.6.2 in Appendix 6 for empirical OLS and 3SLS regression results.

yields with disease pressure is present[32]. The hypothesis that farmers who plant RVs obtain higher yields than those who plant susceptible varieties holds when disease pressure is present. To provide a reference figure in analyzing the relative magnitude of these effects, the mean yield across the sample of 72 farmers is equal to 1526 kg ha^{-1} suggesting the yield-losses avoided from RV adoption equal to 43%.

Additional variables in the yield model that are statistically significant include altitude and the two community-level variables. Altitude has a positive effect on yield. This is expected since altitude in northern Ecuador is positively correlated with both humidity and disease pressure. Since the model does control for disease pressure but not rainfall, the coefficient on altitude likely reflects increased precipitation levels at higher altitudes. It is also important to note the presence of multicollinearity among the four production input variables and their squared counterparts[33]. While the influence of individual inputs cannot be identified, as a group they offer much stronger explanatory power. Given that the coefficients on these variables are not central to the hypotheses of interest, however, the ambiguity created by this multicollinearity is acceptable and no further corrective action is taken.

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[32] DFBETA regression diagnostic statistics for the disease pressure and the interaction between disease pressure and RV adoption were plotted (Figure A.6.1 of Appendix 6). Only one outlier was determined to have an exceptionally large impact on coefficient magnitudes, with its exclusion decreasing disease pressure by 0.51 standard deviations and increasing the interaction term by 0.58 standard deviations. This implies that the initial results provided a conservative estimate. In addition, observations with the highest individual per-hectare yields do not have a statistically significant influence on the coefficient magnitudes.
[33] Variance inflation factors (VIFs) for all production inputs are greater than 10, and an F-test of their joint significance reported a Chi^2 value of 282. These measures suggest the presence of multicollinearity. See Table A.6.4 for empirical VIF test results.

Table 5.3: SUREG Results for the Quadratic Crop Yield and Linear Input Demand Equations, Red Mottled Varieties, Imbabura & Carchi, Ecuador, 2006 (n=73)

	Yield		Fungicide Demand		Insecticide Demand	
Explanatory Variables by Category:	(kg / ha)		(kg AI / ha)		(kg AI / ha)	
Treatment Effect Variables:						
Adopted improved variety (1=yes)	-222	(0.34)	-11.7	(0.02)**	-4.72	(0.01)***
High disease pressure (1=yes)	-486	(0.09)*	-2.70	(0.60)		
Adopted x Disease pressure (1=yes)	1350	(0.00)***	7.34	(0.31)		
High pest pressure (1=yes)	65.3	(0.76)			2.98	(0.04)**
Production Inputs:						
Fungicide AI (kg ha^{-1})	5.73	(0.79)				
Fungicide AI squared	-0.080	(0.63)				
Insecticide AI (kg ha^{-1})	28.8	(0.54)				
Insecticide AI squared	0.167	(0.65)				
Foliar fertilizer AI (kg ha^{-1})	-2.79	(0.87)				
Foliar fertilizer AI squared	-0.012	(0.95)				
Bean seed (kg ha^{-1})	-0.980	(0.92)	0.545	(0.00)***	0.219	(0.00)***
Bean seed squared	0.029	(0.46)				
Plot Characteristics:						
Plot size (ha)	25.6	(0.76)	-2.03	(0.35)	-0.222	(0.80)
Altitude (m.a.s.l.)	0.508	(0.03)**	0.013	(0.02)**	0.003	(0.20)
Loam soil (1=yes)	59.6	(0.73)	-1.49	(0.73)	-0.500	(0.78)
Irrigated plot (1=yes)	-377	(0.32)	-12.6	(0.19)	-4.26	(0.27)
Plot prev. cropped w/ beans (1=yes)	-202	(0.28)	3.74	(0.44)	1.83	(0.36)
Sharecropped plot (1=yes)	137	(0.44)	-9.81	(0.04)**	-4.79	(0.02)**
Rented plot (1=yes)	-465	(0.18)	-13.1	(0.15)	0.045	(0.99)
Household Variables:						
Age of HH (years)	-1.29	(0.84)	-0.716	(0.00)***	-0.246	(0.00)***
Attended pest man. seminar (1=yes)	124	(0.47)	-0.301	(0.95)	-3.49	(0.07)*
Symptom based pest man. (1=yes)			5.99	(0.28)	7.06	(0.00)***
Poor household (1=yes)			-3.01	(0.49)	1.06	(0.55)
Price Variables:						
Market price for beans ($/kg)			-25.3	(0.06)*	-7.23	(0.19)
Cost of transport ($/qq)			-2.26	(0.73)	-4.48	(0.09)*
Avg. price of fungicide ($/kg AI)			-1.39	(0.76)		
Avg. price of insecticide ($/kg AI)					-0.847	(0.62)
Community-Level Variables:						
Chota valley (1=yes)	523	(0.00)***	9.58	(0.08)*	3.52	(0.11)
Prev. extension intervention (1=yes)	321	(0.04)**	-2.76	(0.54)	-1.31	(0.46)
R^2	0.88		0.79		0.80	
Chi^2	587		296		299	
$P>Chi^2$	0.00		0.00		0.00	

Notes: p-values in parentheses; data is from the 2006 B/C CRSP and INIAP farm-level survey

*** significant at 1%; ** significant at 5%; * significant at 10%

Table 5.4: SUREG Results for the Log-Log Yield and Input Demand Equations, Red Mottled Varieties, Imbabura and Carchi, Ecuador, 2006 (*n*=73)

	Log of Yield		Log of Fungicide Demand		Log of Insecticide Demand	
Explanatory Variables by Category:	ln(kg / ha)		ln(kg AI / ha)		ln(kg AI / ha)	
Treatment Effect Variables:						
Adopted improved variety (1=yes)	-0.147	(0.40)	0.230	(0.42)	-0.112	(0.60)
High disease pressure (1=yes)	-0.059	(0.80)	0.568	(0.04)**		
Adopted x Disease pressure (1=yes)	0.606	(0.04)**	-0.411	(0.27)		
High pest pressure (1=yes)	0.009	(0.95)			0.296	(0.07)*
Production Inputs:						
Log of fungicide AI (kg ha^{-1})	-0.084	(0.44)				
Log of insecticide AI (kg ha^{-1})	0.269	(0.06)*				
Log of foliar fertilizer AI (kg ha^{-1})	0.034	(0.37)				
Log of bean seed (kg ha^{-1})	0.581	(0.00)***	0.009	(0.00)***	0.007	(0.01)**
Plot Characteristics:						
Log of plot size (ha)	0.160	(0.25)	-1.37	(0.00)***	-1.25	(0.00)***
Log of altitude (m.a.s.l.)	0.660	(0.00)***	-0.013	(0.95)	-0.085	(0.67)
Loam soil (1=yes)	0.077	(0.58)	-0.146	(0.56)	-0.371	(0.08)*
Irrigated plot (1=yes)	-0.364	(0.27)	0.928	(0.14)	0.701	(0.19)
Plot prev. cropped w/ beans (1=yes)	-0.064	(0.66)	0.240	(0.40)	0.328	(0.17)
Sharecropped plot (1=yes)	0.090	(0.53)	0.021	(0.94)	-0.157	(0.50)
Rented plot (1=yes)	-0.585	(0.03)**	0.189	(0.71)	0.508	(0.23)
Household Variables:						
Log of age of HH (years)	-0.183	(0.38)	0.089	(0.82)	0.136	(0.68)
Attended pest man. seminar (1=yes)	-0.028	(0.84)	-0.141	(0.59)	-0.028	(0.90)
Symptom based pest man. (1=yes)			-0.138	(0.67)	0.097	(0.72)
Poor household (1=yes)			-0.423	(0.10)*	-0.230	(0.28)
Price Variables:						
Log of market price for beans ($/kg)			0.631	(0.21)	0.604	(0.16)
Log of cost of transport ($/qq)			0.055	(0.24)	0.028	(0.90)
Log avg. price of fung. ($/kg AI)			-0.124	(0.50)		
Log avg. price of insect. ($/kg AI)					-0.161	(0.60)
Community-Level Variables:						
Chota valley (1=yes)	0.434	(0.00)***	-0.385	(0.25)	-0.180	(0.52)
Prev. extension intervention (1=yes)	0.288	(0.03)**	-0.211	(0.40)	-0.251	(0.22)
R^2	0.99		0.81		0.76	
Chi^2	15408		34		22	
P>Chi^2	0.00		0.00		0.00	

Notes: p-values parentheses; data is from the 2006 B/C CRSP and INIAP farm-level survey
*** significant at 1%; ** significant at 5%; * significant at 10%

The null hypotheses for the fungicide and insecticide input demand functions (H_{2o}) are rejected at the 5% and 1% levels, respectively (Table 5.3), when disease or insect pest pressure is not present. Other things equal, RV adoption leads to a *decrease* in the quantity of fungicide active ingredient applied by of 11.7 kg ha^{-1} and in insecticide active ingredient by 4.7 kg ha^{-1} (shown by α_1). Again, to compare the relative size of these effects, the mean quantities of pesticides applied across the sample of 72 farmers is equal to 15.8 kg ha^{-1} for fungicides and 6.1 kg ha^{-1} for insecticides. These decreases represent a 74% decrease in fungicide and a 40% decrease in insecticide use. The coefficients on the disease/pest pressure variable are statistically significant only for the insecticide model but large in magnitude in both models. This suggests that while RV adopters reduce their input application rates compared to non-adopters when no disease pressure is present, the difference decreases as disease/pest pressure increase. For example, RV adopters are expected, on average, to apply only 1.7 kg ha^{-1} (28%) less insecticide than non-adopters when disease pressure is present.

Additional variables in the input demand functions that are statistically significant across both models include planting density (kg ha^{-1} of bean seed), whether the plot is sharecropped, and farmer age. An increase in planting density by 1 kg ha^{-1} increases the demand for fungicides by 0.55 kg ha^{-1} and for insecticides by 0.22 kg ha^{-1}. A sharecropping production arrangement results in a decrease in the average amount of pesticides demanded by 9.8 kg ha^{-1} for fungicides and 4.8 kg ha^{-1} for insecticides. This is consistent with the economic theory of sharecropping, which suggests that such output sharing agreements reduce the incentive to provide inputs since the lower expectation of income leads to a lower marginal value product for each unit of input. The age variable indicates that older farmers use lower quantities of pesticides, on average, than do younger farmers. Similar to the yield model, fungicide demand is influenced by altitude and whether the farmer resides in the Chota valley. Against expectations, the market price of beans is negatively correlated with fungicide demand. An increase in the market price of beans is expected to decrease, on average, farmers' use of fungicides. In the insecticide model, however, the cost of transport variable that proxies market transaction costs does agree with intuition, showing that the demand for insecticides decreases as its prices increase.

The log-log specification of the same system of equations is given in Table 5.4. Given that MWD test results rejected the linear models in favor of the log-log model as discussed in Section 5.6, it is important to analyze the robustness of findings with respect to this separate functional form. *H1* and *H2* can be tested in a similar fashion as previously discussed; however the log-log model parameter coefficients now describe the proportional change in the dependent variable for a one-percent change in the value of the explanatory variable. Here, we reject *H1* since the parameter coefficient is statistically significant. Other things equal, farmers who use an RV obtain yields 55% higher than do farmers who plant a local variety. When disease pressure is present, this finding is consistent with the linear specification although slightly larger since the parameter coefficient on disease pressure is not significant. Unlike the linear specification, we cannot reject *H2* for either the fungicide or insecticide demand model. Since *H2* is not robust across model specifications, the conclusion that farmers who adopt an RV apply less pesticide active ingredient than do farmers who plant local varieties should be interpreted with less certainty than *H1*.

5.7.2 Unit Cost Equation

The unit cost function is reported using a log-log model specification and has a high overall statistical significance (F=10.31) and statistical fit ($R^2 = 0.77$)[34]. Given the log-linear specification, coefficient estimates of continuous explanatory variables, X_j, are interpreted as elasticities, which give the expected percentage change in UVC for a 1% increase in X_j, holding all other factors fixed. For binary explanatory variables, the interpretation of log-log coefficient estimates changes slightly. They are interpreted as the expected proportional change in UVC for a change in value from 0 to 1 (Wooldridge 2000, p. 218). Hence, multiplying the coefficient by 100 will provide an approximation of the expected percentage change in UVC.

The null hypothesis (H_{3o}) for the unit cost model is rejected, as shown by the magnitude and significance level of the adoption and disease pressure treatment effect variables (Table 5.5). The coefficient on the interaction term between high disease pressure and RV adoption is significant at the 10% level. The coefficients on the individual disease pressure and adoption variables are not significant, however, and are assumed to be zero for the purpose of testing *H3*. RV adoption is expected to *decrease* UVC by an average of 40%. Thus, the hypothesis that farmers who plant improved varieties have a lower unit variable cost of production than do farmers who plant susceptible varieties holds. It is important to note that this decrease refers only to those costs that are expected to vary upon the adoption of an RV (i.e. pesticide and seed costs), and not to *all* variable costs associated with the production of beans in northern Ecuador. Data provided in Peralta et al. (2001) are used to estimate the overall decrease in variable

[34] See Table A.5.3 in Appendix 6 for regression results from the linear unit cost model.

production costs from RV adoption. Cost of production estimates show that pesticides and seed costs, together, to represent 46% of total variable production costs. A 40% reduction in these costs due to RV adoption translates into an overall decrease in variable production costs of approximately 18.4%.

Apart from the hypothesis of interest, price, output, and community-level variables are also significant. An increase in the prices of both fungicide and bean seed have a positive effect on unit variable costs (UVCs). A one percent increase in the price of fungicides is expected to increase UVCs by .25%. Likewise, a similar increase in the price of bean seed will increase UVCs by .88%. Both output (kg ha^{-1}) and plot size have a negative effect on UVCs, with a 1% increase leading to an average decrease in UVC by .67% or .26%, respectively. Communities where INIAP has previously intervened are expected to have UVCs 25% lower than the base case of no previous intervention. Finally, altitude and renting are both significant determinants of UVC. A 1% marginal increase in altitude is expected to lower UVC by .51%, whereas farmers who rent plots as opposed to own them or enter sharecropping agreements are expected to have 38% higher UVC.

Table 5.5: Regression Results for the Log-Log Unit Variable Cost Function, Imbabura & Carchi, Ecuador, 2006 (*n*=73)

Explanatory Variables by Category:	Log of Unit Variable Cost ($/kg)	
Treatment Effect Variables:		
Adopted improved variety (1=yes)	0.160	(0.20)
High disease pressure (1=yes)	0.106	(0.48)
Adopted x Disease pressure (1=yes)	-0.396	(0.07)*
High pest pressure (1=yes)	-0.064	(0.54)
Price Variables:		
Log of avg. fungicide price ($/kg AI)	0.255	(0.02)**
Log of avg. insecticide price ($/kg AI)	0.008	(0.97)
Log bean seed price ($/kg)	0.882	(0.00)***
Output Variable:		
Log of bean yield (kg ha^{-1})	-0.676	(0.00)***
Plot Characteristics:		
Log of plot size (ha)	-0.261	(0.00)***
Log of altitude (m.a.s.l.)	-0.513	(0.08)*
Loam soil (1=yes)	0.030	(0.75)
Irrigated plot (1=yes)	0.072	(0.73)
Sharecropped plot (1=yes)	-0.140	(0.15)
Rented plot (1=yes)	0.376	(0.04)**
Household Variables:		
Log of age of HH (years)	-0.069	(0.66)
Attended pest man. seminar (1=yes)	0.078	(0.43)
Community-Level Variables:		
Chota valley (1=yes)	-0.015	(0.89)
Prev. extension intervention (1=yes)	-0.249	(0.01)***
Constant	7.11	(0.00)***
R^2	0.77	
F(*k*,*df*)	10.31	
Prob>F	0.00	

p-values in parentheses

* significant at 10%; ** significant at 5%; ***significant at 1%

5.8 Chapter Summary

This chapter analyzed three farm-level hypotheses regarding the adoption of improved bean varieties released by INIAP in northern Ecuador. These hypotheses are that farmers who plant an improved variety 1) obtain higher yields, 2) utilize fewer pesticide inputs, and 3) experience a lower unit cost of production than do farmers who plant local varieties. Three average treatment effect models were developed to test each of these hypotheses using multiple regression techniques: a crop yield model, an input demand model, and a unit cost function.

Regression analysis rejected the null hypotheses for the yield, input demand, and unit variable cost models, as the results summarized in Table 5.6 suggest. Other things equal farmers who adopt an RV obtain higher yields by about 40% when compared to the sample mean of 1590 kg ha^{-1}. Likewise, those adopting an RV apply 70% less fungicides and 43% less insecticide than do non-adopters when compared to the sample means and with or without disease pressure. These percentages are likely much lower when disease

Table 5.6: Summary of Testable Hypotheses and Empirical Results for Farm-Level Regression Models

Model	*Null Hypothesis*	*Result*	*Conclusion*
Yield Model	H_{1o}: $\alpha_1 + \alpha_2 + \alpha_3 \leq 0$	Reject H_{1o}	On average, RV adopters have 40% higher yields than do non-adopters when disease pressure is present. This confirms the productivity-maintenance characteristics of INIAP RV beans.
Input Use Model	$H^j_{2o}: \delta_1 + \delta_2 + \delta_3 \geq 0$	Reject H_{2o}	On average, RV adopters apply 74% less fungicide (and 43% less insecticide) than do non-adopters when disease (insect) pressure is absent. This suggests that farmers may perceive RVs as a substitute for chemical inputs.
Unit Cost Function	H_{3o}: $\eta_1 + \eta_2 + \eta_3 \geq 0$	Reject H_{3o}	On average, RV adopters have 18% lower unit costs of production than do non-adopters when disease pressure is present. This confirms that RV adoption shifts producers' marginal cost curves downwards.

or pest pressure is indeed present. These two impacts lead to an average reduction in unit variable costs of 40% (again, for only those costs that vary upon RV adoption). It is important to note that findings for the yield model are robust across linear and log-log model specifications. The findings for the input use model, however, are significant only for the linear specification and should be interpreted with less confidence. Now that both the diffusion rates and farm-level benefits of the improved varieties have been identified, attention may be turned to estimating the economic impact of bean-breeding research.

CHAPTER SIX:

AN ECONOMIC EVALUATION OF BEAN-BREEDING RESEARCH IN NORTHERN ECUADOR

6.1 Introduction

This chapter introduces the economic surplus approach commonly used in measuring the aggregate economic benefits of agricultural research and calculates two well-known measures of project worth—the net present value (NPV) and the internal rate of return (IRR)—for disease-resistant bean breeding research in northern Ecuador. Discussion is focused primarily on the research-induced supply shift. Basic prior knowledge of supply, demand, and economic surplus concepts is assumed.

Three scenarios are presented in order to determine a range of NPV and IRR values: a *baseline scenario* which bases parameter values on the best estimates available, a *conservative scenario* which utilizes lower-bound parameter values, and a *robust scenario* which uses parameter values at the upper-bound of possible values. For red mottled resistant varieties (RVs), the *ex post* NPV and IRR values are estimated for the period 1982-2006. Since the first RV (Paragachi) was released in 1986, this provides a 21-year benefit stream with which to assess their economic impact. The period of time from 1982-1986 therefore represents a four-year lag period in which research costs were incurred without any research benefits.

For purple mottled varieties, *ex ante* NPV and IRR values are estimated for the period 1998-2024. Given that the first purple mottled RV (La Concepcion) was released in 2004 though the CIAL network, this period was chosen to allow for a 21-year benefit stream similar to that of red mottled RVs for consistency across estimates. The difference in the overall length of the time period considered is due to the longer, six-year lag period between the first research expenditures in 1998 and release of the first variety in 2004.

When appropriate, a comparison of methodologies and parameter values from economic impact assessments of similar technologies will be discussed (Mather et al. 2003, Johnson et al. 2003, Boys et al. 2007, Oehmke and Crawford 1996).

6.2 Conceptual Framework

6.2.1 Research Benefits

The estimation of economic benefits derived from agricultural research is generally undertaken as an exercise in partial-equilibrium analysis. The conceptual underpinnings of this approach, also known as the *economic surplus model*, are fairly straightforward and a large body of literature on the topic exists (see for example Alston et al. 1998 or Masters et al. 1996). While research-induced technological change in the bean sub-sector can also affect other sectors of the economy such as food prices, labor markets, or returns to different factors of production, all secondary effects are considered exogenous and not addressed here.

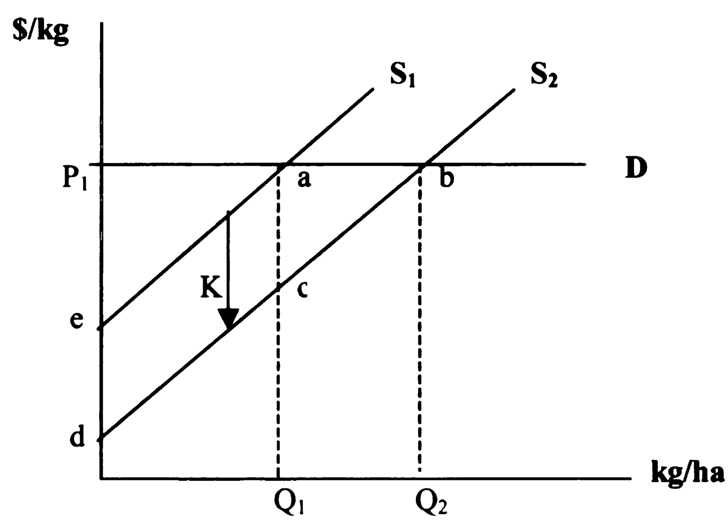
The model presented here is that of a small open economy. The term *open* reflects the export-oriented nature of bean production in northern Ecuador, while the term *small* refers to the supply share of Ecuador's dry bean production with respect to its primary export market, Colombia. In 1998[35], Ecuador exported 11,500 metric tons of dry beans to Colombia, or about 8% of Colombia's total dry bean consumption that year (2000). A small increase in dry bean production in Ecuador, therefore, is not expected to affect market price. This implies a perfectly elastic demand curve. Such an assumption is often

[35] 1998 is the only year for which data was available.

appropriate for impact analyses of agricultural technologies in a small, developing country context (Alston et al. 1998, p. 226).

The magnitude of economic benefits derived from agricultural technology is determined by the size of the downward shift in the supply curve. Graphically, this is akin to the reduction in unit production costs found in Chapter 5 (Figure 6.1). The supply curve under the original technology is labeled S_1, and the initial equilibrium occurs at the point (P_1, Q_1). As cumulative adoption increases, the supply curve shifts outward from S_1 to S_2 and the equilibrium quantity increases from Q_1 to Q_2. The equilibrium price remains unchanged at P_1 given the perfectly elastic demand curve (due to the small open economy assumption). A parallel shift of the supply curve, as diagrammed, is appropriate when 1) the production technology of bean producers is fairly homogenous, and 2) technology is scale neutral, as crop varietal technologies often are. When valid, these assumptions ensure that linear approximations of supply schedules will provide a good basis for estimating research benefits (Alston et al. 1998).

Figure 6.1: Research-Induced Supply Shift



In the small open economy framework, all research benefits accrue to producers as shown by *eabd.* This results in the special case where total economic surplus equals producer surplus. There is no impact on the economic welfare of domestic consumers or importing countries. The portion of the benefit derived from incremental output (holding inputs fixed) is the area *abc*. The portion of benefit derived from reduced production costs (holding output constant) is the area *eacd.*

An empirical measure of annual research benefits in a small open economy for *ex post* analyses can be estimated by the equation,

$$\Delta TS_t = P_1 Q_1 K_t (1 + 0.5 K_t \varepsilon) \tag{6.1}$$

where P_1 represents the exogenous market price for beans, Q_1 represents the initial before-research production level, ε is the supply elasticity of demand, and K_t represents the vertical shift in the supply curve (Alston et al. 1998, p. 227).

The time-path for K_t is determined by three factors: i) ΔUC, the proportional farm-level change in unit costs from RV adoption, ii) *P(D)*, the probability of disease pressure[36], and iii) A_t the cumulative adoption rate at time *t.* This time path is calculated as,

$$K_t = \Delta UC \ x \ P(D) \ x \ A_t \, . \tag{6.2}$$

Specific data and parameter values to be used are presented in Section 6.3.1. Note that in this instance, only A_t varies with time whereas ΔUC and *P(D)*remain constant for the period of analysis. Due to the lag period between the release of an improved variety and

[36] *K* depends on disease pressure in this instance because results from the unit cost model in Chapter 5 indicated a reduction in proportional unit costs only in the presence of disease pressure.

the maximum cumulative adoption level, this time path must be determined before calculating Equation (6.1).

6.2.2 Research Costs

The appropriate identification of research costs begins with a statement of the duration and scope of the research project to be evaluated. All expenditures prior to the research project are considered sunk costs and not included, since these resources would have been spent with or without the current agricultural research program (Masters et al. 1996). Extension expenditures incurred during the period of analysis that would have been spent regardless of the current research program are also not included. Some extension programs, however, are indeed specifically designed to complement the work of plant breeders, such as the local agricultural research organizations, or CIALs, formed in northern Ecuador. In this case, CIAL extension costs are included in the *ex-ante* analysis of purple mottled varieties presented in Section 6.4.4 since their primary focus to assist plant breeders through participatory varietal selection.

Once the time period and scope of the research project are determined, care must be taken in disaggregating research expenditure data so as to reflect only the technology of interest. When operating costs or scientist salaries are not broken down into the level of detail required to estimate research costs, knowledgeable individuals (such as program directors) can be asked to provide estimates of total expenditures and the share of this expenditure devoted to the program or technology of interest (Alston et al. 1998). This is the approach followed here. Details on specific data collected are included in Section 6.3.2.

6.2.3 Measures of Project Worth

In this paper, two economic measures are used to evaluate the stream of benefits and costs associated with the development of the improved bean cultivars, namely the net present value (NPV) and the internal rate of return (IRR). These measures are advantageous since they summarize information about the economic returns to research investments into simple summary statistics.

The NPV calculation combines the flow of research benefits and costs over the period 1982-2006 into a single value in constant 2006 dollars ($USD). Positive values of NPV indicate that a project is profitable, while negative values indicate that a project is not profitable. Profitable in this case implies that all investments plus the opportunity cost of capital are recovered and the project is therefore worth investing in[37].It is calculated by first taking the difference in research benefits and research costs for each time period, t, and then discounting these sums to a single base period using a discount rate, r, using a present value formula,

$$NPV_t = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t} \tag{6.3}$$

where T is equal to the number of time periods (years) under consideration. The value of research benefits minus research costs in any given year is referred to here as the net benefit.

The IRR indicates the value of discount rate, r, from Equation (6.3) for which the NPV is equal to zero:

[37] In the case of a constrained investment budget, the NPV decision rule becomes more complicated. In this case we are only evaluating one alternative, so the present decision rule suffices.

$$0 = \sum_{t=1}^{T} \frac{B_t - C_t}{(1 + IRR)^t}, \tag{6.4}$$

or, equivalently, the discount rate that makes the present value of benefits equal to the present value of costs. The general decision rule for a profitable project is that the IRR be greater than the opportunity cost of capital.

Both measures have their strengths and weaknesses. The NPV provides an excellent measure of total net benefits received, but does not allow for a comparison between alternatives based on the rate of return. Nevertheless, a measure of the NPV is particularly useful in *ex ante* evaluations where priority-setting among alternative projects is still occurring. The IRR, on the other hand, does allow us to rank programs based on the rate of return but does not provide the analyst with information about the scale of benefits or the monetary value of the overall program. A measure of IRR is typically useful in *ex post* studies where information is sought on the actual rate of returns received.

The outcome of both NPV and IRR calculations depends partly on the discount rate, r. In the NPV calculation, the higher the discount rate, the less weight is placed on future benefits. In the IRR calculation, the discount rate is not directly used, but serves as a benchmark to compare IRR and determine relative profitability of investments.

6.3 Data Description

6.3.1 Research Benefits

Determination of annual research benefits and NPV and IRR summary statistics depends on the values used in calculating the time-path of K_t and total surplus, given in Equations (6.2) and (6.1), respectively. Due to uncertainty surrounding some of these values, three scenarios are presented: a *baseline scenario*, a *conservative scenario*, and a *robust scenario*. The baseline scenario utilizes the best estimates available for each parameter value and represents the most likely NPV and IRR. For the conservative scenario, parameter values are chosen so as to provide a lower-bound estimate of NPV and IRR. Likewise, for the robust scenario, parameter values are chosen so as to provide upper-bound estimates of NPV and IRR.

This scenario-based approach to sensitivity analysis provides a range of possible NPV and IRR estimates. While one can perform sensitivity analysis on individual parameters, it is important to recognize that most parameters are mutually dependent and will be expected to co-vary to some degree. Treating individual parameters as independent and considering all cases from high to low could lead to misleading interpretations of NPV and IRR values (Alston et al. 1998).

Parameter values used in calculating the NPV and IRR for each scenario are listed in Table 6.1. The change in unit cost parameter, ΔUC, is assumed equal to 18.4% for the baseline scenario. This is determined by multiplying the percentage reduction in unit variable costs (UVC) from Chapter 5 (found to be 40%) by the proportion of total production costs represented by fungicide, insecticide, and seed costs, which is approximately 46% (Peralta et al. 2001). Values for the conservative and robust scenarios are determined by adjusting the baseline value by 5% in either direction, resulting in ΔUC values of 13% and 23% respectively.

For *P(D)*, no data exist that describe the distribution of farmers who report above average disease pressure. Nor do reliable data exist that describe the relationship between

Table 6.1: Supply Shift Parameter Values Used in *Ex-Post* NPV and IRR Calculations, Disease-Resistant Red Mottled Varieties, Imbabura and Carchi, Ecuador, 1982-2006

Symbol	*Description*		*Parameter Values by Scenario* "Conservative"	"Baseline"	"Robust"
ΔUC	Proportional change in unit costs		0.166	0.184	0.202
P(D)	Incidence of disease pressure		0.42	0.52	0.62
A*t*	Cumulative adoption rates:	1986	1.0%	1.0%	1.0%
		1987	1.5%	2.4%	3.3%
		1988	2.2%	6.0%	9.8%
		1989	3.1%	12.7%	22.3%
		1990	4.5%	19.7%	34.8%
		1991	6.4%	23.9%	41.5%
		1992	8.9%	26.4%	44.0%
		1993	12.1%	28.4%	44.7%
		1994	16.0%	30.4%	44.9%
		1995	20.3%	32.6%	44.9%
		1996	24.7%	34.9%	44.9%
		1997	29.0%	37.0%	45.0%
		1998	32.8%	38.9%	45.0%
		1999	36.1%	40.5%	45.0%
		2000	38.6%	41.8%	45.0%
		2001	40.5%	42.7%	45.0%
		2002	41.9%	43.4%	45.0%
		2003	42.8%	43.9%	45.0%
		2004	43.5%	44.3%	45.0%
		2005	44.0%	44.5%	45.0%
		2006	44.3%	44.7%	45.0%

severity of disease pressure and impact on yields and unit costs. Values reported in Chapter 5 report only average statistics. The baseline *P(D)* parameter value, therefore, is calculated as the average between the proportion of farmers surveyed who reported *both* bean rust and anthracnose (0.43) and those who reported at least one of these diseases (0.89), resulting in a value of 0.64. Parameter values for the conservative and robust scenarios are taken as the high and low values of *P(D)* used in calculating the baseline estimate.

Cumulative adoption rates, A_t, for red mottled RVs are unknown. However, they are expected to fall between the conservative estimate for red mottled RV diffusion (previously shown in Figure 4.2) and the estimated diffusion path of the recently released purple mottled RVs (previously shown in Figure 4.3). Baseline values for A_t in Table 6.1 are then defined as the average cumulative adoption rate between these two figures. For the conservative scenario, values for A_t are obtained from Figure 4.2 since it represents a lower-bound of expected diffusion rates. Likewise for the robust scenario, values for A_t are obtained from Figure 4.3 since the recently released purple mottled RVs are expected to diffuse at least as fast as the earlier red mottled RVs and should provide an appropriate upper bound.

To complete the calculation of total research benefits (ΔTS), data on the supply elasticity, market price, and total production are also needed. The supply elasticity parameter, ε, is assumed equal to 0.7 for all three scenarios. No primary research on supply elasticities for semi-subsistence crops exists for Ecuador. The value is thus assumed identical to that used by Mather et al. (2003) for the supply elasticity of export-oriented bean production in Honduras. This value lies at the mid-point of supply elasticities for developing country agriculture from 0.2 to 1.2 suggested by Masters et al. (1996). Wholesale price data for the red mottled bean variety is available from 2000 to 2005 for the market in Ibarra (SICA 2007b). The price used in this analysis is assumed to be \$600/mt, which is determined by calculating the average wholesale price over the same period (in constant 2005 dollars) and inflating to adjust the wholesale prices for an assumed 20% retail mark-up. Data on total annual dry bean production in the provinces of Carchí and Imbabura is available from 1990 to 2005 (SICA 2007a). For the period from 1980-1989, annual production totals are calculated as the average of annual totals from 1990-1995. For 2006, the production data from 2005 are used.

Together, Imbabura and Carchí are assumed to be responsible for 40% of national dry bean production. Of this, red mottled varieties are assumed to represent 68.4% of the total for Imbabura and Carchí and purple mottled varieties are assumed to represent 12.3% (Table 4.2). However, as suggested by Figure 2.4, the market price is historically volatile. The sensitivity of IRR and NPV findings from the baseline scenario to changes in price and quantity produced will be examined in Section 6.4.1.

6.3.2 Research Costs

The calculation of total research costs relied on records of PRONALEG-GA's total operating budget for bean research for the period from 1982 to 2004. Input from PRONALEG-GA senior staff[38] allowed for a decomposition of these figures (as a share of total expenditure) into two components: total operating expenditures and human resource costs (e.g. plant-breeders and support staff). Within each of these categories, expenses were again decomposed based on the proportion of resources devoted only to those varieties being evaluated[39].

For the period corresponding to research investments in red mottled RVs, from 1982 to 1998, 60% of PRONALEG-GA's total operating expenditure is allocated to the varieties under evaluation. During the same period, 60-80% of bean breeder salaries and 40-80% of technical assistant salaries are allocated to the red mottled varieties under evaluation.

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[38] Ing. Eduardo Peralta, Director of PRONALEG-GA, e-mail message to author, September 15, 2007.
[39] The worksheets and values used are included in Appendix 7.

For the period corresponding to research investments in purple mottled RVs, from 1998 to 2004, two research cost scenarios are considered. The recently released purple mottled RV (La Concepción) represents one of four varieties released through the local agricultural research committees (CIALs) network during this same timeframe. The first scenario uses a similar research cost allocation to that of the red mottled varieties for PRONALEG-GA operating expenditures and employee salaries, but is then multiplied again by 0.25, or the proportion of research costs devoted only to the purple mottled RV itself. The second scenario considers the full set of research costs for all four varieties. This second scenario is intended to analyze whether research benefits derived from the purple mottled RV alone cover research costs for the entire participatory breeding program devoted to disease-resistant varieties from 1998 to 2004.

Data collected on external support indicated three organizations provided financial support to PRONALEG-GA's bean breeding efforts. The first is CIAT, which provided supplemental funding for the development of improved red mottled varieties during 1990-1999. The second is PREDUZA, a Dutch organization that provided funding from 2000 to 2004. The third is the B/C CRSP, which began providing funding in 2003. In all three cases, the share of total funding assumed to be devoted to the development of the improved varieties under consideration is 60%, identical to the assumption made earlier regarding PRONALEG-GA's operating expenditure. Previous B/C CRSP funding and CIAT research expenses incurred outside of Ecuador are considered sunk costs which did not influence INIAP's breeding-efforts for the varieties under evaluation.

6.3.3 Discount Rate

A final important matter is the selection of an appropriate discount rate to use in NPV calculations. Gittinger (1982) indicates a range of discount rates, *r*, between 0.08 and 0.15 that are appropriate for developing country contexts. Higher discount rates, however, are commonly used by governments and/or international donors to evaluate the short-term profitability of different investments. Since no primary research identifying a discount rate specific to Ecuador was identified, the specific discount rate used here, $r = 0.10$, is set equal to that used by both Mather et al. (2003) and Smale et al. (1998) who also evaluated the economic impact of disease-resistant breeding research on agricultural crops. To deal with this uncertainty, the sensitivity of the NPV provided in the baseline scenario to a range of discount rates will be examined in the following section.

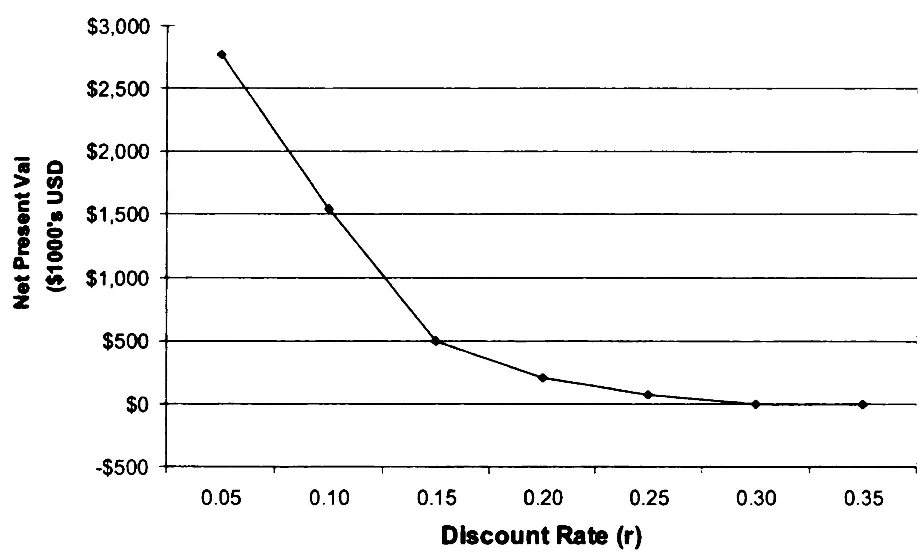
6.4 Results and Discussion

6.4.1 Ex-Post Impact of Disease-Resistant Red Mottled Varieties

Results from the baseline scenario indicate an IRR of 29% and an NPV $1.29 million USD of for bean-breeding research in northern Ecuador related to red mottled RVs for the period 1982-2006 (calculation provided in Table A.8.1 in Appendix 8). Results from the conservative and robust scenarios provide an IRR range of 13-46% and an NPV range of $43,000 USD to $2.74 million USD around the baseline figures (Tables A.8.2 and A.8.3). This implies that research investments in red mottled RVs have been profitable, at minimum, and most likely provide a return well above the assumed opportunity cost of capital ($r = 0.10$). Certainly the baseline estimate of 31% would compete well with alternative investment opportunities in Ecuador. In addition, the NPV values refer to the profit earned by research investments above that which would have been earned by investing the money elsewhere at a rate of return of 10%. A further consideration is that the period of evaluation extends from 1982 to 2006, with no assumption regarding a continuation of benefits. While some decline in total land area planted to improved red mottle varieties may occur due to varietal replacement, the stream of positive research benefits should continue for a number of years and add to this total.

In addition to sensitivity analysis on the supply shift parameters, the impact to both price and quantity and the choice of discount rate are also considered. Using the baseline scenario results, price and quantity were jointly increased and decreased 10%. This resulted in a range of IRR values from 26-33% and in NPV values of $903,000 USD and $1.57 million USD. Given uncertainty of the true opportunity cost of capital in Ecuador, Figure 6.2 presents estimated NPVs graphically for a range of discount rates

Figure 6.2: Sensitivity of NPV to Discount Rate



between 5% and 35%. At discount rate of 5%, results in an NPV over $2.5 million USD whereas discount rates above 29% the NPV becomes negative (as suggested by the IRR) and alternative investments become more attractive.

6.4.2 Ex-Ante Impact of Disease-Resistant Purple Mottled Varieties

In calculating the *ex ante* impact analysis of purple mottled RVs, parameter values from red mottled baseline scenario were used to calculate two IRR and NPV estimates based on the share of research costs considered. The first estimate considers only the proportion of research costs directed towards the development of purple mottled RVs. Results indicate an IRR of 34% and an NPV of $536,000 USD for the period 1998-2024 (calculations provided in Table A.8.5 of Appendix 8). While the IRR is comparable to that found for red mottled varieties, the much smaller NPV figure indicates the much smaller magnitude of research costs and benefits associated with purple mottled RVs.

As with red mottled varieties, sensitivity analysis was carried out around the estimated baseline *ex ante* IRR and NPV values for purple mottled varieties. The price and quantity values were jointly increased and decreased by 10%. This resulted in a range of IRR values from 31% to 37% and of NPV values from $419,000 USD to $665,000 USD.

The second estimate includes all research costs related to the development of the four varieties released through the CIAL network. Results here show an IRR of 17% and an NPV of $295,000 USD (calculations provided in Table A.8.4 of Appendix 8). Thus, in theory, the additional three varieties developed and released through the CIAL networks could produce zero net benefits and the total research expenditure would remain profitable, albeit at a much lower rate of return.

6.5 Chapter Summary

This chapter estimated the stream of annual research benefits derived from investments in disease resistant bean breeding research on red mottled and purple mottled varieties in northern Ecuador and their associated measures of project worth. For each variety class, this entailed the specification of three possible scenarios, namely a conservative, baseline, and robust scenario.

Ex post scenario analysis for disease resistant red mottled varieties for the period 1982-2006 indicated a range of IRR values from 13-46%, with a baseline estimate of 46%. The estimated NPVs for this investment ranged from $43,600 USD to $2.74 million USD and a baseline estimate of $1.29 million USD. The benefit stream is likely to continue for a number of years and add to this total. This indicates that the investment has been profitable and brought returns higher than the assumed opportunity cost of capital (r=0.10). These results are not very sensitive to a 10% change in both the price received and quantity produced.

Ex ante scenario analysis for disease resistant purple mottled varieties for the period 1998-2024 indicate a baseline IRR of 34% and an NPV of $536,000 when only those costs devoted exclusively to purple mottled varieties are considered. These values decrease to 17% and $295,000 USD, respectively, when all costs devoted to release of RVs through the CIAL network. In either case, the research investment on purple mottled varieties is expected to be profitable and bring returns higher than the assumed opportunity cost of capital. The small NPV values relative to those associated with red mottled RVs is due to the fact that purple mottled market class represents a much smaller proportion of total land area planted to beans. Like the red mottled varieties, these results are not very sensitive to a 10% change in both the price received and quantity produced. IRR estimates for both the red mottled and purple mottled RVs approach the IRR of 40% reported by Mather et al. (2003) for investments in bean-breeding research in Honduras and exceed the IRR of 13% reported by Boys et al. (2007) for investments in cowpea technology in Senegal.

REFERENCES

Alston, J., G. Norton, and P. Pardey. 1998. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.* Wallingford, UK: CAB International.

Alston, J., M. Marra, P. Pardey, and T.Wyatt. 2000. Research returns redux: a meta-analysis of the returns to agricultural R&D. *The Australian Journal of Agricultural and Resource Economics* 44(2):185–215.

Arévalo, V. 1985. Sistemas de Producción y Tecnologia del Fréjol Arbustivo en Pimampiro. Documento de Trabajo 85.SE.4, Proyecto INIAP-Cornell. Departamento de Planificación y Economía Agrícola. Instituto Nacional de Investigaciones Agropecuarias. Quito, Ecuador. December, 1985.

Bennett, R., Y. Ismael, U. Kambhampati, and S. Morse. 2004. Economic Impact of Genetically Modified Cotton in India. *AgBioForum* 7:96-100.

Boys, K., M. Faye, J. Fulton, and J. Lowenberg-DeBoer. 2007. The economic impact of cowpea research in Senegal: an ex-post analysis with disadoption. *Agricultural Economics* 36:363-375.

Brookes, G. 2005. The Farm-Level Impact of Herbicide-Tolerant Soybeans in Romania. *AgBioForum* 8:235-241.

CCI. 2000. Inteligencia de Mercados: Frijol. Perfil de Producto No. 8. Corporación Colombia Internacional (CCI). Bogota, Colombia. April-June.

CIAT. 2001. The CIALs at a Glance. Centro Internacional de Agricultura Tropical (CIAT). Cali, Colombia. http://www.ciat.cgiar.org/ipra/ing/glance.htm (accessed May 16, 2006).

Crissman, C., J. Antle, and S. Capalbo, eds. 1998. *Economic, Environmental and Health Tradeoffs in Agriculture: Pesticides and the Sustainability of Andean Potato Production.* Norwell, MA: Kluwer Academic Publishers.

Deaton, A. 1997. *The Analysis of Household Surveys: A Microeconometric Approach to Development Policy.* The World Bank: Washington, DC.

Ernest, E. 2004. Developing improved bush bean varieties in Ecuadorian market classes using farmer participatory crop improvement methods and marker assisted selection of an anthracnose resistance gene. M.S. Thesis. Plant Breeding and Genetics Program, Department of Crop and Soil Sciences. Michigan State University, East Lansing, MI.

Evenson, R., and D. Gollin, eds. 2003. *Crop variety improvement and its effect on productivity: the impact of international agricultural research.* Wallingford, UK: CABI Publishing.

Feder, G., R. Just, and D. Zilberman. 1985. Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change.* 33(2):255-298.

Fernandez-Cornejo, J., C. Klotz-Ingram, and S. Jones. 2002. Farm-Level Effects of Adopting Herbicide-Tolerant Soybeans in the U.S.A. *Journal of Agricultural and Applied Economics.* 34:149-163.

Gardner, J., and C. Nelson. 2007. Genetically Modified Crops and Labor Savings in US Crop Production. Paper presented at the Annual Meeting of the Southern Agricultural Economics Association. Mobile, AL, February 4-7.

Gittinger, J. 1982. *Economic Analysis of Agricultural Projects.* Baltimore: The Johns Hopkins University Press. Second Edition.

Godtland, E., E. Sadoulet, A. de Janvry, and O. Ortiz. 2004. The Impact of Farmer Field Schools on Knowledge and Productivity: A Study of Potato Farmers in the Peruvian Andes. *Economic Development and Cultural Change.* 53:63-92.

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

Gujarati, D. 2003. *Basic Econometrics.* New York, NY: McGraw-Hill Higher Education. Fourth edition.

INEC. 2001. III Censo Nacional Agropecuario. El Instituto Nacional de Estadística y Censos (INEC). Quito, Ecuador.

INIAP 1991a. INIAP-404 Cargabello Seleccionado: Variedad de Fréjol Arbustivo Cargabello Seleccionado. Plegable No. 96. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador. February.

INIAP 1991b. INIAP-411 Imbabello: Variedad de Fréjol Arbustivo. Plegable No. 122. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador. November.

INIAP 1996a. INIAP-418 Je.Ma.: Variedad Mejorada de Fréjol Arbustivo para la Cuenca del Río Chota. Plegable No. 160. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

INIAP 1996b. Paragachi: Variedad Local de Fréjol Arbustivo. Plegable miscelánea. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

INIAP 2004a. INIAP-414 Yunguilla: Variedad Mejorada de Fréjol Arbustivo. Plegable No. 253. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

INIAP 2004b. INIAP-424 Concepción: Variedad Mejorada de Fréjol Arbustivo Morado-Moteado. Plegable No. 254. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

INIAP 2004c. INIAP-425 Blanco Fanesquero: Variedad Mejorada de Fréjol Arbustivo para Consumo en Grano Tierno. Plegable No. 252. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

INIAP 2005. INIAP-420 Canario del Chota: Variedad mejorada de Fréjol Arbustivo de Color Armarillo. Plegable No. 258. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

Johnson, N., D. Pachico, and C. Wortmann. 2003. The Impact of CIAT's Genetic Improvement Research on Beans. Chapter 12 in R. Evenson and D. Gollin, eds. *Crop variety improvement and its effect on productivity: the impact of international agricultural research.* Wallingford, UK: CAB International.

Lépiz, R., E. Peralta, L. Minchala, and R. Jiménez. 1995. Diagnostico Agro socioeconómico del Cultivo de Fréjol en la Sierra Ecuatoriana. Documento de Trabajo INIAP-PROFRIZA No. 1. Proyecto Frijol de la Zona Andina (PROFRIZA). Quito, Ecuador.

Lépiz, R. 1996. Variedades de Frijol Liberadas por los Programas Nacionales de Bolivia, Peru, y Ecuador: Periodo 1988-1995. Proyecto Frijol de la Zona Andina (PROFRIZA). Quito, Ecuador.

Lichtenberg, E. and D. Zilberman. 1986. The econometrics of damage control: why specification matters. *American Journal of Agricultural Economics* 68(2): 261-273.

Marasas, C., M. Smale, and R. Singh. 2003. The Economic Impact of Productivity Maintenance Research: Breeding for Leaf Rust Resistance in Modern Wheat. Agricultural Economics 29(3):253-263.

Maredia, M., D. Byerlee and J. Anderson. 2000. Ex Post Evaluation of Economic Impacts of Agricultural Research Programs: A Tour of Good Practice. In *The Future of Impact Assessment in the CGIAR: Needs, Constraints and Options*. Rome, Italy: CGIAR Technical Advisory Committee Secretariat, FAO.

Masters, W., B. Coulibaly, D. Sanogo, M. Sidibé, and A. Williams. 1996. The Economic Impact of Agricultural Research: A Practical Guide. Unpublished manuscript. West Lafayette, Indiana: Department of Agricultural Economics Purdue University.

Mather, D., R. Bernsten, J. Rosas, A. Viana Ruano, and D. Escoto. 2003. The economic impact of bean disease resistant research in Honduras. *Agricultural Economics* 29:343-352.

Mather, D. 2005. Essays on the Economic Impact Of Disease-Resistant Bean Research In Honduras. Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, East Lansing, MI.

Mazón, Nelson, and Eduardo Peralta. 2005. El Comité de Investigación Agrícola Local (CIAL), una Estrategia para el Mejoramiento de la Produccion Agrícola en Comunidades Rurales: La Experiencia del CIAL "Cuenca del Río Mira." Publicación Miscelánea No. 131. Programa Nacional de Leguminosas y Granos Andinos (PRONALEG-GA), Estación Experimental Santa Catalina, Instituto Nacional Autónomo de Invesigaciones Agropecuarias (INIAP). Quito, Ecuador.

McFadden, D. 1973. Conditional logit analysis of qualitative choice behavior. In P. Zarembka, ed. *Frontiers in econometrics* New York, NY: Academic Press, pp 105-142.

Morris, M., and P. Heisey. 2003. Estimating the benefits of plant breeding research: methodological issues and practical challenges. *Agricultural Economics* 29(3):241–252.

Morris, M., H. Dubin, and T. Pokhrel. 1994. Returns to wheat breeding research in Nepal. *Agricultural Economics* 10(3):269-282.

Myers, R. 2006. Qualitative Response Models. Class Notes from AEC 835: Introductory Econometrics. Department of Agricultural Economics, Michigan State University, East Lansing, MI.

Oehmke, J., and E. Crawford. 1996. The Impact of Agricultural Technology in Sub-Saharan Africa. *Journal of African Economies*. 5(2):271-292

Peralta, E. 1991. Subproyecto 6: Control Integrado de Plagas. Informe Tecnico. Proyecto Frijol de la Zona Andina (PROFRIZA). Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

Peralta, E., V. Barrera, J. Unda, M. Guala, and M. Tacan. 2001. Estudio de la producción, poscosecha, mercadeo y consumo de fréjol arbustivo en el valle del Chota. Publicación Miscelánea. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

Pingali, P. 2001. Milestones in Impact Assessment Research in the CGIAR, 1970-1999. Mexico, D.F.: Standing Panel on Impact Assessment, Technical Advisory Committee of the Consultative Group on International Agricultural Research.

Qaim, M., and A. de Janvry. 2005. Bt cotton and pesticide use in Argentina: economic and environmental effects. *Environment and Development Economics* 10:179-200.

Qaim, M., and G. Traxler. 2005. Roundup Ready soybeans in Argentina: farm level and aggregate welfare effects. *Agricultural Economics* 32:73-86.

Rodríguez-Jaramillo, Lourdes. 1994. *Tenencia de la Tierra en los Valles del Chota y Salinas*. Fondo Ecuatoriano Populorum Progresso, Quito, Ecuador.

Rogers, E. M. 1962. *Diffusion of Innovations*. New York, Free Press of Glencoe.

Sadoulet, E. and A. de Janvry. 1995. *Quantitative Development Policy Analysis*. The Johns Hopkins University Press: Baltimore.

SICA. 2007a. Superficie mensual cosechada de fréjol seco 1990-2001. Servicio de Informacion y Censo Agropecuario (SICA). Ministerio de Agricultura, Ganaderia, Acuacultura y Pesca del Ecuador. http://www.sica.gov.ec/cadenas/frejol/index.html (accessed March 22, 2007).

SICA. 2007b. Precios mayoristas del fréjol tipo rojo moteado en el mercado de Ibarra 2000-2005. Servicio de Informacion y Censo Agropecuario (SICA), Ministerio de Agricultura, Ganaderia, Acuacultura y Pesca del Ecuador. http://www.sica.gov.ec/cadenas/frejol/index.html (accessed January 11, 2007).

SIISE. 2001. Indicadores Sociales. CD-ROM. Sistema Integrado de Indicadores Sociales de Ecuador (SIISE), Ministerio de Coordinación de Desarrollo Social, Gobierno Nacional del Ecuador, Quito, Ecuador.

Smale, M., R. Singh, K. Sayre, P. Pingali, S. Rajaram, and H. Dubin. 1998. Estimating the economic impact of breeding nonspecific resistance to leaf rust in modern bread wheats. *Plant Disease* 82: 1055-1061.

STATA. 2006. Regression with STATA: Regression Diagnostics. Chapter 2 in STATA Web Books, UCLA Academic Tecnology Services. http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm (accessed November 11, 2006).

Subía C., P. Estrella, J. Ocaña, and E. Peralta. 2004. Monitoreo del uso de pesticidas en el control de plagas y enfermedades que afectan al cultivo de fréjol en los valles de Chota y Mira de las provincias de Imbabura y Carchi, Ecuador, 2004. Informe de Trabajo. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

Subía, C., E. Peralta, E. Falconí, D. Mooney, and S. Swinton. 2007. El cultivo de fréjol arbustivo en los valles de Chota y Mira: Sistemas de producción y uso de plaguicidas. Publicación miscelánea No. 138. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

Sunding, D., and D. Zilberman. 2001. The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Industry. In B. Gardner and G.C. Rausser, eds. *Handbook of Agricultural and Resource Economics*, vol. 1, part 1. Amsterdam: North Holland, pp 207-261.

Vasquez, J., E. Peralta, J. Pinzón, and R. Lépiz. 1992. El Fréjol Arbustivo en Imbabura: Sugerencias para su Cultivo. Publicación Miscelanea No. 57. Instituto Nacional Autónomo de Investigaciones Agropecuarias, Estación Experimental Santa Catalina, Programa Nacional de Leguminosas. Quito, Ecuador.

Vernooy, Ronnie. 2003. *Seeds that give: participatory plant breeding*. Ottawa, Canada: International Development Research Centre.

Wooldridge, J. 2000. *Introductory Econometrics: A Modern Approach*. Cincinnati, OH: South-Western College.

Wooldridge, J. 2002. Chapter 18: Estimating Average Treatment Effects, in *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: The MIT Press.

World Bank. 2003. The CGIAR at 31: An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research. Volume 1: Overview Report. Operations Evaluation Department.

APPENDIX ONE:

VILLAGE-LEVEL SAMPLE SELECTION PROCESS

Figure A.1.1
Cartographic Maps Used in Developing the Area Frame

Collapí Bajo L	*Hualchan (o Gualchan)* OT	*La Plata* OT	Map Unavailable	Map Unavailable
Map Unavailable	*La Carolina* *11	*Rió Chutín* H	*Laguna de Porterillo* H	*Guananguicho* H
La Merced de Buenos Aires NC	*Estación Carchí* *15	*Concepción* *8	*El Angel* H	*San Gabriel* H
Cesta Polo OT	*Cahuasquí* NC	*Mira* *10	*Bolivar* *6	Map Unavailable
Cerro Yanaurc OT	*Tumbabiro* *1	*San Vicente de Pusir* *11	*Carpuela* *16	Map Unavailable
Imantag OT	*Atuntaqui* NC	*Ibarra* *3	*Pimampiro* *13	Map Unavailable
Cotacachi OT	*Iluman* OT	*Caranquí* NB	*Mariano Acosta* NB	Map Unavailable

Italicized text = Official name of cartographic map
* = Indicates the number of communities on the map located from 1200 and 2600 m.a.s.l
L = Indicates that map corresponds to targeted area, but lies below 1200 m.a.s.l.
H = Indicates that map corresponds to targeted area, but lies above 2600 m.a.s.l.
NC = Indicates that map corresponds to targeted area but does not contain villages
NB = Indicates that map corresponds to targeted area but does not contain rural villages
OT = Indicates that the entire map lies outside of the targeted area of influence
Source: Cartas Topográficas, Escala 1:50.000. El Instituto Geografico Militar, Quito, Ecuador

Table A.1.1 Villages Located Within Targeted Area of Impact by Map Name

Map Name	Community Names	Map Name	Community Names
La Carolina (11)	La Carolina	**Bolívar (6)**	***El Tambo
	Sn. Juan de Lachas		Los Andes
	Sn. Fco. de Tablas		Puntales Bajo
	Tablas		Sn. Joaquin
	Luz de América		Guarantón
	Chorrera de Tablas		Cuesaca
	Guadal	**Tumbabiro (1)**	Salinas
	Naranjito	**Sn. Vic. de Pusir (11)**	**Sn. Vicente de Pusir
	El Corazón		Mascarilla
	*El Naranjal		*Chota Chiquito (Alor)
	El Rosal		Tababuela
Estac. Carchi (15)	Guadrabamba		**Tumbatú
	Potrerillos		Pusir Chiquito
	Mascarillas		Chota
	*Sta. Marianita Yacucaspi		H. El Refugio
	Yacuscapi		*Chirimoyal (Espadilla)
	**Chamanal		Playa de Ambuquí
	***Sta. Lucía		Ambuquí
	Sn. Francisco	**Carpuela (16)**	Cabras
	Cuajara		La Cruz
	Hato Chamanal		Puntales
	H. La Loma		Sn. Joaquin
	Tarabita		Sn. Fco. De Chután
	Sn. Guillermo		Sn. Fco. De Villacís
	Estación Carchi		El Izal
	H. Cabuyal		*Cunquer
La Concepción (8)	Empedradillo		Pusir
	*El Milagro		*Carpuela
	*Convalecencia		Piquiucho
	***La Concepción		El Rosal
	H. Sta. Ana		El Juncal
	Santa Luisa		*Sn. Fco. De Caldera
	Juan Montalvo		**Chalguayacú
	Santa Ana		*Caldera
Mira (10)	*Cabuyal	**Pimampiro (13)**	*San Rafael
	**Píquer		Pueblo Nuevo
	Huaquer		Yunguilla
	Pueblo Viejo		Pimampiro
	**Mira		San Antonio
	Las Parcelas		*Santa Cecilia (San José)
	**Písquer		*Pugarpuela
	*La Portada		El Tejar
	Loma Sn. Juan Alto		San Juan
	Yascón		**Los Árboles (Yucatan)
Ibarra (3)	***San Clemente		El Inca
	*H. Pimán		La Mesa
	*Yucatan		*Buenos Aires

Notes: Targeted area of impact pertains to the cantons of Mira and Bolivar in the province of Carchí and the cantons of Ibarra and Pimampiro in the Province of Imbabura; 94 total villages.
*** Indicates a CIAL village; automatically included in survey (4)
** Indicates a village with previous INIAP extension intervention; automatically included in survey (10)
* Indicates a village without previous extension intervention and chosen at random (18)

Table A.1.2				
List of villages selected for inclusion in the survey sample				
No.	**Mapa**	**Comunidades**	**Cantón**	**Provincia**
1	La Concepción	*****La Concepción**	Mira	Carchi
2	Estación Carchi	*****Sta. Lucía**	Mira	Carchi
3	Ibarra	*****San Clemente**	Ibarra	Imbabura
4	Bolívar	*****El Tambo**	Bolívar	Carchi
5	Estación Carchi	****Chamanal**	Mira	Carchi
6	Mira	****Píquer**	Mira	Carchi
7	Mira	****Mira**	Mira	Carchi
8	Mira	****Písquer**	Mira	Carchi
9	Sn. Vic. De Pusir	****Sn. Vicente de Pusir**	Bolívar	Carchi
10	Sn. Vic. De Pusir	****Tumbatú**	Bolívar	Carchi
11	Carpuela	****Chalguayacú**	Pimampiro	Imbabura
12	Pimampiro	****Pimampiro (no beans)**	Pimampiro	Imbabura
13	Pimampiro	****Los Árboles**	Pimampiro	Imbabura
14	Pimampiro	****El Inca (Pat. Viejo)**	Pimampiro	Imbabura
15	La Carolina	***Naranjal**	Mira	Carchi
16	Sn. Vic. De Pusir	***Chirimoyal (Espadilla)**	Ibarra	Imbabura
17	Sn. Vic. De Pusir	***Chota Chiquito (Alor)**	Bolívar	Carchi
18	Carpuela	***Carpuela**	Ibarra	Imbabura
19	La Concepción	***El Milagro**	Mira	Carchi
20	Pimampiro	***Santa Cecilia (San Jose)**	Pimampiro	Imbabura
21	Mira	***Cabuyal**	Mira	Carchi
22	Estación Carchi	***Sta. Marianita Yacucaspi**	Ibarra	Imbabura
23	Carpuela	***El Rosal (Cunquer)**	Bolívar	Carchi
24	Estación Carchi	***Piman**	Ibarra	Imbabura
25	Mira	***La Portada**	Mira	Carchi
26	Pimampiro	***Buenos Aires**	Pimampiro	Imbabura
27	Carpuela	***Sn Fco. Chután (Caldera)**	Bolívar	Carchi
28	Pimampiro	***Pugarpuela**	Pimampiro	Imbabura
29	Pimampiro	***San Rafael**	Bolívar	Carchi
30	La Concepción	***Sta. Ana (Convalecencia)**	Mira	Carchi
R1	Sn. Vic. De Pusir	**Tababuela**	Ibarra	Imbabura
R2	La Carolina	**La Carolina**	Ibarra	Imbabura
R3	Ibarra	***Yucatan**	Pimampiro	Imbabura
R4	Carpuela	**Puntales**	Bolívar	Carchi
R5	La Carolina	**El Rosal**	Mira	Carchi
R6	Pimampiro	**San Antonio**	Pimampiro	Imbabura
R7	La Concepción	**Santa Luisa**	Mira	Carchi
R8	Bolívar	**Puntales Bajo**	Bolívar	Carchi
R9	Carpuela	**Sn. Fco. De Villacís**	Bolívar	Carchi
R10	Estación Carchi	**H. La Loma**	Mira	Carchi
R11	Bolívar	**Guarantón**	Bolívar	Carchi
R12	Estación Carchi	**Cuajara**	Ibarra	Imbabura
R13	Bolívar	**Cuesaca**	Bolívar	Carchi
R14	Mira	**Loma San Juan Alto**	Mira	Carchi
R15	Pimampiro	**La Mesa**	Pimampiro	Imbabura

Notes: Villages denoted ** or *** were automatically included in the sample.
*** = CIAL village
** = Non-CIAL village with previous INIAP extension intervention
* = Non-CIAL village without previous INIAP extension intervention
R1-R15 = Reserve communities (chosen at random)

APPENDIX TWO:

CALCULATION OF SURVEY WEIGHTS

Table A.2.1
Calculation of Survey Weights by Cluster

No.	*Cluster (Village)*	*Level of INIAP Intervention[b] (S)*	*Number of Bean Producers[c] (N_{SC})*	*Sample Size (n)*	*Sampling Probability (π_i)*	*Survey Weight (w_i)*
1	La Concepcion	1	3	3	1.00	0.33
2	Santa Lucia	1	4	3	0.75	0.44
3	San Clemente	1	4	3	0.75	0.44
4	El Tambo	1	4	3	0.75	0.44
5	La Concepcion[a]	2	100	4	0.04	25.00
6	Santa Lucia[a]	2	32	4	0.13	8.00
7	San Clemente[a]	2	29	4	0.14	1.79
8	El Tambo[a]	2	90	4	0.04	22.50
9	Chamanal	3	60	4	0.07	15.00
10	Piquer	3	27	4	0.15	6.75
11	Mira	3	48	4	0.08	12.00
12	Pisquer	3	86	4	0.05	21.50
13	San Vincente	3	130	4	0.03	32.50
14	Tumbatu	3	110	4	0.04	27.50
15	Chalguayacu	3	200	4	0.02	50.00
16	Patio Viejo	4	70	4	0.06	17.50
17	Los Arboles	3	30	4	0.13	7.50
18	San José	4	30	4	0.13	7.50
19	Naranjal	4	23	4	0.17	5.75
20	Espadilla	4	44	4	0.09	11.00
21	Alor	4	60	4	0.07	15.00
22	Carpuela	4	300	4	0.01	75.00
23	El Milagro	4	13	4	0.31	3.25
24	Yucatán	4	10	4	0.40	.625
25	Cabuyal	4	30	4	0.13	7.50
26	Pimán	4	44	4	0.09	11.00
27	Caldera	4	100	4	0.04	6.25
28	Imbiola y Sta. Marianita	4	16	4	0.25	4.00
29	La Portada	4	50	4	0.08	12.50
30	Buenos Aires	4	42	4	0.10	10.50
31	Cunquer	4	60	4	0.07	15.00
32	Pugarpuela	4	20	4	0.20	1.25
33	San Rafael	4	160	4	0.03	40.00
34	Convalecencia	4	23	4	0.17	5.75
	Totals		**2078**	**132**		

A – Villages are repeated here since farmers from multiple strata live within the same cluster

b – Level of INIAP intervention is categorized into four stratification levels: 1) CIAL members from a CIAL village, 2) non-CIAL members from a CIAL village, 3) villages with previous INIAP intervention, and 4) villages without prior INIAP intervention

c – All data was obtained from the village-level survey, except for San Clemente, Yucatan, Caldera and Pugarpuela for which data was estimated by INIAP researchers

Table A.2.2
Calculation of Survey Weights by Stratification Level

No.	*Level of INIAP Intervention*[a] *(S)*	*Number of Bean Producers*[b] *(N_S)*	*Number of Sampled Households within each cluster* *(n_s)*	*Sampling Probability* *(π_i)*	*Survey Weight* *(w_i)*
1	1	15	12	0.800	1.25
2	2	251	16	0.064	15.69
3	3	953	32	0.034	29.78
4	4	3008[c]	72	.024	41.78
	Totals	**4227**	**132**		

a – Level of INIAP intervention is categorized into four stratification levels: 1) CIAL members from a CIAL village, 2) non-CIAL members from a CIAL village, 3) non-CIAL members from a village with previous INIAP intervention, and 4) non-CIAL members from a village with no prior INIAP intervention

b – Data for stratification level 1-3 were obtained from the community level survey; data for stratification levels 4 and the total number of producers was obtained from Ecuador's 2001 Agricultural Census

c – The value for N_4 was obtained by subtracting N_1, N_2, and N_3 from N and is therefore treated as a residual. This presents the possibility of biasing the influence of observations from communities without previous INIAP intervention. If the number of bean farmers has increased, then the weight assigned to N_4 will be biased downward. If the number of bean farmers has decreased, then the weight assigned to N_4 will be biased upward.

APPENDIX THREE:

HOUSEHOLD-LEVEL QUESTIONAIRE

EVALUACIÓN DE IMPACTO DE NUEVAS VARIEDADES DE FRÉJOL EN EL NORTE DE ECUADOR

--CUESTIONARIO ACERCA DEL HOGAR--

Declaración de Consentimiento

Nosotros estamos conduciendo un estudio de impacto de variedades de fréjol resistentes a enfermedades liberadas en el Norte de Ecuador. Este estudio es realizado por el INIAP (Instituto Nacional Autónomo de Investigaciones Agropecuarias) en colaboración con Michigan State University (Universidad Estatal de Michigan). Me gustaría observar su campo de fréjol y hacerle algunas preguntas sobre su producción.

Su participación es voluntaria. Si usted no desea participar en esta encuesta o desea suspender su participación, usted no será penalizado de ninguna manera. Esta encuesta consistirá en una sola visita que tomará aproximadamente 45 minutos. Usted tiene plena libertad para no responder a las preguntas que le haga. Sin embargo, yo le alentaría a participar y a responder las preguntas porque sus respuestas nos ayudarán a mejorar los métodos de la producción del fréjol. Toda la información que nos proporcione será **confidencial**, lo cual implica que nadie más tendrá acceso a sus respuestas y su identidad permanecerá protegida en cualquier publicación relacionada con la información que nos proporcione. Su privacidad será protegida al máximo de acuerdo a lo que es permitido por ley.

Si usted tiene cualquier pregunta sobre este estudio, por favor comuníquese con el Profesor Scott M. Swinton en el departamento de Economía Agrícola, Michigan State University, 304 Agricultural Hall, East Lansing MI 48824, Estados Unidos de América. Teléfono (1-517-3537218) y correo electrónico swintons@msu.edu. Si usted tiene preguntas o dudas respecto a sus derechos como participante del estudio o está insatisfecho en cualquier momento con cualquier aspecto del estudio, usted puede comunicarse con el doctor Peter Vasilenko, Ph.D., Jefe del Comité Universitario para Investigaciones que Involucren Aspectos Humanos (UCRIHS), teléfono (1-517-432-4503), correo electrónico irb@msu.edu, correo 202 Olds Hall, East Lansing MI 48824-1047, Estados Unidos de América.

Usted indica su **acuerdo voluntario** de participar en esta investigación en siguiendo con la entrevista.

BEAN/COWPEA/CRSP

EVALUACIÓN DEL IMPACTO DE LAS NUEVAS VARIEDADES DE FRÉJOL ARBUSTIVO EN EL NORTE DEL ECUADOR

--CUESTIONARIO ACERCA DEL HOGAR--

A. Datos Básicos

*****Datos para llenar antes que empieza la entrevista*****

A1. Número de la encuesta del **hogar**: _______

A2. **Fecha** de Entrevista: ___/___/___
día / mes / año

A3. Iniciales del **entrevistador:**_____

A4. Comunidad: **(marca una)**

[1] La Concepción
[2] Santa Lucía
[3] San Clemente
[4] El Tambo
[5] Chamanal
[6] Piquer
[7] Mira
[8] Pisquer
[9] San Vicente
[10] Tumbatú
[11] Chalguayacú
[12] Pimampiro
[13] Los Árboles
[14] El Inca
[15] Naranjal
[16] Espadilla
[17] Puntales
[18] Carpuela
[19] El Milagro
[20] Santa Rosa
[21] Cabuyal
[22] Sta. Marianita
[23] Caldera
[24] Imbiola
[25] La Portada
[26] Yunguilla
[27] Cunquer
[28] Pugarpuela
[29] San Rafael
[30] Santa Ana

A5. Cantón: **(marca una)**

Imbabura:
[11] Ibarra
[12] Pimampiro

Carchi:
[21] Bolívar
[22] Mira

A6. Valle **(marca una)**
[1] Mira
[2] Chota
[3] Salinas

A7. Datos GPS del hogar **(OBSERVACIÓN)**
a. **Latitud** ______ ° ____ . ______′ (grados y minutos N)
b. **Longitud** ______ ° ____ . ______′ (grados y minutos W)
c. **Altitud** __________________ (metros s.n.m.)

B. Datos del Hogar

Antes que discutamos sobre la producción de fréjol, quisiera saber un poco acerca del hogar

B1. Nombre y apellidos del **entrevistado(a):** ________________

Parentesco del entrevistado respecto al jefe del hogar: **(marca una)**

[1] Jefe del hogar
[2] Esposa/o
[3] Hijo/a
[99] Otro, Especifique: ____________

B2. Jefe del Hogar

a. ¿Qué edad tiene? _____

b. ¿Cuántos años de **educación**? _____

c. Jefe(a) del hogar es: [0] Hombre
[1] Mujer

d. ¿Cuál es su **actividad principal**? **(marca una)**

[1] Agricultor	[6] Comerciante
[2] Jornalero	[7] Construcción/Albañil
[3] Ama de casa	[8] Dueño de negocio
[4] Empleada domestica	[9] Jubilado
[5] Empleado/a en oficina/tienda	[99] Otro, Especifique: ____________

e. ¿A qué **organizaciones** pertenece?

i. ¿Agricultores? no / sí
ii. ¿Regantes? no / sí
iii. ¿CIAL? no / sí
iv. ¿Mujeres? no / sí
v. ¿Cooperativa? no / sí

B3. ¿Quién **toma decisiones** sobre el cultivo de fréjol? **(marca una)**

[1] Jefe del hogar ***(pasa a pregunta B4)***
[2] Esposa/o ***(sigue con el orden de preguntas)***
[3] Hijo ***(sigue con el orden de preguntas)***
[99] Otro, Especifique: ____________

a. ¿Qué edad tiene? _____

b. ¿Cuántos años de **educación**? _____

c. Esta persona es: [0] Hombre
[1] Mujer

d. ¿Cuál es su **actividad principal**? **(marca una)**

[1] Agricultor	[6] Comerciante
[2] Jornalero	[7] Construcción/Albañil
[3] Ama de casa	[8] Dueño de propio negocio
[4] Empleado/a domestico/a	[9] Jubilado
[5] Empleado/a en oficina/tienda	[99] Otro, Especifique: ____________

e. ¿A qué **organizaciones** pertenece?

i. ¿Agricultores? no / sí
ii. ¿Regantes? no / sí
iii. ¿CIAL? no / sí
iv. ¿Mujeres? no / sí
v. ¿Cooperativa? no / sí

B4. ¿Cuántos **familiares** vivían en el hogar en enero de 2006? _____

a. ¿De ellos, cuántos trabajan? _____

b. ¿De ellos, cuántos dependen de los que trabajan? _____

B5. ¿Hay algún niño de entre 6 y 12 años que no asista a la escuela?

[0] No
[1] Si

B6. ¿Tiene familiares que le apoyaron económicamente y que vivían **fuera** de la casa en enero de 2006?

[0] No
[1] Si

B7. Vivienda

a. ¿Tiene **electricidad** instalada?

[0] No
[1] Sí

b. ¿Dispone de **agua** en casa?

[0] No
[1] Sí

c. ¿Dispone de **servicio higiénico**?

[0] No
[1] Si

d. Material predominante de **paredes** exteriores

[0] No permanente (plástico, caña, cartón, lata, otros)
[1] Permanente (adobe, bloque, ladrillo, cemento, otros)

e. Material predominante del **piso**

[0] Tierra
[1] Otro material (cemento, madera, mixto, etc.)

f. Número de **cuartos** (sin contar cocina, baño): ________________________

C. Producción del Fréjol

Ahora vamos a hablar acerca de su producción del fréjol en el primer ciclo 2006

C1. ¿Aproximadamente, cuál es la **superficie total** de tierra que usted cultivó?

a. Superficie total: _____

b. Unidad de medida: _____

C2. ¿Aproximadamente, cuánto de esa **superficie sembró con fréjol** en el primer ciclo 2006?

a. Superficie total: _____
b. Unidad de medida: _____

C3. ¿Cuales **variedades sembró** Ud. en el primer ciclo de 2006?

Variedad (nombre que te da el agricultor)	Cantidad de Semilla Sembrado (qq.)	Superficie aproximada (Ha.)	Rendimiento (qq total)
1.			
2.			
3.			
4.			

C4. ¿Dónde **suele vender** el fréjol seco?

[0] La misma localidad que no sea consorcio ***(pasar a pregunta C4)***
[1] Consorico
[2] Ibarra
[3] Pimampiro
[4] Tulcan
[5] Quito
[6] Colombia
[7] El Juncal
[99] Otro, Especifique: ____________

a ¿Cuánto cuesta transportar un quintal de fréjol seco hasta allá? $_____

b.¿Cuánto tiempo de viaje demora en transporte particular? _____ horas

C5. ¿Recibió Ud. algún **crédito** para el cultivo de fréjol durante el primer ciclo de 2006?

[0] No
[1] Sí

C6. ¿Cómo decide **cuándo aplicar** plaguicidas en el cultivo de fréjol?

[0] No aplica plaguicidas en la producción de fréjol ***(pasa a pregunta C15, pg 6)***
[1] Aplica plaguicidas por costumbre (o sea, en intervalos de tiempos fijos)
[2] Aplica plaguicidas cuando aparece algún síntoma de daño
[3] Aplica plaguicidas cuando lo recomienda un técnico
[99] Otro: Especifique ______________

C7. ¿Quién le indica qué **plaguicidas** aplicar?

a. ¿Vendedor? Si / No
b. ¿Técnicos (no vendedores) Si / No
c. ¿Tecnico de consorcio? Si / No
d. ¿familiares? Si / No
e. ¿Vecino? Si / No
f. ¿Propia experiencia? Si / No
g. ¿Radio? Si / No
h. ¿Otro? Si / No, Especifique: _________

C8. ¿Qué tipo de **equipo de fumigar** es el que más usa y cuál es su **capacidad**?

[1] Bomba de mochila Capacidad: ______
[2] Bomba de motor Capacidad: ______
[3] Bomba de motor (manguera) Capacidad: ______
[97] Sin repuesta
[98] No sabe
[99] Otro, Especifique: _______

C9. ¿Durante el primer ciclo de producción de fréjol de 2006, **quién aplicó** los plaguicidas?

[1] ¿Miembros del hogar?* Sí / No
[2] ¿Partidario? Sí / No
[3] ¿Jornalero? Sí / No (Si responden que **NO** pasa a C10)

C10. ¿Por qué se contrata a un jornalero? **(marca uno)**

[1] Miembros del hogar no saben como aplicar plaguicidas
[2] No alcanza el tiempo o familiares disponibles
[3] Prefiere proteger los miembros de la familia de exposición a los plaguicidas
[97] Sin repuesta
[98] No sabe
[99] Otro, Especifique:

**** Si ningún miembro del hogar aplicó plaguicidas (vea la respuesta a pregunta C9a), pasar a la pregunta C16.***
Si algún miembro del hogar si aplicó plaguicidas, seguir con el orden de preguntas.

C11. ¿Durante el primer ciclo de producción de fréjol de 2006, pasó alguna vez que después de aplicar plaguicidas su piel quedaba mojada de producto?

[0] No
[1] Sí

C12. ¿En el primer ciclo de producción de 2006, comió o bebió (refrescos) en el campo durante la aplicación en el cultivo de fréjol?

[0] No
[1] Sí

C13. ¿Durante el primer ciclo de producción de 2006, fumaba mientras fumigó el cultivo de fréjol con plaguicidas?

[0] No
[1] Sí

C14. ¿Cuál es el color de etiqueta de plaguicida de mayor peligrosidad?
(Sin leer los colores, marca una respuesta)

[1] Amarillo
[2] Azul
[3] Rojo
[4] Verde
[97] Sin Respuesta
[98] No sabe
[99] Otro, Especifique:__________

C15. ¿Qué ropa y equipo protector usó para la aplicación de plaguicidas?

Ropa o Equipo	**Sí / No**
a ¿Máscara protectora?	sí / no
b ¿Gafas protectoras?	sí / no
c. ¿Guantes de caucho?	sí / no
d. ¿Protector de la espalda?	sí / no
e. ¿Camisa de manga larga?	sí / no
f. ¿Pantalones protectores?	sí / no
g. ¿Botas?	sí / no
h. ¿Otro?, Especifique: ____	sí / no

C16. ¿Ha asistido a algún seminario sobre el manejo de plagas o la aplicación de plaguicidas en los últimos dos años?

[0] No
[1] Sí, ¿Número de días?: __________

D. Síntomas de Intoxicaciones Agudas

D1. **¿Antes del año 2006,** ha experimentado un miembro del hogar algunos de los siguientes síntomas dentro de pocas horas después de aplicar plaguicidas?

*Ninguno	X		
a. ¿Irritación de la piel?	sí / no	g. ¿Dolor de cabeza?	sí / no
b. ¿Visión nublada?	sí / no	h. ¿Diarrea?	sí / no
c. ¿Irritación de los ojos?	sí / no	i. ¿Dolores musculares?	sí / no
d. ¿Nausea y vómito?	sí / no	j. ¿Dificultades en respirar?	sí / no
e. ¿Molestias estomacales?	sí / no	k. ¿Angustia – Desesperación?	sí / no
f. ¿Mareo?	sí / no	l. ¿Desmayo?	sí / no
		m. ¿Otro?, Especifique: ____________	

D2. ¿Durante el primer ciclo de 2006, en el **cultivo de fréjol** ha experimentado un miembro del hogar algunos de los siguientes síntomas dentro de pocas horas después de aplicar plaguicidas?

*Ninguno	X		
a. ¿Irritación de la piel?	sí / no	g. ¿Dolor de cabeza?	sí / no
b. ¿Visión nublada?	sí / no	h. ¿Diarrea?	sí / no
c. ¿Irritación de los ojos?	sí / no	i. ¿Dolores musculares?	sí / no
d. ¿Nausea y vómito?	sí / no	j. ¿Dificultades en respirar?	sí / no
e. ¿Molestias estomacales?	sí / no	k. ¿Angustia – Desesperación?	sí / no
f. ¿Mareo?	sí / no	l. ¿Desmayo?	sí / no
		m. ¿Otro?, Especifique: ____________	

**** Si respondieron Ninguno en D2, pasar a pregunta E1***
Si respondieron que SI en alguna opción de D2, seguir con las preguntas . . .

Ahora me gustaría preguntarles acerca del síntoma que experimentó después de fumigar el fréjol y sobre los gastos del remedio . . .

D3. ¿Cuánto gastaron en medicinas (**sin receta médica**)? $_____

D4. ¿Número de **días incapacitado** en la casa? _____ días

D5. ¿Buscó **atención médica**? **(marca uno)**
[0] = No ***(pasa a pregunta D6)***
[1] = Sí ***(siga con preguntas abajo)***
a. ¿Número de visitas al doctor o clínica? _____
b. ¿Cuántos adultos acompañaron al enfermo? _____
c. ¿Costo de consulta por visita? $_____
d. ¿Costo de medicación comprada con receta médica? $_____
e. ¿Costo de transporte de ida y vuelta por visita? $_____
f. ¿Tiempo dedicado a visitar la clínica por visita? _____ horas
En caso de haber sido internado:
g. ¿Número de días hospitalizado? _____ días
h. ¿Costo total de estadía en la clínica u hospital? $_____

D6. ¿Había otros gastos relacionados con la intoxicación? (Total) $______
*Especifique: ____________________

FICHA PARCELA

*****Me gustaría visitar la parcela más grande de fréjol sembrada por usted en el primer ciclo de 2006 y preguntarles un poco más sobre la variedad usada y su producción. Además, me gustaría ver semillas de reserva o visitar un lote que esté actualmente con la misma semilla del primer ciclo 2006*****

E. Parcela más Grande Sembrada de Fréjol - Primer Ciclo de 2006

(Nota: Si se presentan más que una variedad sembrada en la parcela, las siguientes preguntas solo debe referirse a la variedad con más superficie y no todas las variedades)

E1. Cómo identifica a la parcela: ______________________

E2. ¿**Tenencia** de la parcela primer ciclo 2006? **(marca uno)**

[1] Es dueño de la parcela
[2] Arrendó la parcela
[3] Fue partidario

E3. **Pendiente** estimada de la parcela: **(marca una)**

[1] Plano
[2] Poco inclinado
[3] Ladera

E4. Clasificación del **suelo** que mejor describa la parcela **(marca una)**

[1] Arcilloso
[2] Arenoso
[3] Limo (Franco)

E5. Presencia de **piedras**: **(marca una)**

[0] Sin piedras
[1] Pocas
[2] Muchas

E6. ¿Dispone de **agua de riego**?

[0] No
[1] Si

E7. ¿Qué **cultivo** estaba sembrado en esta parcela **antes del fréjol** del primer ciclo 2006?

[0] Ninguno
[1] Fréjol
[2] Leguminosa no fréjol (arveja, otros)
[3] Cereal o graminea (maíz, caña, pastos)
[4] Hortaliza (tomate, pimiento, ají, otros)
[5] Frutales (Limon, aguacate, otros)
[6] Raíz o tubérculo
[97] Sin respuesta
[98] No sabe
[99] Otro, Especifique: ____________

F. Variedades del Fréjol

*****Las siguientes preguntas se refieren a la variedad sembrada en el primer ciclo de 2006*****

F1. Variedad de fréjol sembrada:

a. **Nombre Dado por el Productor:**

[1] **Concepción**	[10] Capuli	[18] Rojo
[2] **Paragachi**	[11] Negro	[19] Margarita
[3] **Yunguilla**	[12] Calima rojo	[20] Uribe
[4] **Blanco fanesquero**	[13] Calima negro	[21] Matahambre
[5] **Je.Ma.**	[14] Canario Pallatanga	[22] Toa
[6] **Canario del Chota**	[15] Cargabello	[23] Torta
[7] **Imbabello**	[16] Blanco de leche	[24] Panamito
[8] **Selva**	[17] Campeón	[25] Magola / Magolita
[9] **Injerto**		[99] Otro, Especifique: ________

b. **Color de grano (marca una)**

[1] Rojo moteado	[4] Amarillo	[97] Sin respuesta
[2] Morado moteado	[5] Rojo sólido	[98] No sabe
[3] Blanco	[6] Negro	[99] Otro *Especifique: _______

c. **Comprobación: (marca una)** (Nombre luego de ver la planta/semilla – dado por Encuestador)

[0] No se puede comprobar

[1] **Concepción**	[10] Capuli	[18] Rojo
[2] **Paragachi**	[11] Negro	[19] Margarita
[3] **Yunguilla**	[12] Calima rojo	[20] Uribe
[4] **Blanco fanesquero**	[13] Calima negro	[21] Matahambre
[5] **Je.Ma.**	[14] Canario Pallatanga	[22] Toa
[6] **Canario del Chota**	[15] Cargabello	[23] Torta
[7] **Imbabello**	[16] Blanco de leche	[24] Panamito
[8] **Selva**	[17] Campeón	[25] Magola / Magolita
[9] **Injerto**		[99] Otro, Especifique: ________

F2. ¿De **dónde obtuvo la semilla** que sembró? **(marca una)**

[1] Guardó de la cosecha anterior	
[2] Agricultor de la comunidad	
[3] Agricultor de otra comunidad *Cual: _________	[97] Sin respuesta
[4] Mercado *Cual: ____________	[98] No sabe
[5] Organismo gubernamental, *Cual: ___________	[99] Otro, *Especifique: ______
[6] Organismo no-gubernamental, *Cual: _________	

F3. ¿Porque decidió obtener su semilla de ese lugar/persona/etc.?

____

____

F4. ¿Hace cuántos años que siembra esta variedad? __________

F5. ¿Conoce el **origen** de ésta variedad? **(marca una)**

[1] Agricultor, *De donde: ________ [97] Sin respuesta
[2] Mercado *Cual: ___________ [98] No sabe
[3] Organismo gubernamental, *Cual: __________ [99] Otro, *Especifique: __________
[4] Organismo no-gubernamental, *Cual: _______

F6. ¿Por qué prefiere la variedad actual sobre otras variedades? **(marcar hasta 3 y el orden)**

	Orden (1 a 3):		Orden (1 a 3):
[1] Precio bajo de la semilla	____	[6] Resistencia a enfermedades	____
[2] Alto rendimiento	____	[7] Resistencia a plagas	____
[3] Se vende a mejor precio	____	[8] No hubo otras opciones	____
[4] Requiere menos insumos	____	[9] Autoconsumo	____
[5] Calidad del producto	____	[99] Otro, :	____
		Especifique: ____________	

F7. ¿En el primer ciclo 2006, qué cantidad de semilla sembró en ésta parcela?

a. **Cantidad**: _____ **qq**
b. **Precio**: $_____ / **qq**
c. En que **mes**? _____

F8. ¿Cuál fue el rendimiento total de la parcela?

a. **fréjol seco**: _____ qq
b. **en tierno**: _____ bultos (**grano seco estimado** _____ qq)

F9. ¿Si hubiera contratado jornales sin uso de maquinaria, con cuántos jornales hubiera cosechado y trillado? ______

F10. ¿Cuánto de la cosecha total vendió?

a. **fréjol seco:** ____ qq
b. **en tierno:** ____ bultos

F11. ¿A qué precio vendió la cosecha?

a. **fréjol seco**: $______/qq
b. **en tierno**: $______/bultos
c. En que **mes**? ______

F12. ¿Cómo compara el daño de **enfermedades** durante el primer ciclo de 2006 con años anteriores?

[1] mayor [97] sin respuesta
[2] menor [98] no sabe
[3] lo mismo

F13. ¿Cuáles de estas **enfermedades** se presentaron en esta parcela durante el primer ciclo de 2006, aun si no las reconoce por nombre? **(Deja que el entrevistado identifica cuales usando las fotos)**

1. sí / no	5. sí / no	9. sí / no
2. sí / no	6. sí / no	10. sí / no
3. sí / no	7. sí / no	11. sí / no
4. sí / no	8. sí / no	

F14. ¿Cuáles de estas enfermedades reconoce por nombre, aún si no se presentaron en su finca? **(Enseña las fotos de las enfermedades al entrevistado y marcar con X solamente las enfermedades correctamente identificadas)**

[0] NINGUNA

[1] Antracnosis	[5] Pudrición radicular	[9] Moho blanco
[2] Roya	[6] Mustia	[10] Mancha anillada
[3] Mancha angular	[7] Virus	[11] Añublo de halo
[4] Bacteriosis	[8] Oidio o ceniza	

F15. ¿Cómo compara el daño de **plagas** durante el primer ciclo 2006 con años anteriores?

[1] mayor	[97] sin respuesta
[2] menor	[98] no sabe
[3] lo mismo	

F16. ¿Cuáles **plagas** se presentaron durante el primer ciclo de 2006? **(marca todas que aplican)**

[1] Mosca blanca (palomilla)	[6] Pinda/mariquita/diabrótica	
[2] Trips	[7] Saltador de hojas	[97] Sin respuesta
[3] Trozadores	[8] Minadores	[98] No sabe
[4] Araña roja	[9] Enrollador	[99] Otro *Especifique:
[5] Grillo topo		___________

F17. ¿Qué variedad de semilla sembraba antes que la variedad actual?

a. **Nombre Dado por el Productor:**

[1] **Concepción**	[10] Capuli	[18] Rojo
[2] **Paragachi**	[11] Negro	[19] Margarita
[3] **Yunguilla**	[12] Calima rojo	[20] Uribe
[4] **Blanco fanesquero**	[13] Calima negro	[21] Matahambre
[5] **Je.Ma.**	[14] Canario Pallatanga	[22] Toa
[6] **Canario del Chota**	[15] Cargabello	[23] Torta
[7] **Imbabello**	[16] Blanco de leche	[24] Panamito
[8] **Selva**	[17] Campeón	[25] Magola / Magolita
[9] **Injerto**		[99] Otro, Especifique________

b. **Color de Grano (marca una)**

[1] Rojo moteado	[4] Amarillo	[97] Sin respuesta
[2] Morado moteado	[5] Rojo sólido	[98] No sabe
[3] Blanco	[6] Negro	[99] Otro *Especifique: ______

G. Uso de plaguicidas

G1. ¿Cuántas veces aplicó fertilizantes químicos al suelo? _____

a. ¿Cuantos quintales aplicó en total? _____

G2. ¿Cuántas veces aplicó herbicidas? _____

G3. ¿Cuántas fumigaciones realizó? _____

G4. **Plaguicidas Usados Por Fumigacion** (incluye insecticidas, fungicidas y abonos foliares)

Nombre comercial	*Unidad (marcar unidad)*	*Costo/unidad ($)*	*Dosis usada (por tanque 20 l)*

Aplicación #1: (Número de tanques: _______)

______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________

Nombre comercial	*Unidad (marcar unidad)*	*Costo/unidad ($)*	*Dosis usada (por tanque 200 l)*

Aplicación #2: (Número de tanques: _______)

______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________

Aplicación #3: (Número de tanques: _______)

______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________

Aplicación #4: (Número de tanques: _______)

______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________
______________	______________	________	________

Aplicación #5: (Número de tanques: _______)

________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________

Aplicación #6: (Número de tanques: _______)

________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________
________________	________________	__________	__________

H. Observaciones de la Parcela

H1. Datos GPS de la parcela: (Desde el centro de la parcela)

a. **Latitud** ______ ° ____ . _______′ (grados y minutos N)
b. **Longitud** ______ ° ____ . _______′ (grados y minutos W)
c. **Altitud** ___________________ (metros s.n.m.)

H2. Croquis de la parcela (para medir superficie)

APPENDIX FOUR:

COMMUNITY-LEVEL QUESTIONAIRE

ESTUDIO DE IMPACTO DE VARIEDADES DE FRÉJOL RESISTENTES A ENFERMEDADES LIBERADAS EN EL NORTE DE ECUADOR

--CUESTIONARIO ACERCA DE LA COMUNIDAD--

Declaración de Consentimiento

Nosotros estamos conduciendo un estudio de impacto de variedades de fréjol resistentes a enfermedades liberadas en el norte de Ecuador. Este estudio es realizado por el INIAP (Instituto Nacional Autónomo de Investigaciones Agropecuarias) en colaboración con Michigan State University (Universidad Estatal de Michigan). Me gustaría hacerle algunas preguntas sobre la comunidad y su agricultura.

Su participación es voluntaria. Si usted no desea participar en esta encuesta o desea suspender su participación, usted no será penalizado de ninguna manera. Esta encuesta consistirá en una sola visita que tomará aproximadamente 30 a 40 minutos. Usted tiene plena libertad para no responder a las preguntas que le haga. Sin embargo, yo le alentaría a participar y a responder las preguntas porque sus respuestas nos ayudarán a mejorar los métodos de la producción del fréjol. Toda la información que nos proporcione será confidencial, lo cual implica que nadie más tendrá acceso a sus respuestas y su identidad permanecerá protegida en cualquier publicación relacionada con la información que nos proporcione. Su privacidad será protegida al máximo de acuerdo a lo que es permitido por ley.

Si usted tiene cualquier pregunta sobre este estudio, por favor comuníquese con el Profesor Scott M. Swinton en el departamento de Economía Agrícola, Michigan State University, 304 Agricultural Hall, East Lansing MI 48824, Estados Unidos de América. Teléfono (1-517-3537218) y correo electrónico swintons@msu.edu. Si usted tiene preguntas o dudas respecto a sus derechos como participante del estudio o está insatisfecho en cualquier momento con cualquier aspecto del estudio, usted puede comunicarse con el doctor Peter Vasilenko, Ph.D., Jefe del Comité Universitario para Investigaciones que Involucren Aspectos Humanos (UCRIHS), teléfono (1-517-432-4503), correo electrónico irb@msu.edu, correo 202 Olds Hall, East Lansing MI 48824-1047, Estados Unidos de América.

Usted indica su acuerdo voluntario de participar en esta investigación en siguiendo con la entrevista.

ESTUDIO DE IMPACTO DE VARIEDADES DE FRÉJOL RESISTENTES A ENFERMEDADES LIBERADAS EN EL NORTE DE ECUADOR

--CUESTIONARIO ACERCA DE LA COMUNIDAD--

A. Información General:

A1. Numero de la encuesta **comunitaria**: _______

A2. **Fecha** de Entrevista: ___/___/_____
día / mes / año

A3. Iniciales del **entrevistador:** __

A4. Comunidad: **(marca una)**

[1] La Concepción	[9] San Vicente	[17] Puntales	[25] La Portada
[2] Santa Lucía	[10] Tumbatú	[18] Carpuela	[26] Yunguilla
[3] San Clemente	[11] Chalguayacú	[19] El Milagro	[27] Cunquer
[4] El Tambo	[12] Pimampiro	[20] Santa Rosa	[28] Pugarpuela
[5] Chamanal	[13] Los Árboles	[21] Cabuyal	[29] San Rafael
[6] Piquer	[14] El Inca	[22] Sta. Marianita	[30] Santa Ana
[7] Mira	[15] Naranjal	[23] Caldera	
[8] Pisquer	[16] Espadilla	[24] Imbiola	

A5. Cantón: **(marca una)**

Imbabura:	**Carchi:**
[11] Ibarra	[21] Bolívar
[12] Pimampiro	[22] Mira

A6. Valle **(marca una)**
[1] Mira
[2] Chota
[3] Salinas

B. Servicios Públicos e Infraestructura

Transporte

B1. ¿Qué tipo de **transporte público** llega a la comunidad? (Menciona)

[0] Ninguna *¿Cuántos minutos hay que caminar para encontrar transporte publico?*
[1] Bus de ruta
[2] Camioneta (carrera)
[99] Otro, Especifique: ____________

Educación

B2. ¿Cuál es el nivel de educación más alta que se puede completar dentro de la comunidad?

[0] Ninguna
[1] Primaria / Escuela
[2] Secundaria / Colegio

Salud

B3. ¿Qué facilidades de salud pública y privada se encuentran en la comunidad?

[0] Ninguna
[1] Sub-Centro de salud público
[2] Centro de salud público
[99] Otro, Especifique: ____________

B4. ¿Dónde está la facilidad de salud con un doctor permanente más cercana?

[1] Misma comunidad ***(Pase a pregunta B6)***
[2] Comunidad vecina
[3] Jefatura parroquial
[4] Ciudad secundaria (Mira, Pimampiro, etc.)
[5] Ciudad principal (Ibarra / Tulcán)
[99] Otro, Especifique: ____________

a. Qué tiempo en vehículo _____ horas

b. Costo de viaje (ida y vuelta) : $_____

Infraestructura

B6. ¿Qué tipo de servicio de telefonía tiene la comunidad? **(Marcar todas que aplican)**

[0] Ninguno
[1] Convencional
[2] Celular

C. Información Agrícola

Información demográfica

C1. ¿Cuántas personas habitan en la comunidad? _________
C2. ¿Cuántas familias hay dentro de la comunidad? _________
C3. ¿Cuántas familias se dedican a la agricultura en la comunidad? _________
C4. ¿De ellos (familias agrícolas), cuántos siembran el fréjol? _________

C5. ¿Cuánto se paga el jornal agrícola? (sin almuerzo) ________

C6. ¿Existe alguna diferencia en el costo del jornal, según la labor agrícola (pala, aplicación, etc.)?
[0] No
[1] Si, Razón:
____

Cultivos principales

C7. ¿Cuáles son los cultivos principales en la comunidad?

a. Fréjol no / sí
b. Maíz no / si
c. Tomate no / si
d. Caña no / si
e. Frutales no / si Especifique: ______________
f. Raíces o tubérculos no / si Especifique: ______________
g. Otras leguminosas no / si Especifique: ______________
h. Otros cereales no / si Especifique: ______________
i. Otro no / si Especifique: ______________

Insumos

C8. ¿Dónde se compran los insumos agrícolas? **(marca todos que aplican)**

a. Almacén agropecuaria dentro de la comunidad no / si
b. Comerciantes ambulantes que entran a la comunidad no / si
c. Almacenes fuera de la comunidad no / si
d. Cooperativa / Consorcio no / si
e. Otro no / si Especifique: _______

C9. ¿Existen lotes de producción exclusivamente para hacer **semilla de fréjol** dentro de la comunidad?

[0] No (pasa a pregunta C10)
[1] Si (siga con la pregunta C9.a)

a. ¿Es el productor?

[1] Individual
[2] Empresa privada
[3] Grupo comunitario *Especifique cual:___________

C10. ¿Cuáles variedades están cultivando? **(marca todos que aplican)**

Nombre Dado por el Productor:

[1] **Concepción**	[9] Capuli	[17] Rojo
[2] **Paragachi / Injerto**	[10] Negro	[18] Margarita
[3] **Yunguilla**	[11] Calima rojo	[19] Uribe
[4] **Blanco fanesquero**	[12] Calima negro	[20] Matahambre
[5] **Je.Ma.**	[13] Canario Pallatanga	[21] Toa
[6] **Canario del Chota**	[14] Cargabello	[22] Torta
[7] **Imbabello**	[15] Blanco de leche	[23] Panamito
[8] **Selva**	[16] Campeón	[24] Magola / Magolita
		[99] Otro, Especifique: _____

Observaciones:

____

____

Fuentes de Agua para la producción agrícola

C11. Dispone de agua de riego?

[0] No
[1] Si __________ meses/año
__________ frecuencia de turno promedio (cada cuántos días le corresponde el turno)
__________ % Área de la comunidad bajo riego

Observaciones:

____

____

D. Acceso al Mercado Exterior

D1. A qué distancia se encuentra el mercado de fréjol más importante para la comunidad?

a. En minutos: ________
b. ¿Cuál es el costo de transportar un quintal de fréjol ha este mercado? ________

D2. Mencionen los canales diferentes para vender su cosecha de fréjol y el orden de importancia a la comunidad:

[1] Venta directa al mercado mayorista	Orden ( )
[2] Venta al intermediario en la finca	Orden ( )
[3] Consorcio o Cooperativa	Orden ( )
[99] Otro, Especifique: ________________	Orden ( )

Observaciones:

____

____

E. Organizaciones Comunitarias

¿Cuáles organizaciones comunitarias realizan actividades relacionadas con la producción del fréjol?

Organización #1: ____________________

Tipo de organización:

[0] Ninguna
[1] CIAL
[2] Cooperativa
[3] Asociación de productores
[4] Grupo de semilleristas
[5] Grupo de Mujeres
[99] Otro, Especifique: ______________

¿Con qué se relacionan sus actividades principales?

Semilla	Si / No
Crédito	Si / No
Plaguicidas	Si / No
Comercialización	Si / No
Investigación	Si / No
Otro,	Si / No
Especifique: ________	

Observaciones: ____

Organización #2: ____________________

Tipo de organización:

[0] Ninguna
[1] CIAL
[2] Cooperativa
[3] Asociación de productores
[4] Grupo de semilleristas
[5] Grupo de Mujeres
[99] Otro, Especifique: ______________

¿Con qué se relacionan sus actividades principales?

Semilla	Si / No
Crédito	Si / No
Plaguicidas	Si / No
Comercialización	Si / No
Investigación	Si / No
Otro,	Si / No
Especifique: ________	

Observaciones: ____

F. Apoyo de Organismos Externos

¿Cuáles organismos externos han realizado actividades relacionadas con la producción del fréjol dentro de los últimos cinco años?

#1: Nombre del **organismo**: ___________________________

Tipo de organismo:
[1] Organismo del gobierno
[2] ONG
[3] Empresas privadas (Consorcio)
[99] Otros. Especifique: ______________

Tipo de apoyo:

[1] Semilla	no / si	
[2] Crédito	no / si	
[3] Plaguicidas	no / si	
[4] Comercialización	no / si	
[5] Investigación	no / si	
[6] Capacitación	no / si	En que? ___________
[7] Asistencia técnica	no / si	En que? ___________
[8] Otro	no / si	Especifique:______________________

Duración: **Año que empezó**: __________
Año que terminó: __________

Observaciones:

____

____

#2: Nombre del **organismo**: ___________________________

Tipo de organismo:
[1] Organismo del gobierno
[2] ONG
[3] Empresas privadas (Consorcio)
[99] Otros. Especifique: ______________

Tipo de apoyo:

[1] Semilla	no / si	
[2] Crédito	no / si	
[3] Plaguicidas	no / si	
[4] Comercialización	no / si	
[5] Investigación	no / si	
[6] Capacitación	no / si	En que? ___________
[7] Asistencia técnica	no / si	En que? ___________
[8] Otro	no / si	Especifique:______________________

Duración: **Año que empezó**: __________
Año que terminó: __________

Observaciones____

APPENDIX FIVE:

DESCRIPTION OF THE UNSATISFIED BASIC NEEDS INDEX

The Unsatisfied Basic Needs (UBN) index is used in this thesis as a proxy for household wealth. It is assumed that wealthier households will have met a greater number of basic needs, as defined in Figure A.5.1, than will have less wealthy households. The calculation of household-specific UBN indices was achieved by including relevant questions into the field survey (included in Appendix 3). Survey results from 132 interviews found 46% of household classified as poor, and 17% of households classified as extremely poor.

Figure A.5.1
Description of the Unsatisfied Basic Needs Index

Definition:
The Unsatisfied Basic Needs (UBN) Index is an indicator of poverty used by the government of Ecuador to define the number of persons that live in poverty. A person is considered poor if they belong to a household that fails to meet specific standards of adequate building materials, water and sanitation services, employment, and education.

Methodology:
The index uses methodology developed by the Andean Community (*Comunidad Andina*) which establishes a household as "poor" if at least one of the following conditions is present and as "extremely poor" if they meet two or more of the following conditions:

1. Physically inadequate characteristics: measured as having exterior walls constructed from disposable materials and/or with a dirt floor) .
2. Inadequate water or sanitation services: measured as having no connection to potable water and/or without a latrine or septic tank.
3. High economic dependence: measured as having more than 3 household members per occupied person *and* a head of household with two years of primary school education or less.
4. Lack of education: measured as having at least one child residing in the household between the ages of six to twelve that does not attend school.
5. Dwelling in a state of critical overcrowding: having more than three people per room, on average, without counting the bathroom, kitchen, or principal living room.

Source: SIISE (2001)

APPENDIX SIX:

SUPPLEMENTAL REGRESSIONS AND REGRESSION DIAGNOSTICS FROM CHAPTER FIVE

Table A.6.1: OLS Regression Results for the Yield, Fungicide Demand, and Insecticide Demand Equations, Imbabura and Carchi, Ecuador, 2006

Explanatory Variables by Category:	Yield (kg / ha)		Fungicide Demand (kg AI / ha)		Insecticide Demand (kg AI / ha)	
Treatment Effect Variables:						
Adopted improved variety (1=yes)	-35.1	(0.89)	-16.9	(0.02)**	-4.50	(0.01)***
High disease pressure (1=yes)	-433	(0.15)	-16.3	(0.03)**		
Adopted x Disease pressure (1=yes)	1102	(0.00)*	18.9	(0.09)*		
High pest pressure (1=yes)	122	(0.61)			1.861	(0.26)
Production Inputs:						
Fungicide active ingredient (kg ha^{-1})	0.588	(0.98)				
Fungicide AI squared	-0.048	(0.80)				
Insecticide AI (kg ha^{-1})	65.9	(0.14)				
Insecticide AI squared	-0.102	(0.78)				
Foliar fertilizer AI (kg ha^{-1})	-14.9	(0.42)				
Foliar fertilizer AI squared	0.063	(0.77)				
Bean seed (kg ha^{-1})	-0.982	(0.92)	0.553	(0.00)***	0.220	(0.00)***
Bean seed squared	0.015	(0.72)				
Plot Characteristics:						
Plot size (ha)	21.8	(0.81)	-1.42	(0.31)	-0.255	(0.64)
Altitude (m.a.s.l.)	0.334	(0.16)	0.015	(0.04)**	0.004	(0.15)
Loam soil (1=yes)	-12.1	(0.95)	-2.85	(0.51)	-0.451	(0.83)
Irrigated plot (1=yes)	-13.5	(0.97)	-6.09	(0.64)	-3.99	(0.39)
Plot prev. cropped w/ beans (1=yes)	-388	(0.06)*	2.03	(0.65)	2.25	(0.18)
Sharecropped plot (1=yes)	240	(0.21)	-8.94	(0.04)**	-4.98	(0.04)**
Rented plot (1=yes)	-206	(0.55)	-11.6	(0.14)	0.248	(0.94)
Household Variables:						
Age of HH (years)	2.97	(0.68)	-0.757	(0.00)***	-0.254	(0.01)***
Attended pest man. seminar (1=yes)	151	(0.43)	0.846	(0.87)	-3.55	(0.07)*
Symptom based pest man. (1=yes)			4.34	(0.49)	6.56	(0.07)*
Poor household (1=yes)			-1.83	(0.69)	1.09	(0.60)
Price Variables:						
Market price for beans ($/kg)			-22.4	(0.17)	-6.57	(0.27)
Cost of transport ($/qq)			-3.51	(0.66)	-4.08	(0.05)**
Avg. price of fungicide ($/kg AI)			-10.6	(0.00)***		
Avg. price of insecticide ($/kg AI)					-2.69	(0.30)
Community-Level Variables:						
Chota valley (1=yes)	402	(0.04)**	8.97	(0.08)*	3.50	(0.05)**
Prev. extension intervention (1=yes)	231	(0.19)	0.990	(0.82)	-0.986	(0.61)
Observations	85		73		73	
R^2	0.88		0.80		0.80	
F(*k*,*df*)	19.1		7.92		9.91	
P>Chi^2	0.00		0.00		0.00	

Notes: p-values parentheses; data is from the 2006 B/C CRSP and INIAP farm-level survey; fungicide and insecticide demand models estimated using White's heteroskedastic robust standard errors
*** significant at 1%; ** significant at 5%; * significant at 10%

Table A.6.2: 3SLS Regression Results for the Yield, Fungicide Demand, and Insecticide Demand Equations, Imbabura and Carchi, Ecuador, 2006 (*n*=73)

Explanatory Variables by Category:	Yield (kg / ha)		Fungicide Demand (kg AI / ha)		Insecticide Demand (kg AI / ha)	
Treatment Effect Variables:						
Adopted improved variety (1=yes)	-117	(0.72)	-11.6	(0.02)**	-4.65	(0.01)***
High disease pressure (1=yes)	-287	(0.58)	-2.74	(0.60)		
Adopted x Disease pressure (1=yes)	1215	(0.01)***	7.32	(0.31)		
High pest pressure (1=yes)	-119	(0.79)			2.96	(0.04)**
Production Inputs:						
Fungicide AI (kg ha^{-1})	5.39	(0.94)				
Fungicide AI squared	-0.180	(0.74)				
Insecticide AI (kg ha^{-1})	148	(0.40)				
Insecticide AI squared	-0.582	(0.66)				
Foliar fertilizer AI (kg ha^{-1})	-27.2	(0.47)				
Foliar fertilizer AI squared	0.239	(0.63)				
Bean seed (kg ha^{-1})	3.49	(0.84)	0.545	(0.00)***	0.219	(0.00)***
Bean seed squared	-0.012	(0.88)				
Plot Characteristics:						
Plot size (ha)	76.3	(0.50)	-2.01	(0.36)	-0.215	(0.81)
Altitude (m.a.s.l.)	0.314	(0.38)	0.013	(0.02)**	0.003	(0.19)
Loam soil (1=yes)	125	(0.60)	-1.47	(0.74)	-0.483	(0.79)
Irrigated plot (1=yes)	-437	(0.30)	-12.6	(0.19)	-4.219	(0.27)
Plot prev. cropped w/ beans (1=yes)	-284	(0.19)	3.71	(0.45)	1.778	(0.37)
Sharecropped plot (1=yes)	231	(0.25)	-9.73	(0.04)**	-4.713	(0.02)**
Rented plot (1=yes)	-548	(0.30)	-12.9	(0.16)	0.170	(0.96)
Household Variables:						
Age of HH (years)	1.35	(0.87)	-0.715	(0.00)***	-0.245	(0.00)***
Attended pest man. seminar (1=yes)	159	(0.39)	-0.235	(0.96)	-3.41	(0.08)
Symptom based pest man. (1=yes)			5.98	(0.28)	7.14	(0.00)***
Poor household (1=yes)			-2.99	(0.50)	1.06	(0.55)
Price Variables:						
Market price for beans ($/kg)			-26.2	(0.05)**	-7.95	(0.15)
Cost of transport ($/qq)			-2.25	(0.73)	-4.47	(0.09)*
Avg. price of fungicide ($/kg AI)			-1.33	(0.77)		
Avg. price of insecticide ($/kg AI)					-0.751	(0.66)
Community-Level Variables:						
Chota valley (1=yes)	401	(0.08)*	9.66	(0.08)*	3.56	(0.10)*
Previous extension interv. (1=yes)	405	(0.04)**	-2.79	(0.54)	-1.35	(0.45)
R^2	0.87		0.79		0.80	
Chi^2	522		296		301	
$P>Chi^2$	0.00		0.00		0.00	

Notes: p-values parentheses; fungicide AI and insecticide AI variables treated as endogenous; data is from the 2006 B/C CRSP and INIAP farm-level survey

*** significant at 1%; ** significant at 5%; * significant at 10%

Table A.6.3: OLS Estimates of the Linear Unit Variable Cost Function, Imbabura and Carchi, Ecuador, 2006 (*n*=73)

Explanatory Variables by Category:	Unit Variable Cost ($/kg)	
Treatment Effect Variables:		
Adopted improved variety (1=yes)	0.0121	(0.73)
High disease pressure (1=yes)	0.0112	(0.78)
Adopted x Disease pressure (1=yes)	-0.0518	(0.37)
High pest pressure (1=yes)	-0.0520	(0.07)**
Price Variables:		
Avg. fungicide price ($/kg a.i.)	0.0247	(0.47)
Avg. insecticide price ($/kg a.i.)	0.0490	(0.16)
Bean seed price ($/kg)	0.1759	(0.00)***
Output Variable:		
Bean yield (kg/ha)	$-6.01\text{x}10^{-5}$	(0.00)***
Plot Characteristics:		
Plot size (ha)	-0.0195	(0.11)
Altitude (m.a.s.l.)	$-1.14\text{x}10^{-4}$	(0.01)***
Loam soil (1=yes)	0.0201	(0.42)
Irrigated plot (1=yes)	0.0258	(0.65)
Sharecropped plot (1=yes)	-0.0173	(0.50)
Rented plot (1=yes)	0.1030	(0.04)**
Household Variables:		
Age of HH (years)	-0.0011	(0.26)
Attended pest man. seminar (1=yes)	0.0425	(0.11)
Community-Level Variables:		
Chota valley (1=yes)	-0.0415	(0.15)
Prev. extension intervention (1=yes)	-0.0904	(0.00)***
Constant	0.3374	(0.01)***
R^2	0.59	
(18, 54)	4.34	
rob>F	0.00	

p-values in parentheses

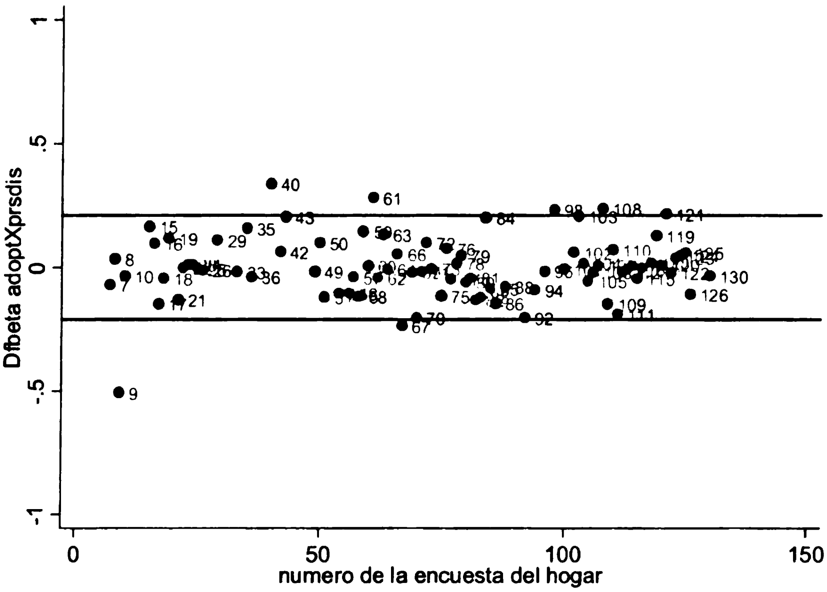
* significant at 10%; ** significant at 5%; ***significant at 1%

Table A.6.4: Variance Inflation Factors (VIFs) for the Quadratic Yield Model

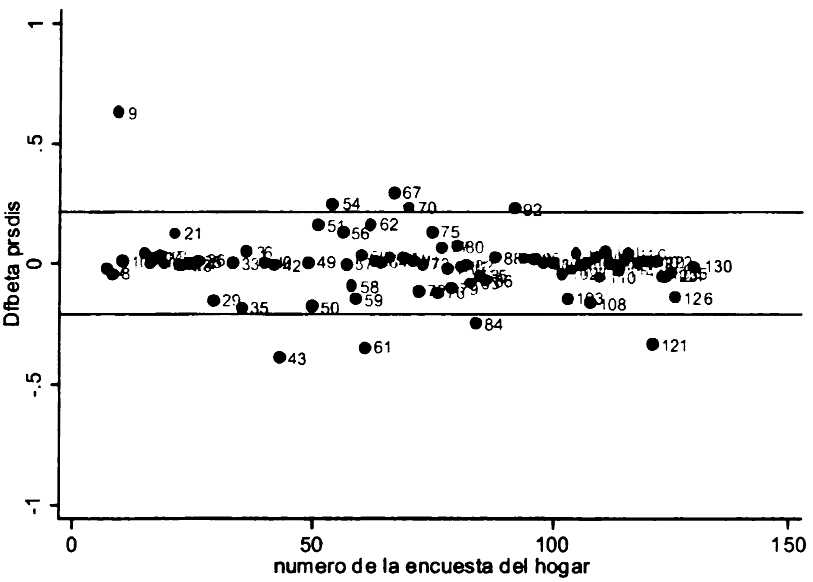
Explanatory Variables by Category:	VIF
Adopted improved variety (1=yes)	2.70
High disease pressure (1=yes)	3.52
Adopted x Disease pressure (1=yes)	3.39
High pest pressure (1=yes)	1.69
Production Inputs:	
Fungicide active ingredient (kg/ha)	86.57
Fungicide a.i. squared	172.16
Insecticide a.i. (kg/ha)	57.42
Insecticide a.i. squared	26.36
Foliar fertilizer a.i. (kg/ha)	32.84
Foliar fertilizer a.i. squared	86.00
Bean seed (kg/ha)	70.74
Bean seed squared	105.97
Plot Characteristics:	
Plot size (ha)	1.49
Altitude (m.a.s.l.)	1.47
Loam soil (1=yes)	1.49
Irrigated plot (1=yes)	1.58
Plot prev. cropped w/ beans (1=yes)	1.38
Sharecropped plot (1=yes)	1.62
Rented plot (1=yes)	1.53
Household Variables:	
Age of HH (years)	1.59
Attended pest man. seminar (1=yes)	1.33
Community-Level Variables:	
Chota valley (1=yes)	1.58
Prev. extension intervention (1=yes)	1.25

Figure A.6.1: Scatter Plots of DFBETA Regression Diagnostic Statistics

a) Scatter Plot of DFBETAs for Coeffcient on Adoption X Disease Pressure Interaction Term (Numbers indicate household ID)



b) Scatter Plot of DFBETAs for Coeffcient on Disease Pressure (Numbers indicate household ID)



Note: Values on the Y-axis indicate the influence of each individual observation on the value of regression coefficients, measured as a proportion of one standard deviation (STATA 2006). Inclusion of the largest outlier (observation #9) decreases the coefficient on the interaction variable and increases the coefficient on the disease pressure variable. No remedial measure is implemented since this outlier has the effect of lowering expected incremental net benefits.

APPENDIX SEVEN:

DATA ELICITATION WORKSHEETS FOR RESEARCH COSTS

Figure A7.1:
Research Cost Worksheet #1: Operation Costs and External Support Dedicated to Varieties Under Evaluation

Period	Year	Currency	Total operation costs + External Support	Proportion of (D) dedicated to varieties under evaluation	Total operation costs considered
(A)	(B)	(C)	(D)	(E)	(G)*
1	1982	USD	31600	.6	18,960
2	1983	USD	31600	.6	18,960
3	1984	USD	31600	.6	18,960
4	1985	USD	31600	.6	18,960
5	1986	USD	31600	.6	18,960
6	1987	USD	31600	.6	18,960
7	1988	USD	31600	.6	18,960
8	1989	USD	31600	.6	18,960
9	1990	USD	15000	.6	9,000
10	1991	USD	23000	.6	13,800
11	1992	USD	25000	.6	15,000
12	1993	USD	34000	.6	20,400
13	1994	USD	40000	.6	24,000
14	1995	USD	35000	.6	21,000
15	1996	USD	35000	.6	21,000
16	1997	USD	35000	.6	21,000
17	1998	USD	35000	.6	21,000
18	1999	USD	39000	.6	23,400
19	2000	USD	4000	.6	2,400
20	2001	USD	6000	.6	3,600
21	2002	USD	6000	.6	3,600
22	2003	USD	55843	.6	33,506
23	2004	USD	62081	.6	37,249

* - Calculated as: (G) = (D) x (E) x (F)

Figure A7.2:

Research Cost Worksheet #2: Human Resource Costs Dedicated to Varieties Under Evaluation

Period	Year	Currency	Number of bean breeders	Avg. annual cost per bean-breeder	Proportion of (H) dedicated to varieties evaluated	Total cost of bean breeders considered	Number of support staff working on bean-breeding	Avg. annual cost per support staff	Proportion of (L) dedicated to varieties evaluated	Total cost of support staff considered
(A)	(B)	(C)	(H)	(I)	(J)	(K)*	(L)	(M)	(N)	(O)**
1	1982	USD	2	2,100	.70	2,940	1	1,700	.80	1,360
2	1983	USD	2	2,300	.70	3,220	1	1,900	.80	1,520
3	1984	USD	2	2,300	.80	3,680	1	2,000	.80	1,600
4	1985	USD	2	2,300	.80	3,680	1	2,000	.80	1,600
5	1986	USD	2	2,400	.80	3,840	1	2,100	.80	1,680
6	1987	USD	2	2,400	.80	3,840	1	2,200	.80	1,760
7	1988	USD	2	2,500	.80	4,000	1	2,300	.80	1,840
8	1989	USD	2	2,600	.80	4,160	1	2,500	.80	2,000
9	1990	USD	3	2,740	.60	4,932	1	2,740	.40	1,096
10	1991	USD	3	3,267	.60	5,881	2	3,267	.40	2,614
11	1992	USD	3	2,652	.60	4,774	2	2,652	.40	2,122
12	1993	USD	3	3,352	.60	6,034	2	3,352	.40	2,682
13	1994	USD	4	5,075	.60	12,180	2	5,075	.40	4,060
14	1995	USD	4	4,281	.60	10,275	2	4,281	.40	3,425
15	1996	USD	3	4,621	.60	8,317	2	4,621	.40	3,696
16	1997	USD	3	4,718	.60	8,492	2	4,718	.40	3,774
17	1998	USD	3	4,172	.60	7,510	2	4,172	.40	3,338
18	1999	USD	3	1,755	.60	3,159	2	1,755	.40	1,404
19	2000	USD	3	2,279	.60	4,102	3	2,279	.40	2,735
20	2001	USD	4	3,337	.60	8,010	3	3,337	.40	4,005
21	2002	USD	4	3,883	.60	9,319	3	3,883	.40	4,660
22	2003	USD	5	6,082	.60	18,246	3	6,082	.40	7,298
23	2004	USD	5	7,592	.60	22,776	3	7,592	.80	18,221

* - Calculated as: (K) = (H) x (I) x (J); ** - Calculated as: (O) = (L) x (M) x (N)

APPENDIX 8

NPV AND IRR CALCULATION TABLES

Table A.8.1: Baseline Scenario for NPV and IRR Calculations, INIAP red mottled varieties, 1982-2006

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Period	*Year*	*ε*	*ΔUC*	*P(D)*	*A*	*K*	*P*	*Q*	*ΔTS*	*RC*	*NB*	*NPV*	*IRR*
1	1982	0.7	0.184	0.64	0.0000	0.000	$600	8.18	$0	$24,730	-$24,730		
2	1983	0.7	0.184	0.64	0.0000	0.000	$600	8.18	$0	$25,310	-$25,310	**In constant 1982 USD:**	
3	1984	0.7	0.184	0.64	0.0000	0.000	$600	8.18	$0	$26,080	-$26,080	**$540,689**	**29%**
4	1985	0.7	0.184	0.64	0.0000	0.000	$600	8.18	$0	$26,080	-$26,080		
5	1986	0.7	0.184	0.64	0.0100	0.001	$600	8.18	$5,782	$26,400	-$20,618	**In constant 2006 USD:**	
6	1987	0.7	0.184	0.64	0.0240	0.003	$600	8.18	$13,869	$26,480	-$12,611	**1,128,788**	**29%**
7	1988	0.7	0.184	0.64	0.0599	0.007	$600	8.18	$34,715	$26,800	$7,915		
8	1989	0.7	0.184	0.64	0.1270	0.015	$600	8.18	$73,789	$27,200	$46,589		
9	1990	0.7	0.184	0.64	0.1968	0.023	$600	7.28	$102,080	$15,028	$87,052		
10	1991	0.7	0.184	0.64	0.2398	0.028	$600	7.19	$123,009	$22,294	$100,715		
11	1992	0.7	0.184	0.64	0.2645	0.031	$600	7.63	$144,238	$21,896	$122,343		
12	1993	0.7	0.184	0.64	0.2842	0.033	$600	8.11	$164,745	$29,116	$135,628		
13	1994	0.7	0.184	0.64	0.3044	0.036	$600	9.52	$207,398	$40,240	$167,158		
14	1995	0.7	0.184	0.64	0.3262	0.038	$600	9.35	$218,288	$34,700	$183,587		
15	1996	0.7	0.184	0.64	0.3486	0.041	$600	5.89	$147,233	$33,013	$114,220		
16	1997	0.7	0.184	0.64	0.3701	0.044	$600	6.01	$159,610	$33,267	$126,343		
17	1998	0.7	0.184	0.64	0.3893	0.046	$600	5.41	$151,291	$31,848	$119,444		
18	1999	0.7	0.184	0.64	0.4053	0.048	$600	5.19	$151,120	$0	$151,120		
19	2000	0.7	0.184	0.64	0.4179	0.049	$600	4.98	$149,622	$0	$149,622		
20	2001	0.7	0.184	0.64	0.4274	0.050	$600	5.64	$173,375	$0	$173,375		
21	2002	0.7	0.184	0.64	0.4343	0.051	$600	5.17	$161,377	$0	$161,377		
22	2003	0.7	0.184	0.64	0.4392	0.052	$600	10.20	$322,200	$0	$322,200		
23	2004	0.7	0.184	0.64	0.4426	0.052	$600	9.97	$317,416	$0	$317,416		
24	2005	0.7	0.184	0.64	0.4450	0.052	$600	16.78	$537,129	$0	$537,129		
25	2006	0.7	0.184	0.64	0.4466	0.053	$600	16.78	$539,109	$0	$539,109		

Table A.8.2: Conservative Scenario for NPV and IRR Calculations, INIAP red mottled varieties, 1982-2006

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Period	*Year*	*ε*	*ΔUC*	*P(D)*	*A*	*K*	*P*	*Q*	*ΔTS*	*RC*	*NB*	*NPV*	*IRR*
1	1982	0.7	0.166	0.42	0.0000	0.000	$600	8.18	$0	$24,730	-$24,730		
												In constant 1982 USD:	
2	1983	0.7	0.166	0.42	0.0000	0.000	$600	8.18	$0	$25,310	-$25,310		
3	1984	0.7	0.166	0.42	0.0000	0.000	$600	8.18	$0	$26,080	-$26,080	**$20,411**	**13%**
4	1985	0.7	0.166	0.42	0.0000	0.000	$600	8.18	$0	$26,080	-$26,080		
												In constant 2006 USD:	
5	1986	0.7	0.166	0.42	0.0100	0.001	$600	8.18	$3,422	$26,400	-$22,978		
6	1987	0.7	0.166	0.42	0.0147	0.001	$600	8.18	$5,043	$26,480	-$21,437	**$42,612**	**13%**
7	1988	0.7	0.166	0.42	0.0216	0.002	$600	8.18	$7,393	$26,800	-$19,407		
8	1989	0.7	0.166	0.42	0.0314	0.002	$600	8.18	$10,761	$27,200	-$16,439		
9	1990	0.7	0.166	0.42	0.0453	0.003	$600	7.28	$13,798	$15,028	-$1,230		
10	1991	0.7	0.166	0.42	0.0642	0.004	$600	7.19	$19,345	$22,294	-$2,950		
11	1992	0.7	0.166	0.42	0.0894	0.006	$600	7.63	$28,622	$21,896	$6,727		
12	1993	0.7	0.166	0.42	0.1214	0.008	$600	8.11	$41,300	$29,116	$12,184		
13	1994	0.7	0.166	0.42	0.1597	0.011	$600	9.52	$63,865	$40,240	$23,625		
14	1995	0.7	0.166	0.42	0.2026	0.014	$600	9.35	$79,614	$34,700	$44,914		
15	1996	0.7	0.166	0.42	0.2473	0.017	$600	5.89	$61,330	$33,013	$28,317		
16	1997	0.7	0.166	0.42	0.2903	0.020	$600	6.01	$73,513	$33,267	$40,246		
17	1998	0.7	0.166	0.42	0.3286	0.023	$600	5.41	$75,008	$31,848	$43,161		
18	1999	0.7	0.166	0.42	0.3606	0.025	$600	5.19	$78,979	0	$78,979		
19	2000	0.7	0.166	0.42	0.3857	0.027	$600	4.98	$81,146	0	$81,146		
20	2001	0.7	0.166	0.42	0.4047	0.028	$600	5.64	$96,472	0	$96,472		
21	2002	0.7	0.166	0.42	0.4186	0.029	$600	5.17	$91,391	0	$91,391		
22	2003	0.7	0.166	0.42	0.4284	0.030	$600	10.20	$184,671	0	$184,671		
23	2004	0.7	0.166	0.42	0.4353	0.030	$600	9.97	$183,415	0	$183,415		
24	2005	0.7	0.166	0.42	0.4400	0.031	$600	16.78	$312,086	0	$312,086		
25	2006	0.7	0.166	0.42	0.4432	0.031	$600	16.78	$314,401	0	$314,401		

Table A.8.3: Robust Scenario for NPV and IRR Calculations, INIAP red mottled varieties, 1982-2006

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Period	*Year*	*ε*	*ΔUC*	*P(D)*	*A*	*K*	*P*	*Q*	*ΔTS*	*RC*	*NB*	*NPV*	*IRR*
1	1982	0.7	0.198	0.89	0.00	0.000	$600	8.18	$0	$24,730	-$24,730		
												In constant 1982	
2	1983	0.7	0.198	0.89	0.00	0.000	$600	8.18	$0	$25,310	-$25,310	**USD:**	
3	1984	0.7	0.198	0.89	0.00	0.000	$600	8.18	$0	$26,080	-$26,080	**$1,313,592**	**46%**
4	1985	0.7	0.198	0.89	0.00	0.000	$600	8.18	$0	$26,080	-$26,080		
												In constant 2006	
5	1986	0.7	0.198	0.89	0.0100	0.002	$600	8.18	$8,655	$26,400	-$17,745	**USD:**	
6	1987	0.7	0.198	0.89	0.0332	0.006	$600	8.18	$28,785	$26,480	$2,305	**2,742,362**	**46%**
7	1988	0.7	0.198	0.89	0.0982	0.017	$600	8.18	$85,480	$26,800	$58,680		
8	1989	0.7	0.198	0.89	0.2226	0.039	$600	8.18	$195,155	$27,200	$167,955		
9	1990	0.7	0.198	0.89	0.3484	0.061	$600	7.28	$273,983	$15,028	$258,955		
10	1991	0.7	0.198	0.89	0.4154	0.073	$600	7.19	$323,818	$22,294	$301,524		
11	1992	0.7	0.198	0.89	0.4396	0.077	$600	7.63	$364,465	$21,896	$342,569		
12	1993	0.7	0.198	0.89	0.4470	0.079	$600	8.11	$393,838	$29,116	$364,722		
13	1994	0.7	0.198	0.89	0.4491	0.079	$600	9.52	$464,757	$40,240	$424,516		
14	1995	0.7	0.198	0.89	0.4498	0.079	$600	9.35	$456,729	$34,700	$422,029		
15	1996	0.7	0.198	0.89	0.4499	0.079	$600	5.89	$288,101	$33,013	$255,088		
16	1997	0.7	0.198	0.89	0.4500	0.079	$600	6.01	$293,951	$33,267	$260,685		
17	1998	0.7	0.198	0.89	0.4500	0.079	$600	5.41	$264,715	$31,848	$232,867		
18	1999	0.7	0.198	0.89	0.4500	0.079	$600	5.19	$253,826	0	$253,826		
19	2000	0.7	0.198	0.89	0.4500	0.079	$600	4.98	$243,610	0	$243,610		
20	2001	0.7	0.198	0.89	0.4500	0.079	$600	5.64	$275,907	0	$275,907		
21	2002	0.7	0.198	0.89	0.4500	0.079	$600	5.17	$252,652	0	$252,652		
22	2003	0.7	0.198	0.89	0.4500	0.079	$600	10.20	$498,691	0	$498,691		
23	2004	0.7	0.198	0.89	0.4500	0.079	$600	9.97	$487,408	0	$487,408		
24	2005	0.7	0.198	0.89	0.4500	0.079	$600	16.78	$820,324	0	$820,324		
25	2006	0.7	0.198	0.89	0.4500	0.079	$600	16.78	$820,310	0	$820,310		

Table A.8.4: Baseline Scenario w/ All Research Costs for NPV and IRR Calculations, INIAP purple mottled varieties, 1988-2024

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Period	*Year*	*ε*	*ΔUC*	*P(D)*	*A*	*K*	*P*	*Q*	*ΔTS*	*RC*	*NB*	*NPV*	*IRR*
1	1998	0.7	0.184	0.64	0.00	0.000	$600	0.94	0	$31,848	-$31,848		
2	1999	0.7	0.184	0.64	0.00	0.000	$600	0.90	0	$27,963	-$27,963	**In constant 1982 USD:**	
3	2000	0.7	0.184	0.64	0.00	0.000	$600	0.87	0	$9,237	-$9,237	**$141,110**	**17%**
4	2001	0.7	0.184	0.64	0.00	0.000	$600	0.98	0	$15,615	-$15,615		
5	2002	0.7	0.184	0.64	0.00	0.000	$600	0.90	0	$17,579	-$17,579	**In constant 2006 USD:**	
6	2003	0.7	0.184	0.64	0.00	0.000	$600	1.77	0	$59,050	-$59,050	**$294,593**	**17%**
7	2004	0.7	0.184	0.64	0.01	0.001	$600	1.73	1,225	$78,246	-$77,021		
8	2005	0.7	0.184	0.64	0.03	0.004	$600	2.92	6,192	$0	$6,192		
9	2006	0.7	0.184	0.64	0.10	0.012	$600	2.92	20,698	$0	$20,698		
10	2007	0.7	0.184	0.64	0.22	0.026	$600	2.90	45,487	$0	$45,487		
11	2008	0.7	0.184	0.64	0.35	0.041	$600	2.90	72,750	$0	$72,750		
12	2009	0.7	0.184	0.64	0.42	0.049	$600	2.90	87,549	$0	$87,549		
13	2010	0.7	0.184	0.64	0.44	0.052	$600	2.90	91,792	$0	$91,792		
14	2011	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
15	2012	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
16	2013	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
17	2014	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
18	2015	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
19	2016	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
20	2017	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
21	2018	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
22	2019	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
23	2020	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
24	2021	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
25	2022	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
26	2023	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
27	2024	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		

Table A.8.5: Baseline Scenario w/ Purple Mottled Research Costs for NPV and IRR Calculations, INIAP purple mottled varieties, 1988-2024

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Period	*Year*	*ε*	*ΔUC*	*P(D)*	*A*	*K*	*P*	*Q*	*ΔTS*	*RC*	*NB*	*NPV*	*IRR*
1	1998	0.7	0.184	0.64	0.00	0.000	$600	0.94	0	$7,962	-$7,962		
2	1999	0.7	0.184	0.64	0.00	0.000	$600	0.90	0	$6,991	-$6,991	**In constant 1982 USD:**	
3	2000	0.7	0.184	0.64	0.00	0.000	$600	0.87	0	$2,309	-$2,309	**$256,660**	**34%**
4	2001	0.7	0.184	0.64	0.00	0.000	$600	0.98	0	$3,904	-$3,904		
5	2002	0.7	0.184	0.64	0.00	0.000	$600	0.90	0	$4,395	-$4,395	**In constant 2006 USD:**	
6	2003	0.7	0.184	0.64	0.00	0.000	$600	1.77	0	$14,763	-$14,763	**$535,825**	**34%**
7	2004	0.7	0.184	0.64	0.01	0.001	$600	1.73	1,225	$19,562	-$18,336		
8	2005	0.7	0.184	0.64	0.03	0.004	$600	2.92	6,192	$0	$6,192		
9	2006	0.7	0.184	0.64	0.10	0.012	$600	2.92	20,698	$0	$20,698		
10	2007	0.7	0.184	0.64	0.22	0.026	$600	2.90	45,487	$0	$45,487		
11	2008	0.7	0.184	0.64	0.35	0.041	$600	2.90	72,750	$0	$72,750		
12	2009	0.7	0.184	0.64	0.42	0.049	$600	2.90	87,549	$0	$87,549		
13	2010	0.7	0.184	0.64	0.44	0.052	$600	2.90	91,792	$0	$91,792		
14	2011	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
15	2012	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
16	2013	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
17	2014	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
18	2015	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
19	2016	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
20	2017	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
21	2018	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
22	2019	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
23	2020	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
24	2021	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
25	2022	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
26	2023	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		
27	2024	0.7	0.184	0.64	0.45	0.053	$600	2.90	93,916	$0	$93,916		