THE ECONOMIC IMPACT OF IMPROVED BEAN VARIETIES AND DETERMINANTS OF MARKET PARTICIPATION: EVIDENCE FROM LATIN AMERICA AND ANGOLA

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Agricultural, Food and Resource Economics

2012

ABSTRACT

THE ECONOMIC IMPACT OF IMPROVED BEAN VARIETIES AND DETERMINANTS OF MARKET PARTICIPATION:
EVIDENCE FROM LATIN AMERICA AND ANGOLA

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This dissertation consists of two essays. The first essay studies the economic impact of improved bean varieties (IVs) in Costa Rica, El Salvador, Honduras, Nicaragua, and Ecuador. In these countries, the National Agricultural Research Systems (NARS), in collaboration with private and public institutions, have actively generated and promoted IVs over the past 20 years. There are two types of yield gains derived from the use of IVs: Type I gains in areas where IVs replace traditional varieties, and Type II gains in areas where new IVs replace old IVs. Previous studies have only estimated Type I benefits in Honduras and northern Ecuador. This study estimated the Type II yield gains associated with varietal development of small red and red mottled bean varieties over time in Central America, Honduras, and northern Ecuador, using experimental yield data. Further, it provided estimates of current total adoption rates of IVs in each country, using bean expert opinions. The economic impact of bean IVs was estimated by combining the Type I and Type II yield gains. The results suggest that the Type II yield gains from small red varieties averaged 0.49% per year for Central American countries and 0.56% per year for Honduras. Similarly, the Type II yield gains from red mottled varieties averaged 1.68% per year for Ecuador. Breeders estimated that adoption rates for 2010 ranged from 46% in Honduras to 82% in Nicaragua. *Amadeus 77* was the most widely adopted small red IV in Central America and accounted for an estimated 49.7% of the total bean area. Similarly, *Portilla*, the most widely planted red mottled IV in northern Ecuador and accounted for an estimated 43%

of the red mottled bean area in northern Ecuador. *Ex post* benefit/cost analysis for the period 1991-2015 indicate that returns to investments in bean research have been negative in Costa Rica and positive in all other countries, with a regional net present value of $358 million and a regional IRR of 32%. The surplus per hectare per year was estimated at $74/ha/yr in the region.

The second essay studies the factors affecting farmers' marketing decisions in the rural highlands of Angola, focusing on potatoes, beans, and onions. This essay uses single equation ordinary least squares regressions for analysis of factors affecting production of potatoes, beans, and onions in the central highlands of Angola. Furthermore, it implements double hurdle (DH) regressions to study the factors associated with farmers' marketing decisions among potato, bean and onion growers, focusing on gender of the household head, asset ownership, and transaction costs, while controlling for potentially endogenous variables. The DH regression results suggest that the factors associated with marketing decisions depend on the crop analyzed and on whether marketing decisions are analyzed conditionally (i.e., probability of selling and, conditional on selling, quantity sold) or unconditionally (i.e., unconditional quantity sold). The results also suggest that boosting sales would be a challenge for the government of Angola, donors, and organizations working with farmers in this region since, due to Angola's strong currency, overcoming the limiting factors found in this study may require large financial and human resources.

Dedicated to Elena, Alexander, Adrián, our baby boy to be named, and to my parents Teresa and Alejandro

ACKNOWLEDGMENTS

I would like to thank my mentor and major professor, Richard Bernsten, for his extremely valuable comments and guidance provided during these past several years. I would also like to thank the feedback and assistance provided by the rest of my examination committee: Mywish Maredia, Cynthia Donovan, Eric Crawford, and James Kelly. I appreciate the assistance provided by the faculty and staff of the Department of Agricultural, Food, and Resource Economics at MSU, especially Songqing Jin, Debbie Conway, Janet Munn, and Nancy Creed. Especial thanks go to my friends and colleagues at MSU, especially Ricardo Hernandez, Alexandra Peralta, Nicky Mason, Wolfgang Pejuan, Sonja Perakis, Tim Komarek, Jake Ricker-Gilbert, and Guilherme Signorini. I am very grateful for the help provided by Juan Carlos Rosas from Zamorano's bean breeding program in Honduras, and by Eduardo Peralta from National Program on Food Legumes and Andean Grains' bean breeding program in Ecuador, during the fieldwork data collection and analysis. Furthermore, I'm also grateful for the help provided by key informants during my fieldwork in Honduras, El Salvador, Nicaragua, Costa Rica, and Ecuador. I'm very thankful for the assistance provided by PRORENDA staff in Angola, especially Deodato Guilherme and Sarah Grindle. While conducting this research, I was fortunate to receive the support of the Dry Grain Pulses Collaborative Research Support Program with funding from the United States Agency for International Development (Cooperative Agreement No. EDH-A-00-07-00005-00). Additional funding was provided by the Bill and Melinda Gates Foundation through its World Vision's ProRenda project, and by the Department of Agricultural, Food, and Resource Economics at MSU. Any opinions and errors are solely my own.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY TO ABBREVIATIONS

ACDI/VOCA	Agricultural Cooperative Development International / Volunteers in Overseas Cooperative Assistance
APE	Average Partial Effect
AY	Agricultural Year
B/C CRSP	Bean Cowpea Collaborative Research Support Program
bgm-1	Gene of resistance to BGYMV
BGYMV	Bean Golden Yellow Mosaic Virus
BNF	Biologic Nitrogen Fixation
BTE	Bean Time Equivalents
CAFTA	Central American Free Trade Agreement
CDF	Cumulative Distribution Function
CENTA	*Centro Nacional de Tecnología Agropecuaria y Forestal*, El Salvador
CIAL	Local Agricultural Research Committee
CIAT	International Center for Tropical Agriculture
CIDA	Canadian International Development Agency
COSUDE	Swiss Agency for Development and Cooperation
COVA	*Comprobación de Variedades*, a national nursery
CPI	Consumer Price Index
DGP CRSP	Dry Grain Pulses Collaborative Research Support Program
DH	Double-Hurdle
DICTA	*Dirección de Ciencia y Tecnología Agropecuaria*, Honduras
DNA	Deoxyribonucleic Acid
ECAR	*Ensayo Centroamericano de Adaptación y Rendimiento*, a regional nursery

ESPAC	*Encuesta de Superficie y Producción Agropecuaria Continua*, Ecuador
FAO	Food and Agriculture Organization
FC	Fixed Costs
Fi	Filial Generation *i*; *i*=1,2,…
FO	Farmer Organization
GARB	Gross Annual Research Benefits
GDP	Gross Domestic Product
IDA	Angolan Institute for Agrarian Development
IMR	Inverse Mills Ratio
INEC	*Instituto Nacional de Estadísticas y Censos*, Ecuador
INIAP	*Instituto Nacional Autónomo de Investigaciones Agropeciarias*, Ecuador
INTA	*Instituto Nicaragüense de Tecnología Agropecuaria*, Nicaragua
INTA-CR	*Instituto Nacional de Innovación y Transferencia en Tecnología*, Costa Rica
IRR	Internal Rate of Return
IV	Improved Variety
MINADER	*Ministério da Agricultura e do Desenvolvimento Rural*, the Ministry of Agriculture of Angola
MLE	Maximum Likelihood Estimator
MPLA	Popular Movement for the Liberation of Angola
MSU	Michigan State University
MT	Metric Tones
NARS	National Agricultural Research Systems
NGO	Non-Governmental Organization
NPV	Net Present Value
NSO	National Statistical Office, one for each country

OLS	Ordinary Least Squares
PE	Partial Effect
PIF	*Programa de Investigaciones en Frijol*, Zamorano, Honduras
PITTA-Frijol	Bean research network of Costa Rica
PPB	Participatory Plant Breeding
PROFRIJOL	*Programa Cooperativo Regional de Frijol para Centro América, México y El Caribe*
PRONALEG-GA	*Programa Nacional de Leguminosas y Granos Andinos*, Ecuador
PVS	Participatory Varietal Selection
R&D	Research and Development
SCARs	Sequence Characterized Amplified Regions
SIECA	Secretariat of Economic Integration of Central America
SIMPAH	Honduran Agricultural Price Information System
TLU	Tropical Livestock Units
TNR	Truncated Normal Regression
UNITA	National Union for the Total Independence of Angola
UPR	University of Puerto Rico
USAID	United States Agency for International Development
VC	Variable Costs
VIDAC	*Vivero de Adaptación Centroamericana*, a regional nursery
Zamorano	*Escuela Agrícola Panamericana*, Zamorano

CHAPTER ONE. INTRODUCTION

1.1 Introduction

The goal of any development project is to positively impact people's life (Maredia 2009). In agriculture, reducing poverty, hunger, and food insecurity is of primary interest. To achieve this, international donors and national governments support a wide range of projects that could assist producers. While many projects focus on generating new technologies (e.g. improved varieties) that offer farmers an opportunity to increase their output, agricultural income, and food security, other projects assist farmers during the production stage by providing technical assistance, access to inputs, etc., or during the post-harvest stage by providing technical assistance regarding storage techniques, better access to markets and information, or assisting farmers to add value to their products.

As agricultural research funding becomes increasingly scarce, the demand for impact assessment studies has increased (Alston *et al*. 2000a) because international donors and national governments must decide where to invest their money and efforts. This increased demand for impact assessment has led to a growing focus and emphasis on a more formal, systematic, and rigorous approach to assessing impacts (Maredia 2009). Although the literature on impact assessment is overwhelming (Feder *et al.* 1985) and most studies have demonstrated that returns to investments are high (Alston *et al*. 2000a), impact assessment studies are (and will be) an important and necessary tool to evaluate investments.

Similarly, studying the factors associated with farmers' decisions of whether to engage in marketing activities is important because these studies can provide valuable information about the constraints farmers' face to participate in markets and increase their agricultural income.

Donors and governments can use this information to efficiently allocate scarce resources into constraining areas to boost market participation and positively affect farmers' welfare.

This study focuses on two areas: (1) the economic impact of new bean varieties used by farmers as inputs in their production process in five countries of Latin America, and (2) studying the factors associated with farmers' marketing decisions in output markets in the Central Highlands of Angola.

To estimate the economic impact of new bean varieties in the region, *first*, experimental yield data were used to econometrically estimate the yield gains associated with the use of new improved bean varieties, compared to old improved bean varieties. This was done because of the time and financial limitations for collecting farm-level data in each country. Furthermore, since the breeding programs in the region continuously release new improved varieties (IVs), farmers can replace old IVs with new IVs and benefit from gains in yields (if any). Thus, the methodology implemented in this study only measures the economic impact derived from these gains. *Second*, key informants associated with the bean subsector were interviewed to collect information related to adoption rates of improved varieties (IVs), research costs, variety-specific information, etc. *Third*, additional data were collected from secondary sources.

Fourth, to evaluate the economic impact of new bean varieties in Latin America, economic surplus concepts were used. This methodology is commonly used to assess the impact of agricultural projects. Although several studies have evaluated the impact of bean research in the region in the past, there was a need to generate updated information, especially for Costa Rica, El Salvador, and Nicaragua, where no economic impact studies have been carried out to date. To assess the economic impact of bean research, the net present value (NPV) and the internal rate of return (IRR) were estimated for Honduras, El Salvador, Nicaragua, Costa Rica, and Ecuador for a base scenario. *Finally*, sensitivity analysis was conducted to evaluate the robustness of the results.

Since bean research programs in the region have received financial support from donors for several years, the information generated from this study can be used by donors to make decisions of whether financial support should be continued and/or which areas require additional work to augment the economic impact of bean research. Furthermore, government officials can use this information to generate policies targeted at increasing the benefits of bean research to farmers.

To study the factors associated with farmers' marketing decisions in Angola, *first*, household-level data were used to estimate factors influencing the production of potatoes, beans, and onions by ordinary least squares (OLS). The household-level data were collected by World Visions' ProRenda project staff in 2009 and included 40 communities across three provinces in the central highlands of Angola. *Second*, the residuals from these regressions were estimated. *Third*, for each crop, a double hurdle regression was estimated to determine which factors affect farmers' marketing decisions, while controlling for self-selection and potential endogeneity problems. *Fourth*, the average partial effects (APEs) of the variables of interest were estimated via bootstrapping. The APEs were used to measure the unconditional (on market participation) effect of the variables of interest on the total quantity sold.

The ProRenda project's main objective was to increase smallholders' income through the establishment of competitive value chains of several crops. Because of this, the sampling methodology implemented by this project was out of our control. This caused limitations in our analysis because the research questions included in the present study were not considered during the sampling and questionnaire development.

1.2 Objectives

The general objective of the study is to generate information that can be used by stakeholders to efficiently allocate resources as to maximize farmers' welfare from using new improved bean varieties in Latin America and from participating in output markets in Angola. Specifically, the study aims to:

1. Estimate the economic impact derived from smallholder farmers' use of improved bean varieties released between 1996 and 2010 in five countries of Latin America.
2. Determine the factors that affect smallholder farmers' marketing decisions in the potato, bean, and onion markets of rural Angola.

The document is divided into three chapters. **Chapter 2** presents information about the motivation and research questions, conceptual framework, data used, and results of the economic impact of new bean varieties in five countries of Latin America. **Chapter 3** presents information about the motivation and research questions, conceptual framework, data used, and results of the factors associated with smallholders' marketing decisions in rural Angola.

CHAPTER TWO. THE ECONOMIC IMPACT OF IMPROVED BEAN VARIETIES IN LATIN AMERICA: A SURPLUS ANALYSIS

2.1 Introduction

The most common approach for analyzing welfare effects of agricultural research in a partial-equilibrium framework is the use of economic surplus analysis (Alston *et al*. 1998). The economic surplus concept can be applied to *ex-ante* and/or *ex-post* evaluation of agricultural projects. Norton and Davis (1981) review the major research techniques used to evaluate returns to agricultural research. They found that *ex post* studies usually use (1) consumer and producer surplus analyses (i.e. average rates of return) and (2) production function analyses (i.e. marginal rates of return) to evaluate returns to agricultural research.

Griliches (1958) first used *ex-post* surplus analysis to estimate the realized social rate of return of private and public investments in research and development of hybrid corn in the US. Since then, hundreds of studies have reported measures of the returns to agricultural research and development (R&D). Alston *et al.* (2000a) assemble all the available evidence on the returns to investments in agricultural R&D for the period 1953-1999. The fact that they assembled 292 studies reporting a total of 1,886 rates of return estimates demonstrate how wide surplus concepts are used for impact evaluation of agricultural research.

Despite its wide use, the surplus approach has been criticized from several perspectives, including: its normativeness (what it should be vs. what is); its potential for measurement error (will surplus measures provide an accurate indicator of changes in social welfare?); the partial-welfare nature of the analysis (it ignores the complex interrelationships with other product and factor markets in the economy); the exclusion from the analysis of (a) externalities and free riders and (b) transaction costs and incomplete risk markets; and its policy irrelevance because (a) of the problems stated previously and (b) important assumptions and variables are usually not explained in the calculations (Alston *et al.* 1998).

However, some of these criticisms (e.g. exclusion of transaction costs and externalities, measurement errors) can be addressed, at least partially, by making refinements to the measure of benefits and costs (Alston *et al.* 1998). In addition, the policy relevance criticism could be tackled by clearly explaining the implications of the results (Alston *et al.* 1998).

There are several alternatives to using surplus analysis for impact evaluation. Alston *et al*. (1998) suggest the use of cost-benefit analysis (although this type of analysis is usually complementary to surplus analysis), econometric models (the most commonly used alternative), domestic resource costs models (with the appeal that they provide a simple measure of the social value of inputs used to generate a unit of net output valued at its true social value), and the congruence rule (where resources are invested in relation to the value of output they provide). However, it is very common to find a mix of methods in the literature. For example, Mather *et al*. (2003) used both econometric and surplus methods to estimate the economic impact of bean research in Honduras. More recently, Mooney (2007) followed a similar approach to estimate the economic impact of bean breeding investments in Ecuador. Both Mather *et al*. (2003) and Mooney (2007) estimated that investments in bean breeding were profitable, a very common finding across the literature.

Despite these criticisms, surplus analysis is a useful methodology because it is common used in all methods for estimating research benefits (Alston *et al.* 1998). This study uses both econometric and surplus concepts to estimate the economic impact of bean breeding research in four countries of Central America and one in South America.

The study focuses on Honduras, El Salvador, Nicaragua, Costa Rica, and northern Ecuador because the National Agricultural Research Systems (NARS) of these countries, in collaboration with private and public institutions, have actively generated and promoted improved bean varieties (IVs) over the past 20 years.[1]

Recent aggregate yield data show that yields have been variable over time (Figure 2.1). For the period of 1990-2009, yields averaged 581 kg/ha (CV[2]=0.20) in Costa Rica; 479 kg/ha (CV=0.33) in Ecuador;[3] 860 kg/ha (CV=0.11) in El Salvador; 717 kg/ha (CV=0.15) in Honduras; and 713 kg/ha (CV=0.12) in Nicaragua. Therefore, yields varied the most in Ecuador and Costa Rica, and were less variable in El Salvador and Nicaragua. In addition, while yields showed a slightly increasing trend in El Salvador, Nicaragua and Costa Rica, the yield trend is constant in Honduras and decreasing in Ecuador (Figure 2.1).

Although most of the variation in yields have been due to weather-related factors (KII, 2010a), the decreasing yield trend in Ecuador is because (1) INIAP's (the national research institute) food legume breeding program, *El Programa Nacional de Leguminosas y Granos Andinos* (PRONALEG-GA) primarily focuses on developing bush-type beans targeted for and adopted by farmers in the northern region[4] (KII, 2010a) and (2) FAOSTAT's dry-bean data does not distinguish between monocropped and intercropped beans, the latter type with lower yields.

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[1] Although Guatemala was initially considered for this study, due to the fact that no bean varieties were released between 1998 and 2009, it was not possible to estimate bean yield gains from breeding research (since no varieties were released). Thus, this country was excluded from the analysis.

[2] CV = coefficient of variation. Estimated by dividing the standard deviation by the mean.

[3] For Ecuador, FAOSTAT yield data combines monocropped and intercropped beans.

[4] Mainly the provinces of Carchi and Imbabura.

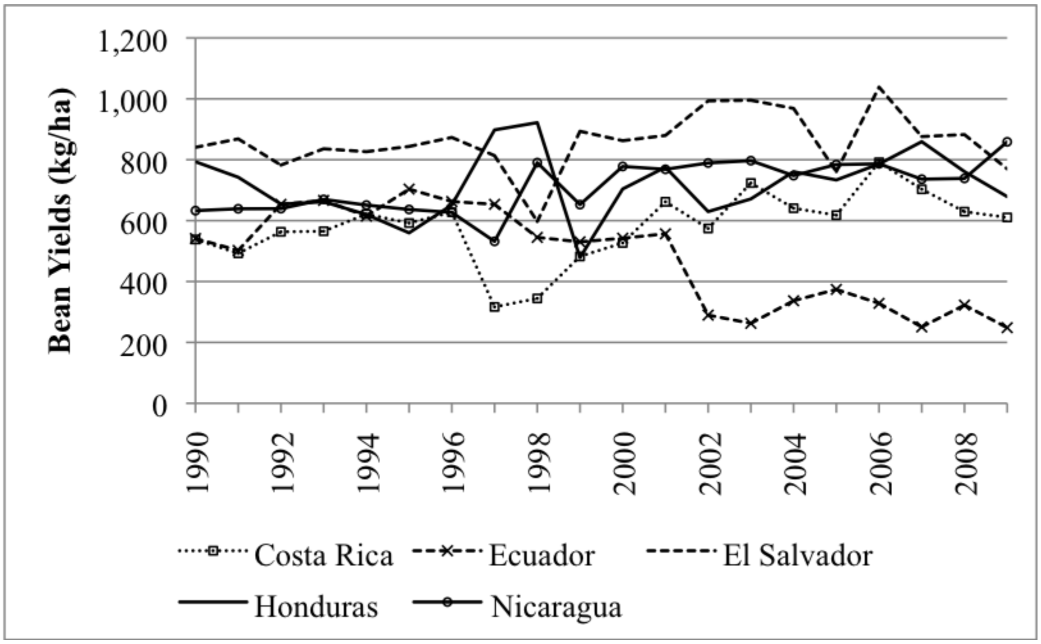

Figure 2.1. National bean yields (kg/ha) in Costa Rica, Ecuador, El Salvador, Honduras, and Nicaragua. FAOSTAT 1990-2009.

The national statistical institute of Ecuador (INEC)[5] reports detailed bean data since 2002. At the national level, INEC and FAOSTAT report the same yield levels for 2002-2009. However, dry bean yields for monocropped beans (estimated from INEC data) averaged 655 kg/ha and dry bean yields for intercropped beans averaged 194 kg/ha. This suggests that intercropped beans may be driving the low average national yields observed in Figure 2.1 for Ecuador. Although it is not clear why yields sharply declined after 2001, it is possible that this may be a medium-term negative effect of the country's 2000 dollarization, which reduced farmers' purchase power for inputs.

[5] The data is published annually in the Encuesta de Superficie y Producción Agropecuaria Continua, ESPAC.

The fact that the yield trend has been constant in some countries does not suggest that bean research has not had a positive effect on (aggregate) production. Morris and Heisey (2003) note that, over time, most successful crop breeding programs generate genetic gains in yields. However, genetic yield gains have two components: (a) increased yield potential, which is observable because yields are higher, and (b) increased biotic and abiotic stress resistance, which is aimed at avoiding losses from stresses (yields may not be higher; instead, losses are averted in the presence of stresses). Therefore, without bean research, it is possible that in these countries, yields could have been much lower. Because of this, it is important to empirically estimate whether improved bean varieties released over time show genetic yield gains and what has been the economic impact of investments in bean research in the past two decades.

2.2 Research Gap

Much of the returns-to-research literature has dealt with varietal improvement research (Pardey *et al*. 2006). In his pioneering work, Griliches (1958) estimated the realized social rate of return on public and private funds invested in hybrid-corn research. For this, he estimated the annual gross social returns[6] and subtracted the cost of producing hybrid seed to obtain an annual flow of net social returns. In addition, he estimated yearly private and public research expenditures. He then brought forward the net returns and expenditures to the year of interest (i.e. 1955) and estimated that at least 700 percent per year was earned (in 1955) on the average dollar invested in hybrid-corn research in the U.S..

Byerlee and Traxler (1995) used total economic surplus concepts to estimate the benefits of wheat improvement research. Although the concepts used were similar to the ones

[6] Also called the gross annual research benefits (GARB) by other authors.

implemented by Griliches (1958), they estimated IVs' yield advantage from (a) IVs replacing traditional varieties (TVs) and (b) new IVs replacing old IVs, by using experimental yield data. These authors found that the *ex post* rate of return of investments in wheat improvement research during the post-green revolution period was above 50%, and projected that the return on future investments would be between 37% and 48%.

Pardey *et al.* (2006) used examples of varietal improvement research in Brazil, focusing on rice, edible beans, and soybeans, to attribute the benefits of varietal improvements to different research institutions. They used the total gross annual research benefits (GARB) approach first implemented by Griliches (1958) for this purpose. Contrary to Griliches (1958), Pardey *et al*. (2006) used experimental yield data to generate indexes of varietal improvement to estimate the change in yield from the use of new crop varieties.[7] Furthermore, they used the last-cross rule and the geometric rule[8] to attribute the credit (of the benefits) to different research institutions. These authors found that, when the benefits are attributed to different institutions, the benefit-cost ratio fall from 78:1 when no distinction is made to 16:1 for the institution of interest (the Brazilian public research corporation *Embrapa* in their case).

In a similar fashion, Maredia *et al*. (2010) used the GARB approach to attribute the benefits of bean research to different research institutions in Michigan, U.S. Following Pardey *et al*. (2006), they used experimental yield data to estimate yield gain indexes from the use of IVs and attributed benefits to the different institutions working on bean research in Michigan. These

[7] While both Byerlee and Traxler (1995) and Pardey *et al.* (2006) used experimental yield data to estimate benefits, the former used total economic surplus analysis (instead of GARB).

[8] While the last-cross rule attributes all the credit to the breeder institution that produced the variety, the geometric rule attributes the credit to different institutions depending on the share of the genetic material coming from each institution in the variety.

authors found that bean research investments made by a public institution (Michigan State University in their case) generated benefit-cost ratios between 0.7:1 and 2.2:1.

Marasas *et al.* (2003) used net present value (NPV), internal rate of return (IRR), and benefit-cost ratios to estimate the economic impact of efforts made by the International Maize and Wheat Improvement Center (CIMMYT) to generate disease-resistant wheat varieties in developing countries. Their study differs from Byerlee and Traxler (1995) in that they estimated the benefits of research in terms of yield losses avoided with the use of IVs, instead of yield gains. These authors found that the *ex post* IRR of investments made to generate disease-resistant wheat varieties was 41% and that the benefit-cost ratio was 27:1.

In the countries of interest, several studies have been carried out to estimate adoption of improved varieties and the economic impact of varietal improvement research. Mather *et al*. (2003) used econometric methods to estimate adoption rates of bean IVs in two major bean-producing regions of Honduras and the yield loss averted from the use of bean IVs. They estimated that 41-46% of bean farmers had adopted IVs, planting them in 22-37% of the bean area.[9] Additionally, they found that IV adopters gained the equivalent of 7-16% in bean income from the yield loss averted through the use of IVs. These authors then used surplus concepts to estimate the profitability of bean research investments and found that the *ex post* internal rate of return to bean research was 41.2% (from 1984-2010).

Hernández and Elizondo (2006) used descriptive statistics to estimate adoption of IVs in one of the largest bean-producing regions of Costa Rica, the Brunca Region. They estimated that, in 2004, IVs were planted in approximately 70% of the bean area. Although these authors

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[9] The area planted to IVs varied by season and region.

provided detailed information about adoption rates, the study did not include an estimate of the economic benefits derived from adoption of IVs in Costa Rica.

Similar to Mather *et al*. (2003), Mooney (2007) used econometric and surplus analysis to estimate the impact of bean research in northern Ecuador. He estimated that, when diseases are present, IV adopters enjoy 40% higher yields and 20% lower per-unit production costs than non-adopters. Furthermore, he estimated that bean research investments (in red mottled beans) have an *ex post* internal rate of return of 29% (from 1982-2006).

In contrast, CENTA (2004) documented the advantages and disadvantages of one bean IV (*CENTA San Andrés*) developed by the breeding program of El Salvador. Although it reported detailed information about the characteristics of this variety and its acceptability (by farmers), the study did not include an analysis about the economic benefits from the use of this IV. Similarly, there are no studies that estimate the returns to bean improvement research in Nicaragua. Thus, estimating the economic impact of bean research investments in the countries of interest will provide valuable information that could be used by stakeholders. This study is a step in that direction.

Many studies use surplus methods to estimate the economic impact of agricultural research; however, they differ in the way they estimate the benefits of research. For example, while Griliches (1958), Byerlee and Traxler (1995), Pardey *et al.* (2006), and Maredia *et al*. (2010) estimate the benefits of agricultural research investments in terms of yield gains, Marasas *et al.* (2003), Mather *et al*. (2003) and Mooney (2007) estimate the benefits in terms of yield loss averted by the use of IVs.

Within the studies that estimate benefits in terms of yield gains, there are differences in the way these yield gains are estimated. While Griliches (1958) use experts' estimates, Byerlee and Traxler (1995), Pardey *et al.* (2006), and Maredia *et al*. (2010) use experimental data to estimate these gains. Similarly, there are differences in the way yield loss averted is estimated. While Marasas *et al.* (2003) use experimental data to estimate the yield loss averted by the use of IVs, Mather *et al*. (2003) and Mooney (2007) use a combination of farm-level data and experimental data to estimate these parameters. This study implements a combination of expert opinions and experimental yield data to estimate the economic benefits from the use of bean IVs.

As noted, several studies demonstrate that investments in bean breeding have been profitable. Despite this, it is necessary to generate additional and updated information about the economic benefits of bean research in the countries mentioned above. For countries such as El Salvador, Nicaragua and Costa Rica, this information will be useful for learning whether investments in bean improvement research have been profitable, since no such information currently exists.

The contribution of this study is two-fold. *First*, it provides estimates of adoption rates and yield gains of IVs released over time for four Central American countries and one South American country, using expert opinions and experimental yield data. *Second*, it estimates the economic impact of bean improvement research in these countries and provides policy recommendations based on these results.

Within the countries included in the study, several NARS collaborate to develop bean IVs, mostly using the same genetic materials to develop bean IVs.[10] Therefore, attributing benefits to each research institutions is not pursued in this study.

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[10] The exception is the Ecuadorian breeding program because it does not collaborate with NARS from the other countries included in this study. Although the International Center for Tropical Agriculture (CIAT) played an important role in the 1980s and 1990s, during the last decade its contribution has drastically decreased.

2.3 Research Questions

Although the study's main objective is to generate information about the economic impact of bean research in Latin America, it also attempts to answer the following research questions:

- What were the adoption rates of improved varieties in the 2009/2010 agricultural year and which IVs were most widely planted in each country?
- What is the cumulative adoption rate of IVs over time?
- What are the estimated yield gains from IVs released during the last decade?
- What is the economic effect of bean improvement research in the countries of interest?
- What policy recommendations can be provided based on these results?

2.4 Conceptual Framework

This section presents the economic rationale to estimate research benefits, costs and measure of project worth. Although the methodology is based in surplus concepts, the analysis is tailored to the situation faced in each of the five countries of interest.

2.4.1 Research Benefits

The rationale for the use of economic surplus models is straightforward and a large body of literature explains this topic (see for example Alston *et al.* 1998). Although the research-induced technical changes in the bean sub-sector could affect different sectors of the economy (e.g. labor markets), it is assumed that these secondary effects are exogenous and were not addressed in the analysis.

For each country, a small open economy surplus model was used (Alston *et al.* 1998). The assumption of an *open* economy is appropriate because the countries of interest trade (export and import) beans with each other and with other countries in the world. Similarly, the term *small* is fitting because the bean supply of each country does not influence international prices. While it is common that Central American countries trade beans freely[11] with each other, Ecuador's main bean-trade partner is Colombia, its northern neighbor.

In the small open economy set up (where quantity supplied does not affect world prices), the demand curve is perfectly elastic and all of the benefits accrue to producers because there is no research-induced reduction in price (Alston *et al.* 1998). Therefore, the change in total surplus (Δ *TS*) equals the change in producer surplus (Δ *PS*).

Following Maredia and Byerlee (2000), Mather *et al.* (2003) and Mooney (2007), it is assumed that the supply curve is linear and that its shift (due to technological change) is parallel. One potential problem of this assumption is that the benefits from a parallel shift may be overestimated (almost twice) if the supply shift is indeed pivotal (Alston *et al.* 1998). However, assuming parallel shifts is appropriate in this context because (a) previous studies have shown that adoption of IVs is scale-neutral (Mather *et al.* 2003) and (b) the production technology of bean producers is relatively homogeneous (Mooney 2007).

Figure 2.2 illustrates the economic benefits derived from the technological changes. Typically, the curves in Figure 2.2 are defined as annual flows (Alston *et al*. 1998). The original supply curve (before research investments) is represented by S_0 and the equilibrium price and quantity under this technology are represented by P_0 and Q_0, respectively. As farmers adopt the

[11] The Central American Free Trade Agreement (CAFTA) allows Central American countries to export and import beans freely.

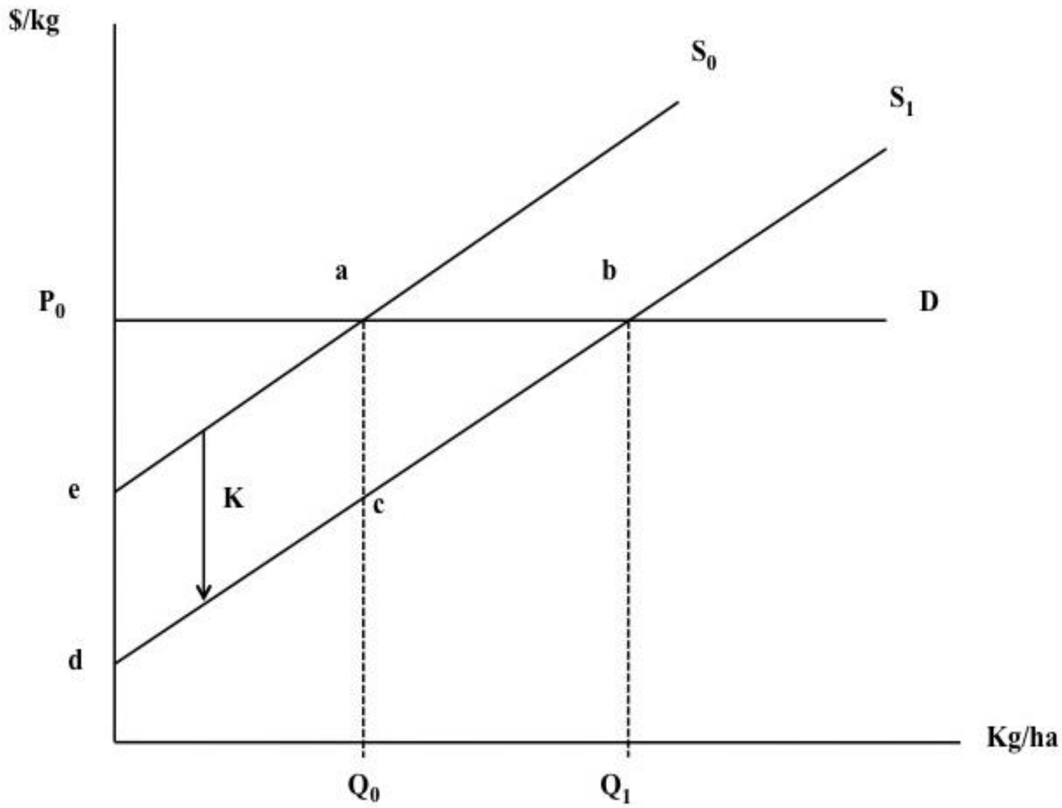

Figure 2.2. Research-induced supply shift in a small open economy set up.

new technology (i.e. IVs), the original supply curve shifts outwards to S_1 and the new equilibrium quantity shifts from Q_0 to Q_1. Given that the demand curve (*D*) is perfectly elastic, the price remains constant at P_0.

The total benefit from research-induced supply shift is equal to the area beneath the demand curve, *D*, and between the two supply curves, S_0 and S_1 (area *eabd* in Figure 2.2). This benefit is given by the sum of (a) the cost savings on the original quantity produced (area *eacd*) and (b) the economic surplus from incremental production (area *abc*) (Alston *et al*. 1998).

Empirically, in the case of a small open-economy, the formula for estimating research benefits from a parallel shift in the supply curve is given by:

(2.1) $$\Delta TS = \Delta PS = P0 \times Q0 \times Kt\,(1 + 0.5\,Kt\,\varepsilon)$$

where P_0 is the exogenous market price for beans, Q_0 is the initial quantity produced before bean research, K_t represents the shift in the supply curve for each year, and ε represents the supply elasticity (Alston *et al*. 1998).

The most critical variable in Equation (2.1) is the supply-shift parameter K_t (Maredia *et al.* 2010). This parameter can be estimated in different ways. For example, for each IV, Mather *et al.* (2003) estimated K_t by multiplying the change in net bean income due to yield loss (due to disease pressure) averted from adopting an IV by the adoption rate. Similarly, Mooney (2007) estimated K_t by multiplying the proportional change in unit cost (from IV adoption) by the probability of disease pressure and the cumulative adoption rate. These authors used experimental and farm-level data in their estimations.

In contrast, Byerlee and Traxler (1995), Pardey *et al.* (2006), and Maredia *et al*. (2010) used experimental yield data to estimate yield gains by generating yield gain indexes and then used this information to estimate the supply-shift parameter K_t. In this study, experimental yield data were used to estimate yield gains from new bean varieties released over time in the countries of interest. Thus, these gains reflect the gains obtained by farmers “with” bean research vs. “without” bean research during the period of evaluation. The supply-shift parameter K_t is represented by:

(2.2) $$K_t = A_t * k_t$$

where A_t is the share of the bean area planted to improved bean varieties in year t and k_t is the research-induced yield advantage of new bean varieties; that is, the yield gains from new IVs over old IVs. The methodology for estimating K_t is detailed below.

2.4.1.1 Estimation of Potential Genetic Yield Gains

There are two types of yield gains derived from the use of improved varieties: ***Type I***, which occurs in areas where improved varieties are replacing traditional varieties (i.e. new adopters of IVs), and ***Type II***, which occurs in areas where new improved varieties are replacing old improved varieties (i.e. current adopters replace old IVs with new IVs) (Byerlee and Traxler 1995). Although an ad-hoc estimation of *Type I* yield gains was conducted, the main focus of the study was on estimating *Type II* yield gains (explained below). Therefore, benefits from bean research shown in the base scenario may be underestimated.

Experimental yield data were used to estimate the *Type II* yield gains of the commercially successful bean varieties released to date in the countries of interest. The advantage of using experimental yield data is that most variables that influence yields are deliberately held constant; hence, the differences in yields reflect the effect of the variety *per se* (Pardey *et al*. 2006). The disadvantage of using experimental data is that experimental yields are usually higher than farmers' yields. However, Pardey *et al.* (2006) noted that using experimental yields may be appropriate because farmers' yields are affected by many factors (e.g. weather, change in relative price of inputs and outputs) and, although experimental treatments (e.g. fertilizer levels) may change over time and among locations, this variability is smaller than the variability of farmers' yields. Additionally, it is yield gains, not yield levels that are relevant in this study.

Following Maredia *et al*. (2010), for each country, the yields of variety i in location j and year t, Y_{ijt}, was estimated by least squares using the following regression model:

$$(2.3a) \qquad Y_{ijt} = \alpha + \sum_{t=1}^{T-1} \beta_t D_t + \sum_{i=1}^{I-1} \gamma_i D_i + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{r=1}^{R-1} \pi_r D_r + \mu_t$$

where D_t are the dummy variables for each year, D_i are the dummy variables for each variety included in the dataset (i.e. equal to one if Y_{ijt} corresponds to yields of variety i; zero otherwise), D_j are dummy variables for each location included in the dataset within each country r,[12] D_r are dummy variables for each country, u_t are error terms, and α, β_t, γ_i, δ_j, and π_r are the estimated coefficients.

The model in Equation (2.3a) can be estimated with a complete dataset. However, the dataset used in this study was not complete. That is, yield information for every variety for every location within a country and in every year was not available because the trials were not included in the same locations each year (Table A 2). Therefore, following Maredia *et al*. (2010), the model in Equation (2.3a) was modified to:

$$(2.3b) \qquad Y_{it} = \alpha + \sum_{t=1}^{T-1} \beta_t D_t + \sum_{i=1}^{I-1} \gamma_i D_i + \sum_{r=1}^{R-1} \pi_r D_r + \mu_t$$

where now Y_{it} is the yield of variety i (averaged across all locations within a country) in year t. Although averaging across locations does not allow us to estimate the effect of the genotype by environment interaction, each year the breeding programs usually use the same format (i.e. average yields across locations) to report their results; therefore, averaging yields across

[12] In Central America, the variety trials are evaluated in several locations across several countries. In Ecuador the trials are only evaluated within the country.

locations is plausible. For Ecuador, dummies for countries were not included because the trials are not conducted in other countries. Therefore, for Ecuador, Equation (2.3b) now becomes:

$$(2.3c) \qquad Y_{it} = \alpha + \sum_{t=1}^{T-1} \beta_t D_t + \sum_{i=1}^{I-1} \gamma_i D_i + \mu_t$$

Since the models in Equations (2.3b and 2.3c) were estimated with an intercept, and to avoid the “dummy” variable trap, one dummy variable for each year, each variety, and each country (except Ecuador) was dropped from the regression. Once the parameters were estimated, the fitted values ($\hat{Y}_{it}$) for the experimental yields of each variety for every year were computed. Using these (fitted) values provided more accurate estimates of the yield effect because they take into account the year effect on variety *i*; that is, they adjust the mean upwards or downwards to reflect the fact that variety *i* may have not been tested in high- or low- yielding years (Maredia *et al.* 2010).

The predicted yields from Equations (2.3b and 2.3c) were used to estimate the effect of a vintage variable V_i on yield gains, using the following simplified “vintage”[13] models (adapted from Maredia *et al.* 2010):

$$(2.4a) \qquad \ln(\hat{Y}_{it}) = \alpha + \sum_{t=1}^{T-1} \beta_t D_t + \sum_{r=1}^{R-1} \pi_r D_r + \lambda V_i + \mu_t \qquad \text{for Central America}$$

$$(2.4b) \qquad \ln(\hat{Y}_{it}) = \alpha + \sum_{t=1}^{T-1} \beta_t D_t + \lambda V_i + \mu_t \qquad \text{for Ecuador}$$

where V_i is the year in which variable *i* was released (e.g. 1996) and ln ($\hat{Y}_{it}$) is the natural log of the fitted values from Equation (2.3b) for the Central American data and from Equation (2.3c)

[13] The term vintage refers to the year when the variety was released. Thus, a vintage model is a model that includes the year of release as an explanatory variable.

for the Ecuadorian data.[14] Therefore, the relative (percent) per year yield increase is given by 100 dln $(\hat{Y}_{it})/dV_i = 100\,\lambda$.

Once the per year yield gain (λ) was estimated using Equations (2.4a and 2.4b), it was necessary to reflect the impact of these benefits on farmers who had adopted IVs. For this, the research-induced yield advantage was weighted by the yearly cumulative adoption rate of IVs.[15] Furthermore, the research-induced yield advantage was assumed to grow at a compound rate; i.e. $k_t = (1 + \lambda)^s$, where λ is the yield gains from new bean IVs obtained from Equation (2.4) and $s = (t - 1996)$. Therefore, research-induced Type II yield gains were given by:

(2.5) $$\mathrm{K}^{\mathrm{II}}_{\mathrm{t}} = \mathrm{A}_{\mathrm{t-1}} * [(1 + \lambda)^{\mathrm{s}} - 1]$$

where K^{II}_t measures the benefit from new bean IVs released over time and adopted by farmers who were already adopters in previous time period (A_{t-1}). Following Equation (2.1), the total Type II benefits from varietal improvement in country r at time t are given by:

(2.6) $$\text{Type II } \Delta PS_{rt} = P_{rt} \times Q_{rt} \times K^{II}_t (1 + 0.5\, K^{II}_t\, \varepsilon)$$

<u>*Type I*</u> benefits were estimated using available data from previous research conducted in the region. For this (ad-hoc) estimation, Equation (2.5) was modified to:

(2.7) $$K_t^I = \left(A_t - A_b\right) * k^I$$

where A_t is the adoption rate at time t, A_b is the adoption rate in the base year (i.e. 1996), and k^I is the yield gain associated with replacing traditional varieties with improved varieties, obtained

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[14] In practice, 2.4a and 2.4b are the same models, except for Ecuador, where there are no dummy variables for countries where the trials were conducted.

[15] Total adoption through time was estimated using the logistic diffusion curve (explained in Section 2.4.1.2 below).

from previous research and assumed to be constant through time. Following Equation (2.1), the total Type I benefits from varietal improvement in country *r* at time *t* are given by:

(2.8) $$\text{Type I } \Delta PS_{rt} = P_{rt} \times Q_{rt} \times K_t^I (1 + 0.5\, K_t^I\, \varepsilon)$$

Thus, Equation (2.8) assesses the economic benefit for farmers who replace their traditional varieties with improved varieties (i.e. new adopters). Following Byerlee and Traxler (1995), the total benefits from varietal improvement in country *r* at time *t* are given by the sum of Type I and Type II benefits; that is, the sum of Equations (2.6) and (2.8).

2.4.1.2 Total Adoption Rates

To estimate Equations (2.5) and (2.7), it was necessary to obtain estimations of adoption rates of IVs for each year. For this, a logistic diffusion curve was estimated for each country using total adoption rates of IVs at two points in time (i.e. 1996 and 2010). The logistic diffusion curves for each country *r* were estimated using the following formula (from Alston *et al*. 1998, pg. 357-358):

(2.9) $$A_{rt} = \frac{A_r^{MAX}}{1 + e^{-(\alpha_r + \beta_r * t)}}$$

where A_{rt} is the total adoption rate of IVs in country *r* and time *t* (i.e. observed adoption rates), A_r^{MAX} is the maximum adoption rate (adoption ceiling) in country *r*, and α_r and β_r are parameters that define the path of the adoption rate of IVs that asymptotically approaches its ceiling. The practicality of this formula is that the curve can be generated with as little as three parameters: A_r^{MAX}, α_r, and β_r.

The expression above can be rearranged and written as:

(2.10) $$\ln\left(\frac{A_{rt}}{A_r^{MAX} - A_{rt}}\right) = \alpha_r + \beta_r * t$$

From this equation, α_r, and β_r can easily be estimated because, for each country *r*, we know A_r^{MAX} and two combinations of A_{rt} and *t*.[16]

Although Equation (2.9) does not allow for the possibility of disadoption of the variety, this is not expected to be a problem because all current breeding programs are mature (i.e. constantly releasing new varieties); therefore, it is expected that cumulative adoption is increasing.[17]

2.4.2 Research Costs

Constructing the time-series data of research costs can be difficult and time consuming (Alston *et al*. 1998). Several considerations must be taken into account to accurately estimate research costs. *First*, one must define the duration and scope of the research that will be evaluated (Mooney 2007). *Second*, it is necessary to develop a clear understanding of the institutional history of the research project (Alston *et al*. 1998) in order to be able to collect accurate cost data.

Alston *et al*. (1998) indicate that there can be three possible sources of funding: the core funds (usually from the government and used to cover routine or core expenditures such as salaries, consumables, etc.); other government funds (used for non-core activities such as

[16] That is, Equation (2.10) needs to be estimated two times using: (1) adoption in the base year and (2) adoption at the time of the study. Then, these two equations can be set equal to each other to obtain α_r and β_r.

[17] As will be explained below, only in Costa Rica, adoption of IVs has decreased over time. This formula is still valid to estimate the decreasing adoption rate in this case.

publications, equipment, etc.) that usually are more volatile than the core funds; and donor funds and grants (from public or private institutions). In the countries of interest, most breeding programs receive core funds and some receive both core and donor funds. In this study, both core and donor funds were considered.

Additionally, all expenditures incurred prior to the research program were not considered because, as Belli *et al.* (2001) point out, costs incurred in the past are sunk costs that cannot be avoided; therefore, they should be (and were) ignored from the analysis. Furthermore, extension expenditures that would have been spent regardless of the current research program were also excluded from analysis. However, in two of the countries of interest (Honduras and Ecuador), the research programs provide financial and technical assistance to local agricultural research committees (CIAL),[18] which complement the work of plant breeders through participatory varietal selection and/or participatory plant breeding. For these countries, these costs were included.

Once the duration and scope of the research are defined, it is important to disaggregate costs in a way that only the costs of the project are reflected (i.e. costs are not overestimated). For example, a breeder may provide additional services that are not related to the research itself, such as teaching. Once the disaggregation categories have been specified, knowledgeable individuals (such as program leaders) can be asked to provide estimates of total program expenditures and the share of total expenditures devoted to the program of interest (Alston *et al*. 1998). In this study, this approach was followed.

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[18] A CIAL is a village-based farmer research group that, among other research activities, conducts varietal selection to develop new varieties (Ashby *et al*. 2000).

Finally, in agricultural research, it is common to observe a lag between commencing a research activity and generating the new technology (i.e. new varieties) (Alston *et al.* 1998).[19] It is assumed that this lag will be of six years because bean-breeding programs usually take five to seven years to develop and release a new bean variety, and multiply and distribute seed. During this period, only expenses are generated.

2.4.3 Measures of Project Worth

After the stream of program benefits and costs are estimated, it is necessary to estimate the returns to research in each country. For this, two economic measures were used: Net Present Value (NPV) and Internal Rate of Return (IRR). These measures are useful because they compress the annual flows of benefits and costs into a summary statistic by aggregating the flows over time, which allows comparison and evaluation of alternative investments (Alston *et al*. 1998).

The NPV is commonly used for *ex ante* research evaluation; however, in this study it was used to estimate *ex post* research benefits. NPV estimation combines the stream of program benefits and costs over the period of the research. The decision rule is simple: a program is profitable if NPV $\geq$ 0. A NPV greater than zero means that the initial investment plus the opportunity cost of capital are recovered (AEC-865 2008). The formula for calculating NPV is:

(2.11) $$NPV = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t}$$

[19] Lags are also observed between generating the new technology and seeing it adopted (Alston *et al*. 1998). However, the estimation of logistic adoption curves takes this into consideration.

where T is the total number of years under consideration, B_t is the calculated (from Equation (2.8)) value for annual research benefits in year t, C_t is the program cost in year t, and r is the discount rate. The numerator in Equation (2.11) is the net benefit.

The IRR is commonly used for *ex post* research evaluation. The decision rule is also simple: a program is profitable if the IRR is greater than the opportunity cost of capital. The IRR is estimated by setting the NPV from Equation (2.11) equal to zero and solving for r; that is:

$$(2.12) \qquad 0 = \sum_{t=1}^{T} \frac{B_t - C_t}{(1 + IRR)^t}$$

Therefore, the IRR is the rate of return that will make the present value of benefits equal to the present value of costs (Alston *et al*. 1998). The IRR is usually estimated by "trial and error," although available software easily does this.

Although useful and relatively easy to estimate, both NPV and IRR have their advantages and disadvantages (AEC-865 2008). Although NPV reflects the size of the investment (i.e. shows the absolute magnitude of incremental net benefits) and the decision rule is simple (i.e. a project is profitable when NPV $\geq$ 0), it requires explicit specification of the discount rate and implicitly assumes that profits are reinvested at a rate equal to the chosen discount rate. In contrast, the advantage of IRR is that it does not require knowledge of the exact opportunity cost of capital; however, it does not reflect the size of the investment. Although projects could be ranked by either NPV or IRR, NPV is usually preferred because it considers the size (i.e. magnitude) of the benefits and investments (Alston *et al*. 1998). In the literature, it is a common practice to estimate both economic measures of project worth. Therefore, in this study both measures were estimated.

Finally, it is worth mentioning that, when estimating NPV, the higher the discount rate, the less weight is placed on future benefits. Therefore, one must be careful in deciding what discount rate to use. Often, high discount rates are used when estimating NPV of programs located in developing countries (vs. programs in developed countries) because the risk of investing in developing countries is higher (AEC-865 2008). However, recent literature (Alston *et al*. 1998; Maredia *et al.* 2010) suggests using a lower (e.g. 3-5%) real discount rate (adjusted for inflation). Using real discount rates is especially common when evaluating the profitability of medium- to long-term, risk-free projects (Alston *et al*. 1998; Bazelon and Smetters 2001). In this study, a real discount rate of 4% (average of the range mentioned above) was used.

2.4.4 Sensitivity Analysis

Sensitivity analysis is commonly used to assess the robustness of the results (Alston *et al*. 1998). These authors point out that with this type of analysis, it is important to recognize the fact that the parameters are mutually dependent (e.g. adoption rates likely depend on yields). Therefore, varying each parameter and considering all combinations is not adequate. In this study, NPV and IRR were estimated for a *base scenario* in which breeders' estimations of adoption rates, econometric estimations of yield gains, and a 4% real discount rate (among other parameters) were used. To test the robustness of results, the NPV and IRR were also estimated using a 10% discount rate (as was used by Mather *et al*. 2003 and Mooney 2007). Thus, for the sensitivity analysis, the following parameters from the base scenario were modified as follow:

1. *Scenario A*: Type II yield gains and 2010 adoption rates were modified to reflect a +10% difference from the base scenario. All other parameters were held constant.

2. *Scenario B*: Type II yield gains and 2010 adoption rates were modified to reflect a -10% difference from the base scenario. All other parameters were held constant.

Finally, the minimum Type II yield gains and 2010 adoption rates needed to recover investment (i.e. when NPV=0, or break even values) were estimated separately (e.g. Type II yield gains were changed until NPV=0, while holding all other variables constant).

2.5 Data Description

The data used in this study were obtained from different sources, including: experimental trials yield data, expert opinion estimates, secondary sources, and parameters from previous studies conducted in the region. The experimental yield data was obtained from the following bean breeding programs: (1) the *Programa de Investigaciones en Frijol* (PIF) of Zamorano in Honduras and (2) the *Programa Nacional de Leguminosas y Granos Andinos* (PRONALEG-GA) in Ecuador. Before explaining the data, it is important to provide general information about the breeding process in the countries of interest. For this, *first*, the breeding programs of Central America[20] and Ecuador are described. *Second*, a review of the outcomes of these programs during the past two decades is provided. *Finally*, the data used to estimate benefits and costs are described.

[20] Which include Honduras, Guatemala, El Salvador, Nicaragua and Costa Rica. Although Guatemala is excluded from the analysis, it has collaborated in testing lines in the last decade.

2.5.1 Bean Research Programs

<u>Central America</u>[21]

Profrijol, a regional bean research network established in 1981 by CIAT and supported by the Swiss Agency for Development and Cooperation (COSUDE) was the only bean research network conducting bean research in Central America during the 1980s and 1990s. This network included researchers from the national agricultural research systems (NARS) of Mexico, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, and the Caribbean countries of Haiti, the Dominican Republic, Cuba, and Puerto Rico (Rosas 2010a). During this period, Zamorano, a private university located in Honduras, had little participation in this network because only NARS conducted research to generate new varieties.

In 1983, the Bean/Cowpea Collaborative Research Support Program (B/C CRSP) became involved in bean research in the region; however, its impact was small. In 1990, although Zamorano and the University of Puerto Rico (UPR) began participating in *Profrijol*, they did not generate breeding materials through crosses.[22] In addition, these institutions received only limited funding from *Profrijol* (Rosas 2010a).

In 1996 Zamorano, using funds from the B/C CRSP and *Profrijol*, was given a mandate to lead efforts to breed small red beans for the region.[23] In 1999, Zamorano also became responsible for breeding small black beans for Central America (mostly for Guatemala). In 2002, COSUDE's funding to *Profrijol* ended and CIAT's participation in the region was drastically

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[21] The information in this section comes from Rosas (2010a).

[22] These institutions were in charge of selecting bean varieties with heat tolerance and biologic nitrogen fixation (BNF) properties only.

[23] In the same year, UPR took the lead of the breeding process of Andean beans for Panama and the Caribbean region.

reduced (Rosas 2010a). However, given that the network (established with *Profrijol*) provided a great advantage for testing and disseminating breeding materials, *Profrijol* members continued to collaborate and the B/C CRSP became the major supporter of this (now informal) network (Rosas 2010a).[24] Since then, Zamorano's bean program has provided leadership to the region's bean research network, which currently includes NARS from Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Puerto Rico, and Haiti.

In 2004, CIAT, in collaboration with this regional network, implemented *Agrosalud*,[25] a biofortification research project designed to benefit Central American and Caribbean (Cuba and Haiti) countries through the development, promotion, and dissemination of biofortified crops (including beans). By 2007, the Dry Grain Pulses CRSP (follow up to the B/C CRSP) unofficially became the major supporter of the regional network through funds provided to Zamorano (Rosas 2010a).

One of the major contributions of *Profrijol* was the establishment of regional bean nurseries (or trials) in which lines from different breeding programs were put together in nurseries that were distributed to collaborators for testing. These nurseries generated information needed to select materials[26] adapted to a wide range of environments. Currently, Zamorano's bean program is responsible for supplying breeding material which is included in nurseries throughout the region, including: VIDAC (Central American Adaptation Nursery) and ECAR (Central American Adaptation and Yield Trial).

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[24] Although the B/C CRSP never provided funds directly to *Profrijol*, it provided funds to Zamorano's breeding program. Therefore, it has indirectly supported the bean network because Zamorano's bean breeding materials are used by NARS throughout the region.

[25] This project is coordinated by CIAT and funded by the Canadian International Development Agency (CIDA).

[26] The words "materials" and "lines" are used interchangeable in this document.

Figure 2.3 illustrates the sequence of steps required to generate a new bean variety in Central America. As the figure illustrates, Zamorano's bean program makes crosses and puts together the regional nurseries of homogeneous materials that are distributed to collaborators. These nurseries also contain materials from CIAT and UPR (Rosas 2010a).

From the regional nurseries, the NARS select materials to include in their own national nurseries.[27] Over the breeding process, while the number of lines decreases in each nursery, the plot size per line increases. These (regional and national) nurseries are used to select material that is used to develop new bean varieties.

[27] Sometimes, a particular program (from other country) requests Zamorano to make crosses of specific lines that they want to improve. After the crosses are made, Zamorano sends segregating lines to that particular program for breeding. This case is not illustrated in Figure 2.3.

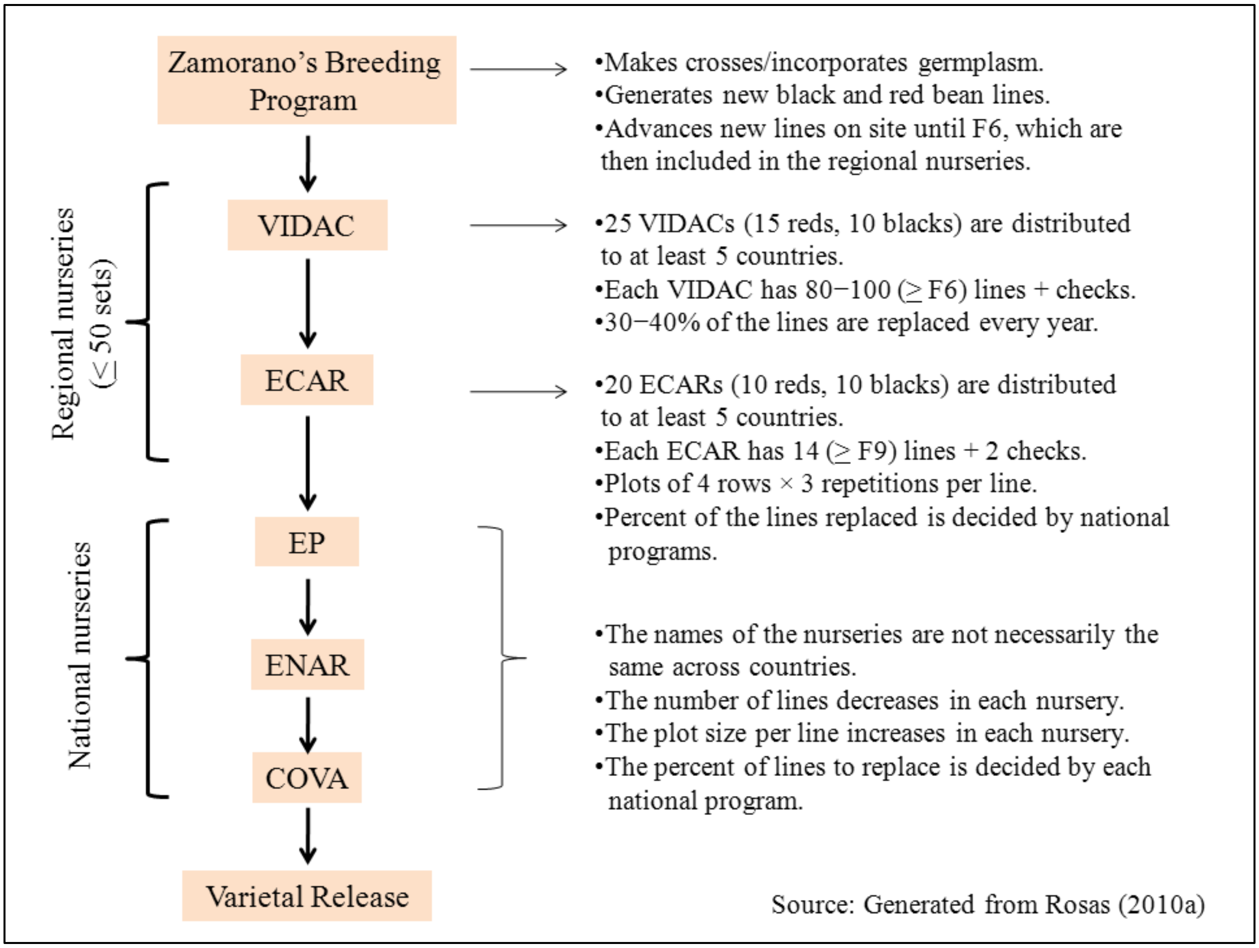

Figure 2.3. Flow of breeding materials in the regional and national nurseries in Central America. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

One key step is that, together with the regional nurseries, Zamorano provides a spreadsheet for NARS to collect data from these trials and a copy of the data is returned to Zamorano for further analysis. Each year, approximately 50% of the datasets (i.e. half the number of nurseries) are returned to Zamorano. Zamorano uses the information from the regional nurseries to select the best materials until a variety is released. Without this collaboration, testing lines would be limited and more expensive (Rosas 2010a).

Ecuador

Ecuador's national program on food legumes and Andean grains, *El Programa Nacional de Leguminosas y Granos Andinos* (PRONALEG-GA) is in charge of conducting bean-breeding activities in the country. PRONALEG-GA is located at the Santa Catalina Research Station in Quito, Ecuador and is part of the country's national agricultural research institute, *El Instituto Nacional Autónomo de Investigaciones Agropecuarias* (INIAP). PRONALEG-GA consolidated its activities in 1990 and, since 1994 it has supported other experimental stations throughout the country (INIAP 2009).

In the 1990s, the PRONALEG-GA program collaborated with *Profriza*, an Andean bean research network established by CIAT and supported by COSUDE.[28] During this period, PRONALEG-GA depended on CIAT to generate new varieties (i.e. no crosses were made in Ecuador). Although PREDUZA, a Dutch organization provided funding to PRONALEG-GA from 2000-2004 (Mooney 2007), since 2003, the CRSP has been the major external supporter of bean research in Ecuador. Through this collaboration, PRONALEG-GA has been able to make its own bean crosses, which has reduced its germplasm-dependence on other institutions (Peralta 2010).

Although several bean varieties were released prior 1990, the varieties that have had the largest impact were developed post 1990. In addition, in 2000 PRONALEG-GA implemented participatory research methods to develop and disseminate new varieties (INIAP 2009). Although farmers are involved in the breeding process, segregating materials are evaluated at the Santa Catalina Research Station.

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[28] *Profriza* was established following the Central American model of *Profrijol*. Both programs were coordinated by CIAT and supported by COSUDE.

Although most of its research is done on bush-type beans, the PRONALEG-GA program also conducts research on climbing beans and other legumes. Currently, PRONALEG-GA collaborates with international institutions (e.g. CIAT, Michigan State University), and with local NGOs and local farmers groups (CIALs). Its current collaboration with Michigan State University (MSU) has allowed it to supply black and red mottled bean lines to Rwanda's bean program, the first time that this program has supplied materials to another continent (KII, 2010a).

PRONALEG-GA has three main nurseries for testing advanced lines: (1) *Prueba*, (2) *Comprobación* and (3) *Producción*. These nurseries generally include different market classes and are tested in different locations under farmer conditions. Similar to the Central American case, while the number of lines decrease from one nursery to another, the plot size per line increases. The *Producción* nursery is the last step before releasing a variety.

Participatory Research: Participatory plant breeding (PPB) vs. participatory varietal selection (PVS)

Participatory research is a methodology through which farmers are involved in the breeding process by providing them with either early or late generation materials to select from (Ceccarelli *et al.*, 2000). In principle, farmers can be provided with a set of segregating (i.e. >F3)[29] or homogeneous (i.e. >F6) materials to select from and, assisted by scientists, release a variety. There are two major types of participatory research: participatory plant breeding (PPB) and participatory varietal selection (PVS). While PPB is the process where farmers are given a set of segregating materials to select from, PVS is the process where farmers are given a set of homogeneous materials to select from (Ceccarelli *et al.*, 2000).

[29] In the breeding literature, *Fi* is the *ith* generation after crosses were made. Thus, F3 is the third generation, etc.

Within the countries of interest, all countries are currently implementing participatory breeding approaches (KII, 2010a). However, only in Honduras, Nicaragua, Costa Rica and Ecuador, have new bean varieties been released using this approach. While participatory breeding was implemented in 2006 in El Salvador, no bean varieties have yet been released using this methodology (KII 2010a). Furthermore, this methodology is implemented differently across countries. The major differences lie in the degree of farmer participation (i.e. PPB vs. PVS) and the type of group of farmers included in the process. In Costa Rica, Ecuador, El Salvador, and Nicaragua, farmers participate in the breeding process by evaluating and selecting advanced (i.e. >F6) materials.[30] In contrast, in Honduras, farmers evaluate both segregating (i.e. >F3) and advanced (i.e. >F6) materials.[31]

Regarding the types of group of farmers participating in plant breeding, in Honduras and Ecuador, the process is implemented in collaboration with farmers organized in CIALs. In contrast, in Costa Rica, El Salvador, and Nicaragua, this process is implemented with farmers organized in cooperatives or associations. The major difference between the CIALs and the cooperatives is that the former are smaller groups of farmers set up to conduct research locally and are usually located in niche (marginal) environments.

2.5.2 Bean Varieties Released between 1990-2010

Between 1990 and 2010, a total of 90 bean varieties (all market classes) were released in the five countries of interest. However, some of the varieties released in Central America were

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[30] However, in Costa Rica and Ecuador, farmers sometimes evaluate segregating materials at experimental stations.

[31] The farmers' group implements either PPB or PVS. That is, the same group does not implement both methods at the same time.

released in several countries, usually with a different name in each country. The varieties released in more than one country are: *Dorado* and *Amadeus 77* (four countries each), *Tío Canela 75* (three countries), and *Deorho*, *Carrizalito*, *DOR 390* and *Don Silvio* (two countries each). Hence, 78 unique varieties were released in all five countries. From these, most varieties were small reds or reds (46 of 78), followed by red mottled (10 of 78), and blacks (7 of 78). Furthermore, at least 44 of the 78 varieties were developed using (direct or indirect) CRSP funding (Table A 2.2-Table A 2.6).

In Costa Rica, as many as 18 improved bean varieties have been released in the last two decades, 56% of them since 2000. The PITTA-Frijol network released all of these varieties. From these varieties, three have *Tío Canela 75* (Line ID: MD 3075), a variety released in Honduras in 1996 with resistance to BGYMV, as a parent. Surprisingly, although black beans are most widely consumed in Costa Rica, the last black variety was released in 2000 (UCR 55) and it was not widely adopted (Table A 2.2).

In El Salvador, only nine improved varieties have been released in the last two decades, five since 2000. Furthermore, all varieties released over the past 20 years are small red varieties and were released by CENTA, the national center in charge of bean research (Table A 2.3). Five of the nine varieties were developed using indirect funding provided by the CRSP (through germplasm provided by Zamorano), all five in the last decade.

In Honduras, as of 2010, 21 bean IVs have been released in the last two decades, 76% in the last decade and 57% (12 out of 21 IVs) were developed using participatory methods (Table A 2.4). From these varieties, four have *Amadeus 77* germplasm (Line ID: EAP 9510-77), a variety released in the country in 2003, which is resistant to BGYMV and has a light red seed color, as a parent. *Amadeus 77* was developed using *Tío Canela 75* as one of its parents. Moreover, three other varieties had *Tío Canela 75* as a parent, which brings the total number of varieties with genetic share of *Tío Canela 75* to eight. Similar to El Salvador, all varieties released to date are small reds. In addition, 81% of the varieties released over the last 20 years were developed using CRSP funding. Three institutions supported the development of varieties using participatory methods: CIALs, NGOs assisting farmers, and Zamorano.

In Nicaragua, 16 bean IVs have been released in the last two decades, less than half were released since 2000 and all varieties were developed using participatory methods (Table A 2.5). Three of these varieties have *Tío Canela 75* as one of its parents. In Nicaragua, most varieties released to date are small reds. Although most varieties were released by INTA, one of these varieties (INTA Pueblo Nuevo JM) was released in collaboration with CIPRES, an NGO.

Among all of the countries, Ecuador has released the highest number of bean varieties in the past two decades--26 varieties in total. From these, 17 varieties were developed using direct CRSP funding, 16 varieties were released in the last decade, and 12 varieties were developed through participatory methods (Table A 2.6). Although the CRSP is currently the main external supporter of this program, CIAT played an important role in the 1990s, when it was the main supplier of germplasm to the program.[32] In contrast to all other countries, PRONALEG-GA's efforts have focused on developing varieties of several market classes (Table A 2.6). However, the three main market classes are: red mottle (38% of varieties belong to this market class), yellow (23% of varieties) and white (12%). Furthermore, both INIAP and CIAL groups are credited with the release of most varieties developed through participatory breeding, with the exception of *Canario Guarandeño*, *Libertador*, and *Canario Siete Colinas*, credited only to INIAP.

[32] For example, *Paragachi Andino*, released in 2009, came from a CIAT cross.

2.5.3 Research Benefits

In order to estimate the value of research benefits, yield gains and adoption rates were needed. The data used to estimate these parameters are explained below.

2.5.3.1 Estimating Yield Gains

There are two types of yield gains derived from adopting IVs: Type I, in areas where farmers replace traditional varieties with IVs, and Type II in areas where farmers replace old IVs with new IVs. Type I gains were obtained from previous studies and are detailed in section 2.6.4. To estimate Type II gains from new bean varieties released through time (i.e. Equations 2.3b, 2.3c, 2.4a and 2.4b), experimental yield data were used. The rest of this sub-section explains the Central American and Ecuadorian data used for estimations of Type II yield gains and the market classes analyzed.

Central America

As explained above, the experimental yield data were obtained from Zamorano's bean breeding program. These data were used to estimate λ for red beans.[33] There were two nurseries from which data could be drawn: VIDAC and ECAR. The ECAR data were used because it had an adequate number of observations (not as many as the VIDAC), it had three repetitions per line evaluated (vs. no repetitions in the VIDAC), and it was planted in several countries each year (Table A 2.1).

Although the ECAR nursery has been implemented since the 1990s, data on red varieties were only available for the period 1999-2009. The ECAR included 14 advanced lines plus one local check (usually a traditional variety) plus one universal check (Dorado, one of the first IVs

[33] Although there is a similar nursery for black beans, it was not possible to estimate λ for this market class because none of the few black varieties released were in the dataset (since they were released in 2001 or before, thus they likely were evaluated before 1999).

released in the region), for a total of 16 lines per nursery. Each of the (16) lines had three repetitions (Table A 2.1). The data were averaged across repetitions. Although the trial dataset contained information for other countries outside the region of interest, only information from Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua was used in the analysis since we were interested in the effect of IVs in this region.[34]

On average, the ECAR nursery was planted in six locations across four Central American countries each year (Table A 2.1). The data were averaged across locations to obtain one yield observation per country per year. As explained above, this would control for the fact that in some years, the trial was not planted in every location. Thus, the data used reflected average yields at the country level.

Although many varieties were released in the last decade in the region, the ECAR dataset did not contain yield information for all varieties. Table 2.1 summarizes which varieties were included in the dataset. As expected, data for varieties released in Honduras were included the most. In contrast, the dataset contained information for only two of the varieties released in Nicaragua, for example.

Ecuador

Similar to Central America, there were three nurseries from which data could be drawn for the analysis: *Prueba*, *Comprobación* and *Producción*. The *Prueba* data were used because of similar reasons to the ones stated above: the number of lines was large, there were several repetitions per nursery (although the repetitions were in different locations, not in the same location), and it was the most common nursery for which information was available.

[34] Although Guatemala is not included in the study, the trial data from this country was included in the dataset because of its proximity with El Salvador and Honduras and to increase the number of observations.

Table 2.1. Red bean varieties included in the red ECAR trial data. Zamorano, Honduras, 1999-2009.

Year of release [1]	Country(ies) where released [2]	Variety Name	Line ID in trial data
1989, 1990, 1992, 1992, 1993	ES, HND, GUA, CR, NIC	Dorado	DOR 364
2002, 2002, 2003, 2003	ES, NIC, HND, CR	Amadeus 77	EAP 9510-77
2003	HND	Cedron	PTC 9557-10
2003	HND	Cayetana 85	PRF 9653-16B-2A
2003, 2004	HND, CR	Carrizalito	EAP 9510-1
2005	ES	CENTA Pipil	PRF 9653-16B-3
2007	HND	Don Cristobal	SRC 1-12-1-8
2007	CR	Tongibe	BCH 9901-14
2007	HND	Cardenal	MER 2226-41
2007, 2008	HND, ES	Deorho	SRC 2-18-1
2008	ES	CENTA C.P.C.	PPB 11-20-MC
2009	HND	Briyo AM	IBC 306-95
2009	HND	La Majada	IBC 301-182

Source: Programa de Investigaciones en Frijol Metadata, Zamorano, Honduras.
[1] When more than one year of release, the first year corresponds to the first country listed in the column to the right; the second year corresponds to the second country, etc.
[2] CR = Costa Rica; ES = El Salvador; GUA = Guatemala, HND = Honduras; NIC = Nicaragua.

This dataset contained information for the period 2003-2010. It included an average of 13 advanced lines plus several checks (Table A 2.1) that were not included in the dataset because these were different for each market class and these varied across locations and years. As with the Central American dataset, the data were averaged across repetitions (when available) and across locations.

In contrast to Central America, this nursery was planted in the same location for 1-2 years. This was because, once farmers tested the *Prueba* trial for one or two seasons, they selected the best lines and advanced them to the next nursery (i.e. *Comprobación*) and they did not plant the prior nursery until a new breeding cycle began (generally several years later).

Similar to the Central American case, although many varieties have been released in the last decade, the dataset did not contain yield information for all varieties. Table 2.2 summarizes which varieties were included in the dataset. As expected, data for red mottled varieties were the most common. Therefore, due to limitations in the number of observations, λ was estimated only for red mottled bean varieties developed by Ecuador's breeding program. Thus, Equation (2.4) was estimated for (a) small red bean varieties in Central America and (b) red mottled bean varieties in Ecuador.

Table 2.2. Improved bean varieties included in the PRUEBA trial data. PRONALEG-GA / INIAP, Ecuador, 2003-2010.

Year of release	Variety ID	Variety Name[1]	Market Class	Line ID in trial data
1996	I427	Blanco Imbabura	White	Blanco Imbabura
2003	I422	Blanco Belen	White	I-Blanco Belen
2003	I423	Canario	Yellow	I423 Canario
2004	I414	Yunguilla	Red mottled	I414 Yunguilla
2004	I424	La Concepcion	Purple mottled	I424 Concepcion
2004	I424	La Concepcion	Purple mottled	MIL UNO
2004	I425	Blanco Fanesquero	White	ABE4
2004	I425	Blanco Fanesquero	White	I-Blanco Fanesquero
2005	I420	Canario del Chota	Yellow	ACE1
2005	I420	Canario del Chota	Yellow	I420 Canario del Chota
2007	I427	Libertador	Red mottled	I-Libertador
2007	I428	Canario Guarandeno	Yellow	I-Guarandeno
2009	I429	Paragachi Andino	Red mottled	AND 1005
2009	I429	Paragachi Andino	Red mottled	I429 Paragachi Andino
2009	I430	Portilla	Red mottled	I430 Portilla
2009	I430	Portilla	Red mottled	Yunguilla X Mil Uno, S23
2009	I480	Rocha	Yellow	ACE1 x (Cocacho x San Antonio) s26 p1
2009	I480	Rocha	Yellow	I480 Rocha
2010	I481	Rojo del Valle	Red mottled	TP6
2010	I482	Afroandino	Black	A55
2011	I483	InTag	Purple mottled	(Concepcion x (G916 x Concepcion))-1

Source: INIAP/PRONALEG-GA Metadata, Ecuador.

[1] Sometimes two names shown because the variety had two line IDs. Thus, information in the last column refers to the same variety.

2.5.3.2 Estimating Adoption Rates

In order to estimate the logistic diffusion curves for IVs for each country, three parameters were needed: (1) the current adoption rates, A_t, (2) the base year adoption rates, A_b, and (3) the maximum adoption rates, A^{MAX}.

(1) *Current adoption rates of IVs, A_t*. The current total (i.e. for all IVs) adoption rates were obtained from estimations provided by bean breeders in each country. Breeders generally estimate adoption rates taking into consideration farmers' re-use of grain as seed and parameters from previous studies. Although Maredia *et al*. (2010) used bean seed sales data to estimate adoption rates in Michigan, U.S., this approach was not appropriate in the Latin American context since most farmers do not purchase seed.

Current adoption rates reflect 2010 levels of adoption of IVs in each country, for which bean breeders were asked to estimate adoption rates of IVs in 2010. In most countries of Central America farmers grow only one market class. Thus, the adoption rates reflect the same market class. However, in Costa Rica and Ecuador, farmers plant several market classes. Therefore, in these two countries, experts were asked to specify the share of adoption of IVs to each market class.

In addition, in Ecuador both bush and climbing beans are produced. Since our interest is only on bush beans, climbing bean estimations of adoption were not collected.[35] Furthermore, the analysis only focused on the northern provinces of Carchi and Imbabura since this is where most of PRONALEG-GA's legume breeding effort is targeted. Thus, adoption rates only refer to adoption of bush beans in northern Ecuador.

Although seed distribution/sales data were collected, these data were used only to demonstrate the strength of the seed systems in each country. Seed data suggest that the seed systems may be stronger in Central America than in Ecuador (Table A 2.7). However, in all Central American countries with the exception of Costa Rica, governments have implemented

[35] This may underestimate the economic benefit from bean research in Ecuador since a few improved climbing beans were released by PRONALEG-GA.

programs that distribute free or subsidized seed to farmers. Therefore, the apparent strong seed system in these countries highly depends on the continuity of the government-funded seed programs. Key informants related to the bean subsector suggested that without these government programs, seed production will most likely drastically decline because (a) most farmers do not purchase seed and (b) the estimated market price of the seed distributed by these programs (if it were sold at full price) is too high (KII 2010a; KII 2010c; KII 2010d).

(2) *Base year adoption rates of IVs*, A_b. To estimate the diffusion curve, the adoption rates for 1996 were obtained from previous research conducted in the region. The year 1996 was used as the base year because, in most countries, many new varieties were released after this year. The adoption rates for 1996 and 2010 were used together to estimate the diffusion curves (i.e. total adoption rates over time) for all countries.

(3) *Maximum adoption rate of IVs*, A^{MAX}. Since most bean programs are mature, it is expected that 2010 adoption rates are approaching the maximum levels of adoption. Thus, it was assumed that the maximum adoption rate is two percentage points above the current adoption rate.[36] Given that many breeders reported high adoption rates, this assumption is reasonable.

These three parameters of adoption rates provided the setting to evaluate the economic effect of bean IVs under bean breeders' estimations of adoption, referred to as the '*base scenario*' from now on. For *Scenarios A* and *B* in the sensitivity analysis, while the adoption rates for 2010 (hence maximum adoption rates) were modified to reflect a ±10% difference from the base scenario, the adoption rates for 1996 were held constant (i.e. logistic curve had a pivotal shift).

[36] Except for Costa Rica, where adoption of IVs has decreased.

2.5.4 Research Costs

As mentioned in Section 2.4.2, obtaining cost information is often difficult and requires knowledge about the institutional history of the breeding programs. The history of the breeding programs was explained above. Since Zamorano's breeding program supplies breeding materials to all NARS in Central America, the costs of generating these materials were imputed to Zamorano. Although this overestimates Zamorano's costs, it is impossible to attribute these costs to the different programs. Furthermore, costs incurred by donors in their respective countries (e.g. U.S. costs for the DGP CRSP) were not included in these cost estimations.

Bean breeding program leaders were asked to identify their 2010 external sources of funding and how much they received from each source. In addition, they were asked to estimate the amount of funding they received during the last ten years from large donors. Funding provided by large donors for several years was easily accessible (e.g. DGP CRSP). However, program leaders found it difficult to estimate their annual core budget (i.e. from their own institution).[37]

To estimate the core budget of each program, program leaders were asked how many staff members their programs employed in 2010 and the share of their time devoted to bean-related activities (to estimate their bean time equivalent, BTE). Furthermore, they were asked to classify their staff by education level and state whether the number of staff has increased/decreased/remained constant over the last decade. Over the past ten years, the number of staff has remained constant across all education levels in Nicaragua and Honduras (Zamorano only). In contrast, the number of staff has decreased across all education levels at DICTA in

[37] Except for PRONALEG-GA (Ecuador) and Zamorano (Honduras), where this information was reported without distinction in the total budget and/or was available in the literature (see Mather 2003 and Mooney 2007).

Honduras. However, in Costa Rica, while the number of staff holding a Ph.D. degree has remained constant, the number of staff holding a M.Sc., B.S., or <Technical degrees has decreased in the last decade. Similarly, in El Salvador, while the number staff holding a M.Sc. has remained constant, the number of staff holding a B.S. has decreased over time. Likewise, in Ecuador, while the number of staff holding a M.Sc. or a Technical degree has remained constant, the number of staff holding a B.S. degree has increased in the last decade.

The following average monthly salaries[38] were used to estimate the 2010 core budget (Table A 2.8):[39] Ph.D = $2,500 in Costa Rica (KII 2010a); M.Sc. = $2,250 in El Salvador and Nicaragua (Mejia 2012)[40] and M.Sc. = $2,000 in Costa Rica (KII 2010a); B.S. = $1,250 in Honduras, El Salvador, and Costa Rica and B.S. = $875 (70% of Honduras' salary) in Nicaragua (Mejia 2012); Technician = $1,000 in Honduras (Mejia 2012); and <Technician = $500 in Costa Rica (KII 2010a). Although salary costs only refer to 2010, it was assumed that for previous years the costs of salaries were at the 2010 level for El Salvador, Nicaragua, and Costa Rica. However, Mather (2003) reported DICTA's budget (salaries + operational) for years prior to 1994. Therefore, DICTA's budget (salaries + operational) for 1995-2009 was estimated assuming a proportional (linear) change over time using the 1994 and 2010 values (DICTA's operational budget for 2010 was reported at $5,992). While using constant values for salaries

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[38] Zamorano (Honduras) and PRONALEG-GA (Ecuador) were excluded from this estimation since the budget provided by program leaders already included salaries.

[39] This only reflects expenses associated with bean research. In addition, all program leaders were able to provide operational budgets (not shown), which were separated from salaries.

[40] Personal communication. Mejia, O. works for Swisscontact in Honduras and is in charge of Monitoring and Evaluation activities. Swisscontact collaborates with the Ministry of Agriculture (MoA). The salaries reported by Mejia refer to salaries paid by the MoA in Honduras. Since most salaries were not available for other countries, the salaries for Honduras were used, except where indicated otherwise.

across time may overestimate/underestimate costs (especially in years prior to 2000), data were not available to estimate salary costs in earlier years.

Among all programs for which salaries were estimated, INTA's bean program from Nicaragua had the highest expenses for salaries (Table A 2.8). The bean program of Nicaragua is a special case because, while segregating lines are evaluated at a central experimental station, advanced lines are evaluated at five research regions,[41] each with an average of 40 testing sites. This is possible because each research region receives government funding (and have their own staff) for this purpose. Thus, this explains the high number of staff reported by the program leader (although their time devoted to bean activities was low).

After total research costs were estimated, these costs were weighted by the small red IVs' share of the bean varieties released in Costa Rica in the last two decades (using the information in Table A 2.2), and the share of costs devoted to developing red mottled IVs in Ecuador estimated by Michigan State University's bean breeder (who is the U.S. Principal Investigator for the MSU-PRONALEG-GA program). Therefore, the costs in Table 2.3 for Costa Rica and Ecuador only reflect the cost associated with developing the market classes of interest in these countries. In all other countries, total costs were not weighted since either no other market classes have been released during the period of evaluation or almost the entire bean production corresponds to small reds. As this table shows, Nicaragua had the highest average annual real cost associated with the development of red bean varieties ($376,101/year) and Ecuador had the lowest average annual real cost associated with the development of red mottled bean varieties ($39,116/year). As explained above, most of the costs reported in Nicaragua relate to salaries (87% on average).

[41] Different lines go to different regions (KII, 2010a).

Table 2.3. Bean research investments ($) devoted to the development of red beans (Central America) and red mottled beans (Ecuador). 1990-2010.

	Total Bean Research Costs (real $, 2009=100) per country[1]				
Year	**Costa Rica**	**El Salvador**	**Honduras**	**Nicaragua**	**Ecuador**
1990	165,294	204,360	196,998	510,997	16,034
1991	158,619	196,108	258,564	490,362	22,827
1992	153,984	190,377	211,207	476,032	21,763
1993	149,508	184,843	197,282	462,196	28,098
1994	145,776	180,228	171,351	450,657	37,864
1995	141,758	179,485	125,563	438,237	31,751
1996	137,692	174,337	111,262	425,668	29,341
1997	134,604	170,427	122,252	416,120	28,903
1998	132,540	163,864	129,429	409,738	27,246
1999	129,676	160,323	135,488	400,884	23,406
2000	132,136	155,110	164,462	387,847	7,480
2001	129,454	150,818	168,242	377,116	12,295
2002	96,711	109,713	155,937	323,952	13,626
2003	123,918	107,269	160,481	317,584	44,755
2004	121,616	104,486	156,797	309,346	57,762
2005	118,514	101,062	169,698	299,208	57,749
2006	115,666	97,904	164,844	289,858	55,944
2007	113,295	95,193	212,451	281,831	61,120
2008	109,907	91,673	205,016	271,410	131,810
2009	86,725	92,000	155,897	271,650	57,375
2010	88,094	107,438	187,248	287,435	54,294
Average	***127,880***	***143,667***	***169,546***	***376,101***	***39,116***

Source: CRSP (2011); KII (2010a); Mather (2003); Mooney (2007); Zbinden (2005).

[1] Costs reflect the share of total bean research costs devoted to small red beans (Central America) and red mottled beans (Ecuador). Since in Costa Rica, 12 of the 18 IVs released between 1990-2010 were red beans, Costa Rica's costs reflect 67% of total bean research costs. For El Salvador, Honduras, and Nicaragua, costs reflect 100% of total bean research costs because either all IVs released in these countries are small reds or almost the entire bean production corresponds to small reds. Finally, for Ecuador, MSU's bean breeder estimated the share of the costs devoted to developing red mottled varieties at 65%. This estimation was used since it was judged more accurate than using the share of red mottled IVs released since 1990.

Cost data used for NPV and IRR estimations reflect a 6-year lag between when breeding started and when a variety was released. Therefore, cost are only included for the period 1991-2009, while benefits are accounted from 1997 until 2015. This gives an 18-year period for which benefits are evaluated, which is consistent with the period of evaluation used in previous research. Finally, although the governments of Honduras, Nicaragua, and El Salvador currently are implementing (free or subsidized) seed-distribution programs, these costs were not included in the economic analysis since they were not available. Therefore, the returns to investments only reflect returns to investments made directly on bean research, which may overestimate benefits.

2.5.5 Additional Parameters

To estimate the change in total surplus (Equation (2.8)), three additional parameters were needed: yearly bean price, yearly quantity produced, and estimations of supply elasticity. The sources for this information are explained below.

Bean Prices

In this study, average yearly wholesale prices for the period 1997-2010 were used. The bean market prices for all Central American countries were collected from MERCANET/*Consejo Nacional de Producción*, a Costa Rican organization that compiles yearly market prices for all countries in Central America and that provides historic data in U.S. Dollars. For each year, price data were averaged across countries and a unique price was used for all Central American countries. For Ecuador, prices were collected from previous research (reported as real prices) and from the Central Bank of Ecuador.

Prices were adjusted to reflect 2009 real prices by using the U.S. consumer price index (CPI) because the prices were reported in U.S. Dollars. The CPI came from the U.S. Department of Labor, Bureau of Labor Statistics from 1990-2010. The advantage of using real prices is that we can compare prices over time. The prices were adjusted using the following formula:

$$\textit{Real price in year t} = (CPI_B / CPI_t) * \textit{Nominal price in year t}$$

where *CPI* is the consumer price index, *t* is the year of interest and *B* stands for the base year (i.e. 2009). The average real price for 1997-2010 was highest for Central American countries ($984/MT) and lowest for Ecuador ($673/MT). While average real price ranged from $518/MT to $1,412/MT for Central American countries, real price ranged from $566/MT to $1,039/MT for Ecuador. For years after 2010, the price was assumed as the average of the previous five years (i.e. 2006-2010).

Quantity Produced

Yearly production data for the period 1990-2009 were obtained from FAOSTAT. Although data from each national statistical office (NSO) were collected, these data were not complete for the period of interest. However, for years when both FAOSTAT and NSO data were available, the data were compared and the differences between these two sources were small. Therefore, only FAOSTAT data were used.

FAOSTAT reports dry bean data for all countries. However, while dry bean data refers to bush beans in Central America, these data refers to both bush and climbing beans in Ecuador. Since our interest is only on bush beans, the NSO data from Ecuador[42] were used (for available years) to estimate the share of dry bean production to each bean type. It was estimated that, between 2002-2009, approximately 51% of total dry bean production corresponds to bush beans. Furthermore, besides bush beans, in Ecuador, we were only interested in bean production in the northern region (i.e. provinces of Carchi and Imbabura) since this is the main focus area of the bean program of Ecuador. Thus, using the national data, it was estimated that approximately 39% of total dry (bush) bean production came from these provinces. These shares were used to estimate bush-bean production in northern Ecuador from FAOSTAT data.

[42] ESPAC data published by INEC only available for 2002-2009.

Finally, in all Central American countries both red and black beans are produced. Key informants were asked to estimate the share of production to red and black beans.[43] While 97% of El Salvador's and 95% of Honduras' bean production corresponds to red beans, 85-90% of production corresponds to this market class in Nicaragua and only 20-30% in Costa Rica (KII, 2010a). Furthermore, Mooney (2007) estimated that in northern Ecuador, 68.4% of the bean area is planted to red mottled varieties (traditional and improved). These shares were used to estimate red/red mottled bean production in Central America and northern Ecuador from FAOSTAT data.

Elasticity and Discount Rate

The supply elasticity parameter, ε, was assumed equal to 0.7. Since no primary research on supply elasticity exists for the countries of interest, this parameter was assumed identical to that used by Mather *et al*. (2003). Mooney (2007) also used an identical elasticity parameter to that of Mather *et al*. (2003) in his bean study in Ecuador. In general, the short-run and intermediate supply responses of a semi-subsistence crop like beans are generally assumed inelastic (Mather *et al*. 2003). Therefore, assuming an elasticity parameter equal to 0.7 is appropriate in this context.

In this study, a 4% real discount rate was used. Recent literature (Alston *et al*. 1998; Bazelon and Smetters 2001; Maredia *et al.* 2010) suggests that using real discount rates (adjusted for inflation) is appropriate when evaluating long-term profitability of projects and suggest discount rates in the 3-5% range. Maredia *et al.* (2010) used a 4% discount rate to evaluate the benefits of bean research in Michigan. Thus, the discount rate used is comparable to previous studies. Furthermore, the results were re-estimated using a 10% discount rate to assess their robustness.

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[43] Although in Costa Rica white beans are also produced, due to the small quantities produced, this market class was not expected to account for a significant share of production (KII, 2010a).

2.6 Results

This section contains the results of the analysis and is divided into five sub-sections. *First*, estimations of adoption of IVs for 1996 and 2010 are provided. While adoption rates were drawn from previous research for 1996, these parameters were estimated using bean expert opinions for 2010. The *second* sub-section includes the diffusion curves estimated from the logistic function for all countries for the base scenario. *Third*, the econometric results of bean yield gain estimations are provided. *Fourth*, estimations of NPV and IRR are provided for each country for the base scenario. *Finally*, the sensitivity analysis results are shown.

2.6.1 Adoption of Improved Bean Varieties

Adoption rates for the base year (i.e. 1996) were obtained from previous research conducted in the region. In order to estimate adoption of IVs in 2010, bean breeders were asked to provide the names of the most widely planted bean IVs and to estimate their respective adoption rates. Although total adoption could be disaggregated by variety for 2010, this was not possible for 1996.

<u>Adoption rates in 1996</u>

Most adoption rates for the base year (i.e. 1996) for Central American countries came from a CIAT publication (CIAT 2001b) and PROFRIJOL's web page.[44] However, for Honduras, CIAT estimates of adoption for 1996 were not used. This was because Mather *et al.* (2003) provided an econometric estimation of adoption rates in Honduras for 1996, based on a random sample of bean farmers distributed throughout the country. While CIAT's rates suggest

[44] Both sources report the same estimations of adoption rates. For PROFRIJOL's web page, see: http://www.guate.net/profrijol/aportes.htm

that 46% of the bean area was planted to IVs,[45] Mather's rates suggest that only 31% of the area was planted to red IVs in 1996 (Table 2.4). To be conservative, we used Mather's rates. For Ecuador, Mooney's estimations of adoption rates for red mottled beans in northern Ecuador were used (Mooney 2007).

Breeders' estimates of adoption for 2010

In each country, bean breeders were asked to estimate adoption rates for the most widely planted varieties (all market classes). This information was used to estimate total adoption rates for the market classes of interest. Breeders estimated that in their country, the one or two IVs of

Table 2.4. Estimations of adoption rates (%) of improved small reds and red mottled bean varieties for 1996 and 2010.

	Adoption rates for 1996 (from previous research)				Adoption rates for 2010 (breeders' estimations)[3]
Country	**CIAT[1]**	**Mather *et al.***	**Mooney**	**Adoption rate used**	
Costa Rica	85	n.a.	n.a.	85	80
El Salvador	25	n.a.	n.a.	25	60
Honduras	46	31	n.a.	31	46
Nicaragua	30	n.a.	n.a.	30	82
Ecuador[2]	n.a.	n.a.	12	12	50

Source: CIAT (2001b); KII (2010a, 2010d); Mather et al. (2003); Mooney (2007).

[1] For Costa Rica, CIAT's rate combines black and red beans. It was not possible to separate between these market classes for 1996. For all other countries, adoption rates refer to small red beans.

[2] For Ecuador, adoption rates refer to red mottled bush-beans grown in northern Ecuador, not at the country level.

[3] These adoption rates refer to the share of the small red/red mottled bean area planted to small red/red mottled improved varieties.

n.a. = not applicable.

[45] Although black beans are planted in 5% of the area, it is assumed that this rate only refers to red beans since no black bean varieties have been released in Honduras since 1990.

the market classes of interest planted most widely in 2010 were: (a) Honduras--*Deorho* (23% of the small red bean area) and *Amadeus 77* (16% of the small red bean area), (b) El Salvador--*CENTA San Andres* (40%) and *CENTA Pipil* (14%), (c) Nicaragua--*INTA Rojo* (70%) and *INTA Masatepe* (8%), (d) Costa Rica--*Cabecar* (80% of the small red bean area), and (e) northern Ecuador--*Portilla* (43% of the red mottled bean area) and *Paragachi Andino* (7%). Furthermore, *Amadeus 77*, a variety developed by NARS through Bean/Cowpea and Pulse CRSP partial support and released under a different name in each country, was widely planted across all Central American countries in this study, was the most widely adopted small red IV in 2010, and accounted for an estimated 49.7% of the total area harvested to beans (235,028 ha).

As expected, adoption rates in 2010 varied greatly across countries (Table 2.4). Bean breeders' estimations suggest that, on average, 67% of the area harvested to small red beans in Central America and 50% of the area harvested to red mottled beans in northern Ecuador was planted to IVs. Furthermore, these estimates suggest that adoption rates were highest in Nicaragua (82%) and lowest in Honduras (46%).

Although estimates of small red bean adoption in Costa Rica were available from breeders for 2010, data were not available to estimate adoption rates of small red beans for 1996 (since the adoption rates reported by CIAT and PROFRIJOL were not detailed by market class). Therefore, the total adoption rate (i.e. small reds and black beans) was used for 1996 to estimate the diffusion curve for Costa Rica. Using the adoption rates for 1996 and 2010 allows estimating the diffusion curves (i.e. total IV adoption rates over time) for each country.

2.6.2 Estimated Rates of Diffusion

The methodology used to estimate the diffusion curves was explained in section 2.4.1.2. As that section explains, for each country, two parameters were needed to estimate the path of adoption of IVs over time (i.e. diffusion curves): α and β. Table A 2.9 contains this information and is not further discussed here.

Although the parameters were estimated for the scenarios previously explained, only the results for the *base scenario* are discussed here. For most countries, total adoption of improved bean varieties has increased since 1996 (Figure 2.4). In contrast, adoption rates of bean IVs in Costa Rica may have slightly decreased over time. There are a few reasons that could explain this. *First*, in 1996, the *Consejo Nacional de Producción* (CNP), then the government unit in charge of grain purchases stopped regulating market prices. Because of this, many farmers may have reduced the bean area they plant (KII, 2010a), imports drastically increased, and is likely that many farmers may have shifted to produce crops other than beans.

Second, adoption rates may have decreased due to the strong consumer preference for light red beans, which makes it more difficult to sell dark red beans (most red IVs have darker seed compared to landraces) (KII 2010a). In Costa Rica, the supply chain works differently than in other countries in the region. Currently, most farmers sell beans to large packers/processors who then sell beans through supermarkets, where final consumers purchase them (KII 2010e). Since farmers mainly sell to bean packers/processors, these packers highly influence which varieties farmers grow. When some of these packers/processors were asked about the market classes they prefer, they mentioned that, for red beans, they only buy light reds because that is the market class consumers prefer. Further, they do not give price discounts (as in other countries in the region) for dark red beans; instead, they do not buy them (KII 2010e). This suggests that to

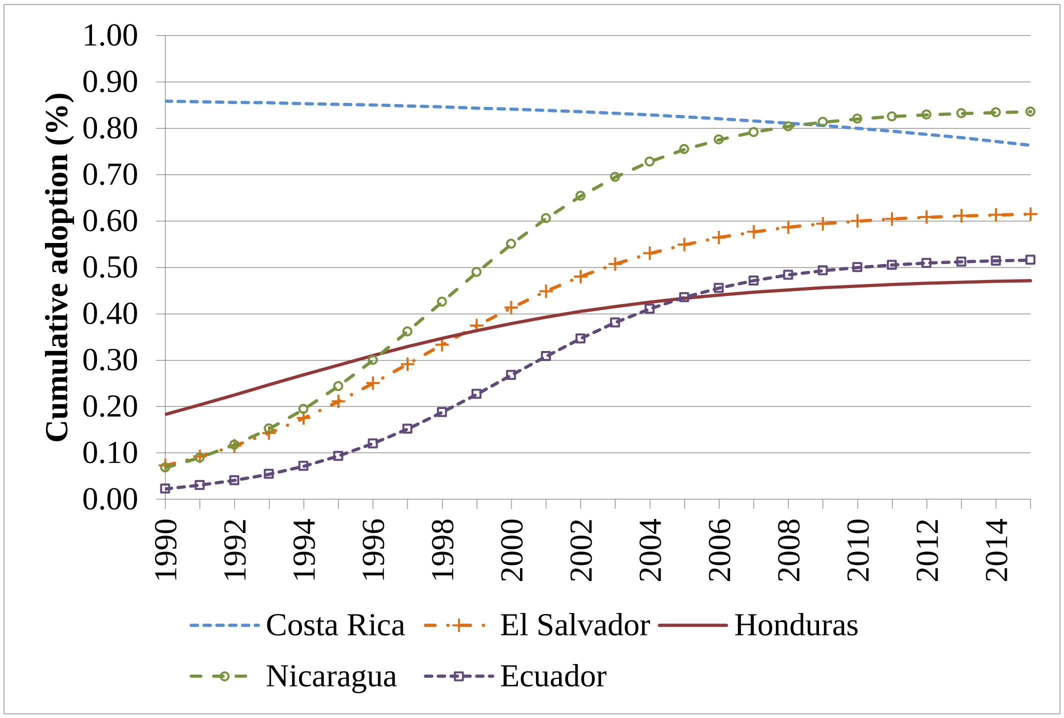

Figure 2.4. Base scenario: Total adoption rates of improved bean varieties. 1990-2015.

increase adoption of red IVs, the bean program should continue improving the market value (i.e. color) of new red IVs. *Third*, since CIAT (CIAT 2001b) used expert opinion to estimate adoption rates for 1996, these experts may have overestimated adoption for that year.

While adoption of IVs has increased most rapidly (i.e. slope of the curve is steeper) in Nicaragua, Ecuador and El Salvador, IVs have been adopted at a slower rate in Honduras (Figure 2.4). However, in 1990, adoption was higher in Honduras compared to all other countries with increasing diffusion curves.

Table A 2.10 contains the adoption rate values for each country for each year. To estimate the values for Scenarios A and B, adoption rates for 2010 (provided by bean breeders) were adjusted by plus/minus 10% and the diffusion curves were re-estimated. The adoption rate values for these two scenarios are included in Table A 2.11 and Table A 2.12.

2.6.3 Bean Yield Gains Estimation Using Experimental Yield Data

Bean yield gain results are presented as follows. *First*, descriptive statistics of the experimental yields are briefly discussed. *Then*, the econometric results from the vintage model are explained. In the descriptive statistics section, results for the Central American countries (combined) and Ecuador (separately) are presented. In contrast, in the econometric results section, results for the Central American countries (combined), Honduras (separately) and Ecuador (separately) are presented. The reasons for this are explained in each section below.

2.6.3.1 Descriptive Results

In this section, descriptive statistics of the experimental data for the Central American countries (combined) and Ecuador (separately) are presented.[46] In Central America, while only 13 of the 45 varieties released between 1990-2010 were reported in the experimental trial data, 12 of the 13 varieties were released post 1999 (year when data are available) and they represent 35% of the small red IVs released since 1999 (see Table A 2.2 through Table A 2.5 for a list of varieties). This was expected because (a) it is likely that national programs also released varieties tested in different (national) nurseries, which were not included in the ECAR nursery and (b) the data were only available since 1999; thus, it is likely that all varieties released prior to 2002 were evaluated in this trial before 1999.[47] There were a total of 108 observations[48] to use in the

[46] Although results for Honduras (separately) are discussed in the econometric results section, descriptive statistics are only discussed for Central America as a region. It is expected that these statistics are also valid for Honduras.

[47] Dorado is the exception. Although this variety was released in late 1980s-early 1990s, it was used as a universal check in this nursery. Thus, this allowed comparing yield gains of new varieties (post 2001) to this old variety.

[48] The original number of observations was higher. However, yields of each IV were averaged across locations, which reduced the number of observations for analysis.

regressions and the average experimental yield was 2,125 kg/ha. As expected, experimental yields were higher than yields obtained by farmers (i.e. reported by FAOSTAT). However, since we were interested in yield gains between old and new IVs, the value of this variable is not critical. Furthermore, yields were highly variable and ranged from an average of 1,400 kg/ha to 3,140 kg/ha (Table 2.5).

In Ecuador, five of the 10 red mottled varieties released between 1990-2010 were reported in the experimental trial data (Table 2.6). However, all five varieties represent 100% of the red mottled varieties released since 2004 (see Table A 2.6 for a list of varieties), which allowed comparing yield gains from varieties released since 2004 (i.e. very recent varieties). There were a total of 26 observations[49] to use in the regressions and the average experimental yield was 1,252 kg/ha. As expected, experimental yields were much higher than yields obtained by farmers (i.e. reported by FAOSTAT). Furthermore, yields were highly variable, ranging from an average of 702 kg/ha to 1,815 kg/ha.

[49] Similar to Central America, the original number of observations was higher.

Table 2.5. Estimated mean yields (kg/ha) and other statistics of red bean varieties based on the experimental trial data. Central America, 1999-2009.

Year of release	Variety Name	N	Mean yield (kg/ha)	Std. Dev.	Std. Err.	Minimum	Maximum
1989	Dorado (DOR 364)	35	2,011	786	133	523	3,954
2002	Amadeus 77	5	1,963	237	106	1,704	2,292
2003	Carrizalito	10	2,216	839	265	912	4,118
2003	Cayetana 85	3	1,922	90	52	1,863	2,026
2003	Cedron	11	1,972	720	217	1,057	3,534
2005	CENTA Pipil	12	2,248	823	237	1,179	3,658
2007	Tongibe	5	1,983	590	264	1,303	2,895
2007	Cardenal	2	2,005	324	229	1,776	2,235
2007	Don Cristobal	4	2,490	1,122	561	1,634	4,010
2007	Deorho	9	2,272	764	255	1,446	3,460
2008	CENTA C.P.C.	3	1,890	352	203	1,683	2,297
2009	La Majada	3	2,357	678	391	1,744	3,086
2009	Briyo AM	6	2,294	726	297	1,383	3,257
Average			**2,125**	**619**	**247**	**1,400**	**3,140**

Source: Programa de Investigaciones en Frijol Metadata, Zamorano, Honduras.

Table 2.6. Estimated mean yields (kg/ha) and other statistics of red mottled bean varieties based on the experimental trial data. Ecuador, 2003-2010.

Year of release	Variety Name	N	Mean yield (kg/ha)	Std. Dev.	Std. Err.	Minimum	Maximum
2004	Yunguilla	7	1,138	578	219	531	1,979
2007	Libertador	2	1,305	127	90	1,215	1,395
2009	Paragachi Andino	6	1,102	432	176	495	1,716
2009	Portilla	8	1,256	564	199	551	2,052
2010	Rojo del Valle	3	1,460	649	374	720	1,932
Average			**1,252**	**470**	**212**	**702**	**1,815**

Source: INIAP/PRONALEG-GA Metadata, Ecuador.

2.6.3.2 Econometric Results

<u>*Central America*</u>

Due to sample size limitations, it was not possible to estimate yield gains for each country separately, except for Honduras. Therefore, the experimental data from the four Central American countries were used to estimate yield gains from small red IVs released over time in the region.[50] That is, Equations (2.3b) and (2.4a) were estimated using data from the four Central American countries. Consequently, the results from the vintage model are interpreted as the yield gains of small red IVs released over time in the region as a whole.

The results of the ordinary least squares (OLS) estimation of Equation (2.3b) are presented in Table A 2.13. While yields were significantly higher in 2001, 2003 and 2008 compared to 1999 (all statistically significant at least at the 10% level), yields in all other Central American countries were significantly lower compared to Honduras (1% level). Furthermore, while most IVs yielded more than Dorado, only Cardenal showed statistically significant (5% level) higher yields than Dorado.

The results of the vintage model (i.e. Equation 2.4a) suggest that the gain in yield potential from varieties released from 1989 to 2009 in the region averaged 0.49% (Table 2.7). This is consistent with previous research that estimated yield gains in Michigan (Maredia *et al*. 2010). However, these yield gains were not used for Honduras. Because there were enough observations to obtain reliable results (N=88), it was possible to estimate the vintage model for Honduras separately.

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[50] From the 108 observations available for analysis, 88 observations came from trials conducted in Honduras. Thus, the data from Honduras was also included in the regional estimations; otherwise, the number of observations for the regional analysis would be very small.

Table 2.7. Linear regression results of the vintage model using experimental yields of small red bean varieties released in Central America. 1999-2009.

	N = 108	
	Prob > F = 0.000	
	R-squared = 0.9565	
Variables	Coefficient	p-value
***Year dummy variables* (1=Yes):**		
2000	0.09	***0.000
2001	0.38	***0.000
2002	-0.03	0.227
2003	0.36	***0.000
2004	0.12	***0.000
2005	-0.10	***0.006
2006	0.14	***0.000
2007	0.12	***0.000
2008	0.34	***0.000
2009	0.21	***0.000
***Country dummy variables* (1=Yes):**		
Costa Rica	-0.42	***0.000
El Salvador	-0.33	***0.000
Guatemala	-0.91	***0.000
Nicaragua	-0.31	***0.000
***Vintage variable* (year of release)**	0.0049	***0.000
Constant	-2.11	0.124

*, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Year 1999 and country Honduras were excluded to avoid the dummy trap. Robust standard errors used to estimate p-values because variances are not equal (Prob > Chi2 = 0.0451).

Source: Programa de Investigaciones en Frijol Metadata, Zamorano, Honduras.

The yield gain results, combined with the information in Table 2.5, indicates that, in Central America, the gain in yield potential averaged roughly 10 kg/ha/year.[51] This number was obtained by multiplying the mean yields of each year by the yield gains, and averaging across years.

[51] Is likely that farmers obtained lower yield gains since their yields are generally lower than experimental yields. This fact was accounted for when estimating the economic benefits by using FAOSTAT yields (for the base year) instead of experimental yields.

<u>Honduras</u>

In Honduras, the breeding program of Zamorano uses yield information from trials conducted in the region (i.e. all countries) to decide which lines to advance to the next stage of breeding. Therefore, trial data from the region were used to estimate yield gains for Honduras. The difference with respect to the estimations discussed above, is that while the estimations for Central America included all IVs released in all Central American countries, the estimations for Honduras only included varieties released in Honduras.

The results of the OLS estimation of Equation (2.3b) for Honduras are presented in Table A 2.14. As these results are similar to the ones discussed for Central America as a whole they are not discussed further. The results of the vintage model suggest that the gain in yield potential from varieties released in Honduras from 1989 to 2009 averaged 0.56% (Table 2.8), which is slightly higher than for Central American countries as a region. Therefore, the vintage results suggest that, in Honduras, the gain in yield potential averaged roughly 12 kg/ha/year, which is slightly higher than in Central American countries as a region.

Table 2.8. Linear regression results of the vintage model using experimental yields of small red bean varieties released in Honduras. 1999-2009.

	N = 88	
	Prob > F = 0.000	
	Adj. R-squared = 0.9616	
Variables	Coefficient	p-value
***Year dummy variables* (1=Yes):**		
2000	0.08	***0.000
2001	0.39	***0.000
2002	-0.07	***0.005
2003	0.38	***0.000
2004	0.13	***0.000
2005	-0.06	**0.028
2006	0.15	***0.000
2007	0.11	***0.000
2008	0.34	***0.000
2009	0.20	***0.000
***Country dummy variables* (1=Yes):**		
Costa Rica	-0.46	***0.000
El Salvador	-0.30	***0.000
Guatemala	-0.92	***0.000
Nicaragua	-0.30	***0.000
***Vintage variable* (year of release)**	0.0056	***0.000
Constant	-3.48	**0.012

*, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Year 1999 and country Honduras were excluded to avoid the dummy trap.

Source: Programa de Investigaciones en Frijol Metadata, Zamorano, Honduras.

<u>*Ecuador*</u>

In Ecuador, the OLS estimation of Equation (2.3c) suggests that yields were significantly higher (at least at the 10% level) in most years compared to 2003. Although most IVs yielded more than *Yunguilla* (except for *Paragachi Andino*), none of these differences were statistically significant (Table A 2.15).

The results of the estimation of Equation (2.4b) suggest that the gain in yield potential from red mottled varieties released in Ecuador from 2004 to 2010 averaged 1.68% (Table 2.9), which is slightly higher than expected and much higher than the gains found for Central America and Honduras. Therefore, this result together with the information in Table 2.6 suggests that in Ecuador the gain in yield potential averaged roughly 21 kg/ha/year, much higher than in all other countries in this study.

Table 2.9. Linear regression results of the vintage model using experimental yields of red mottled bean varieties released in Ecuador. 2003-2010.

	N = 26 Prob > F = 0.000 R-squared = 0.9491	
Variables	Coefficient	p-value
***Year dummy variables* (1=Yes):**		
2004	0.58	***0.000
2005	1.28	***0.000
2006	0.57	***0.000
2007	0.87	***0.000
2008	0.35	***0.000
2009	1.19	***0.000
2010	0.81	***0.000
***Vintage variable* (year of release)**	0.0168	*0.051
Constant	-27.46	0.106

*, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Year 2003 excluded to avoid the dummy trap. Robust standard errors used to estimate p-values because variances are not equal (Prob > Chi2 = 0.094).

Source: INIAP/PRONALEG-GA Metadata, Ecuador.

2.6.4 Net Present Value and Internal Rate of Return

The estimates of bean yield gains, in combination with estimations of adoption rates, annual bean prices, elasticity of supply, and the annual quantity of bean produced of the market classes of interest were used to estimate the value of benefits realized at the farm level for the period of 1997-2015 for each country of interest. Once this information was obtained, annual research costs and a real discount rate of 4% were used to estimate the net present value and the internal rate of return to bean research investments in each country, assuming a six-year lag period between the start of research and the time when farmers start using the varieties.

One more point is worth clarifying before discussing the results. As previously explained, Type II gains were obtained by estimating λ from equations 2.4. In contrast, Type I gains were obtained from the literature. In Honduras, Mather *et al*. (2003) estimated that adopters gain the equivalent to 7-16% of bean income from yield loss averted from the use of IVs. Thus, for Honduras, the Type I yield gains were assumed to be 11.5%, the average of the values reported by Mather *et al*. (2003). Since no other studies have reported yield gains at the farm level[52] for other Central American countries, Mather's values were used for these countries. In Ecuador, Mooney (2007) estimated that adopters enjoy 18.4% lower unit costs when planting IVs in northern Ecuador. Thus, for this country, the Type I yield gains were assumed to be 18.4%.

A summary of the NPV and IRR findings is presented in Table 2.10. Results from the *base scenario* suggest that in all countries except Costa Rica, investments in bean research have been profitable and provided a return well above the assumed opportunity cost of capital because the NPV is positive and the IRR is greater than the discount rate used. When the discount rate

[52] CENTA (2004) provides estimations of Type I yield gains for El Salvador. However, its estimations are for test trials in farmers' fields, which generally are much higher than yields obtained by farmers. Thus, since these were judged to be too high, Mather's gains were used.

was increased to 10%, NPV was also greater than zero for all countries except Costa Rica, suggesting that the results are not greatly affected by the discount rate. The net losses found for Costa Rica are due to the fact that (a) the area planted to beans has decreased since 1996 (and only the red-bean share was included in the estimations) and (b) the adoption rates between 1996 and 2010 have also decreased. Therefore, net losses were expected. Although this is true for small red beans, it is possible that positive gains could be found for black beans because (a) most farmers have adopted the black bean IVs *Brunca* (released in 1982) and *Guaymi* (released in 1996) and (b) the area planted to black IVs is more than twice the area planted to red beans (KII 2010a, 2010d). However, estimating the economic impact of black beans for Costa Rica was not possible because only a few varieties have been released recently and available experimental data did not include yield information for these varieties.

Table 2.10. Summary of net present value (NPV) and internal rates of return (IRR) estimations of investments on bean research in Central America and Ecuador. 1991-2015.

	Scenario (in constant 2009 US$)						**For 1997-2015**
	Base		**Scenario A**		**Scenario B**		**Producer surplus per ha per year**
Country	**NPV($)**	**IRR**	**NPV($)**	**IRR**	**NPV($)**	**IRR**	
Costa Rica	-2,016,054	-5%	-1,610,978	-3%	n.e.	n.e.	26
El Salvador	77,510,816	40%	93,170,299	43%	62,688,130	37%	84
Honduras	58,250,437	34%	73,724,174	37%	43,698,030	31%	63
Nicaragua	214,002,964	42%	254,621,317	45%	175,583,202	39%	73
Ecuador	10,920,047	37%	13,216,135	39%	8,832,204	35%	196
Central American countries	347,748,163	32%	419,904,813	35%	281,969,362	32%	72
All countries	358,668,210	32%	433,120,948	35%	290,801,566	32%	74

Source: Generated by the Author.

NOTES: n.e. = not estimated.

Scenario A assumes a 10% increase over estimations of Type II yield gains and 2010 adoption rates simultaneously.

Scenario B assumes a 10% decrease over estimations of Type II yield gains and 2010 adoption rates simultaneously.

Surplus per hectare per year estimated by dividing each year's total surplus (base scenario) by the area planted with IVs.

For El Salvador, the NPV ranged from $63 million (*Scenario B*) to $93 million (*Scenario A*) and NPV was estimated at $78 million for the *base scenario*, which represents a surplus of $84 per hectare planted with IVs per year.[53] Similarly, for Honduras, the NPV ranged from $44 million to $74 million and NPV was estimated at $58 million for the *base scenario*, which represents a surplus of $63 per hectare planted with IVs per year.

For Nicaragua, the NPV under the *base scenario* was estimated at more than $214 million, which represents a surplus of $73 per hectare planted with IVs per year (Table 2.10). There are two reasons for this: (1) the area planted to beans has more than doubled since 1996 and (2) adoption of improved varieties has greatly increased since 1996 due to investments made by donors and the government, especially after hurricane MITCH in 1998.

Although the economic benefits are more modest in northern Ecuador than in Central America, the results suggest that investments in bean research have been profitable under all scenarios, with NPV ranging from $9 million to $13 million and IRR ranging from 35% to 39%. The NPV was estimated at $11 million for the *base scenario*, which represents a surplus of $196 per hectare planted with IVs in northern Ecuador per year, the largest surplus among all countries.

As a region (i.e. all countries), investments in bean research were profitable, generating a net present value of more than $358 million, most of which came from Central American countries, particularly Nicaragua. This is due to the fact that Nicaragua is the largest bean producer in the region and the adoption rates in this country were relatively high in 2010. Further, the governments of Nicaragua, Honduras, and El Salvador have implemented (free or

[53] See last data-column of Table 2.10.

subsidized) seed distribution programs that most likely have contributed to the observed (and large) economic benefits.

In contrast, the economic impact was small in Ecuador because the area of impact was relatively small (i.e. concentrated in the north region) and the deficient formal seed system in Ecuador has limited the access to high-quality bean seed. To overcome this limitation, PRONALEG-GA is promoting alternative ways to produce and sell high-quality, low-cost bean seed through seed producers located in villages across different regions. However, PRONALEG-GA's efforts have most likely had limited impact because the amount of seed produced and sold has been relatively small and its limited resources have not allowed to scale up these initiatives.

The estimated IRR for the region was 32%, which more than offsets the opportunity cost of capital. Details about estimations of NPV and IRR for the *base scenario* for each country are presented in Table A 2.16 to Table A 2.20. Although estimations for *scenarios A* and *B* were made for all countries, only the estimations for the *base scenario* are included as appendices since the estimation procedures for *scenarios A* and *B* were similar to the procedures described above.

Although there were no Type I benefits in Costa Rica because farmers have disadopted IVs through time (thus there are no new adopters), the realized Type II yield gains were not enough to recover investments in bean research. In Costa Rica, the NPV would be zero if the value of λ were 114% higher than estimated.

While the benefits derived from Type II gains accounted for less than one-half of the change in total surplus in El Salvador (42%) and Nicaragua (39%), Type II benefits accounted for more than 50% of the change in total surplus in Honduras (61%) and Ecuador (53%). These values were obtained using the change in surplus values in Table A 2.17 through Table A 2.20.

Finally, although break-even values (i.e. values that would make NPV=0) of λ and adoption rates were separately estimated using the parameters from the *base scenario*, the results suggest that for all countries except Costa Rica, even if λ=0 (hence Type II gains = 0), the NPV would be positive. This is because adoption of IVs is assumed to increase (at the *base scenario* rate) over time, generating enough Type I benefits (from new adopters) to realize positive NPV values. Similarly, it was not possible to estimate break-even values of 2010 adoption rates for these countries since, even if the 2010 adoption rate was only 1% above the 1996 adoption rate (e.g. 26% in El Salvador in 2010 instead of 60%), NPV would still be positive. This was because even with a small increase in adoption of IVs over time, both Type I and Type II benefits are realized and these are large enough to offset the cost of research. In addition, as the 2010 adoption rate decreases (and gets closer to the 1996 adoption rate), the share of the benefits derived from Type I gains become smaller and that of Type II gains become larger.

2.7 Chapter Summary and Policy Recommendations

2.7.1 Chapter Summary

There are two types of yield gains derived from the use of improved varieties: Type I gains in areas where improved varieties replace traditional varieties (i.e. new adopters), and Type II gains in areas where new improved varieties replace old improved varieties (i.e. current adopters). This essay estimated the Type II yield gains associated with varietal development of small red and red mottled bean varieties over time in Central America, Honduras, and northern Ecuador separately. Furthermore, it provided estimates of current total adoption rates of IVs in each country. The adoption rates were estimated using bean expert opinions. A base scenario was constructed using the information from econometric regressions, key informants, and secondary sources, and sensitivity analysis was carried out under two additional scenarios: Scenario A where Type II yield gains and 2010 adoption rates were assumed to simultaneously be 10% higher than in the base scenario, and Scenario B where Type II yield gains and 2010 adoption rates were assumed to simultaneously be 10% lower than in the base scenario.

OLS regressions using vintage models were conducted to estimate the Type II yield gains from IVs released over time. Results from the vintage model regressions suggest that the gain in yield potential from small red varieties released over time averaged 0.49% per year for Central American countries and 0.56% per year for Honduras. Similarly, the gain in yield potential from red mottled varieties released over time averaged 1.68% per year for Ecuador.

Breeders estimated that adoption rates for 2010 ranged from 46% in Honduras to 82% in Nicaragua. Furthermore, breeders estimated that *Amadeus 77*, the most widely adopted small red IV, accounted for an estimated 49.7% of the total area harvested with beans across the Central American countries (235,028 ha). Similarly, *Portilla*, the most widely planted red mottled IV in northern Ecuador, accounted for an estimated 43% of the red mottled bean area harvested in northern Ecuador.

Ex post benefit/cost analysis of improved small red and red mottled bean varieties for the period 1991-2015 indicate that returns to investments in bean research have been negative in Costa Rica and positive in all other countries. In Costa Rica, negative net gains were observed because both the total bean area and the area planted to small red IVs have decreased over time. Furthermore, small red beans represent a much smaller proportion of total land area planted to beans, compared to black beans. In addition, in contrast to all other Central American countries in this study, Costa Rican farmers do not receive price discounts for dark red beans; instead, they just cannot sell them. Therefore, developing small red varieties that farmers will adopt is more challenging. An analysis to estimate the economic impact of black varieties could not be carried out due to data limitations.

Among the countries with positive NPV, under the base scenario, the results indicate a range of IRR values from 34% in Honduras to 42% in Nicaragua. Although this range was different under Scenario A and Scenario B, the countries had the same rank under all scenarios. Furthermore, the estimated NPVs for investments in bean research under the base scenario ranged from $11 million in northern Ecuador to $214 million in Nicaragua. The disparity of benefits is due in part to the limited area of impact and deficient seed system in Ecuador, and the high adoption rates and increased government intervention through seed distribution programs in Nicaragua.

Under the base scenario, the NPV was over $347 million among Central American countries and over $358 million across all countries. The regional IRR (i.e. all countries) was estimated at 32%. While the surplus per hectare per year was highest in northern Ecuador ($196/ha/yr) and lowest in Costa Rica ($26/ha/yr), the regional surplus averaged $74/ha/yr.

2.7.2 Policy Recommendations

The results of the study support the following policy recommendations:

- In Costa Rica, to increase adoption rates, future bean research on small red varieties should give priority to developing varieties that are more acceptable to farmers (i.e. with better market value). Furthermore, since black beans are the most widely produced market class in Costa Rica, increased efforts should be devoted to developing new black varieties.
- In Ecuador, additional efforts should be devoted to increasing seed production. As briefly discussed, the seed system in Ecuador is the most deficient among all five countries. In order

to increase seed production, financial assistance would likely be required because PRONALEG-GA’s human and financial resources are stretched thin. Financial support from the Government of Ecuador and donors will be key to find alternatives to increase seed production in Ecuador. Although the quantity of seed distributed/sold in Honduras, El Salvador, and Nicaragua is large, the seed provided to farmers is either subsidized or free, which is not sustainable in the long term. Therefore, alternative ways to produce and commercialize low-cost high-quality seed is key to develop a sustainable seed system.

- In all countries except Costa Rica, investments in bean research have been profitable. Because of this, donors and governments should continue funding bean research programs in these countries. Although investments in bean research were negative in Costa Rica, this does not imply that funding should be cut in this country. Instead, the bean program of Costa Rica needs to devote efforts to develop better small red varieties and new black bean varieties.
- Most research centers in the countries included in the study are highly dependent on external assistance to conduct their activities. A continuous supply of funds from donors is necessary to support varietal development research activities.
- The bean programs of Central America collaborate with each other in their breeding activities (through supply of germplasm, data, etc.) This research model has proven successful. Therefore, this model could be implemented in other regions of the world to successfully conduct breeding activities and make a positive economic impact on producers. However, one weakness of the model is that the breeding programs in this region highly depend on Zamorano’s bean program to obtain segregating lines to breed. Thus, if Zamorano’s program in Honduras could no longer provide segregating lines, other bean

programs would likely struggle to generate new varieties until finding another source of segregating lines.

<u>CHAPTER THREE.</u> DETERMINANTS OF MARKET PARTICIPATION DECISIONS: EVIDENCE FROM THE CENTRAL HIGHLANDS OF ANGOLA

3.1 Introduction

Agricultural households can be classified into three categories based on their net position relative to the market: net buyers, net sellers, or autarkic (non-participants).[54] Market participation is both a cause and a consequence of development (Boughton *et al*. 2007; Barrett 2008). Markets provide households the opportunity to benefit from trade; i.e. they can sell their surpluses and purchase goods and services they need, according to their comparative advantage (Boughton *et al*. 2007; Barrett 2008). Further, as a household's income increases, its demand for goods and services also increases, hence stimulating development (Boughton *et al*. 2007). However, the net position of the households not only depends on market prices; it also depends on households' access to productive technologies (e.g. improved varieties, inputs, etc). and adequate private and public goods (Barrett 2008) and services.

To date, price-based, top-down macro and trade policy interventions have not been enough to stimulate smallholder market participation and agricultural and rural transformation (Barrett 2008). However, understanding the impact of these policies on smallholder farmers' market participation is important. The fact that market participation is heterogeneous has important implications when studying households' response to governmental policy interventions and should be considered in policy response estimation (Key *et al.* 2000).

[54] Goetz (1992) called this classification the household trichotomy.

Farm households are typically located in environments characterized by a number of market failures[55] (Sadoulet and de Janvry 1995, ch. 6, pg. 9). These authors point out that any market could fail for a particular household when the margin between the low price at which the household could sell a commodity and the high price at which it could buy it is large; hence the household may be better off by being autarkic. This introduces us to the concept of price bands, which are widely described in the literature (De Janvry *et al.* 1991; Sadoulet and de Janvry 1995; Key *et al.* 2000). The price band refers to the difference between the effective price paid by buyers and received by sellers (both market participants), which determines the household's net market position.

To boost market participation, one of the government and private sector's goals could be to target investments at reducing the magnitude of the price band. This magnitude could be affected by transaction costs, the existence of shallow local markets,[56] and price risks and risk aversion (Sadoulet and de Janvry 1995). This paper analyzes the effect of gender of head, transaction costs, and productive assets on household's marketing decisions, using cross-sectional data from three provinces of Angola.

Angola ended its 27-year long civil war in 2002. During the war period, each of the two combatant sides controlled the two major commodities of the country: oil and diamonds. While the Popular Movement for the Liberation of Angola (MPLA) monopolized oil exports and revenue, the National Union for the Total Independence of Angola (UNITA) controlled much of

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[55] De Janvry *et al.* (1991) demonstrated that market failure was household, not commodity specific.

[56] For details see Sadoulet and de Janvry (1995, ch. 6, pg. 9). The idea is that there is a negative covariation between household supply and prices because when the harvest is good and surplus could be traded, the price falls because all other households also have good harvests, widening the price band (the opposite is also true).

the diamond wealth of the north and eastern interior (Munslow 1999). Although these two commodities provided significant revenues to the country,[57] during the war, these revenues were used to sustain Angola's rival armies (Munslow 1999). The war had a large impact in the country's infrastructure[58] and caused the demise of the rural economy and the subsequent sharp rise of the urban population (World Bank 2007). Land mines and conflict made it dangerous to stay in rural areas and to farm.

Other effects were the loss of life of over 1 million people and migration (rural to urban, but also to neighboring countries) (World Bank 2007). Since the Peace Accords, continued rural to urban migration, urbanization, high population growth rate, and increasing household incomes have contributed to an increase in the demand for food in the major cities of the country. For example, the estimated 2005 annual demand for potatoes, onions, carrots, and dry beans in Luanda (the capital city) was a little over 197,000 MT, 61% of which was imported from neighboring countries, especially South Africa (World Vision 2008).

Although expenditures in 2003 in energy, agriculture, mining, and transportation were high (10.2% of GDP; US$1.4 billion), by 2005, expenditure in these areas was drastically reduced to only 2.2% of GDP (or US$734 million) (World Bank *et al.* 2007), suggesting that rural households may still face many limitations to actively participate in markets and reduce import requirements.

[57] In 1997, crude oil exports were estimated at over US $4.5 billion, while diamond production in 1998 was estimated to be worth over US $0.5 billion (Munslow 1999). However, oil production was expected to peak in 2010, after which, it is expected to decrease (World Bank *et al*. 2007) suggesting that the share of other sectors in the economy will grow.

[58] It is estimated that US $4 billion will be necessary just to restore the road and bridge network of the country (World Bank 2007).

In addition to the country's transition from war to peace, the country went from a centralized market to a free market (Munslow 1999). However, food aid and assistance programs undermine private sector investments and government control has resulted in a poorly developed trading network (World Bank 2007). Furthermore, Angola has been cut off from agricultural technological advances (e.g. new crop varieties), and increasing farmers' productivity[59] still remains a challenge because of the disadvantages of Angola's strong currency and high transportation costs (World Bank 2007).

Understanding which factors are associated with farmers' marketing decisions is important to target government and private donors' resources, boost crop sales, and increase farmers' incomes and their food security. Because of this, the study focuses on estimating the determinants of market participation and the quantity of food traded, including the effect of gender, transaction costs and productive asset endowments on marketing behavior, following Boughton *et al*. (2007), Barrett (2008), and Bellemare and Barrett (2006). Thus, this study will provide the government and private donors the information necessary to better target their assistance and improve smallholder farmers' livelihoods in rural Angola.

3.2 Research Gap

Many studies related to the analysis of market participation by agricultural households have focused on (1) dealing with potential problems of sample selection bias when testing hypotheses about market participation and (2) understanding the role of transaction costs and market failures on households' marketing decisions.

[59] Although Angola enjoys better rainfall than many of its neighbors, crop yields are much lower.

Heckman (1979) discussed sample selection bias as a specification error and provided a technique that allowed for the use of simple regression to estimate behavioral functions free of selection bias in the case of a censored sample. Examples of censored samples include data related to market wages, earnings of trainees, or earnings from selling in the market.[60] Sample selection bias arise because (1) individuals may self-select themselves (i.e. they choose whether to participate in the activity) or (2) analysts decide to use only a subset of a random sample obtained from a population (which works in the same way as self-selection). The problem with censored samples is that the functions estimated (e.g. wage or earnings) on selected samples generally do not estimate population (i.e. random sample) parameters. For example, if we are interested in estimating the effect of training on earnings and we only use trainees' earnings, the parameter of interest (i.e. training) may be biased because it may confound the effect of the probability of receiving the training and the effect of the training itself.[61]

The solution proposed by Heckman (1979) to obtain unbiased estimators was simple.[62] *First*, he demonstrated that the bias that results from using (non-randomly) selected samples could arise from a problem of omitted variables. *Second*, he proposed that, for the full sample (e.g. trainees and non-trainees), a probit analysis could be used to estimate the probability that an individual may be in the selected sample (e.g. will participate in training). *Third*, he

[60] For example, the earnings of trainees generally do not provide reliable estimates of what non-trainees would have earned had they decided to participate in the training. Gujarati (2003) explains that censored samples are samples in which information on the dependent variable is available only for some observations.

[61] A similar problem happens with truncated samples where data is observed only if a certain event is true.

[62] See Heckman (1979) for a detailed explanation.

demonstrated that by using this probability as a regressor in the equation of interest (e.g. trainees' earnings) one could obtain unbiased estimators.

In his widely cited work, Goetz (1992) modeled the agricultural household's discrete decision of whether to participate in markets separately from the continuous decision of how much to trade, conditional on market participation;[63] an innovation in market participation analysis at the time. Elaborating on the groundbreaking work of Goetz (1992), Key *et al.* (2000) studied the effect of proportional and fixed transaction costs on household supply response. They implicitly modeled the household as making the discrete market participation choice simultaneously with the continuous decision of how much to trade.[64] In constructing their agricultural structural household model, they separated the structural supply functions from the production threshold functions. By estimating this model, they were able to separately identify the effect of proportional and fixed transaction costs on supply response, while avoiding the problem of selection bias described by Heckman (1979).

As noted, some authors assume households make marketing decisions sequentially, while other assume they make these decisions simultaneously. Bellemare and Barrett (2006) developed a two-stage econometric method that allowed them to test whether rural households in developing countries make market participation and volume decisions simultaneously or sequentially. Using household data from Kenyan and Ethiopian livestock markets, they found evidence in favor of sequential decision making. The major implication of this finding is that households that make sequential marketing decisions are more price-responsive and less vulnerable to trader exploitation.

[63] That is, he assumed households make sequential choices: they *first* decide whether or not to participate in the market; *then,* conditional on participation, they decide how much to trade.
[64] In contrast to Goetz (1992) who assumed households make sequential marketing choices.

Although many recent studies have focused on the effect of transaction costs; farmers' assets and wealth also affect marketing decisions. Boughton *et al.* (2007) took an asset-based approach to analyze smallholder market participation in Mozambique. They assumed households made sequential marketing decisions[65] and developed a simple structural model of the household's choice problem, facing two constraints: budget and asset allocation constraints.

Fafchamps and Vargas-Hill (2005) analyzed the factors associated with coffee producers' decision to sell at the market vs. at the farmgate. Although their study did not focus on the decision to participate in the market,[66] it provides insights about why farmers choose different places for their sales. They constructed a simple model of farmers' form of sale choice, focusing on the relationship between wealth and farmgate sales. They estimated the model with and without access to public transportation.

Barrett (2008) provides a detailed literature review about evidence on smallholder market participation in eastern and southern Africa, focusing on staple foodgrains markets. He found that the empirical evidence suggests that most smallholders do not participate as sellers[67] because they face two basic classes of barriers to entry; (1) at the micro-level, households have insufficient access to productive assets, financing, and new production technologies and (2) at the macro-level, especially in remote areas, high transaction costs limit household's market access, market-level spatial price transmission, and trader competition. Another reason not mentioned by Barrett (2008) is that farmers may not have surpluses they could sell.

[65] Similar to Goetz (1992).

[66] All coffee producers are sellers because coffee is a cash crop. Therefore, household consumption may be very small, if any.

[67] At least not at any significant scale.

Markets rarely work perfectly. Market failures are an important consideration for policy analysis because when markets fail, the household's ability to respond to price incentives is constrained. Household modeling under missing markets is well explained by Sadoulet and de Janvry (1995). De Janvry *et al.* (1991) analyzed the effect of missing markets on farmers' supply response. They developed a model of household behavior under various conditions of labor and food market failures and empirically tested their model using simulations. They found that programs directed at reducing the incidence of market failures[68] are very important to increasing the supply elasticity of households--hence increasing household's response to price incentives.

The contribution of this study is as follows. *First*, it uses a double hurdle approach to control for self-selection bias and provides unconditional effects of variables of interest on the quantity sold. *Second*, besides focusing on transaction costs, this study also analyzes the effect of productive assets on marketing decisions, following Boughton *et al.* (2007),[69] and the effect of gender of household head on marketing decisions.[70] *Third*, it provides new empirical results to the rather limited literature on market participation in Africa, especially in Angola, by looking at farmers' participation in three crop markets in Angola: potatoes, beans and onions.

This paper focuses on potatoes, beans, and onions because:[71] (1) these crops, especially potatoes, are very important in the country's agricultural sector because of their high potential to generate profits to smallholder farmers; (2) there is a strong unmet demand for these crops in

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[68] Infrastructure investments (which reduce transaction costs), better circulation of information on prices, and access to credit markets (an indirect source of market failure) for example.

[69] Bellemare and Barrett (2006) did not explicitly study the effect of productive assets on marketing behavior.

[70] Donors are interested in learning about the role of gender on household decisions, especially because after the war, many households are led by females.

[71] A detailed explanation is provided in Section 3.5 below.

large cities of Angola that currently is satisfied by imports from neighboring countries; and (3) recent private and public investments targeted at improving supply chains in rural Angola are focusing on these crops (World Vision, 2008). Therefore, generating information about the factors affecting smallholder farmers' marketing decisions will be valuable to target assistance to farmers.

3.3 Research Questions

Although the study's main objective is to generate information about the factors affecting smallholder farmers' marketing decisions, it also attempts to answer the following research questions:

- What are the characteristics of farmers who trade potatoes, beans, and onions in the central highlands of Angola, compared to non-traders?
- For each crop, what factors affect production?
- For each crop, what factors are influencing farmers' decision of whether to sell their surpluses?
- Conditional on market participation, what factors affect the quantity of food traded by farmers?
- What is the unconditional effect of gender, productive assets, and transaction costs on supply of each crop?
- What policies could the government and private sector participants implement, based on the empirical evidence, to boost market participation?

3.4 Conceptual Framework

In this section, first, the economic rationale for analyzing household's marketing decisions is explained. Then, an econometric framework is presented to empirically estimate the economic model while addressing the econometric challenges of the analysis.

3.4.1 Economic Model

To analyze the factors associated with farmer's marketing decisions, following Boughton *et al.* 2007 and Barrett 2008, a simple model of household choice is developed. It is assumed that households will maximize their utility U, by consuming a vector of agricultural commodities, s^C, for c = 1, 2, 3 crops, and a Hicksian composite of other tradables, x. It earns income from production and possibly sale of any or all crops, and possibly off-farm income, Y, which could be earned or unearned.

Crop production is determined by a crop-specific production technology,[72] $f^C(A^C, G)$, which depends on the flow of inputs (e.g. fertilizer, pesticides, seed, labor) and services provided by privately held quasi-fixed productive assets, represented by the vector $\boldsymbol{A}$. This function is also affected by the availability of public good and services, $\boldsymbol{G}$, such as extension services, and farmer associations, because farmers may have access to price information, receive inputs or technical assistance, among other benefits that may affect output.

The vector $\boldsymbol{M}$ represents farmer's choice of whether or not to participate in each market as a seller, represented by the vector M^{cv}, or as a buyer, represented by the vector M^{cb}. The vector M^{cv} takes value 1 for every crop c the farmer decides to sell and M^{cv} = 0 for crops not

[72] Due to the nature of the crops, each one could be produced using different technologies.

sold. Similarly, the vector M^{cb} takes value 1 for every crop c the farmer decides to buy and M^{cb} = 0 for crops not bought.[73] Net sales of a particular crop, $NS^{C} \smile f^{C}(A^{C}, G) - s^{C}$, are positive if and only if M^{cv} = 1 and negative if and only if M^{cb} = 1. However, due to data availability, the focus of this paper is restricted to comparing farmers' choice as to whether or not to participate in each market as a seller.

The parametric market price each household faces, p^{cm}, is affected by crop-and-household-specific transaction costs, τ^{C} (**A**, **G**, Y, **Z**, $\mathbf{NS^{C}}$). That is, the household faces wide price margins (i.e. a price band) between the low price at which it could sell a crop and the high price at which it could buy that crop (Sadoulet and de Janvry 1995).[74] These transaction costs create a kinked price schedule, which leads some households to self-select out of the market for some crops (de Janvry *et al.* 1991; Sadoulet and de Janvry 1995; Boughton *et al.* 2007; Barrett 2008). Following Boughton *et al*. (2007) and Barrett (2008), transaction costs are assumed to be a function of household's productive assets, ***A***, access to public good and services, ***G*** (e.g. good roads and/or participating in farmer organizations may reduce transaction costs), liquidity from off-farm income, *Y*, household-specific characteristics, ***Z***, and amount traded, ***NS***.

The household's choice can be represented by the following optimization problem:

$$\underset{s^{c},\, x,\; A^{c},\, M^{ci}}{Max} \quad U(s^{c}, x)$$

[73] As mentioned by Boughton *et al.* (2007) and Barrett (2008), households will not both buy and sell the same crop in this one-period model because of the price wedge created by transaction costs. Therefore, there exists a complementary slackness condition, $M^{CV} * M^{CB} = 0$, at any optimum.

[74] As mentioned above, shallow local markets and price risks and risk aversion also affect the magnitude of the price band (Sadoulet and de Janvry 1995).

Subject to the liquidity constraint

$$Y - p^x x + \sum_{c=1}^{3}\left[p^{c*}\left(M^{cv} + M^{cb}\right)\left(f^c\left(A^c, G\right) - s^c\right)\right] = 0$$

And equilibrium conditions for non-tradables

$$A = \sum_{c=1}^{3} A^c$$

$$f^c\left(A^c, G\right) \geq s^c\left(1 - M^{cb}\right) \qquad \text{for c = 1, 2, 3}$$

With each household-specific crop price determined by the household's net market position:

$$p^{c*} = p^{cm} + \tau^c\left(A, G, Y, Z, NS^c\right) \qquad \text{if } M^{CB} = 1 \text{ (i.e. net buyer)}$$

$$p^{c*} = p^{cm} - \tau^c\left(A, G, Y, Z, NS^c\right) \qquad \text{if } M^{CV} = 1 \text{ (i.e. net seller)}$$

$$p^{c*} = p^a \qquad \text{if } M^{CB} = M^{CV} = 0 \text{ (i.e. autarkic)}$$

Where p^a is the autarkic (i.e. non-tradable) shadow price that equates household supply and demand. The second equilibrium condition for non-tradables implies that, if the household does not purchase crop *c* (i.e. $M^{cb} = 0$), production must be greater than or equal to the quantity of crop *c* consumed (may be a net seller) and, if the household does purchase crop *c* (i.e. $M^{cb} = 1$), production must be greater than or equal to zero (may produce crop *c* or not; regardless of which, the household is a net buyer).

To find the optimal solution, two steps are necessary. First, the system must be solved for the optimal solution, conditional on the participation regime (i.e. net seller, net buyer, or autarkic). Then, the market participation regime that yields the highest utility level is chosen (Key *et al*. 2000). That is, the optimal choices of {$\mathbf{s^C}$, $\mathbf{A^C}$, $\mathbf{x}$} must be replaced into the utility function to obtain the indirect utility function, ***V***. This indirect utility function must be evaluated under each feasible combination of $\mathbf{M}^{\mathbf{cv}}$ and $\mathbf{M}^{\mathbf{cb}}$ [75] to identify the market participation vectors $\{\mathbf{M}^{\mathbf{cv}}, \mathbf{M}^{\mathbf{cb}}\}$ that yield the highest level of ***V*** (Key *et al*. 2000; Barrett 2008).

Based on the structural model described above, the reduced form of each choice variable can be represented as a function of observable (exogenous) variables *A, G, Y, Z*, p^{cm}, and p^{x}. This structural model assumes non-separability[76] in household's production and consumption decisions because the parametric prices are endogenous (because of transaction costs). Because of this, production and consumption behaviors are estimated simultaneously (Sadoulet and de Janvry 1995) in this maximization problem.

It is expected that both market participation and quantity traded will be positively affected by asset endowment and access to public goods and services, and negatively affected by transaction costs. In this study, transaction costs include all costs associated with a transaction (e.g. transportation of output to the market, fees paid). Smallholder farmers in rural Angola generally sell their surpluses to itinerant traders at low prices (World Vision 2008). Although this suggests that there may be low barriers to participate in the market, due to high transaction costs (e.g. obtaining price information) farmers' per unit returns will be small. Therefore, understanding what factors affect smallholder market participation decisions will be useful in designing policies regarding public and private investments oriented to boost market participation by smallholder farmers in rural Angola.

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[75] There are 27 possible combinations to evaluate for.

[76] This implies that production decisions are made as if the household was maximizing profits, while consumption decisions are made as if the household was maximizing utility. For further reading see de Janvry *et al.* (1991) and Sadoulet and de Janvry (1995).

3.4.2 Econometric Estimation

As mentioned above, this study attempts to estimate the factors associated with households' marketing decisions, focusing on households who sell potatoes, beans and/or onions in rural Angola. Given that sales are only observed for a subset of the sampled population because farmers who did not sell any or all of these crops reported zero sales, the function estimated (i.e. quantity traded) on the selected sample may not estimate the population (i.e. random sample) function (Heckman 1979) due to self-selection problems.[77] Therefore, if the parameters were estimated by least squares, they would be biased and inconsistent (Wooldridge 2009).

There are at least three alternatives to least squares to estimate unbiased, consistent, and efficient parameters. The ***first*** alternative is to estimate the parameters using the standard Heckman sample selection model (two step version[78]) used by Goetz (1992), Benfica *et al*. (2006), and Boughton *et al*. (2007). With Heckman two-step approach, one first estimates a probit model of market participation; then, in the second step, one fits a regression of quantity traded (*regression equation* below) by least squares, conditional on market participation (Wooldridge 2003). From the probit, one could derive the Inverse Mills Ratio (IMR) and include it as a regressor into the second equation to control for selection bias and obtain unbiased, consistent, and efficient estimators using OLS (for details, see Wooldridge 2003, p. 560-562).

A Heckman selection approach would be appropriate in this context because many households reported zero sales. However, the Heckman regression is designed for incidental truncation, where the zeros are unobserved values (e.g. as with wage rate models where the

[77] Self-selection arises due to transaction costs, which are reflected in the endogenous market prices faced by farmers.

[78] Heckman could also be solved by full maximum likelihood (StataCorp 2009).

sample includes unemployed persons) (Ricker-Gilbert *et al.* 2011). Therefore, a corner solution model is more appropriate in this context because, due to market and agronomic conditions, the zeros in the data reflect farmers' optimal choice rather than a missing value (as with Heckman).

The ***second*** and ***third*** alternatives to least squares (both corner solution models) are the Tobit estimator proposed by Tobin (1958) and the double hurdle (DH) proposed by Cragg (1971),[79] respectively. Although the Tobit model could be used to model farmers' marketing decisions, its major drawback is that it requires that the decision to sell a particular crop and the decision about how much of that crop to sell be determined by the same process (i.e. the same variables), which makes it fairly restrictive (Wooldridge 2003 and Ricker-Gilbert *et al.* 2011).[80] In addition, in a Tobit model, the partial effects of a particular variable, x_j, on the probability that the farmer will sell and on the expected value of the quantity traded, conditional on participation, have the same signs (Wooldridge 2008).

The DH model is a more flexible alternative than the Tobit because it allows for the possibility that factors influencing the decision to sell a crop are different than factors affecting the decision of how much to sell. Therefore, the DH model proposed by Cragg (1971) is utilized in this paper.

In the DH model,[81] the first hurdle estimates the decision of whether or not to participate in the market (i.e. to sell a crop) and, conditional on market participation, the second hurdle estimates the quantity traded (i.e. quantity sold). Conceptually, a simple corner-solution model is where:

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[79] He proposed a double-hurdle model that nests the usual Tobit model.

[80] For details about the Tobit model, see Wooldridge (2003), pg. 540-546.

[81] Also called two-tiered model.

$y_i = s\ y_i^*$ if $y_i^* > 0$

$y_i = 0$ if $y_i^* \leq 0$

where

$y_i^* = \alpha + \mathbf{X_i}\, \boldsymbol{\beta} + \varepsilon_i$

s = 1 if participates in the market; s = 0 otherwise

In this model, y_i is the quantity traded by farmer *i*, α is the intercept, β is a vector of coefficients, X_i is a vector of explanatory variables, and ε_i is the error term.

The binary variable, *s*, is used to estimate the maximum likelihood estimator (MLE) of the first hurdle and is assumed to follow a probit model. Therefore, the probability of a farmer choosing not to participate in the market is given by:

(3.1) $P(s = 0 \mid x_1) = P(y = 0 \mid x_1) = 1 - \Phi\,(x_1\, \gamma)$

where Φ is the standard normal CDF and γ is the vector of coefficients of x_1.

In the second hurdle, the continuous variable, *y* (i.e. quantity traded), is assumed to follow a truncated normal distribution. Therefore, the MLE is obtained by fitting a truncated normal regression model[82] to the quantity traded (Cragg 1971 and Burke 2009):

(3.2) $f\,(y \mid x_1, x_2) = [\Phi\,(x_1\, \gamma)\,(2\pi)^{-1/2}\, \sigma^{-1} \exp\{-(y - x_2\, \beta)^2 / 2\,\sigma^2\}\,]$

$/\ \Phi\,(x_2\, \beta / \sigma)$ for $y > 0$

[82] The model is called truncated because the distribution of *y* is truncated at zero to guarantee non-negativity (Cragg 1971).

where f is the probability density function of positive values of y and σ^2 is the variance of the distribution. Therefore, Cragg's model integrates Equations (3.1) and (3.2) to obtain:

$$(3.3) \quad f(s, y \mid x_1, x_2) = [1 - \Phi(x_1 \gamma)]^{1(s=0)} \; [\Phi(x_1 \gamma) (2\pi)^{-1/2} \sigma^{-1} \exp\{-(y - x_2 \beta)^2 / 2\sigma^2\} \; / \Phi(x_2 \beta / \sigma)]^{1(s=1)}$$

where, as mentioned above, s is a binary indicator equal to 1 if y is positive and 0 otherwise. Equation (3.3) demonstrates that the probability of market participation (i.e. $y > 0$) and the analysis of quantity traded (i.e. value of y), conditional on market participation, could be determined by different factors (the vectors γ and β, respectively) (Burke 2009). The model also puts no restrictions in the variables included in x_1 and x_2, implying that these could be the same (i.e. $x_1 = x_2$) or have several or no variables (i.e. $x_1 \neq x_2$) in common. Furthermore, Equation (3.3) yields the standard Tobit density when $\gamma = \beta / \sigma$ and $x_1 = x_2$ (Wooldridge 2002 and Burke 2009).

In order to fit Cragg's model to the data, it is necessary to assume that s and y^* are independent, conditional on explanatory variables $\boldsymbol{X}$ (Wooldridge 2008); that is:

$$D(y^* \mid s, \mathbf{X}) = D(y^* \mid \mathbf{X})$$

where D is the distribution of the latent variable y^*. The above equation implies that the expected value of y conditional on $\boldsymbol{X}$ and s is:

$$E(y \mid X, s) = s \bullet E(y^* \mid X, s) = s \bullet E(y^* \mid \mathbf{X})$$

From Cragg's model, one could estimate the same probabilities and expected values as with Tobit. However, Cragg's model uses an updated functional form (Equation (3.3) above).

The probabilities regarding market participation (i.e. whether y is positive) are:

(3.4) $P(y_i = 0 \mid x_{1i}) = 1 - \Phi(x_{1i}\,\gamma)$ i.e. no market participation[83]

(3.5) $P(y_i > 0 \mid x_{1i}) = \Phi(x_{1i}\,\gamma)$ i.e. market participation

The expected value of *y*, conditional on market participation (i.e. $y > 0$) is:

(3.6) $E(y_i \mid y_i > 0, x_{2i}) = x_{2i}\,\beta + \sigma \times \lambda\,(x_{2i}\,\beta / \sigma)$

where $\lambda\,(x_{2i}\,\beta / \sigma)$ is the Inverse Mills Ratio (IMR)

$$\lambda\,(x_{2i}\,\beta / \sigma) = \mathit{\Phi}\,(x_{2i}\,\beta / \sigma) / \Phi\,(x_{2i}\,\beta / \sigma)$$

where $\mathit{\Phi}$ is the standard normal probability distribution function. The "unconditional"[84] expected value *y* of is:

(3.7) $E(y_i \mid x_{1i}, x_{2i}) = \Phi\,(x_{1i}\,\gamma)\ [x_{2i}\,\beta + \sigma \times \lambda\,(x_{2i}\,\beta / \sigma)]$

From the DH model above, one could estimate the "unconditional" partial effect (PE) of a particular variable, x_j, for each observation *i*. Using these PE, one could estimate the average partial effect (APE) of the variable of interest (i.e. x_j) by averaging the PE across all observations in the dataset. However, the standard deviation reported with the APE should not be used as a standard error for inference about the population because it describes only the data. Instead, two alternatives could be used: (a) standard deviations could be re-estimated by bootstrapping or (b) standard errors could be approximated by the delta method (i.e. Taylor expansion around the data mean) (Burke 2009). Burke (2009) provides the Stata programming necessary to make

[83] Equations (3.4) to (3.7) were taken from Burke (2009).

[84] "Unconditional" refers to market participation (i.e. random population) since all expectations are "conditional" on the explanatory variables.

inferences on an “unconditional” APE using methods (a) and (b) above. In this paper, bootstrapping at 500 repetitions was used.

Key *et al.* (2000) showed that while market participation (i.e. household’s decision of whether or not to participate in the market) depends on both fixed and proportional transactions costs, the quantity supplied, conditional on participation, is only affected by proportional transactions costs. The DH model described above allows for different factors to affect the first and second hurdles. However, the variables used as proxies for fixed costs (i.e. distance to market and quality of the road) were included in both the market-participation and the quantity-traded regressions to test whether fixed costs only affect the first hurdle among Angolan farmers.

Although the independent variables included in the regressions are explained in the next section, the quantity harvested (included in both hurdles) is worth mentioning here. Quantity harvested is potentially endogenous to the decision of whether or not to participate in the market as a seller and on the decision of how much to sell. For instance, if a farmer produces a crop with the intention of selling his/her surplus, whether he/she participates in the market will depend on how much he/she harvests--i.e. if the quantity harvested is small, he/she might decide not to sell or to sell a smaller amount. Furthermore, market conditions will influence the amount a farmer produces because if the farmer perceives that he/she could sell in the market, he/she may decide to produce more for this purpose. Because of these factors, there may be correlation between the error term in a reduced equation of quantity harvested and the error term of the probability of participation and quantity traded.

To deal with this potentially endogenous variable, an OLS regression will be estimated on the quantity produced of each crop. Then, the residuals from these OLS regressions will be estimated and included in both the probit and truncated normal regressions as an additional explanatory variable. This allows determining if the quantity produced is truly endogenous (i.e. if the coefficient of this variable is statistically significant, the quantity produced is endogenous). Although several variables included in the OLS regressions are also included in the DH regressions, the former includes additional variables that are not expected to directly affect marketing participation decisions.

3.5 Data Used

Data used in this study come from the cross sectional household- and village-level survey implemented by World Vision's ProRenda project in Angola in 2009. World Vision, in collaboration with ACDI/VOCA,[85] the Ministry of Agriculture and Rural Development of Angola, and the Angolan NGO HORIZONTE are implementing a four-year project[86] targeted at increasing smallholder-farming families' annual income from non-perishable crops (World Vision 2008). The ProRenda project attempts to increase smallholder's incomes, especially those of women, by establishing competitive value chains for potatoes, beans, onions, and other high-value crops. Michigan State University has been contracted to conduct impact assessment of this project.

The baseline survey was implemented from January through April of 2009 and collected data about the latest harvest between September 2007 and December 2008. In Angola, the agricultural year goes from September through May of the following year (MINADER and FAO 2003). Therefore, the data collected refers to the 2007-2008 agricultural year and the first season of the 2008-2009 agricultural year.

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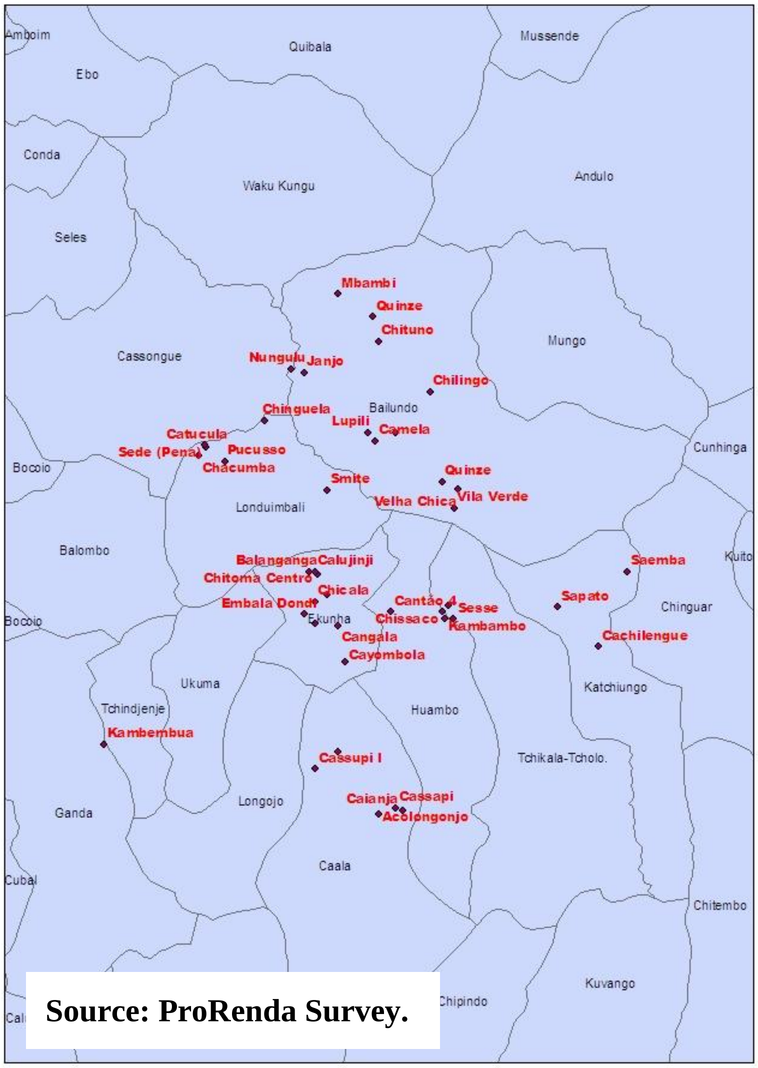
[85] Agricultural Cooperative Development International/Volunteers in Overseas Cooperative Assistance.

[86] The ProRenda Project, which is financed by the Bill and Melinda Gates Foundation.

The survey was implemented in three provinces of the central highlands of Angola: Huambo, Bie, and Benguela. These provinces have the most productive lands within the highland region (World Vision 2008) because of good rainfall distribution and environmental conditions; however, yields are usually low (MINADER and FAO 2003). The major crops produced in the highlands are: corn, wheat, rice, potatoes, sweet potatoes, beans, cassava, sugarcane, peanuts, sunflower, sesame, tobacco, and vegetables (MINADER and FAO 2003).

The survey included a total of 656 households[87] across 40 villages (Figure 3.5.1). The households were selected using a clustered sampling methodology. This means that the villages were selected first from a listing of all the potential villages within the action area of the ProRenda project. The villages were selected systematically using probability proportional to size for three categories of villages: 1) primary villages for ProRenda project activities; 2) secondary villages for ProRenda project activities and 3) control villages. After selection of the villages in each category, a household listing for each village was used to identify the classification of each household, based on four categories: male head, female head, and participation or no participation in a farmer organization at the time of the listing. Within each

[87] Although 656 households were surveyed, only 620 surveys were valid and were used for analysis.



Source: ProRenda Survey.

Figure 3.5.1. Distribution of villages included in the ProRenda 2009 survey. The text in the figure is not meant to be readable but is for visual reference only.

category a random systematic sample of households were selected.[88] In order for the sample estimates to be representative of the population covered by the survey, sampling weights were used. The basic weight for each sampled household is the inverse of its probability of selection (see Reyes *et al*. 2010 for details).

88 Details about the sampling methodology and weight estimation can be found in Reyes *et al*. (2010).

The household-level survey collected information about household socioeconomic characteristics, productive and non-productive assets, participation in farmer organizations, and production and marketing information of beans, potatoes, onions, carrots, and cabbages. The village-level survey collected information regarding the distance between the village and the main commercial town, availability of public services (e.g. local markets, agricultural extension services) and public transportation, and quality of the road between the village and the main commercial town.

The independent variables included in the regressions were classified into five categories: (1) household characteristics, (2) private assets, (3) public assets and quasi-fixed factors, (4) production- and marketing-related variables, and (5) squared and interaction terms (Table 3.5.1). These variables were included because they were theoretically expected to affect production and marketing decisions. A total of 34 independent variables were used in various combinations to estimate the three models proposed in the previous section: (a) linear regression model of quantity produced, (b) probit model of market participation, and (c) truncated normal regression model of quantity traded.

Although most variables are self-explanatory, a brief explanation of key variables is provided next. The dependency ratio was estimated by dividing the number of people younger than or equal to 17 by the household size. Having a household member participating in a farmer organization (FO) refers to any member of the household who participated in a FO within the previous 12 months. Adult literacy refers to members older than 17 who can read and write (self-declared, not tested). The number of tropical livestock units was estimated using FAO conversion factors for South Africa where, for example, one cattle equals 0.70 livestock units and one sheep equals 0.10 livestock units (FAO 2010).

Table 3.5.1. Independent variables included in the production and marketing decision regressions. Angola, 2009.

No.	Variable	Model where included[1]	Description of variable
	Dependent:		
	Quantity produced (kg)	1	Quantity produced of each crop.
	Market participation (1=yes)	2	Whether or not participates in the market as a seller.
	Quantity sold (kg)	3	How much was sold.
	Household (HH) Characteristics:		
1	Age of HH head (yr)	1, 2, 3	
2	Gender of HH head (1=male)	1, 2, 3	
3	Dependency ratio	1, 2, 3	Number of dependants (≤17 yr) divided by HH size.
4	HH member is in a farmer organization (1=yes)	1, 2, 3	
5	No. adults who can read & write	1, 2, 3	Adults refer to people older than 17 yr of age.
6	Number of TLU[2] owned	1, 2, 3	Includes oxen, cattle, goats, sheep, pigs, chicken, and rabbits.
7	HH has zinc roof (1=yes)	1	
8	Asset Index	2, 3	Estimated using principal component analysis for 9-11 types of assets owned by the HH.
	Private Assets (1=yes):		
9	Own plow	1	Plow used to prepare the soil.
10	Own backpack sprayer	1	Sprayer used to apply pesticides.
11	Own motorcycle	2, 3	
12	Own bicycle	2, 3	
	Public Assets and Quasi-fixed Factors:		
13	IDA office in the village (1=yes)	1, 2, 3	IDA is the government's Institute for Agrarian Development.
14	Public market available in the village (1=yes)	1, 2, 3	Farmers could buy/sell food in the public market.
15-21	Seven dummy variables for municipalities (1=yes)	1, 2, 3	Although eight municipalities were surveyed, only seven dummies were included to avoid the dummy variable trap.

Table 3.5.1 (cont'd).

No.	Variable	Model where included[1]	Description of variable
22	Distance from village to commercial town (km)	2, 3	
23	Road between village and commercial town in poor condition (1=yes)	2, 3	Poor condition means the road is a clay road, not rehabilitated (i.e. without maintenance).
	Production- and Marketing-related Variables:		
24	Seed used (kg)	1	
25	Type of plot (1=rainfed plot)	1	Rainfed plots are the most commonly used plots.
26	Planted intercropped (1=yes)	1	Only beans could be planted intercropped.
27	Planted seed of local variety (1=yes)	1	Local varieties are usually low-quality seed.
28	Used fertilizer (1=yes)	1	
29	Used pesticides (1=yes)	1	
30	Reported production costs (Kw/kg)	1	Includes expenses on seed, pesticides, labor, transport from field to home
31	HH reports lower harvest (1=yes)	1	Obtained by comparing current year with a normal year.
32	Seller sought price information prior to sales (1=yes)	3	
33	Reported marketing costs (Kw/kg)	3	Includes expenses on bags, transportation, load/unload, taxes
34	Quantity produced (kg)	2, 3	The predicted residuals are also included in models 2, 3
	Squared terms:		
	Age of HH head squared	1	
	Dependency ratio squared	1	
	No. adults who read & write squared	1	
	No. TLU squared	1	
	Seed used squared	1	
	Interaction of 30 * 31	1	

[1] 1 = Ordinary Least Squares for production; 2 = Probit for market participation; 3 = Truncated Normal Regression for quantity sold.

[2] TLU = Tropical Livestock Units, calculated using FAO conversion tables.

An asset index was estimated as a proxy for household wealth. This index was estimated using principal component analysis. Details about this index are included in Section 3.6.2 below. However, several asset variables were included in the regressions separately from the asset index (e.g. having a home with zinc roof, owning a motorcycle). The quasi-fixed variables included seven dummies for the municipalities where the households were located to control for variations in environment and marketing conditions faced by farmers (at the macro-level).[89] Transaction costs (TC) included the distance between the village and the main commercial town and the quality of the road between these two places.

The production-related variables are self-explanatory except for 'type of plot.' Angolan farmers in these provinces could cultivate in one (or several) of four possible types of plots: *nacas*, *ombandas*, *otchumbo*, and *lavras*.[90] *Nacas* are irrigated lowland areas located close to river deltas, used during the dry season (by exploiting residual moisture), and account for 4% of the cultivated area. *Ombandas* are medium-level lands with access to gravity-fed irrigation, used in all seasons, and account for 15% of the cultivated area. *Otchumbo* are small areas close to the homestead, intensively cultivated all year round, and account for 4% of the cultivated area. Finally, *lavras* are upland areas used for rainfed agriculture and account for 77% of the cultivated area (World Vision 2008). *Lavras* are the most commonly used types of plots, thus a dummy variable was created to account for whether the crop was produced in this type of plot.

Unit production costs were estimated by adding reported expenditures on fertilizers, seed, pesticides, hired labor, and transport from the field to the home and dividing this by the total quantity produced. Family labor contributions were not valued. Similarly, unit marketing costs

[89] Although it would have been ideal to include dummy variables for each village, this was not practical because there were 40 villages.

[90] These are Portuguese names with no English translation.

were estimated by adding farmers' reported expenditures for bags, sewing of these bags, transportation costs, loading and unloading of the output, and taxes and fees paid at the market and dividing this by the total quantity sold. The squared terms were included to allow for non-linear relationships between independent and dependent variables.

Finally, the land area owned by each household and the area planted of each crop were not included the analysis because the instrument used to collect the household-level information did not include these questions. To control for this potential bias, two variables were included as explanatory variables: the asset index to compensate for the omission of land owned and the amount of seed used to compensate for the omission of area planted.

3.6 Results

This section is divided into five subsections. The first subsection describes the sample and provides the socioeconomic characteristics of farm families, focusing on the variables of interest for the double hurdle analysis. For each crop, the results are disaggregated by market participation. The second subsection briefly describes households' wealth (economic status index). The third subsection discusses household-level receipts and margins for households selling key crops (i.e. potatoes, beans and onions). Subsection four presents the OLS regression results of the quantity produced per crop. The last subsection details the double hurdle regression results.

3.6.1 Descriptive Statistics

Beans were planted by the highest number of farmers, followed by potatoes and onions. While almost three out of four farmers planted beans, 55% of farmers planted potatoes, and 46%

of farmers planted onions (Table 3.6.1). Further, less than 10% of farmers planted other vegetables, which was expected since farmers in this region mostly depend on maize, bean, and potato production. While 27% of farmers planted both potatoes and onions, 29% of farmers planted beans and onions, and 32% planted potatoes and beans, the most common combination. Regarding sales, approximately 71% of farmers producing potatoes sold part of their harvest, 69% of farmers producing beans were sellers, and 68% of farmers producing onions sold a share of their harvest. In contrast, close to 90% of farmers growing a combination of crops sold at least one of the crops they produced.

Table 3.6.1. Percentage of households growing key crops, per economic status index and gender of household head (HHH). Central Highlands of Angola, 2009.

	Economic Status Index by tercile [1]						**Gender of HHH [1]**			
Crop	**Lowest**		**Middle**		**Highest**		**Male**	**Female**		**Total**
					(% of households)					
Potatoes	45%	a	49%	a	64%	b	58%	48%	**	55%
Beans	77%		73%		68%		69%	75%		71%
Onions	33%	a	49%	b	54%	b	51%	37%	***	46%
Other vegetables [2]	3%	a	5%	a	17%	b	11%	4%	***	9%
Potatoes and onions	23%	a	20%	a	36%	b	30%	22%	*	27%
Potatoes and beans	24%	a	30%	ab	40%	b	35%	26%	**	32%
Beans and onions	23%		31%		34%		32%	23%	**	29%
Number of observations	164		184		130		276	250		526

NOTES: All variables are binary (0=NO, 1=YES). Number of observations in Economic Status Index smaller than in last column because of missing values in this variable. Estimates weighted to reflect population (except number of observations).

[1] Bonferroni test of difference between means: for Economic Status Index, different letters imply differences are significant at 10%; for Gender of HHH, * significant at 10%; ** significant at 5%; *** significant at 1%. Economic Status Index estimated using principal component analysis.

[2] Other vegetables only include carrots and cabbages.

Source: ProRenda survey, Angola, 2009.

Cultivating potatoes, onions, other vegetables, or a combination of potatoes and onions or potatoes and beans was more common among richer farmers (as classified by their asset index[91]) and male-headed households. In contrast, most households planted beans--across different economic strata and regardless of the gender of the head (Table 3.6.1). This was expected since, though beans are generally produced for home consumption, they can easily be sold in the markets and are an important source of income for rural households. Further, a higher share of male-headed households planted both beans and onions, compared to female-headed households.

Table 3.6.2 reports the descriptive statistics of households in the Central Highlands of Angola, disaggregated by crop and their market participation (i.e. non-sellers vs. sellers). Although most farmers planted beans (Table 3.6.1), they marketed a larger quantity of potatoes than beans or onions. On average, each farmer supplied 200 kg of potatoes, 96 kg of beans, and only 50 kg of onions, which corresponds to roughly 77%, 49%, and 68% of total (i.e. non-sellers' and sellers') potato, bean, and onion production, respectively (Table 3.6.2). Furthermore, farmers who did not sell produced less than sellers.

While farmers who sold onions were, on average, five years younger than non-sellers (10% significance level, SL), the differences in age between sellers and non-sellers of potato and beans were not statistically significant at the 10% level (Table 3.6.2). Furthermore, as expected, more male- than female-headed households sold their surpluses. Although the proportion of male-headed households participating and not participating in the market (i.e. sellers vs. non-sellers) were similar for beans, among potato and onion producers, the share of male-headed households selling their output was much larger than that of female-headed households (1% SL; Table 3.6.2).

[91] Asset index and economic status index are used interchangeable in this section.

Table 3.6.2. Descriptive statistics of the variables used in the Double Hurdle analysis. Central Highlands of Angola, 2009.

	Potato					**Bean**					**Onion**				
	Non-sellers		**Sellers**			**Non-sellers**		**Sellers**			**Non-sellers**		**Sellers**		
Demographics	Mean	S.E.	Mean	S.E.	MT[1]	Mean	S.E.	Mean	S.E.	MT[1]	Mean	S.E.	Mean	S.E.	MT[1]
Quantity sold (kg)	n.a.		200	22.36	--	n.a.		96	19.49	--	n.a.		50	5.49	--
Household Characteristics															
Age of head (years)	42	3.858	39	0.411		44	0.810	43	0.400		47	5.412	42	0.811	*
Gender of head (% male)	52	0.283	78	0.195	***	70	0.268	68	0.274		61	0.345	82	0.157	***
Dependency ratio[2]	0.50	0.018	0.58	0.022	**	0.53	0.007	0.56	0.020		0.54	0.021	0.55	0.015	
HH member is in FO[3] (% yes)	4	0.025	11	0.054	*	10	0.026	1	0.006	***	0.7	0.006	8	0.044	*
Family members older than 17 who are literate[4]	0.9	0.198	0.7	0.085		0.6	0.082	0.9	0.103	***	0.8	0.126	1.0	0.139	
No. TLU[5]	0.47	0.121	0.36	0.083		0.38	0.125	0.44	0.083		0.22	0.039	0.45	0.068	***
Modified Asset Index[6]	-0.14	0.284	0.37	0.212	***	0.04	0.250	0.07	0.239		0.37	0.400	0.22	0.126	
Owns motorcycle (% yes)	4	0.022	10	0.026		11	0.051	10	0.026		12	0.061	7	0.044	
Owns bicycle (% yes)	25	0.155	29	0.061		14	0.050	20	0.064		17	0.067	26	0.058	
Public Assets and Quasi-fixed factors															
IDA[7] office in village (% yes)	17	0.052	26	0.040		8	0.078	20	0.028	***	17	0.084	17	0.024	
Public market available in village (% yes)	19	0.052	16	0.052		6	0.045	19	0.023	***	11	0.035	11	0.045	
Mean[8] sales price, local market (kw/kg)	88.4	5.246	75.1	2.995	***	64.4	1.140	67.8	0.899	**	83.0	6.155	97.8	6.167	**
Percent of HH in following municipalities:															
Caala	23	0.065	11	0.020	**	12	0.030	5	0.010	**	15	0.031	6	0.021	*
Ekunha	1	0.008	2	0.017		6	0.035	3	0.020		0.6	0.007	2	0.014	
Bailundo	21	0.062	19	0.053		46	0.048	53	0.040		44	0.040	37	0.069	
Londuimbali	35	0.054	15	0.030	***	16	0.019	28	0.024	**	30	0.096	23	0.017	

Table 3.6.2 (cont'd).

	Potato					Bean					Onion				
	Non-sellers		Sellers			Non-sellers		Sellers			Non-sellers		Sellers		
Demographics	Mean	S.E.	Mean	S.E.	MT[1]	Mean	S.E.	Mean	S.E.	MT[1]	Mean	S.E.	Mean	S.E.	MT[1]
Katchiungo	4	0.014	15	0.021	**	11	0.051	3	0.008	***	2	0.019	9	0.024	
Tchicalachuluanga	7	0.029	2	0.016	**	6	0.038	2	0.010	**	2	0.012	4	0.022	
Chiguar	9	0.041	36	0.059	***	4	0.039	6	0.038		6	0.052	20	0.059	**
Babaera	0.6	0.005	0.2	0.002		0.5	0.004	0.2	0.002		0.1	0.001	0	n.a.	--
Distance from village to commercial town (km)	10.3	0.990	11.4	0.908		8.0	1.009	10.0	0.405		9.7	2.238	8.0	0.945	
Road between village and commercial town in poor condition[9] (% yes)	66	0.100	81	0.029	**	80	0.067	73	0.065		53	0.052	81	0.048	***
Production and Marketing variables															
Quantity produced (kg):	30	8.85	230	29.72	***	53	12.95	143	25.41	***	16	3.25	58	5.66	**
In Caala	50	16.02	359	59.52	--	26	4.42	41	3.47	--	24	5.37	103	21.27	--
In Ekunha	66	0.00	417	54.89	--	26	5.85	176	47.20	--	75	0.00	109	26.76	--
In Bailundo	12	1.91	42	11.47	--	41	4.03	137	16.31	--	16	5.85	29	2.49	--
In Londuimbali	30	15.44	172	26.64	--	149	45.39	201	51.86	--	17	9.63	102	39.15	--
In Katchiungo	20	11.34	224	51.70	--	35	0.00	41	8.74	--	2	0.00	53	48.29	--
In Tchicalachuluanga	16	2.66	136	15.89	--	23	8.77	71	9.52	--	5	0.45	44	24.96	--
In Chiguar	37	11.36	312	61.55	--	12	0.89	72	14.59	--	6	0.52	50	19.16	--
In Babaera	12	3.12	92	9.64	--	9	1.40	38	11.57	--	5	0.00	0	n.a.	--
Seller sought price information prior to sales (% yes)	n.a.		63	0.045	--	n.a.		71	0.008	--	n.a.		63	0.068	--
Reported marketing costs (Kw/kg)	n.a.		2.9	0.249	--	n.a.		3.0	0.703	--	n.a.		3.1	0.435	--
Number of observations	75		165			89		216			49		125		

Table 3.6.2 (cont'd).

[1] MT = test of difference between means: *significant at 10%; **significant at 5%; ***significant at 1%; -- not tested; n.a. = not applicable.

[2] Dependency ratio estimated by dividing the number of people 17 years or younger by the household size. A high dependency ratio means more dependants in the household.

[3] FO = Farmer organization.

[4] Literacy refers to people who can read and write (self-declared, not confirmed).

[5] TLU = Tropical Livestock Units (estimated using FAO conversion factors).

[6] Modified Asset Index excludes owning a motorcycle and owning a bicycle to be able to estimate the effect of these variables on marketing decisions separately from other assets included in the index.

[7] IDA = Government's Institute for Agrarian Development.

[8] For farmers who sold in local markets, their reported price was averaged per community. Communities with missing prices use average price per the next political division (i.e. town, municipality). This price was imputed to non-sellers.

[9] Poor condition means the road is a clay road, not rehabilitated (i.e. without maintenance).

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

On average, there were slightly more than one dependent for every two adults in the household (the average dependency ratio was 0.52). Furthermore, potato sellers had more dependents than non-sellers (5% SL; Table 3.6.2). As Table A 3.1 shows, potato sellers had 1.5 children younger than five vs. only one among non-sellers (1% SL).

Less than 11% of households had at least one member who participated in a farmer organization (FO) in the year prior to the interview (Table 3.6.2). A higher percent of households selling potatoes and onions, compared to non-sellers, reported having a member participating in a FO (10% SL). In contrast, a higher percent of households producing beans solely for consumption (i.e. non-sellers) reported having a household member participating in a FO (1% SL; Table 3.6.2), which was unexpected. Given that bean non-sellers reported other crops as their major source of crop income and that the large majority of bean sellers reported beans as their major source of crop income (Table A 3.2), it is likely that non-sellers participate in FO related to these other crops, thus explaining this finding.

Among bean producers, households selling beans had more literate adults (i.e. older than 17) living at home (1% SL). While the differences in the number of tropical livestock units (TLU) owned between sellers and non-sellers were not statistically significant at the 10% level for potatoes and beans, onion sellers reported more TLU than non-sellers (1% SL; Table 3.6.2).

In this study, an asset index, which was estimated using 11 assets, was used as a proxy for household wealth. Details about its estimation and interpretation are included in Section 3.6.2. Households selling potatoes were wealthier than non-sellers (1% SL). While there were no statistically significant differences (at the 10% level) in the asset index between bean and onion sellers vs. non-sellers, it was surprising to find that onion non-sellers had a higher asset index than onion sellers (Table 3.6.2). Since a higher percent of onion non-sellers (20% vs. 2% sellers) reported remittances and other transfers as their major source of non-crop income (Table A 3.2), it is likely that non-sellers invest part of these transfers on improving their home or purchasing assets; thus, explaining this finding.

Most of the differences (between sellers and non-sellers) regarding access to public assets and quasi-fixed factors were statistically significant for potato and bean producers (Table 3.6.2). While 19% of bean sellers reported having access to a public market for purchasing food in their villages, only six percent of non-sellers reported having access to this public good (1%SL). Similarly, access to the government's Institute for Agrarian Development (IDA) office (which provides extension services) was more common among bean sellers (20% vs. 8% non-sellers, 1% SL) (Table 3.6.2).

As previously explained, sales prices were collected for farmers who sold at least part of their output. Farmers reported selling their output in different places, including at their farm, their home, local markets, and other markets. To control for (potential) endogeneity problems in market prices, for farmers who reported selling at local markets, the average sale price was estimated for each crop. However, in some villages, none of the farmers who sold their output did so in local markets; thus, the average price could not be estimated. In these cases, the average price of the next political division (i.e. town, municipality) was estimated and used. Although this information is presented in Table 3.6.2, it was excluded from the double hurdle analysis because it was judged to be inaccurate. In villages with no sellers, prices collected at the next political division (e.g. municipality) were imputed to non-sellers in these villages. It is likely that these non-sellers were imputed too high of a price, thus offsetting any positive effect of this variable.[92]

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[92] Furthermore, as one would expect, current prices are likely endogenous.

The average distance between the villages and their main commercial town was 9.6 km (Table 3.6.2). Among potato and bean producers, a higher percent of sellers than non-sellers were located in villages farther from the main commercial town (although the differences were not statistically significant); thus, the average distance from their villages to their main commercial town was higher for sellers. Furthermore, a higher share of potato and onion sellers was located in villages with poor quality road between the village and the main commercial town (5% and 1% SL, respectively).

Regarding the variables used to control for macro-level environmental and market conditions, potato and onion production was highest in Ekunha municipality among both sellers and non-sellers. In contrast, bean production was highest in Londuimbali (Table 3.6.2). Since Londuimbali accounted for the largest percentage of beans produced, the municipality coefficients from the regression results (of all crops) were compared to this municipality.[93] Furthermore, since no farmers in Babaera municipality sold onions, the binary variable for this municipality was excluded from the double hurdle regressions for this crop.

Finally, close to two-thirds of the farmers who sold their output obtained price information before selling their crop and sellers reported an average marketing cost of three Kwanzas[94] per kilogram sold, with the highest marketing costs reported by onion sellers (Table 3.6.2).

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[93] Although there was one dummy variable for each municipality, the variable for Londuimbali was excluded from the regressions to avoid the dummy variable trap.

[94] The exchange rate at the time of the survey was 75 Angolan Kwanzas per US$.

3.6.2 Wealth of the Households

To analyze wealth across various types of assets, researchers have developed asset indices that take into account the relative importance of the asset in the sample (i.e. giving less weight to assets commonly owned and more weight to assets owned by a few). In this study, following Filmer and Pritchett (2001), McKenzie (2005) and Reyes *et al*. (2010), principal component analysis was used to estimate an economic status (or asset) index, based on asset ownership. Reyes *et al*. (2010) details the index estimation process, using the same dataset used for this study; thus, interested readers can refer to these authors for more details on the theory and the construction of the index.

In constructing the index, ownership of the following assets was considered: tractors, trucks, cars, plows, carts, backpack sprayers, motorcycles, bicycles, cell phones, radio, and televisions. The index also considered ownership of water storage facilities and a latrine at the homestead, and whether the roof was made of zinc or 'lusalite,' both considered improved materials. From the 14 indicators, tractors, trucks, and cars were excluded because no household in the sample owned these items. A high value for the index indicates a higher level of ownership of these assets, implying greater wealth (Reyes *et al*., 2010).

Households were sorted according to their wealth index and the population was split into three groups or terciles (Table A 3.3). These terciles were used to analyze households' crop margins in the next subsection. The consistency of the index is reflected in the terciles percentages: only 5% of the poorest tercile (lowest 33% of the population) had water storage facilities at home, whereas 19% of the middle tercile and 42% of the highest tercile had this facility at home (Table A 3.3). The mean value of the index (by construction) is zero and its standard deviation is 1.5. The poorest tercile households had an average index of -1.26 while the richest tercile had an average index of 1.72, a difference of 2.98 units (Table A 3.3). One example of a combination of assets that would produce this difference is having a plow (1.11) and a cart (1.87).

The wealth index suggests that male-headed households are richer than female-headed ones (Table 3.6.3). Similarly, farmers who grew potatoes and onions are richer than farmers who did not grow these crops (5% and 1% SL, respectively). The differences in the index between bean growers and non-growers were not statistically significant at the 10% level. These results are confirmed by a graphical analysis of the cumulative distribution of the index by gender and crop grown (Figure 3.6.1 and Figure A 3.1 to Figure A 3.3).

While potato sellers were wealthier (as per their asset index) than non-sellers (1% SL), farmers who did not sell onions were wealthier than onion sellers (10% SL, Table A 3.4). As explained above, a larger share of onion non-sellers had zinc roof (with a "weight" in the asset index of 0.79, see first data column on Table 3.6.3) and, as Table A 3.4 shows, a higher share of non-sellers owned a motorcycle (with a "weight of 1.71) and a television ("weight" of 1.98, the highest among all assets). Although there were slight differences in the index between bean sellers and non-sellers (sellers had a higher index), these were not statistically significant at the 10% level, suggesting that bean growers have similar wealth, regardless of their market orientation.

Table 3.6.3. Scoring factors and means per gender of household head (HHH) and crop grown for asset indicators entering the computation of the first principal component (asset ownership).

Asset indicators	Scoring Factor / Std. Dev.	Percentage of households owning the asset: Gender of HHH: Male	Female	MT	Potato grower: No	Yes	MT	Bean grower: No	Yes	MT	Onion grower: No	Yes	MT
Own plow	1.11	13%	2%	--	7%	11%	--	14%	7%	--	9%	9%	--
Own cart	1.87	0%	0%	--	0%	1%	--	1%	0%	--	0%	1%	--
Own backpack sprayer	1.65	3%	0%	--	2%	3%	--	4%	1%	--	1%	4%	--
Own motorcycle	1.71	10%	3%	--	7%	8%	--	5%	9%	--	5%	11%	--
Own bicycle	0.82	30%	4%	--	18%	25%	--	30%	18%	--	20%	24%	--
Own cell phone	1.27	9%	3%	--	5%	9%	--	2%	9%	--	6%	8%	--
Have water storage at home	0.66	25%	19%	--	26%	20%	--	30%	20%	--	19%	27%	--
Have latrine in the house	0.23	95%	70%	--	87%	87%	--	85%	88%	--	87%	88%	--
Have lusalite or zinc roof	0.79	50%	32%	--	38%	50%	--	51%	42%	--	46%	43%	--
Own radio	0.71	54%	19%	--	37%	48%	--	44%	43%	--	30%	58%	--
Own television	1.98	2%	1%	--	2%	2%	--	1%	2%	--	2%	2%	--
		Mean by group											
Economic Status Index		0.512	-0.625	***	-0.037	0.269	**	0.270	0.070		-0.081	0.364	***
Number of observations	478	242	236		202	276		130	348		289	189	

Notes: Three of the 14 indicators were dropped because they had zero variance. Scoring Factor is the "weight" assigned to each indicator or eigenvector in the linear combination of the variables that constitute the first principal component. The percentage of the covariance explained by the first principal component is 21.06%. The first eigenvalue is 2.32. Data provided in the last eight columns were estimated with weights to reflect population (except number of observations). MT = Bonferroni test of difference between means: * significant at 10%; ** significant at 5%; *** significant at 1%; -- not tested.

Source: ProRenda survey, Angola, 2009.

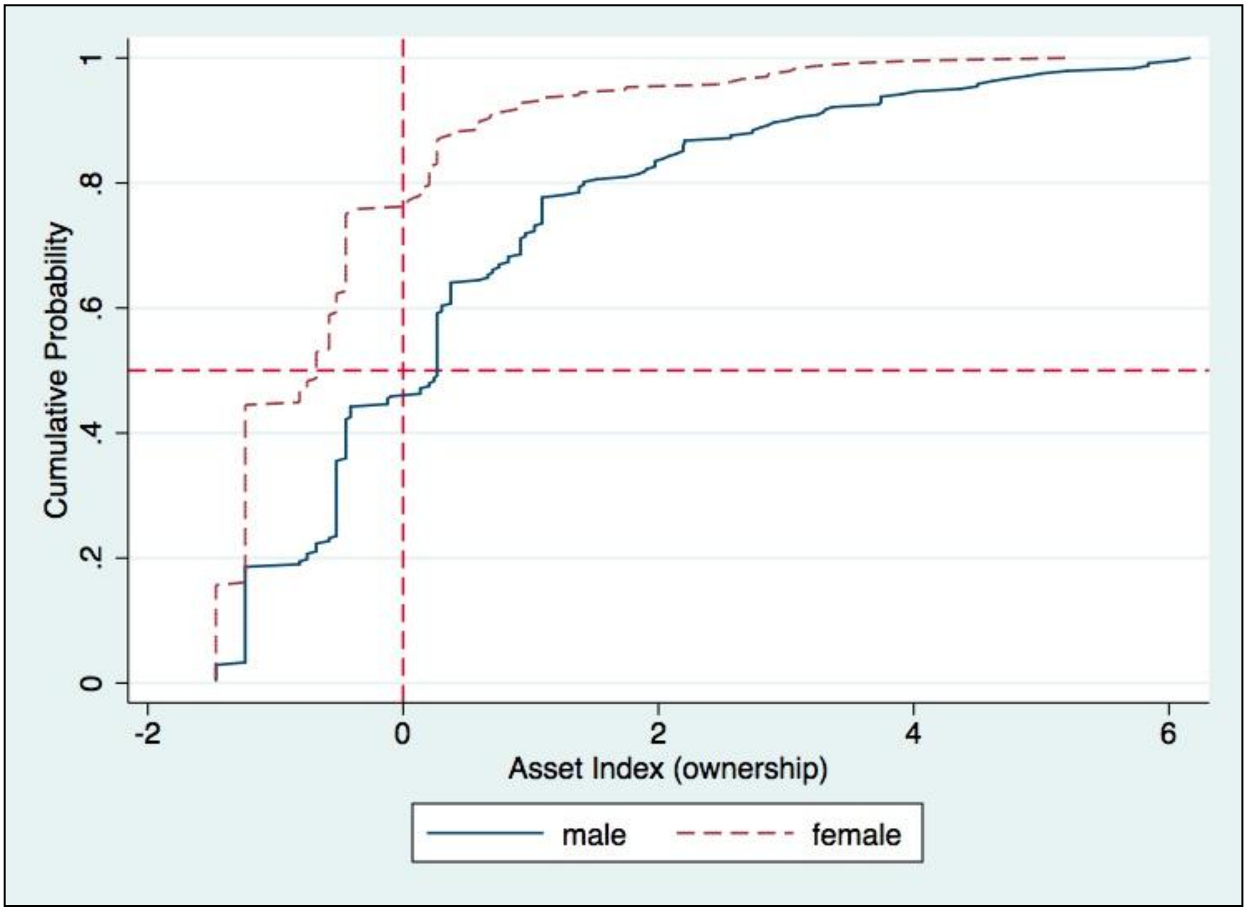

Figure 3.6.1. Cumulative distribution of asset index by gender of household head. Central Highlands of Angola, 2009.

3.6.3 Households' Gross Margins

In this study, households' gross margins equal receipts from sales, which are based only on marketed quantities of potatoes, beans and onions, minus cash expenditures on production and marketing activities. Table 3.6.4 presents households' margins disaggregated by asset index terciles and gender of the household head. While the richest households and male-headed households reported the highest receipts, these households also reported the highest costs. Regardless of the high costs, households' margins were higher for households in the middle and highest terciles (10% SL) and for male-headed households (1% SL).

Table 3.6.4. Average receipts, costs and margins of households selling key crops,[1] per economic status index and gender of household head (HHH). Central Highlands of Angola, 2009.

	Economic Status Index by tercile [2]						Gender of HHH [2]			
Detail	**Lowest**		**Middle**		**Highest**		**Male**	**Female**		**Total**
Receipts (Kw)	5,142	a	9,283	a	19,021	b	14,625	5,103	***	12,150
Total Costs (Kw)	3,143	a	4,945	a	11,436	b	8,487	3,229	***	7,121
Margins (Kw)	2,178	a	4,573	ab	8,170	b	6,420	2,337	***	5,359
Number of observations	119		143		114		241	178		419

NOTES: Kw = Kwanzas. Costs include purchased inputs, hired labor, and reported marketing costs. Variables are at the household level. Number of observations in Economic Status Index smaller than in last column because of missing values in this variable. Estimates weighted to reflect population.

[1] Key crops include potato, onion, and bean sales.

[2] Bonferroni test of difference between means: for Economic Status Index, different letters imply differences are significant at 10%; for Gender of HHH, * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: ProRenda survey, Angola, 2009.

Margins were also analyzed in detail for each crop (Table A 3.5 to Table A 3.7). Although the highest receipts were obtained from potato sales, followed by bean and onion sales, farmers who sold potatoes also reported the highest costs. In contrast, farmers selling beans reported the lowest costs. This was expected since, as is common in developing countries where beans are an important staple, bean producers seldom apply purchased inputs (e.g. fertilizer) to their crop (Reyes, 2011). In our sample, while 66% of potato producers and 49% of onion producers applied fertilizers, only 3% of bean producers applied fertilizer (Table A 3.8). Because of this, bean sellers obtained the highest margins. Furthermore, both richest farmers and male-headed households obtained approximately 2.6 and 3.3 times higher margins from their bean sales (10% and 1% SL) than their counterparts, respectively (Table A 3.6).

One additional finding is worth mentioning here. As Table A 3.7 shows, on average, onion sellers in the lowest and highest terciles reported losses, mainly due to the high per unit production costs reported. However, the differences in margins across terciles and gender of household head were not statistically significant across onion sellers.

3.6.4 OLS Regression Results of Factors Influencing Production

As explained in the previous section, it was suspected that production could be an endogenous covariate in the double hurdle analysis. Thus, for each crop, linear regression (OLS) estimation was used to determine which factors were affecting production. Then, the residuals of these regressions were included as an additional explanatory variable in the double hurdle analysis and tested for endogeneity. This subsection *first* discusses the descriptive statistics of factors affecting crop production. *Second*, for each crop, it presents the results of the OLS regressions on quantity produced.

The descriptive results of the factors influencing production are included in Table A 3.8. On average, farmers produced almost 170 kg of potatoes, 90 kg of beans, and 46 kg of onions. Potato producers were slightly younger than both bean and onion producers, had slightly more dependents, more had members of their household participating in a FO, and more had homes with zinc roof (Table A 3.8). In contrast, more female-headed households produced beans and bean producers had more TLUs than potato and onion producers. Furthermore, onion producers had slightly more literate adults in the household (Table A 3.8).

Regarding productive assets, a slightly higher share of potato producers owned plows and backpack sprayers (compared to bean and onion producers), which they used to prepare their fields and apply pesticides. Additionally, potato producers had more access to the government's IDA offices (Table A 3.8).

Farmers were asked how much seed they used and whether the seed was a local or imported (usually improved) variety. Potato producers used more seed. However, since the planting rate is higher for potatoes than for beans, the estimated area planted to potatoes was smaller than the area planted to beans (0.015 ha vs. 0.393 ha, respectively).[95] Furthermore, it was more common for potato producers to use improved varieties--almost all bean producers and more than 90% of onion producers reported using local varieties (Table A 3.8).

While almost 95% of bean producers planted in rainfed plots (i.e. *lavras*), less than one-half of potato producers (44%) and 57% of onion producers planted in this type of field (Table A 3.8).[96] Furthermore, almost 60% of bean producers planted beans as an intercrop, which was expected. Not surprisingly, the use of fertilizer and pesticides was more common among farmers producing potatoes and onions; therefore, these farmers also reported higher production costs (Table A 3.8). Finally, more than 54% of farmers reported lower harvests, compared to a normal year.

3.6.4.1 Potato OLS Results

The econometric results of the OLS regression for potatoes are presented in Table 3.6.5. The model had a R-squared of 0.49. The results show that, although male-headed households produced more than female-headed households, these differences were not statistically

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[95] Potato planting rate = 2,750 kg/ha. Bean planting rate = 60 kg/ha. For onion producers, it was not possible to estimate the area planted using seed data.

[96] Although most farmers produced in *Lavras*, a high percentage of farmers produced potatoes (38%) and onions (25%) in irrigated lowland plots located close to river deltas (i.e. *Nacas).*

Table 3.6.5. Linear regression models of factors influencing potato, bean and onion quantity produced (kg). Central Highlands of Angola, 2009.

	Potato		**Bean**		**Onion**	
	N = 281		N = 380		N = 162	
	R-squared = 0.4947		R-squared = 0.6757		R-squared = 0.4417	
Independent variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Household (HH) Characteristics						
Age of HH head (Years)	10.37	0.198	2.05	**0.031	-1.27	0.572
Gender of HH head (1=Male)	36.61	0.198	19.57	0.155	22.87	*0.057
Dependency ratio[1]	-265.46	0.229	-23.54	0.609	-408.42	*0.069
HH member is in farmer organization (1=Yes)	181.33	0.143	16.27	0.249	16.26	0.485
No. adults (>17 yr) literate[2]	13.37	0.739	40.75	**0.018	-37.52	**0.017
No. of Tropical Livestock Units	-16.64	0.755	33.55	*0.084	-1.74	0.946
Home has zinc roof (1=Yes)	68.26	**0.032	-20.34	0.109	65.43	*0.053
Productive Assets Ownership (1=Yes)						
Owns a plow	186.16	0.275	53.10	***0.004	6.33	0.818
Owns a backpack sprayer	53.22	0.587	20.19	0.105	-60.90	0.142
Public Assets and Quasi-fixed Factors (1=Yes)						
IDA office in village	52.83	0.290	23.78	*0.058	-46.06	**0.037
Public market in village	-34.88	0.439	0.62	0.894	-22.78	0.214
HH in Caala Municipality	101.77	0.115	-24.96	***0.001	-63.57	0.146
HH in Ekunha Municipality	125.13	0.157	-9.61	0.455	-76.34	*0.085
HH in Bailundo Municipality	33.43	0.468	1.58	0.544	-56.44	*0.078
HH in Katchiungo Municipality	63.16	0.434	-3.82	0.762	-47.08	0.377
HH in Tchicalachuluanga Municipality	40.11	0.406	10.12	*0.083	-112.46	**0.028
HH in Chiguar Municipality	123.56	**0.020	-11.36	0.277	-43.99	0.351
HH in Babaera Municipality	-96.35	0.358	-44.83	***0.010	-28.10	0.368

Table 3.6.5 (cont'd).

Independent variables	Potato		Bean		Onion	
	N = 281		N = 380		N = 162	
	R-squared = 0.4947		R-squared = 0.6757		R-squared = 0.4417	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Production-related variables						
Total seed used (kg)	3.36	**0.012	3.08	***0.000	-47.85	0.663
Planted in rainfed plot (1=Yes)	25.88	*0.056	3.80	0.563	-18.06	0.406
Planted intercropped (1=Yes)	n.a.		-3.94	0.531	n.a.	
Planted local variety (1=Yes)	-80.79	0.157	-33.75	**0.012	-22.45	0.594
Used fertilizer (1=Yes)	30.14	**0.027	-6.71	0.604	51.99	***0.001
Used pesticides (1=Yes)	85.55	**0.013	43.48	***0.007	49.74	0.351
Reported production costs (Kw/kg)	-0.96	0.200	-0.75	**0.014	-0.26	0.191
HH reported lower harvest (1=Yes)	-101.04	0.110	-41.67	**0.029	-6.30	0.791
Squared and interaction terms						
Age squared	-0.15	0.113	-0.03	**0.035	-0.02	0.393
Dependency ratio squared	234.79	0.444	30.52	0.654	329.71	*0.052
No. adults literate squared	-13.68	0.451	-12.69	**0.016	11.83	**0.015
Tropical Livestock Units squared	-5.84	0.600	-9.55	**0.030	2.55	0.507
Total seed used squared	-0.003	**0.011	-0.005	***0.000	129.256	**0.028
Production costs * HH reported lower harvest	0.76	0.348	0.79	**0.016	0.12	0.457
Constant	-96.33	0.140	13.04	0.384	296.44	*0.052

Notes: *, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. n.a. = not applicable. All municipalities compared to Londuimbali municipality.

[1] Dependency ratio estimated by dividing No. members ≤17 yr by household size.

[2] Literacy refers to adults who can read and write.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

significant at the 10% level. Thus, providing technical assistance (related to production) to potato producers will likely generate the same outcome regardless of the gender of the head. However, since female-headed households are poorer, it may be appropriate to devote additional efforts to assist female-headed households. Surprisingly, having members of the household participating in a farmer organization had no statistically significant effect on potato production.

Production was positively associated with owning a home made with improved roof materials--farmers who owed a home with a zinc roof produced, on average, 68 kg more potatoes than their counterparts (5% SL). As previously discussed, farmers who produced potatoes were relatively wealthy (see Table 3.6.3); thus, this finding was not a surprise.

Although owning productive assets had a positive effect on potato production, the differences between farmers who owned productive assets vs. farmers who did not own these assets were not statistically significant at the 10% level.

The variables related to different municipalities were included to control for variations in environmental and market characteristics. Farmers producing potatoes in the Chinguar municipality produced approximately 124 kg more potatoes (5% SL) than farmers in the Londuimbali municipality. The differences in production between all other municipalities and Londuimbali were not statistically significant at the 10% level.

Most production-related variables had statistically significant effects on production (Table 3.6.5). Since the dependent variable in these models was production (not yield), it was expected that, as seed use increased, quantity produced would increase (at a decreasing rate). This was true for potatoes (5% SL). Surprisingly, farmers who planted potatoes in rainfed fields obtained higher production (10% SL) than farmers planting in other types of fields. This was because although most farmers (44%) produced potatoes in *Lavras* or upland rainfed fields, a large share of farmers (38%) produced potatoes in *Nacas* or irrigated lowlands fields close to river deltas, generally with poorer soil quality compared to *Lavras*. Furthermore, during the period of analysis, rainfall may have been sufficiently abundant to achieve a good harvest on upland fields. Potato producers who reported obtaining lower harvests (compared to a normal year) stated that the main cause of this was the little or no use of fertilizer (60% of farmers reported this) rather than weather-related problems, thus confirming this finding.

Although farmers planting local varieties obtained lower production, the differences between farmers who used local varieties and farmers who used improved varieties were not statistically significant at the 10% level. Since 26% of potato farmers reported using IVs, this suggests that available IVs do not perform better than traditional varieties; thus, efforts to generate better IVs will likely benefit farmers.

Potato producers who used fertilizer obtained higher production (5% SL) than farmers who did not apply fertilizer to their fields. Similarly, potato producers who applied pesticides obtained higher production (5% SL) than farmers who did not apply pesticides (Table 3.6.5). The results do not suggest whether farmers did not have access to these inputs or could not afford them (i.e. due to high price). However, given that fertilizer accounted for the largest share of production costs and that more than 65% of farmers applied fertilizer, is likely that most farmers could not afford to purchase the required amounts of fertilizer.

Finally, as per unit production cost increased, quantity produced decreased. Similarly, farmers who reported lower harvest during this period (compared to a normal year) obtained lower production. However, the differences in these two variables were not statistically significant at the 10% level (Table 3.6.5).

3.6.4.2 Bean OLS Results

The econometric results of the OLS regression for beans are presented in Table 3.6.5. The model had a R-squared of 0.68. The results show that age of the head of the household was positively (at a decreasing rate) associated with bean production. Among bean producers, age was positively associated with production until farmers become 34 years old.[97] After this, age was negatively associated with the bean quantity produced.

Similar to potato, although male-headed households produced more than female-headed households, the differences were not statistically significant at the 10% level (Table 3.6.5). Thus, providing technical assistance (related to production) to bean producers will likely generate the same outcome regardless of the gender of the head. However, since female-headed households in general and bean growers in particular are poorer, it may be appropriate to devote additional efforts to assist female-headed households and households producing beans.

Bean production was positively associated with the number of literate adults in the household (5% SL) and with the number of TLU owned by the household (10% SL). The number of literate adults in the household had a positive effect on production until there were 1.61 literate adults at home, after which its effect becomes negative, suggesting that more educated households may depend less on the bean crop. Bean producers who owned one additional TLU produced, on average, 14.45 kg more beans (Table 3.6.5).[98] Since medium to small animals can easily be sold to relief cash constraints faced by poor bean growers, these farmers are likely using their TLUs to purchase inputs (even in small quantities) for bean

[97] Setting the derivative of the bean production model with respect to the age variable equal to zero and solving for the age variable allows us to find this value.

[98] This amount was obtained by evaluating the derivative of the bean production model with respect to the TLU variable at one TLU.

production. Since this variable was only significant for farmers producing beans (i.e. not for richer farmers producing potatoes or onions), increasing bean farmers' access to agricultural credit would greatly benefit them.

Similarly, bean production was positively associated with owning a productive asset. Farmers who owned a plow produced, on average, 53 kg of beans more than farmers who did not own this implement (Table 3.6.5). Since plows are used to prepare fields for planting, thus allowing the plants to grow better, it was expected that owning a plow would positively affect production. Since less than 1% of farmers producing beans owned a backpack sprayer (see Table A 3.8), it is not surprising that there was no statistically significant effect of this variable on bean production.

Although having access to public markets in the villages had no statistically significant effect on production, the presence of the government's extension office in the village had a statistically significant positive effect on bean production (10% SL; Table 3.6.5). Farmers located in villages with an IDA office obtained, on average, 24 kg more beans than their counterparts, suggesting that extension agents are helping these relatively poor farmers overcome some of their production constraints.

Bean producers in the Tchicalachuluanga municipality produced, on average, 10 kg more beans (10% SL) than farmers in Londuimbali. In contrast, farmers in Caala and Babaera municipalities produced fewer beans (1% SL) than farmers in Londuimbali. However, the differences in production between all other municipalities and Londuimbali were not statistically significant at the 10% level. Since bean production is concentrated in Londuimbali, it was expected that production would be the same or lower in other municipalities.

As with potatoes, most production-related variables had statistically significant effects on production (Table 3.6.5). Since the dependent variable in this model was production (not yield), it was expected that, as seed use increased, quantity produced would increase (at a decreasing rate). This was true for beans (1% SL). In contrast to potatoes (and onions), planting a local (traditional) bean variety negatively affected production (5% SL). Bean producers who planted local varieties obtained, on average, 34 kg fewer beans than farmers using improved varieties. This result is consistent with the literature. For example, Reyes (2011) found that bean producers in Honduras obtained lower yields when using local varieties versus using improved varieties. Furthermore, since less than two percent of bean growers planted IVs (Table A 3.8), efforts should be devoted at developing and promoting the use of IVs in these regions. Making low cost, high quality seed of IVs available to farmers could also greatly benefit them.

As expected, bean production was positively associated with use of pesticides. Bean producers who applied pesticides obtained, on average, 43 kg more beans than farmers who did not apply pesticides. Furthermore, as per unit production cost increased, quantity produced decreased (5% SL). Farmers reported that the largest share of their production costs was due to expenses of purchasing seed (most likely grain), followed by payments for services (e.g. labor). Thus, this result suggests that the seed used by farmers may have poor quality (e.g. low germination rates), which directly affects the quantity produced. This suggests that providing farmers with better (low-cost) seeds may greatly benefit them.

Farmers who reported lower harvest during this period (compared to a normal year) obtained lower bean production (5% SL). Farmers who reported harvest losses said that the main reason for these losses was weather related (50%), followed by pest and disease incidence (25%)

and lack of fertilizer (21%). This suggests that breeding programs need to develop bean IVs tolerant to abiotic (e.g. droughts) and biotic (e.g. diseases) stresses.

The interaction term between per unit production costs and a household reporting lower harvest had a statistically significant positive effect on production (5% SL). However, the overall effect of an increase in production costs would depend on whether farmers reported lower harvest during the period (the opposite is also true). Thus, for farmers who did not report harvest losses during the period (i.e. normal year), as production costs increased, quantity produced decreased. Although for farmers who reported harvest losses during the period, an increase in production costs would positively affect quantity produced, the magnitude of this effect was small--0.04 kg.[99]

3.6.4.3 Onion OLS Results

The econometric results of the OLS regression for onions are presented in Table 3.6.5. The model had a R-squared of 0.45. The results show that male-headed households produced more onions than female-headed households (10% SL)--male-headed households produced, on average, 23 kg more onions than female-headed ones. Therefore, targeting technical assistance to households led by a woman will greatly benefit them since, in addition to them being poorer than male-headed households,[100] they produce fewer onions.

Furthermore, the number of dependents in the household was negatively associated with the quantity produced (10% SL), perhaps because households with more dependents typically

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[99] This value is found by evaluating the derivative of the bean production model with respect to the production cost variable at ‘reported lower harvest’ = YES.

[100] The mean asset index values among onion producers were -0.21 and 0.44 for female- and male-headed households, respectively.

have many young children who cannot work in the field. Households with 0.54 dependents (mean dependency rate value) produced approximately 52 kg[101]less. However, the dependency ratio was negatively associated with production until the number of dependents becomes 0.62.[102] After this, the dependency ratio was positively associated with onion production.

Onion production was negatively associated with the number of literate adults living in the household (5% SL; Table 3.6.5). Since the average number of literate adults was higher among households producing onion, compared to households producing beans or potatoes, this finding was not surprising since more educated households may be less dependent on agricultural outputs, including onions.[103] In addition, onion producers owning a home with improved roof materials produced more onions (10% SL). As previously discussed, farmers who produced potatoes and onions were wealthier than farmers producing beans (see Table 3.6.3); thus, this finding was not a surprise.

Onion production was not statistically significantly associated with owning productive assets (Table 3.6.5). This may have been because, in general, farmers plant a smaller area with onions (compared to potatoes and beans), thus reducing the need to own (or rent) a plow to prepare the soil. Furthermore, only a very small percent (4%; Table A 3.8) of onion farmers applied pesticides to their crop, thus making owning a backpack sprayer too expensive to afford.

Although having access to public markets in the village had no statistically significant effect on production of onions, the presence of the government's extension office in the village

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[101] This value is found by evaluating the derivative of the onion production model with respect to the dependency ratio variable at the mean value.

[102] Setting the derivative of the onion production model with respect to the dependency ratio variable equal to zero and solving for the dependency ratio variable allows us to find this value.

[103] This variable has a negative effect on onion production until there are 1.59 literate adults at home, then, its effect becomes positive.

was negatively associated with onion production (5% SL; Table 3.6.5). The latter suggests that the government's extension office perhaps provides greater assistance to farmers producing beans (a staple) than to farmers producing onions. Whether to provide greater assistance to farmers producing onions would depend on many factors including the extension agent's training and available time, the relative importance of onions compared to staple crops, etc.

While farmers producing onions in Ekunha, Bailundo, and Tchicalachuluanga produced fewer onions (1% SL, 1% SL, and 5% SL) than farmers in Londuimbali (Table 3.6.5), the differences in production between all other municipalities and Londuimbali were not statistically significant at the 10% level.

Regarding the production-related variables, only the use of fertilizer had a statistically significant effect on onion production (Table 3.6.5). Onion producers who used fertilizer obtained, on average, 52 kg more onions (1% SL) than farmers who did not apply fertilizer to their onion crop. Although the results do not suggest whether farmers did not have access to fertilizers or could not afford them (i.e. due to high price), given that the largest share of production costs were due to expenses in fertilizer and that 49% of farmers applied fertilizer, is likely that most farmers could not afford to purchase the required amounts of fertilizer.

Although farmers were asked how much onion seed they used, given that this amount is generally reported in grams, farmers had difficulty in estimating/recalling how many grams they used. This may explain the unexpected (albeit not statistically significant) sign of this variable in the regression since is likely that there were errors in measuring this variable.

3.6.5 Double Hurdle Regression Results of Factors Affecting Marketing Decisions

This subsection presents the double-hurdle regression results for each crop separately. The descriptive statistics for the variables included in these models were already discussed at the beginning of this section (see Table 3.6.2); therefore, this subsection focuses on the double hurdle (DH) regression results.

Two additional points are worth discussing here. First, the asset index discussed in section 3.6.2 was re-estimated without two variables: owing a motorcycle and owning a bicycle. This was done to be able to estimate the effect of these variables on marketing decisions separately from other assets included in the index. As expected, the magnitude of the new index was different.[104] Although the results were similar for most comparisons (e.g. male-headed households still were richer than female-headed households) when re-estimated, the differences in the index between bean growers vs. non-growers became statistically significant (10% SL), suggesting that households growing beans were poorer than non-growers. The descriptive statistics discussed at the beginning of the results section refers to this re-estimated index.

Second, the coefficient of the OLS regression residuals (estimated from the regressions in subsection 3.6.4) was not statistically significant in any of the two hurdle regressions for potatoes (p-value=0.723 for hurdle 1 and p-value=0.183 for hurdle 2) and beans (p-value=0.272 for hurdle 1 and p-value=0.267 for hurdle 2). Similarly, the onion OLS regression residuals variable was not statistically significant in the first hurdle of the onion regressions (p-value=0.577). These results suggest that quantity produced was not endogenous; therefore, this variable was excluded from both hurdles in the potato and bean regressions and from the first hurdle in the onion

[104] The economic status index became: 0.4 and -0.58 (1% SL) for male- and female-headed households, respectively; -0.07 and 0.22 (5% SL) for potato non-growers and growers, respectively; 0.25 and 0.02 (10% SL) for bean non-growers and growers, respectively; and -0.09 and 0.29 (1% SL) for onion non-growers and growers, respectively.

regressions. However, the residuals variable was included in the truncated normal regression for onions (second hurdle) since its coefficient was highly significant (p-value=0.002), suggesting that quantity produced was endogenous in this regression.

The DH results are presented for each crop separately. Further, for each crop, the discussion is divided into conditional and unconditional (on market participation) results.

3.6.5.1 Potato DH Results

Conditional results

The double hurdle regression results for potatoes are presented in Table 3.6.6. While male-headed households were more likely to participate in the market as sellers (5% SL), once the market participation decision has been made, gender of the head had no statistically significant effect on the quantity of potatoes sold. Therefore, targeting assistance to female heads may be necessary to increase their participation in the potato market as sellers, which would benefit them due to increased income from potato sales.

In contrast, as the number of literate adults in the household increase, farmers were less likely to sell potatoes (5% SL). However, after the participation decision has been made, having more literate adults in the household had no statistically significant effect on the amount of potatoes sold.

As discussed above, the asset index was used as a proxy for household wealth. Wealthier households were more likely to sell potatoes (1% SL); however, conditional on selling potatoes, richer households sold fewer potatoes (5% SL; Table 3.6.6). These results suggest that, although richer households are more likely to participate in the market as sellers, they sell fewer potatoes.

Table 3.6.6. Double-Hurdle model of factors influencing potato marketing decisions. Central Highlands of Angola, 2009.

	HURDLE 1		HURDLE 2	
	Probability of selling		Quantity sold (kg)	
	Probit Estimator		Truncated Normal Regression Estimator	
Independent variables: the coefficients displayed are the conditional average partial effects (APEs).	N = 240		N = 159	
	Pseudo R2 = 0.5006		Prob > Chi2 = 0.000	
	Coefficient	p-value	Coefficient	p-value
Age of HH head (Years)	-0.001	0.506	-0.299	0.532
Gender of HH head (1=Male)	0.125	**0.023	21.726	0.139
Dependency ratio	0.179	0.103	14.564	0.655
HH member is in farmer organization (1=Yes)	0.078	0.110	18.430	0.347
No. adults (>17 yr) literate	-0.065	**0.024	5.492	0.484
No. of Tropical Livestock Units	-0.073	0.114	8.776	0.222
Asset Index	0.051	***0.009	-10.771	**0.021
Owns motorcycle (1=Yes)	-0.043	0.700	17.110	0.689
Owns bicycle (1=Yes)	-0.073	0.251	37.889	**0.024
IDA office in village (1=Yes)	0.110	*0.090	44.309	**0.012
Public market in village (1=Yes)	-0.185	**0.018	-16.755	0.263
HH in Caala Municipality (1=Yes)	-0.162	0.162	73.411	*0.083
HH in Ekunha Municipality (1=Yes)	-0.063	0.605	83.047	**0.024
HH in Bailundo Municipality (1=Yes)	0.183	**0.016	-100.143	**0.043
HH in Katchiungo Municipality (1=Yes)	0.201	***0.004	32.464	0.195
HH in Tchicalachuluanga Municipality (1=Yes)	-0.039	0.685	-5.838	0.797
HH in Chiguar Municipality (1=Yes)	0.180	**0.031	-3.190	0.904
HH in Babaera Municipality (1=Yes)	-0.086	0.529	-29.850	0.289
Distance from village to sede (km)	0.003	0.336	-1.046	0.414
Road between village and sede in poor condition (1=Yes)	-0.016	0.789	-68.381	**0.015
Seller sought price information prior to sales (1=Yes)	n.a.		-3.418	0.814
Reported marketing costs (Kw/kg)	n.a.		-0.529	0.577
Total potato production (kg)	0.002	***0.000	0.543	***0.000

Notes: *, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Coefficients and p-values obtained using the *margins* command in Stata.
Dependency ratio estimated by dividing No. members $\leq$17 yr by household (HH) size. Literacy refers to adults who can read and write.
n.a. = not applicable because variable was not included in the regression.
Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

It was expected that owning vehicles would be positively associated with marketing decisions. While owning a bicycle was not associated with the probability of selling potatoes, owning this type of vehicle (conditional on market participation) was positively associated with the quantity of potatoes sold (5% SL). This was perhaps due to the fact that a bicycle could easily be used to transport potatoes to local markets or other places for sale.

Having a government's extension office in the village had a statistically significant effect on both market participation and quantity traded (10% SL and 5% SL, respectively). In contrast, having access to public markets for purchasing food/selling outputs in the village was a significantly negative factor in market participation (Table 3.6.6), which was unexpected. The main reason for this may be the fact that a higher share of non-sellers reported that public markets were available in their villages (19% vs. 16% sellers). Once the market participation decision has been made, this factor had no statistically significant effect on the quantity of potatoes sold.

In contrast to Key *et al*. (2000) the results suggest that one of the proxies for fixed costs (i.e. road quality) had a statistically significant (5% SL) negative effect on the quantity of potatoes sold. Farmers located in villages with poor road quality between the village and the main commercial town sold fewer potatoes. Although only 33% of farmers reported selling at least one of their outputs in other markets (i.e. outside the village, for whom road quality may be important), these farmers sold more than double the amount sold by farmers selling at home or in the local market (308 kg vs. 145 kg, 1% SL). Thus, investing in improving roads could be an important factor to boost potato sales.

Finally, production was a significantly positive factor on the probability of market participation and quantity traded. This was expected since farmers who have greater production have more surpluses they could sell. Although the magnitude on farmers' market participation decision was small, farmers producing one extra kilogram (above the mean) sold approximately 0.54 kg more potatoes.

In summary, these conditional results suggest that, to increase the likelihood that a smallholder farmer in the central highlands of Angola would become a seller, investments are needed to (a) assist female-headed households since this type of households are less likely to sell potatoes, (b) support households with fewer literate adults since adult literacy was negatively associated with the probability of selling potatoes, (c) assist (e.g. production, marketing) poorer potato producers (as classified by the asset index) since these are less likely to sell potatoes, and (d) support farmers with low access to extension services and farmers located in villages without public markets. Conditional on being a seller, the quantity sold would increase if investments are made to (a) assist (e.g. production, marketing) poorer farmers (as per their asset index) and farmers with low access to extension services, and (b) improve the infrastructure, especially the quality of the roads. Further, both the likelihood of a farmer becoming a seller and the conditional quantity sold would be positively affected if farmers increase their production. Therefore, investments are needed to help farmers increase their production (e.g. access to inputs, farm credit, better crop management).

Unconditional results

The unconditional (on market participation) average partial effects (APE) of all variables are included in Table A 3.9. The APE incorporates the partial effect of both hurdles, which allows making unconditional inferences about the factors affecting the quantity of potatoes sold. Although male-headed households sold more potatoes, the differences between these households and female-headed households were not statistically significant at the 10% level. Thus, the unconditional quantity of potatoes sold was gender neutral. This may be explained by the fact that 41% of female-headed households reported their (male) spouses as the ones responsible for sales (vs. 26% of male-headed households reporting female spouses as responsible for sales). This result suggests that households led by (married) females rely on their (male) spouses for marketing-related decisions; therefore, explaining why the differences in the quantity sold were not statistically significant.

In contrast to the conditional quantity of potatoes sold, having a member of the household participating in a farmer organization was positively associated (10% SL) with the unconditional quantity of potatoes sold (Table A 3.9). Thus, promoting participation in these organizations or establishing farmer organizations in villages without them could boost potato sales.

Furthermore, the asset index was negatively associated with the unconditional quantity of potatoes sold (10% SL). However, the magnitude of this effect was very small--an increase of one unit in the asset index would reduce the quantity sold by approximately 7 kg. The finding that richer households sell fewer potatoes may be explained by the fact that a lower percent (39%) of richer potato producers reported potatoes as the major source of crop income (compared to 43% of farmers in the poorest tercile) and because a larger percent (30%) of richer potato producers reported services as the main source of non-crop income (compared to 1% of farmers in the poorest tercile). Thus, richer farmers have diverse sources of income, which make them less dependent on potato sales.

Owning a bicycle was positively correlated with the unconditional quantity of potatoes sold (1% SL). As previously discussed, a bicycle could easily be used to transport potatoes for sale. Similarly, the presence of an IDA office in the village was positively correlated with the unconditional quantity of potato sold (Table A 3.9). Farmers in villages with IDA offices sold, on average, 43 kg more potatoes than farmers in villages without IDA offices. Thus, providing farmers with extension services could contribute to increase potato sales.

Not surprisingly, farmers located in villages with poor road quality between the village and the main commercial town sold fewer potatoes (1% SL). Lastly, farmers producing one extra kilogram (above the mean) sold approximately 0.58 kg more potatoes (1% SL). Therefore, investing in public infrastructure (i.e. improving roads) and helping farmers increase their production could positively affect the unconditional quantity of potatoes sold.

In summary, these unconditional results suggest that, to boost the unconditional quantity of potatoes sold by smallholder farmers in the central highlands of Angola, investments are needed to (a) promote farmer participation in organizations and/or establish farmer organizations in villages without them, (b) provide assistance (e.g. production, marketing) to poorer potato producers (as classified by the asset index); however, since this crop requires investments, this assistance cannot focus on farmers who are too poor, (c) support farmers with low access to extension services, (d) improve the infrastructure, especially the quality of the roads, and (e) help farmers increase their potato production, which can be done by making inputs more affordable (e.g. establish credit programs) and/or available. Thus, boosting potato sales would be a challenge for the government of Angola and donors since, due to its strong currency, overcoming these limiting factors would need financial and human resources.

3.6.5.2 Bean DH Results

Conditional results

The double hurdle regression results for beans are presented in Table 3.6.7. In contrast to potato production, the gender of the head had no statistically significant effect on the market participation decision or the quantity sold. Although households with a member participating in a farmer organization were less likely to participate in the bean market (1% SL), once the participation decision has been made, having a member in a farmer organization had no statistically significant effect on the amount of beans sold. Having a member in a farmer organization was expected to have no positive effect on marketing decisions because only a small share (1%) of bean sellers reported having a member of the family participating in a farmer organization (vs. 10% non-sellers).

In contrast to potato producers, marketing decisions were not associated with the household's wealth. This may be explained by the fact that bean producers were the poorest, with an average asset index of 0.07 (vs. 0.269 for potato and 0.364 for onion producers; see Table 3.6.3).

Owning a transportation vehicle had a statistically significant effect on marketing decisions. As expected, owning a motorcycle was negatively associated with both the probability of becoming a seller and, conditional on being a seller, the quantity of beans sold. This is because, owning a motorcycle is also an indicative of wealth; hence, farmers who own this type of vehicle may be too rich and less dependent on the bean crop as a source of crop income. This is confirmed by the fact that, while 63% of bean sellers reported the bean crop as their major source of crop income, only 29% of non-sellers reported beans as their major source of crop

Table 3.6.7. Double-Hurdle model of factors influencing bean marketing decisions. Central Highlands of Angola, 2009.

	HURDLE 1		HURDLE 2	
	Probability of selling		Quantity sold (kg)	
	Probit Estimator		Truncated Normal Regression Estimator	
Independent variables: the coefficients displayed are the conditional average partial effects (APEs).	N = 305		N = 206	
	Pseudo R2 = 0.2452		Prob > Chi2 = 0.000	
	Coefficient	p-value	Coefficient	p-value
Age of HH head (Years)	-0.002	0.428	-0.435	0.167
Gender of HH head (1=Male)	-0.054	0.413	9.242	0.236
Dependency ratio	-0.068	0.593	-9.951	0.469
HH member is in farmer organization (1=Yes)	-0.409	***0.000	17.282	0.237
No. adults (>17 yr) literate	0.063	0.326	4.359	0.308
No. of Tropical Livestock Units	-0.045	0.491	5.268	0.328
Asset Index	-0.004	0.904	1.471	0.684
Owns motorcycle (1=Yes)	-0.312	*0.060	-31.898	**0.012
Owns bicycle (1=Yes)	-0.114	0.226	26.971	**0.026
IDA office in village (1=Yes)	-0.018	0.889	2.216	0.866
Public market in village (1=Yes)	0.115	0.207	-12.830	0.207
HH in Caala Municipality (1=Yes)	-0.232	*0.091	-14.464	0.362
HH in Ekunha Municipality (1=Yes)	-0.147	0.204	24.203	0.184
HH in Bailundo Municipality (1=Yes)	-0.066	0.421	19.040	*0.071
HH in Katchiungo Municipality (1=Yes)	-0.076	0.622	-18.010	0.107
HH in Tchicalachuluanga Municipality (1=Yes)	-0.115	0.316	-12.267	0.250
HH in Chiguar Municipality (1=Yes)	-0.030	0.833	-1.614	0.914
HH in Babaera Municipality (1=Yes)	0.196	**0.037	-41.862	***0.003
Distance from village to sede (km)	0.011	***0.009	0.149	0.691
Road between village and sede in poor condition (1=Yes)	0.153	*0.095	-4.850	0.659
Seller sought price information prior to sales (1=Yes)	n.a.		-12.430	0.200
Reported marketing costs (Kw/kg)	n.a.		-0.428	0.374
Total bean production (kg)	0.003	***0.002	0.499	***0.000

Notes: *, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Coefficients and p-values obtained using the *margins* command in Stata.

Dependency ratio estimated by dividing No. members $\leq$17 yr by household (HH) size. Literacy refers to adults who can read and write.

n.a. = not applicable because variable was not included in the regression.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

income (see Table A 3.2). Furthermore, farmers selling beans also depended on selling their labor in other farms as a source of non-crop income, which suggest that these farmers may have limited resources (e.g. land, capital) to diversify the crops they plant.

In contrast, having a cheaper transportation vehicle (i.e. a bicycle) was positively associated with the amount of beans sold (5% SL). This was no surprise since approximately 15% of farmers in the region owned a bicycle (vs. only 7% owning a motorcycle; see Table A 3.3). Furthermore, a bicycle could easily be used to transport bean surpluses to the place of sale.

Having a government's extension office in the village had no statistically significant effect on marketing decisions (i.e. both hurdles). However, having an IDA office in the village was positively associated with bean production (see Table 3.6.5). These suggest that extension agents may be providing more assistance related to production techniques than to marketing strategies.

Both the distance between the village and the main commercial town, and having a poor condition road between the village and the main commercial town oddly had a positive effect on the probability of selling beans. The fact that farmers located farther away were more likely to sell beans highlights that constrained farmers generally produce and sell beans, regardless of how far they are from the main commercial town. This is perhaps because beans could easily be stored and sold at any time after harvest.

Several reasons can help explain why poor road quality had a positive effect on becoming a bean seller. First, 76% of farmers reported selling at least one of their outputs at home or in local markets (for whom distance to commercial town and road quality may not be important). Second, although these farmers sold, on average, close to one-half of the amount sold by farmers selling in other markets (77 kg vs. 151 kg, 1% SL), the aggregated volume sold by them was much higher. Third, most farmers selling at home or in local markets reported convenience (58%) and lack of transportation (21%) as the main reasons for selling locally. Fourth, since beans are less perishable and could easily be stored, it is a good crop for farmers to grow when roads are bad since they could sell the crop through time either in local or distant markets (by transporting small quantities over time). Therefore, since bean trade is likely concentrated in local markets, is possible that poor quality roads incentivize participation in *local* markets.

Finally, bean production was a positively associated with the probability of market participation and the conditional quantity traded. As with potatoes, this was expected since farmers who produce more have more surpluses they could sell. Furthermore, although the magnitude on farmers' market participation decision was small, farmers producing one extra kilogram (above the mean) sold approximately 0.50 kg more beans.

In summary, these conditional results suggest that, to increase the likelihood that a smallholder farmer would become a bean seller, investments are needed to (a) assist households with no members participating in farmer organizations since having a member of the family in a FO was negatively associated with selling beans, (b) support farmers with no transportation vehicles, perhaps on alternative ways to market their surpluses, and (c) assist (e.g. production, marketing) farmers located in villages farther away from and with poor road quality to the main commercial town. Conditional on being a seller, the quantity sold would increase if investments were made to assist farmers with no or low-cost transportation vehicles (e.g. marketing alternatives). Since gender of the household head had no statistical effect on both hurdles, any assistance should be targeted to both male- and female-headed households producing beans. Further, both the likelihood of a farmer becoming a seller and the conditional quantity sold would be positively affected if farmers increase their production. Therefore, investments are needed to help farmers increase their production.

Unconditional results

The unconditional (on market participation) average partial effects of all variables are included in Table A 3.10. Similar to the conditional results, the unconditional APEs suggest that bean sales were gender neutral. This may be explained by the fact that 40% of female-headed households reported their (male) spouses as the ones responsible for sales (vs. 20% of male-headed households reporting female spouses as responsible for sales). Thus, as with potatoes, households led by (married) females rely on their (male) spouses for marketing-related decisions. In contrast, unconditional bean sales were positively correlated (10% SL) with the number of literate adults living in the household (albeit in a very small magnitude), which suggests that teaching family members to read and write would increase sales perhaps due to the fact that literate adults can make better informed decisions related to marketing activities.

Owning transportation vehicles had the same statistical effect on the unconditional sales of beans (Table A 3.10). While owning a motorcycle was negatively associated (1% SL) with the amount of beans sold, owning a bicycle was positively associated (1% SL) with the quantity of beans sold. Furthermore, distance between the village and the main commercial town oddly had a positive effect on the unconditional quantity of beans sold. However, the magnitude of this effect was small. As explained above, this highlights the fact that constrained farmers generally produce and sell beans, regardless of how far they are from the main commercial town.

While seeking price information prior to sales was negatively associated with the unconditional quantity of beans sold (1% SL), the magnitude of this effect was small (Table A 3.10). The reason for this could be related to the quality of the information received by farmers, which may have been questionable. Among farmers who sought price information prior to sales, 48% reported receiving this information from a fellow friend (most likely another farmer) and 43% from a trader. It is possible that farmers who sought price information did not trust their source of information or perhaps were expecting a better (higher) price. Thus, after learning about the price, they decided to sell fewer beans. This suggests that investments to establish marketing information systems may be needed to provide farmers with reliable market information so they can make better marketing decisions.[105]

Lastly, farmers producing one extra kilogram (above the mean) sold approximately 0.48 kg more beans. Similar to potatoes, this finding suggests that investing in activities targeted at helping farmers increase their bean production could greatly boost bean sales.

In summary, these unconditional results suggest that, to boost the unconditional quantity of beans sold by smallholder farmers in the central highlands of Angola, investments are needed to (a) provide assistance (e.g. production, marketing) to younger farmers, (b) teach farmers (and educate children) how to read and write so they can make better informed decisions related to marketing activities, (c) establish marketing information systems to provide farmers with reliable market information, especially about prices, and (d) help farmers increase their bean production, which can be done by providing them with access to education, productive assets, extension services, improved varieties, inputs, and agricultural credit. Thus, as with potatoes, boosting bean sales would be a challenge for the government of Angola and donors.

[105] Although there may be another possible explanation related to the existence of shallow markets, proving this is more difficult and outside the scope of this study.

3.6.5.3 Onion DH Results

Conditional results

Table 3.6.8 shows the double hurdle regression results for onions. While older farmers were less likely to sell onions (10% SL), conditional on selling, older farmers sold more onions than younger farmers (5% SL) perhaps due to the fact that older farmers may be better connected with traders (i.e. social capital) and may have more marketing experience.

Similar to bean production, the gender of the head had no statistically significant effect on the market participation decision or the quantity sold, suggesting that marketing decisions are gender neutral. Although households with more dependents were less likely to sell onions (10% SL), once the marketing participation decision has been made, households with more dependents sold more onions (5% SL). In contrast to bean production, households with a member participating in a farmer organization were more likely to sell onions; however, this factor had no statistically significant effect on the quantity sold. Thus, establishing farmer organizations in villages without them would contribute to increase market participation.

The number of TLUs was positively associated (5% SL) with the probability of selling onions. However, conditional on market participation, this factor was negatively associated (5% SL) with the quantity of onion sold. In contrast, the asset index (proxy for household wealth) was negatively associated (5% SL) with the probability of selling onions. This was expected since non-sellers were richer (as per their asset index; see Table A 3.4) than onion sellers. Furthermore, non-sellers reported having additional sources of non-crop income, including transfers and remittances, and other activities (see Table A 3.2), which may be invested in

Table 3.6.8. Double-Hurdle model of factors influencing onion marketing decisions. Central Highlands of Angola, 2009.

	HURDLE 1		HURDLE 2	
	Probability of selling		Quantity sold (kg)	
	Probit Estimator		Truncated Normal Regression Estimator	
Independent variables: the coefficients displayed are the conditional average partial effects (APEs).	N = 174		N = 103	
	Pseudo R2 = 0.3767		Prob > Chi2 = 0.000	
	Coefficient	p-value	Coefficient	p-value
Age of HH head (Years)	-0.005	*0.092	0.286	**0.039
Gender of HH head (1=Male)	0.141	0.132	0.346	0.968
Dependency ratio	-0.323	*0.061	16.448	**0.018
HH member is in farmer organization (1=Yes)	0.177	***0.005	-2.438	0.667
No. adults (>17 yr) literate	0.053	0.164	2.228	0.235
No. of Tropical Livestock Units	0.281	**0.012	-7.777	**0.030
Asset Index	-0.087	**0.015	-1.596	0.454
Owns motorcycle (1=Yes)	-0.199	0.201	3.766	0.765
Owns bicycle (1=Yes)	0.105	0.257	-0.987	0.881
IDA office in village (1=Yes)	-0.024	0.803	3.737	0.702
Public market in village (1=Yes)	0.142	*0.057	1.551	0.804
HH in Caala Municipality (1=Yes)	-0.082	0.604	2.857	0.844
HH in Ekunha Municipality (1=Yes)	-0.192	0.407	6.849	0.494
HH in Bailundo Municipality (1=Yes)	-0.093	0.361	0.776	0.945
HH in Katchiungo Municipality (1=Yes)	0.055	0.693	8.279	0.459
HH in Tchicalachuluanga Municipality (1=Yes)	-0.125	0.339	0.269	0.976
HH in Chiguar Municipality (1=Yes)	0.200	*0.082	-0.036	0.996
Distance from village to sede (km)	-0.014	**0.011	-0.509	0.310
Road between village and sede in poor condition (1=Yes)	0.253	**0.021	7.166	0.352
Seller sought price information prior to sales (1=Yes)	n.a.		2.626	0.244
Reported marketing costs (Kw/kg)	n.a.		-0.192	0.285
Total onion production (kg)	0.003	**0.044	0.810	***0.000
Residual from onion production equation	n.a.		-0.107	**0.025

Notes: *, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively; p-values obtained via bootstrapping at 500 repetitions in hurdle 2; coefficients in both hurdles along with p-values in hurdle 1 obtained using the *margins* command in Stata.

Dependency ratio estimated by dividing No. members ≤17 yr by household (HH) size. Literacy refers to adults who can read and write.
n.a. = not applicable because variable was not included in the regression.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

improving the home or purchasing household assets, both reflected in the asset index. These results suggest that non-sellers were less dependent on onions since they had diverse sources of income.

While having a public market in the village was positively associated (10% SL) with the likelihood of selling onions, once this decision has been made, this factor was not statistically associated with the quantity of onions sold. In contrast, onion producers located farther away from the main commercial town were less likely to sell onions (5% SL). However, once this decision has been made, the distance between the village and the main commercial town had no statistical effect on the quantity of onions sold perhaps due to the small amounts sold by onion sellers (50 kg; see Table 3.6.2).

Strangely, having a poor quality road between the community and the main commercial town was positively associated (5% SL) with the probability of selling onions. This may be given by the fact that 81% of farmers selling onions were located in villages with poor road quality between the village and main commercial town (vs. only 53% of non-sellers; see Table 3.6.2). Additionally, since 74% of farmers sold at least one of their harvests either at home or in local markets and since the differences in the quantity sold by farmers selling in local markets compared to farmers selling in other markets were not statistically significant, it is possible that poor road quality incentivized local sales (as also suggested by the effect of having a public market in the village), reflecting sales targeted at meeting local demand. Once the market participation decision has been made, the quality of the road had no statistically significant effect on the amount sold.

Finally, onion production was a significantly positive factor on the probability of market participation and the quantity traded. Even after controlling for endogeneity in the second hurdle, quantity produced was a highly statistically significant positive factor in the quantity traded. Although the magnitude on farmers' market participation decision was small, farmers producing one extra kilogram (above the mean) sold approximately 0.81 kg more onions.

In summary, these conditional results suggest that, to increase the likelihood that a smallholder farmer in the central highlands of Angola would become an onion seller, investments are needed to (a) assist (e.g. production, marketing, storage) younger farmers and poorer farmers, (b) promote or establish farmer organizations where farmers could participate in (and perhaps find alternative ways to market their surpluses) and public markets where farmers could trade their surpluses, (c) mitigate cash constraints (e.g. agricultural credit) affecting onion producers since the number of tropical livestock units (proxy for cash availability) was positively associated with being a seller, and (d) assist (e.g. production, marketing, storage) farmers located in villages closer from and with poor road quality to the main commercial town. Conditional on being a seller, the quantity sold would increase if assistance (e.g. production, marketing, storage) is provided to (a) older farmers, (b) households with more dependents, and (c) farmers facing cash constraints (as per the number of tropical livestock units owned). Since gender of the household head had no statistical effect on both hurdles, any assistance should be targeted to both male- and female-headed households producing onions. Further, both the likelihood of a farmer becoming a seller and the conditional quantity sold would be positively affected if farmers increase their onion production. Therefore, as with potatoes and beans, investments are needed to help farmers increase their onion production (e.g. access to inputs, farm credit, better crop management).

Unconditional results

The unconditional APEs of all variables are included in Table A 3.11. Similar to potato and beans, the quantity of onions sold was gender neutral. Since 34% of female-headed households reported their (male) spouses as the ones responsible for sales and 32% of male-headed households reported their (female) spouses as responsible for sales, this finding was not surprising.

In contrast, the unconditional quantity of onion sold was positively associated with the number of literate adults in the household, suggesting that teaching family members to read and write would increase sales perhaps due to the fact that literate adults can make better informed decisions related to marketing activities.

Richer onion producers owning more assets (as indicated by the asset index) would sell fewer onions (1% SL). This was expected since richer farmers may be less dependent on the onion crop as a source of income. Although the presence of an IDA office in the village had no statistically significant (at the 10% level) effect on onion sales, having a public market in the village would positively affect sales (Table A 3.11).

Similar to the conditional results, the distance between the village and the main commercial town was negatively associated (5% SL) with the unconditional quantity of onions sold (Table A 3.11). Surprisingly, having a poor quality road between the village and the main commercial town positively affect sales. As explained above, the lack of alternative places for sale and the fact that most transactions occur in local markets may help explaining this finding. Furthermore, since the quantity traded is relatively small, it is perhaps not worth for farmers to travel to other (distant) markets to sell their outputs.

Not surprisingly, as per unit marketing costs increased, the unconditional quantity sold decreased (10% SL; Table A 3.11). Since most of the marketing costs were due to transportation costs, this also helps explain why farmers located farther away would sell less. Finally, farmers producing one extra kilogram (above the mean) sold approximately 0.68 kg more onions. As with potatoes and beans, this finding suggests that investing in activities targeted at helping farmers increase their onion production will greatly boost onion sales.

In summary, these unconditional results suggest that, to boost the unconditional quantity of onions sold by smallholder farmers in the central highlands of Angola, investments are needed to (a) teach farmers (and educate children) how to read and write so they can make better informed decisions related to marketing activities, (b) provide assistance to poorer onion producers (as classified by the asset index); however, since the onion crop requires investments, this assistance should not focus on farmers who are extremely poor, (c) promote or establish public markets within villages, (d) reduce transaction costs related to marketing activities, especially transportation costs, and (e) help farmers increase their onion production, which can be done by providing them with access to agricultural inputs.

3.7 Chapter Summary and Policy Recommendations

3.7.1 Chapter Summary

This essay uses single equation ordinary least squares regressions for analysis of factors affecting production of potatoes, beans, and onions in the central highlands of Angola. Furthermore, it implements double hurdle regressions to study the factors associated with marketing decisions among potato, bean and onion growers, focusing on gender of the household head, asset ownership, and transaction costs. The data used in this study came from the cross sectional household- and village-level survey implemented by World Vision's ProRenda project in 2009, which collected information from 656 households distributed across 40 villages and three provinces in the central highlands of Angola. The results suggest that the quantity produced is exogenous in potato, bean, and onion models for market participation (first hurdle) and in potato and bean models for quantity sold (second hurdle). In contrast, in the onion model for quantity sold, the amount of onion produced is found to be endogenous.

The wealth analysis using the asset index determined that male-headed households had more assets than female-headed households and that bean growers had the lowest economic status index among farmers growing potatoes, beans or onions. Furthermore, while potato and onion growers were richer than non-growers, there were no statistically significant differences in wealth between bean growers and non-growers. In contrast, while potato sellers were richer than their counterparts, onion sellers were poorer than non-sellers and there were no statistically significant differences in wealth between bean sellers and non-sellers. The latter finding was no surprise since beans are a staple crop grown both for consumption and sale by farmers across all wealth categories. The assets with more 'weight' (i.e., more important) in the estimation of the asset index included owning a television, a cart, a motorcycle, and a backpack sprayer.

The OLS regression results suggest that potato production was gender neutral. Furthermore, potato production was positively associated with owning a home with improved roof materials (i.e. zinc roofs). Surprisingly, owning productive assets had no statistically significant effect on potato production. Similarly, although using local varieties negatively affected production, the effect was not statistically significant at the 10% level. Further analysis in this area may be valuable to learn about the effects of using local vs. improved potato varieties. As expected, use of agricultural inputs (i.e., fertilizer and pesticides) positively affected production. The results suggest that, although inputs were available, is likely that farmers could not afford them, which is understandable since Angola's strong currency makes inputs very expensive.

Regarding bean production, the OLS regression results suggest that older farmers produced more beans perhaps because they have better production experience. Similar to potato production, bean production was gender neutral. Furthermore, having more literate adults at home and owning more tropical livestock units (a quick source of cash if needed) were positively associated with bean production. Likewise, owning a productive asset and having a government extension office in the village positively affected production.

Not surprisingly, using local varieties had a statistically significant negative effect on bean production. Making available to farmers low-cost, high-quality seed of improved bean varieties would greatly benefit them because (a) farmers who reported lower harvest said that the main reasons for this were weather- and pest and disease-related, which highlights the need to develop/provide IVs with resistance to diseases and tolerance to abiotic factors (e.g. droughts), (b) only a small share of bean producers used IVs, which highlights the need to promote existing bean IVs, and (c) the largest share of production costs was incurred in purchasing seed (most likely grain), which suggest that the quality of the seed used by farmers is low. Furthermore, the use of pesticides was positively associated with the quantity of beans produced. As with potatoes, affording pesticides appears to be the limiting factor.

The OLS regression results suggest that, in contrast to potatoes and beans, onion production was higher among male-headed households. Thus, assisting households led by females would contribute to reduce poverty and food insecurity since these households are at disadvantage. Furthermore, having more dependents and more literate adults at home was negatively associated with onion production. In contrast, onion production was positively associated with owning a home with improved roof materials (i.e. zinc roofs). Surprisingly, the presence of a government extension office in the village was negatively associated (5% SL) with onion production, perhaps because extension services may be targeted at farmers producing staple crops (e.g. beans) instead of farmers producing high-value crops (e.g. onions). As expected, use of agricultural inputs (i.e., fertilizer) positively affected production. As with potatoes and beans, it appears that farmers cannot afford purchasing fertilizers.

The double hurdle regression results suggest that the factors associated with marketing decisions depend on the crop analyzed and on whether marketing decisions are analyzed conditionally (i.e., probability of selling and, conditional on selling, quantity sold) or unconditionally (i.e., unconditional quantity sold).

For potatoes, the conditional results suggest that male-headed households were more likely to sell, and that households with more literate adults and having access to a public market in the village were less likely to sell potatoes. However, once the market participation decision has been made, gender of the head, number of literate adults, or having a public market in the village had no statistically significant effect on the quantity of potatoes sold.

In contrast, although richer households (as per their asset index) were more likely to participate in the market as sellers, once this decision has been made, richer households sold fewer potatoes. Furthermore, while owning a bicycle was not associated with the probability of selling potatoes, owning a bicycle was positively associated with the conditional quantity of potatoes sold. Moreover, although the quality of the road between the village and the main commercial town was not associated with the probability of selling potatoes, poor quality road was negatively associated with the amount of potatoes sold.

Both having a government's extension office in the village and the amount of potato produced had statistically significant positive effects on both the likelihood of being a seller and, conditional on selling, the quantity sold. Although the magnitude of the latter on the market participation decision was small, approximately 54% of increased production, conditional on market participation, would be sold.

The unconditional analysis suggests that potato sales were gender neutral. Furthermore, having a household member participating in a farmer organization, owning a bicycle, the presence of an IDA office in the village, and quantity produced all positively influenced the unconditional quantity of potatoes sold. For each additional kilogram produced, approximately 58% would end up being sold. In contrast, the asset index and having a poor quality road between the village and the main commercial town both negatively affected the unconditional quantity sold.

For beans, the conditional results suggest that marketing decisions were gender neutral. Furthermore, while households with a household member participating in a farmer organization were less likely to sell beans, households located farther away from the main commercial town or with poor road quality between the village and main commercial town oddly were more likely to sell beans. The fact that farmers located farther away or with poor road quality were more likely to sell beans highlights the fact that constrained farmers generally produce and sell beans, regardless of how far they are from the main commercial town or the quality of the road between these two places perhaps because beans are an important source of cash. Once the market participation decision has been made, participating in a farmer organization, distance to main commercial town, or road quality had no statistical effect on the conditional quantity sold.

While owning a motorcycle was a significantly negative factor on both the probability of becoming a seller and, conditional on being a seller, the quantity of beans sold, owning a bicycle was positively associated only with the conditional quantity of beans sold. Furthermore, the amount of beans produced positively affected both the likelihood of being a seller and, conditional on selling, the quantity sold. Approximately 50% of increased production, conditional on market participation, would be sold.

The unconditional analysis suggests that bean sales also were gender neutral. Furthermore, the number of literate adults living in the household, owning a bicycle, distance to main commercial town, and quantity produced all positively influenced the unconditional quantity of beans sold. For each additional kilogram produced, approximately 48% would end up being sold. In contrast, owning a motorcycle and seeking price information prior to sales both negatively affected the unconditional quantity sold.

Lastly, for onions, the conditional results suggest that the likelihood of selling onions was negatively affected by age of the household head and the dependency ratio. However, conditional on selling, these factors positively affected quantity sold. As with beans, marketing decisions were gender neutral. In contrast, households with a household member participating in a farmer organization, with access to a public market in the village, or reporting poor quality road between the village and main commercial town were more likely to sell beans. However, once the market participation decision has been made, participating in a farmer organization, access to a public market in the village, or road quality had no statistical effect on the conditional quantity sold.

Richer households (as per their asset index) and households located farther away from the main commercial town were less likely to sell onions. Once the market participation decision has been made, these factors had no statistical effect on the quantity sold. Furthermore, while the probability of selling onions was positively associated with the number of tropical livestock units owned, conditional on selling, quantity sold was negatively associated with the number of TLUs owned. As expected, the amount of onions produced positively affected both the likelihood of being a seller and, conditional on selling, the quantity sold. Approximately 81% of increased production, conditional on market participation, would be sold.

The unconditional analysis suggests that onion sales also were gender neutral. Furthermore, the number of literate adults living in the household, having a public market in the village, having a poor quality road between the village and the main commercial town, and quantity produced all positively influenced the unconditional quantity of onions sold. For each additional kilogram produced, approximately 68% would end up being sold. In contrast, the asset index, distance from village to main commercial town, and per unit marketing costs all negatively affected the unconditional quantity of onions sold.

3.7.2 Policy Recommendations

The results suggest that different policies would be needed to increase the participation of farmers in crop-markets as sellers and the quantity they sell. The specific policies would depend on the crop being analyzed.

Thus, for potatoes, the following policy recommendations are proposed:

A. To boost the participation of farmers in the potato market as sellers, the government of Angola, donors, and organizations that work with farmers should target their assistance to female-headed households (because they are less likely to sell potatoes), households composed by a high number of illiterate adults, and households without access to local public markets. Furthermore, since potato production requires the use of inputs and since the likelihood of selling potatoes was positively associated with the asset index, a larger impact could be achieved by assisting farmers who are not extremely poor. Additionally, providing extension services would also increase market participation.

B. To increase the unconditional quantity of potatoes sold by smallholder farmers in the central highlands of Angola, investments are needed to (1) promote farmer participation in organizations and/or establish farmer organizations in villages without them, (2) provide assistance (e.g. production) to poorer potato producers (as classified by the asset index); however, since this crop requires investments, this assistance should not focus on farmers who are extremely poor, (3) provide farmers extension services related to both production and marketing aspects, and (4) improve the infrastructure, especially the quality of the roads.

For beans, the following policy recommendations are proposed:

A. To encourage the participation of farmers in the bean market as sellers, the government of Angola, donors, and organizations that work with farmers should target their assistance to both male- and female-headed households, households with no members participating in farmer organizations, and households without transportation vehicles. Furthermore, assistance should be provided to farmers located in distant markets and with poor road access.

B. To boost the unconditional quantity of beans sold by smallholder farmers in the central highlands of Angola, investments are needed to (a) provide assistance to younger farmers, (b) teach farmers (and educate children) how to read and write so they can make better informed decisions related to marketing activities, and (c) establish marketing information systems to provide farmers with reliable market information, especially about prices.

For onions, the following policy recommendations are proposed:

A. To boost the participation of farmers in the onion market as sellers, assistance should target both female- and male-headed households, households led by young heads, households composed by fewer dependents for every adult, households that are asset-constrained, and households located closer to main commercial towns. Furthermore, although it was not possible to separate cause from effect, promoting farmer participation in organizations and/or establish farmer organizations in villages without them would most likely increase market participation.

B. To boost the unconditional quantity of onions sold by smallholder farmers in the central highlands of Angola, investments are needed to (a) teach farmers (and educate children) how to read and write so they can make better informed decisions related to marketing activities, (b) provide assistance to poorer onion producers (as classified by the asset index); however, since the onion crop requires investments, this assistance should not focus on farmers who are extremely poor, (c) promote or establish public markets within villages, and (d) reduce transaction costs related to marketing activities, especially transportation costs.

Finally, although the quantity sold of each of the three crops was gender neutral, given that female-headed households were poorer than their counterparts, there is a need for special programs targeted at female-headed households to help them move out from poverty. Furthermore, since the quantity sold of each of the three crops would increase if farmers' outputs were increased, investments should be made to help farmers increase their outputs. For potatoes, this could be achieved by making inputs more affordable and/or available on credit. For beans, providing farmers with access to education, productive assets, extension services, improved varieties, agricultural inputs, and agricultural credit would contribute to increase their production. Finally, for onions, providing farmers with access to agricultural inputs (perhaps through credit) would positively affect their production. Thus, boosting sales would be a challenge for the government of Angola, donors, and organizations working with farmers since, due to its strong currency, overcoming these limiting factors may require large financial and human resources.

APPENDIX

Table A 2.1. Bean trials planted in Central America and Ecuador. 1999-2010.

ECAR details	Year												Mean
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Central America: "*ECAR*[1] *trials*"													
# trials included in analysis	9	9	9	5	7	6	5	10	8	6	5	n.a.	7.2
# countries where planted	3	3	5	3	4	3	3	4	4	3	3	n.a.	3.5
# locations where planted[2]	7	9	9	4	7	6	3	8	6	4	5	n.a.	6.2
# lines per trial[3]	16	16	16	16	16	16	16	16	16	16	16	n.a.	16
# replications per line	3	3	3	3	3	3	3	3	3	3	3	n.a.	3
Ecuador: "*Prueba Trials*"													
# locations where planted[2]	n.a.	n.a.	n.a.	n.a.	2	2	1	3	11	1	5	1	3
Average # lines per trial[3]	n.a.	n.a.	n.a.	n.a.	17	18	18	8	13	11	12	10	13

Source: Programa de Investigaciones en Frijol Metadata, Zamorano, Honduras. n.a. = not available.

[1] ECAR = *Ensayo Centroamericano de Adaptacion y Rendimiento*.

[2] For Central America: sometimes, the same location is used twice per year (i.e. two seasons). Therefore, the number of locations may be different (less) than the number of trials planted. For Ecuador: # locations is the same as the number of trials included in the study.

[3] For Central America: from the 16 lines, one is a local check and one is an universal check. Therefore, this nursery contains only 14 advanced lines. For Ecuador: number only includes advanced lines and is the average of the number of lines planted in each location (the number of lines varied per location).

Table A 2.2. Costa Rica: Improved bean varieties released. 1990-2010.

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
1	2009	Disquis	MR 14215-9	(SEA 15 x MD 2324) F1 x (MD 3075 x G 21212) F1 / MC-6P-MQ-MC-IIC-MC-MC	Red	YES	YES	n.a.
2	2009	Suru	MEB 2232-29	PAN 68 x MD 2324	White	YES	YES	n.a.
3	2007	Tongibe	BCH 9901-14	MD 3075 // SRC 1-1-18 / SRC 1-12-1	Red	YES	YES	n.a.
4	2006	Changuena	MR 13652-39	(BRIBRI x (VAX 1 x RABA 655)) F1 / (NN) Q-(NN)-C	Red	YES	YES	n.a.
5	2006	Curre	MPCR 202-26-1	Selection from MPCR 202	Red	YES	YES	n.a.
6	2006	Gibre	MPCR 202-30-2	Selection from MPCR 202	Red	YES	YES	n.a.
7	2004	Telire	EAP 9510-1	MD 3075 / DICTA 105	Small red	YES	YES	n.a.
8	2003	Cabécar	EAP 9510-77	MD 3075 / DICTA 105	Small red	YES	YES	n.a.
9	2000	UCR 55	NJBC-20601-1-CM(71)	NAB 44 // ROS 24 / G 13689	Black	n.a.	NO	NO
10	2000	Bribri	MD 2324	(RAB 310 x XAN 155) x (DOR 391 x Pompadour G)	Small red	YES	YES	YES
11	1996	Guaymí	MUS 106	XAN 176 x IN 63	Black	n.a.	NO	n.a.
12	1996	Maleku	RAB 572	(MUS70 x RAO27) x (SEL960 x (RAO29 x (RAB58 x (DOR 164 x IN 199))))	Small red	n.a.	NO	n.a.
13	1995	CIAT 95	MUS 181	(XAN 226 x MUS 46) x (G 18252 x (G 13920 x (G 13920 x (G 13920 x G2333))))	Black	n.a.	NO	n.a.
14	1995	Chirripo Rojo	DOR 489	DOR 367 x (DOR 364 x BAT 1298)	Small red	n.a.	NO	n.a.
15	1994	UCR 52	DOR 390	(DOR 364 x G 18521) x (DOR 365 x LM 30630)	Black	NO	NO	n.a.
16	1993	UCR 51	DOR 474	DOR 367 x (DOR 364 x BAT 1298)	Small red	n.a.	NO	n.a.

Table A 2.2 (cont'd).

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
17	1993	Puricise	BAT 76	(G 1741 x G 2045) x (G 4792 x G 5694)	Black	n.a.	NO	n.a.
18	1992	UCR 50	DOR 364	BAT 1215 x (RAB 166 x DOR 125)	Small red	NO	NO	n.a.

Source: CIAT (2001a), INTA and UCR (2005), Hernandez (2010), Martinez (2003), and KII (2010a). n.a. = not available.

[1] Same pedigree implies that the lines are sisters, i.e. they come from the same parents.

NOTES: Varieties Bribri, Changuena, Curre, and Gibre came from crosses made at the breeding program of Zamorano, which receives CRSP funds.

Table A 2.3. El Salvador: Improved bean varieties released. 1990-2010.

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
1	2008	CENTA Nahuat	SRC 2-18-1	SRC 1-12-1 / MD 3075	Small red	YES	NO	n.a.
2	2008	CENTA C.P.C.	PPB 11-20 MC	Concha Rosada / SRC 1-1-18 / SRC 1-2-12	Small red	YES	NO	n.a.
3	2005	CENTA Pipil	PRF 9653-16B-3	Bribri / MD 3037 // RS 3	Small red	YES	NO	YES
4	2002	CENTA San Andres	EAP 9510-77	CENTA 2000 x DICTA 105	Small red	YES	NO	YES
5	2000	CENTA 2000	MD 3075	DOR 483 x (DOR 391 x Pompadour J)	Small red	YES	NO	NO
6	1997	ROJO Salvadoreño 1	DOR 482	DOR 367 x (DOR 364 x LM 30649)	Small red	NO	NO	NO
7	1995	CENTA Costeño	DOR 585	DOR 364 x SEL 1079	Small red	NO	NO	YES
8	1993	DOR 582	DOR 582	n.a.	Small red	NO	NO	NO
9	1989	CENTA Cuscatleco	DOR 364	BAT1215 x (RAB 166 x DOR 125)	Small red	NO	NO	YES

Source: CENTA (2005), CIAT (2001a), Martinez (2003), Reyes (2010), and KII (2010a). n.a. = not available.

[1] Same pedigree implies that the lines are sisters, i.e. they come from the same parents.

Table A 2.4. Honduras: Improved bean varieties released. 1990-2010.

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
1	2009	Quebradeño	IBC307-7	TC75//TC75/Cincuenteño	Small red	YES	YES	NO
2	2009	La Majada AF	IBC301-182	Amadeus77//Amadeus77/Paraisito	Small red	YES	YES	NO
3	2009	Briyo AM	IBC306-95	Amadeus77//Amadeus77/Rojo de Seda	Small red	YES	YES	NO
4	2009	Milagrito	F0243	Mass selection from landrace	Small red	YES	YES	NO
5	2007	Cardenal	MER 2226-41	SRC 1-12-1-47 / Amadeus 77	Small red	YES	NO	NO
6	2007	Deorho	SRC 2-18-1	SRC 1-12-1 / MD 3075	Small red	YES	NO	YES
7	2007	Victoria	SRS56-3	Amadeus77/SEA5	Small red	YES	YES	NO
8	2007	Don Cristóbal	SRC1-12-1-8	DOR476//XAN155/DOR364	Small red	YES	YES	NO
9	2007	Conan 33	PRF9653-25B-1	EAP 9503 / RS3 // Bribri / MD 30-37 //// EAP 9503 / RS3 // A429 / K2 /// V8025 / XR 16492 // APN83 / CNC	Small red	YES	YES	NO
10	2005	Palmichal 1	PRF 9707-36	UPR 9356-26 / TC-75 // EAP 9507 / AL12	Small red	YES	YES	NO
11	2005	Nueva Esperanza 01	DICZA 9801	UPR 9606-2-2 / MD 30-37	Small red	YES	YES	NO
12	2004	Macuzalito	PPB 9911-44-5-13M	Concha Rosada // SRC 1-1-18 / SRC 1-12-1	Small red	YES	YES	NO
13	2003	Amadeus 77	EAP 9510-77	MD 3075 / DICTA 105	Small red	YES	NO	YES
14	2003	Carrizalito	EAP 9510-1	MD 3075 / DICTA 105	Small red	YES	NO	YES
15	2003	Cedrón	PTC 9557-10	EAP 9021 / Bribri // UPR 9356-26 / UPR 9438-129	Small red	YES	YES	NO
16	2003	Cayetana 85	PRF 9653-16B-2A	EAP 9503 / RS3 // Bribri / MD 30-37 //// EAP 9503 / RS3 // A429 / K2 /// V8025 / XR 16492 // APN83 / CNC	Small red	YES	YES	NO
17	1997	DICTA 113	DICTA 113	DOR 364 x APN 83	Small red	NO	NO	NO

Table A 2.4 (cont'd).

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
18	1997	DICTA 122	DICTA 122	DOR 364 x APN 83	Small red	NO	NO	NO
19	1996	Tío Canela 75	MD 3075	DOR 483 // DOR 391 / Pompadour J	Small red	YES	NO	YES
20	1992	Don Silvio	DOR 482	(DOR 367 x (DOR 364 x LM 30649))	Small red	NO	NO	NO
21	1990	Dorado	DOR 364	(BAT 1215 x (RAB 166 x DOR 125))	Small red	NO	NO	YES

Source: CIAT (2001a), DICTA (1987, 1998), Escoto (2000, 2006), Martel-Lagos (1995), Pejuan (2005), PIF/EAP and DICTA/SAG (2002a, 2002b), PIF/EAP (2003), ASOCIAL Yorito-Sulaco-Victoria *et al.* (2004), ASOCIALAYO (2005a, 2005b), PIF/EAP and DICTA/SAG (2005a, 2005b), Rosas (2006), and KII (2010a).

[1] Same pedigree implies that the lines are sisters, i.e. they come from the same parents.

n.a. = not available

Table A 2.5. Nicaragua: Improved bean varieties released. 1990-2010.

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
1	2009	INTA Fuerte Sequia	SX 14825-7-1	n.a.	Dark red	YES	YES	n.a.
2	2006	INTA Precoz	SRC 2-18	Rojo Nacional // Bribri / MD 3075	Red	YES	YES	n.a.
3	2006	INTA Pueblo Nuevo JM	MR 13046-28-SM4	(VAX 3 x Catrachita) x MD 3075	Red	NO	YES	NO
4	2002	INTA Rojo	EAP 9510-77	MD 3075 x DICTA 105	Light red	YES	YES	YES
5	2001	INTA Nueva Guinea	DOR 390	(DOR 364 x G 18521) x (DOR 365 x LM 30 630)	Black	NO	YES	NO
6	2001	INTA Cardenas	DOR 500	(DOR 364 x G 18521) x (DOR 365 x IN 100)	Black	NO	YES	NO
7	2001	INTA Canela	MD 3075	DOR 483 // DOR 391 / Pompadour J	Small red	YES	YES	YES
8	1996	COMPAÑIA	RAB 463	G 18244 x MUS 6	Small red	NO	YES	NO
9	1994	CNIGB 93	DOR 391	DOR 367 x(DOR 364 x LM 30649)	Small red	NO	YES	NO
10	1993	COMPAÑIA 93	PVA 692	G 14013 x(G 13352 x G 21720)	Small red	NO	YES	NO
11	1993	DOR 364	DOR 364	BAT 1215 x (RAB 166 x DOR 125)	Small red	NO	YES	YES
12	1990	ESTELI 90A	CNIGB 1-90	Orgulloso x BAT 1654	Small red	NO	YES	NO
13	1990	ESTELI 90B	CNIGB 2-90	Orgulloso x BAT 1836	Small red	NO	YES	NO
14	1990	ESTELI 150	CNIGB 3-90	Chile Rojo x RAO 36	Small red	NO	YES	NO
15	1990	INTA Masatepe	DOR 582	n.a.	Dark red	NO	YES	YES
16	1990	INTA Estelí	CM-12214-25	n.a.	Red	NO	YES	NO

Source: CIAT (2001a), INTA (2006), Martinez (2003), and KII (2010a).

[1] Same pedigree implies that the lines are sisters, i.e. they come from the same parents. n.a. = not available

Table A 2.6. Ecuador: Improved bean varieties released. 1990-2010.

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
1	2010	Rojo del Valle	INIAP-481	SEL1308/Red Hawk // JeMa/3/Paragachi	Red Mottle	YES	YES	n.a.
2	2010	Afroandino	INIAP-482	Selection of CIAT A55	Black	YES	YES	n.a.
3	2009	Paragachi Andino	INIAP-429	SUG 26 x CAL 82	Red Mottle	YES	YES	YES
4	2009	Portilla	INIAP-430	INIAP 414 x INIAP 424	Red Mottle	YES	YES	YES
5	2009	Rocha	INIAP-480	INIAP 420 x (Cocacho x San Antonio), s26 p1	Yellow	YES	YES	YES
6	2007	Libertador	INIAP-427	G 12722 x G 21720	Red Mottle	YES	YES	n.a.
7	2007	Canario Guarandeno	INIAP-428	Selection of local variety	Yellow	YES	YES	n.a.
8	2005	Canario del Chota	INIAP-420	CAP 9 x Canario Bola	Yellow	YES	YES	n.a.
9	2004	Yunguilla	INIAP-414	ICA 24 x ICA 10009 x Mulato Gordo	Red Mottle	YES	YES	NO
10	2004	La Concepción	INIAP-424	Selection of local variety Mil Uno	Purple Mottled	YES	YES	YES
11	2004	Blanco Fanesquero	INIAP-425	SUG 55 x INIAP 417	White	YES	YES	NO
12	2004	Canario Siete Colinas**	INIAP-426	TIB 3042 X G 11732	Yellow	YES	YES	n.a.
13	2003	Blanco Belen	INIAP-422	WAF 82 x INIAP 417	White	YES	NO	n.a.
14	2003	Canario	INIAP-423	CAP 9 x Canario Bola	Yellow	YES	NO	n.a.
15	2003	Boliche	INIAP-473	AFR 298	Red Kidney	YES	NO	n.a.
16	2003	Doralisa	INIAP-474	AFR 722	Red Mottle	YES	NO	n.a.
17	1999	Bolívar**	INIAP-421	G 12670 x G 12488	Red	YES	NO	n.a.
18	1998	Chaupeño	INIAP-419	S 24990 x A 197	Cream (Bayo)	NO	NO	n.a.

Table A 2.6 (cont'd).

No.	Year of release	Variety Name	Line ID	Genealogy[1]	Market class	Used CRSP funds?	Developed through PPB?	Ever widely planted?
19	1996	Blanco Imbabura	INIAP-417	n.a.	White	NO	NO	n.a.
20	1996	Je.Ma.	INIAP-418	G 12722 x G 21720	Red Mottle	NO	NO	n.a.
21	1995	Canario	INIAP-416	Selection of G 11780F	Yellow	NO	NO	n.a.
22	1993	Toa**	INIAP-412	(L 38 x Cargamanto) x (Mortiño x Diacol Calima)	Red Mottle	NO	NO	n.a.
23	1993	Vilcabamba	INIAP-413	ICA 15423 x BAT 1620	Cranberry	NO	NO	n.a.
24	1993	Yunguilla	INIAP-414	G 13922 x (G 21721 x G 6474)	Red Mottle	NO	NO	n.a.
25	1991	Imbabello	INIAP-411	Selection of local variety Cargabello	Red Mottle	NO	NO	n.a.
26	1990	Colorado	INIAP-472	G 13922 x A 195	Red Kidney	NO	NO	n.a.

Source: Mooney (2007) [Who used the following sources: Lepiz (1996); INIAP (1991a, 1991b, 1996a, 1996b, 2004a, 2004b, 2004c, and 2005)]; CIAT (2001a); INIAP (2004a, 2004b, 2004c, 2004d, 2005, 2007a, 2007b, 2009a, 2009b, 2009c, 2010); Peralta et al. (2009), and KII (2010a).

[1] Same pedigree implies that the lines are sisters, i.e. they come from the same parents. n.a. = not available.

NOTE: most varieties are developed for the northern region. Yellow varieties are developed for the central region and climbing varieties (denoted by **) are targeted for the southern region.

Table A 2.7. Quantity (MT) of seed of improved bean varieties sold or distributed by government programs in 2010.

Country	Total bean area (ha)[1]	Total seed (MT)[2]	Share (%) of total seed per market class				
			Red	Black	Red mottled	Purple mottled	Yellow
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Costa Rica	3,944	286	31	70	n.a.	n.a.	n.a.
El Salvador	100,940	1,265	100	n.a.	n.a.	n.a.	n.a.
Honduras	98,856	1,818	100	n.a.	n.a.	n.a.	n.a.
Nicaragua	217,518	1,717	100	n.a.	n.a.	n.a.	n.a.
Ecuador	3,288	16	n.a.	n.a.	57	22	22

Source: KII (2010a, 2010d).

[1] In Central America, area refers to red beans only. In Ecuador, area refers to bush-type, red-mottled beans in Carchi and Imbabura only.

[2] In Costa Rica, seed data refers to both black and red beans. In El Salvador, Honduras and Nicaragua, seed refers to red beans only (seed of black beans was not distributed/sold). In Ecuador, seed refers to red mottled, purple mottled and yellow beans.

n.a. = not applicable

Table A 2.8. Estimated average yearly salaries ($) of bean breeding programs' permanent staff for Costa Rica, El Salvador, Honduras (DICTA only) and Nicaragua by education level. 2010.

		Ph.D.			M.Sc.			B.S.			Technicians			< Technician			
Country	**Institution**[1]	**No.**	**BTE**[2] **(%)**	**Salary**[3] **($/yr)**	**No.**	**BTE (%)**	**Salary ($/yr)**	**No.**	**BTE (%)**	**Salary ($/yr)**	**No.**	**BTE (%)**	**Salary ($/yr)**	**No.**	**BTE (%)**	**Salary ($/yr)**	**Total salaries ($/yr)**
Costa Rica	PITTA-Frijol	1	15	4,500	4	44	42,240	3	70	31,500	0	n.a.	n.a.	6	80	28,800	107,040
El Salvador	CENTA	0	n.a.	n.a.	1	100	27,000	2	100	30,000	0	n.a.	n.a.	0	n.a.	n.a.	57,000
Honduras	DICTA	0	n.a.	n.a.	0	n.a.	n.a.	1	80	12,000	1	50	6,000	0	n.a.	n.a.	18,000
Nicaragua	INTA	0	n.a.	n.a.	3	90	72,900	50	35	183,750	0	n.a.	n.a.	0	n.a.	n.a.	256,650

Source: The Author, using information provided by KII (2010a) and Mejia (2012, Personal Communication).

[1] Zamorano (Honduras) and PRONALEG-GA (Ecuador) were not included because the budget provided by program leaders already includes salaries. PITTA-Frijol includes INTA-CR's and UCR's permanent staff only.

[2] BTE = bean time equivalent (i.e. share of staff's time devoted to bean research).

[3] Salaries expressed in nominal US$ and only reflect the time devoted to bean-related activities (i.e. monthly salary x 12 x BTE).

NOTES: Yearly salaries estimated using the following monthly salaries: Ph.D = $2,750 in Honduras, El Salvador, and Nicaragua and Ph.D. = $2,500 in Costa Rica; M.Sc. = $2,250 in Honduras, El Salvador, and Nicaragua and M.Sc. = $2,000 in Costa Rica; B.S. = $1,250 in Honduras, El Salvador, and Costa Rica and B.S. = $875 (70% of Honduras' salary) in Nicaragua; Technician = $1,000 in all countries listed; and <Technician = $442 in Honduras, El Salvador, and Nicaragua and <Technician = $500 in Costa Rica. Salaries exclude temporary workers. Over the past ten years, the number of staff has: (a) remained constant in Nicaragua, (b) remained constant or decreased in Costa Rica and El Salvador, and (c) decreased in Honduras (DICTA only). Thus, yearly salaries are likely underestimated for all countries except Nicaragua.

n.a. = not applicable

Table A 2.9. Parameters α and β used for the estimation of logistic diffusion curves in the countries of interest.

	Scenario					
	Base		Scenario A		Scenario B	
Country	**α**	**β**	**α**	**β**	**α**	**β**
Costa Rica	4.406	-0.094	2.358	0.068	4.840	-0.156
El Salvador	-2.289	0.271	-2.562	0.288	-1.971	0.251
Honduras	-0.667	0.181	-1.073	0.205	-0.141	0.151
Nicaragua	-2.738	0.307	-2.992	0.324	-2.447	0.288
Ecuador	-3.415	0.316	-3.640	0.331	-3.162	0.299

Source: Generated by the Author.
Scenario A assumes a 10% increase over the 2010 estimation of adoption rate and Scenario B assumes a 10% decrease over the 2010 estimation of adoption rate.

Table A 2.10. Base scenario: Estimations of total adoption rates (%) of improved bean varieties using a logistic diffusion curve. 1990-2015.

Year	Costa Rica	El Salvador	Honduras	Nicaragua	Ecuador
1990	0.86	0.07	0.18	0.07	0.02
1991	0.86	0.09	0.20	0.09	0.03
1992	0.86	0.12	0.23	0.12	0.04
1993	0.85	0.14	0.25	0.15	0.05
1994	0.85	0.17	0.27	0.19	0.07
1995	0.85	0.21	0.29	0.24	0.09
1996	**0.85**	**0.25**	**0.31**	**0.30**	**0.12**
1997	0.85	0.29	0.33	0.36	0.15
1998	0.85	0.33	0.35	0.43	0.19
1999	0.84	0.37	0.36	0.49	0.23
2000	0.84	0.41	0.38	0.55	0.27
2001	0.84	0.45	0.39	0.61	0.31
2002	0.84	0.48	0.41	0.65	0.35
2003	0.83	0.51	0.42	0.69	0.38
2004	0.83	0.53	0.43	0.73	0.41
2005	0.82	0.55	0.43	0.75	0.44
2006	0.82	0.56	0.44	0.78	0.46
2007	0.82	0.58	0.45	0.79	0.47
2008	0.81	0.59	0.45	0.80	0.48
2009	0.81	0.59	0.46	0.81	0.49
2010	**0.80**	**0.60**	**0.46**	**0.82**	**0.50**
2011	0.79	0.60	0.46	0.83	0.51
2012	0.79	0.61	0.47	0.83	0.51
2013	0.78	0.61	0.47	0.83	0.51
2014	0.77	0.61	0.47	0.83	0.51
2015	0.76	0.61	0.47	0.84	0.52

Source: Generated by the Author.

Numbers in bold were used to estimate all other rates using the logistic diffusion curve formula.

Table A 2.11. Scenario A: Estimations of total adoption rates (%) of improved bean varieties using a logistic diffusion curve. 1990-2015.

Year	Costa Rica	El Salvador	Honduras	Nicaragua	Ecuador
1990	0.83	0.06	0.16	0.06	0.02
1991	0.83	0.08	0.18	0.08	0.03
1992	0.84	0.11	0.20	0.11	0.04
1993	0.84	0.13	0.23	0.14	0.05
1994	0.84	0.17	0.26	0.19	0.07
1995	0.85	0.21	0.28	0.24	0.09
1996	**0.85**	**0.25**	**0.31**	**0.30**	**0.12**
1997	0.85	0.30	0.34	0.37	0.15
1998	0.86	0.35	0.36	0.44	0.19
1999	0.86	0.39	0.38	0.52	0.24
2000	0.86	0.44	0.40	0.59	0.29
2001	0.86	0.48	0.42	0.65	0.33
2002	0.87	0.52	0.44	0.71	0.38
2003	0.87	0.55	0.45	0.76	0.42
2004	0.87	0.58	0.46	0.80	0.45
2005	0.87	0.60	0.47	0.83	0.48
2006	0.87	0.62	0.48	0.85	0.50
2007	0.88	0.63	0.49	0.87	0.52
2008	0.88	0.65	0.50	0.88	0.53
2009	0.88	0.65	0.50	0.89	0.54
2010	**0.88**	**0.66**	**0.51**	**0.90**	**0.55**
2011	0.88	0.66	0.51	0.91	0.56
2012	0.88	0.67	0.51	0.91	0.56
2013	0.88	0.67	0.51	0.91	0.56
2014	0.88	0.67	0.52	0.91	0.56
2015	0.89	0.68	0.52	0.92	0.57

Source: Generated by the Author.
Numbers in bold were used to estimate all other rates using the logistic diffusion curve formula.
This scenario assumes a 10% increase over the 2010 estimation of adoption rate.

Table A 2.12. Scenario B: Estimations of total adoption rates (%) of improved bean varieties using a logistic diffusion curve. 1990-2015.

Year	Costa Rica	El Salvador	Honduras	Nicaragua	Ecuador
1990	0.86	0.09	0.22	0.08	0.03
1991	0.86	0.10	0.23	0.10	0.03
1992	0.86	0.13	0.25	0.13	0.04
1993	0.86	0.15	0.27	0.16	0.06
1994	0.86	0.18	0.28	0.20	0.07
1995	0.85	0.22	0.30	0.25	0.10
1996	**0.85**	**0.25**	**0.31**	**0.30**	**0.12**
1997	0.85	0.28	0.32	0.35	0.15
1998	0.84	0.32	0.33	0.41	0.18
1999	0.84	0.35	0.35	0.46	0.21
2000	0.83	0.38	0.36	0.51	0.25
2001	0.83	0.41	0.37	0.56	0.28
2002	0.82	0.44	0.37	0.60	0.32
2003	0.81	0.46	0.38	0.63	0.35
2004	0.80	0.48	0.39	0.66	0.37
2005	0.79	0.50	0.39	0.68	0.39
2006	0.78	0.51	0.40	0.70	0.41
2007	0.77	0.52	0.40	0.71	0.42
2008	0.75	0.53	0.41	0.73	0.43
2009	0.74	0.53	0.41	0.73	0.44
2010	**0.72**	**0.54**	**0.41**	**0.74**	**0.45**
2011	0.70	0.54	0.42	0.74	0.46
2012	0.68	0.55	0.42	0.75	0.46
2013	0.65	0.55	0.42	0.75	0.46
2014	0.63	0.55	0.42	0.75	0.46
2015	0.60	0.55	0.42	0.76	0.47

Source: Generated by the Author.
Numbers in bold were used to estimate all other rates using the logistic diffusion curve formula.
This scenario assumes a 10% decrease over the 2010 estimation of adoption rate.

Table A 2.13. Linear regression results of factors influencing experimental yields of small red bean varieties released in Central America. 1999-2009.

	N = 108 Prob > F = 0.000 R-squared = 0.4249	
Variables	Coefficient	p-value
***Year dummy variables* (1=Yes):**		
2000	234.87	0.367
2001	868.32	***0.010
2002	34.56	0.903
2003	805.44	**0.028
2004	310.90	0.283
2005	-242.98	0.421
2006	304.78	0.612
2007	156.74	0.645
2008	704.55	*0.072
2009	313.31	0.262
***Released varieties dummy variables* (1=Yes):[1]**		
Carrizalito	177.13	0.583
Amadeus 77	82.80	0.809
Cedron	-21.85	0.934
Cayetana	-2.13	0.995
CENTA Pipil	110.34	0.681
Don Cristobal	114.73	0.852
Deorho	203.86	0.451
CENTA C.P.C.	-110.28	0.502
Tongibe	161.09	0.368
Cardenal	451.34	**0.025
Briyo	369.04	0.141
La Majada	354.66	0.134
***Country dummy variables* (1=Yes):**		
Costa Rica	-944.76	***0.002
El Salvador	-716.81	***0.000
Guatemala	-1791.46	***0.000
Nicaragua	-681.14	***0.000
Constant	2155.46	***0.000

*, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Year 1999, variety Dorado and country Honduras were excluded to avoid the dummy trap. Robust standard errors used to estimate p-values because variances are not equal (Prob > Chi2 = 0.0167).

[1] Carrizalito, Amadeus 77 and Deorho were released in more than one country.

Source: Programa de Investigaciones en Frijol Metadata, Zamorano, Honduras.

Table A 2.14. Linear regression results of factors influencing experimental yields of small red bean varieties released in Honduras. 1999-2009.

	N = 88 Prob > F = 0.000 R-squared = 0.3986	
Variables	Coefficient	p-value
***Year dummy variables* (1=Yes):**		
2000	213.83	0.401
2001	877.40	**0.020
2002	-43.75	0.882
2003	876.77	**0.041
2004	266.93	0.377
2005	-158.29	0.619
2006	322.25	0.593
2007	146.81	0.674
2008	694.62	*0.085
2009	303.38	0.281
***Released varieties dummy variables* (1=Yes):**		
Carrizalito	186.44	0.586
Amadeus 77	91.92	0.786
Cedron	4.15	0.988
Cayetana	8.98	0.979
Don Cristobal	60.88	0.923
Deorho	170.72	0.536
Cardenal	358.86	*0.078
Briyo	369.04	0.154
La Majada	354.66	0.148
***Country dummy variables* (1=Yes):**		
Costa Rica	-1017.94	***0.005
El Salvador	-648.21	***0.002
Guatemala	-1787.99	***0.000
Nicaragua	-640.41	***0.000
Constant	2128.95	***0.000

*, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Year 1999, variety Dorado and country Honduras were excluded to avoid the dummy trap. Robust standard errors used to estimate p-values because variances are not equal (Prob > Chi2 = 0.0135).

Source: Programa de Investigaciones en Frijol Metadata, Zamorano, Honduras.

Table A 2.15. Linear regression results of factors influencing experimental yields of red mottled bean varieties released in Ecuador. 2003-2010.

	N = 26 Prob > F = 0.001 Adj. R-squared = 0.6984	
Variables	Coefficient	p-value
***Year dummy variables* (1=Yes):**		
2004	418.75	0.152
2005	1392.00	***0.000
2006	493.01	*0.070
2007	794.09	***0.006
2008	230.74	0.364
2009	1262.50	***0.000
2010	660.47	*0.078
***Released varieties dummy variables* (1=Yes):**		
INIAP 427 Libertador	75.91	0.758
INIAP 429 Paragachi Andino	-58.61	0.733
INIAP 430 Portilla	117.07	0.442
INIAP 481 Rojo del Valle	214.60	0.314
Constant	482.47	**0.037

*, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Year 2003 and variety INIAP 414 Yunguilla were excluded to avoid the dummy trap.

Source: INIAP/PRONALEG-GA Metadata, Ecuador.

Table A 2.16. Costa Rica: Base scenario Net Present Value (NPV) and Internal Rate of Return (IRR) calculations for improved small red bean varieties. 1991-2015.

Year	Period	Area harvested (ha)	Production (mt)	Adoption rate (%)	λ growth (%)	Kt Type I	Kt Type II	Supply Elasticity e	Real Price ($/mt)	Change in TS Type I	Change in TS Type II	Research Costs ($, real)	Net Benefit ($)
1991	-5	17,395		0.86						0	0	158,619	-158,619
1992	-4	15,790		0.86						0	0	153,984	-153,984
1993	-3	14,758		0.85						0	0	149,508	-149,508
1994	-2	14,217		0.85						0	0	145,776	-145,776
1995	-1	14,081		0.85						0	0	141,758	-141,758
1996	Base	8,119	4,063	0.85						0	0	137,692	-137,692
1997	1	11,040	5,524	0.85	0.0049	0.000	0.004	0.7	1,412	0	32,530	134,604	-102,074
1998	2	9,280	4,643	0.85	0.0098	0.000	0.008	0.7	1,212	0	47,026	132,540	-85,513
1999	3	9,063	4,535	0.84	0.0148	0.000	0.012	0.7	1,152	0	65,598	129,676	-64,078
2000	4	7,707	3,856	0.84	0.0197	0.000	0.017	0.7	960	0	62,027	132,136	-70,110
2001	5	5,828	2,916	0.84	0.0247	0.000	0.021	0.7	867	0	52,980	129,454	-76,474
2002	6	5,522	2,763	0.84	0.0298	0.000	0.025	0.7	857	0	59,643	96,711	-37,068
2003	7	5,212	2,608	0.83	0.0348	0.000	0.029	0.7	518	0	39,709	123,918	-84,209
2004	8	4,087	2,045	0.83	0.0399	0.000	0.033	0.7	804	0	55,228	121,616	-66,389
2005	9	4,087	2,045	0.82	0.0450	0.000	0.037	0.7	880	0	67,993	118,514	-50,521
2006	10	3,509	1,756	0.82	0.0501	0.000	0.041	0.7	728	0	53,576	115,666	-62,091
2007	11	3,004	1,503	0.82	0.0552	0.000	0.045	0.7	901	0	62,410	113,295	-50,885
2008	12	2,757	1,379	0.81	0.0604	0.000	0.049	0.7	1,411	0	97,578	109,907	-12,329
2009	13	3,944	1,974	0.81	0.0656	0.000	0.053	0.7	963	0	103,044	86,725	16,319
2010	14	3,460	1,731	0.80	0.0708	0.000	0.057	0.7	1,109	0	111,747		111,747
2011	15	3,460	1,731	0.79	0.0761	0.000	0.061	0.7	1,022	0	110,027		110,027
2012	16	3,460	1,731	0.79	0.0813	0.000	0.065	0.7	1,022	0	116,877		116,877
2013	17	3,460	1,731	0.78	0.0866	0.000	0.068	0.7	1,022	0	123,579		123,579
2014	18	3,460	1,731	0.77	0.0920	0.000	0.072	0.7	1,022	0	130,109		130,109
2015	19	3,460	1,731	0.76	0.0973	0.000	0.075	0.7	1,022	0	136,444		136,444
		In constant 1991 US$:			**NPV =**	**-956,905**			***In constant 2009 US$:***			**NPV =**	**-2,016,054**
												IRR =	**-5%**

Source: Estimations made by The Author. See Table Notes in Table A 2.21.

Table A 2.17. El Salvador: Base scenario Net Present Value (NPV) and Internal Rate of Return (IRR) calculations for improved small red bean varieties. 1991-2015.

Year	Period	Area harvested (ha)	Production (mt)	Adoption rate (%)	λ growth (%)	Kt Type I	Kt Type II	Supply Elasticity e	Real Price ($/mt)	Change in TS Type I	Change in TS Type II	Research Costs ($, real)	Net Benefit ($)
1991	-5	75,097		0.09						0	0	196,108	-196,108
1992	-4	76,795		0.12						0	0	190,377	-190,377
1993	-3	72,110		0.14						0	0	184,843	-184,843
1994	-2	72,042		0.17						0	0	180,228	-180,228
1995	-1	58,801		0.21						0	0	179,485	-179,485
1996	Base	65,659	51,920	0.25						0	0	174,337	-174,337
1997	1	80,495	63,652	0.29	0.0049	0.005	0.001	0.7	1,412	427,014	110,126	170,427	366,714
1998	2	75,709	59,866	0.33	0.0098	0.010	0.003	0.7	1,212	696,425	207,818	163,864	740,379
1999	3	72,178	57,074	0.37	0.0148	0.014	0.005	0.7	1,152	944,756	324,292	160,323	1,108,724
2000	4	76,659	60,618	0.41	0.0197	0.019	0.007	0.7	960	1,098,834	431,117	155,110	1,374,841
2001	5	82,624	65,335	0.45	0.0247	0.023	0.010	0.7	867	1,303,870	580,788	150,818	1,733,841
2002	6	80,707	63,819	0.48	0.0298	0.026	0.013	0.7	857	1,461,830	734,146	109,713	2,086,264
2003	7	81,362	64,337	0.51	0.0348	0.030	0.017	0.7	518	996,931	560,563	107,269	1,450,226
2004	8	84,432	66,764	0.53	0.0399	0.032	0.020	0.7	804	1,749,924	1,094,180	104,486	2,739,618
2005	9	82,989	65,624	0.55	0.0450	0.034	0.024	0.7	880	2,011,168	1,389,285	101,062	3,299,391
2006	10	84,758	67,022	0.56	0.0501	0.036	0.028	0.7	728	1,786,251	1,354,845	97,904	3,043,192
2007	11	91,785	72,579	0.58	0.0552	0.038	0.031	0.7	901	2,490,189	2,062,075	95,193	4,457,072
2008	12	102,529	81,075	0.59	0.0604	0.039	0.035	0.7	1,411	4,483,899	4,032,474	91,673	8,424,700
2009	13	100,940	79,818	0.59	0.0656	0.040	0.038	0.7	963	3,083,689	2,997,390	92,000	5,989,079
2010	14	92,600	73,224	0.60	0.0708	0.040	0.042	0.7	1,109	3,313,509	3,465,898		6,779,408
2011	15	92,600	73,224	0.60	0.0761	0.041	0.046	0.7	1,022	3,096,535	3,471,581		6,568,116
2012	16	92,600	73,224	0.61	0.0813	0.041	0.049	0.7	1,022	3,128,228	3,745,398		6,873,627
2013	17	92,600	73,224	0.61	0.0866	0.042	0.053	0.7	1,022	3,152,659	4,017,819		7,170,478
2014	18	92,600	73,224	0.61	0.0920	0.042	0.056	0.7	1,022	3,171,444	4,289,200		7,460,644
2015	19	92,600	73,224	0.61	0.0973	0.042	0.060	0.7	1,022	3,185,860	4,559,919		7,745,779
			In constant 1991 US$:		**NPV =**	**36,789,922**				***In constant 2009 US$:***		**NPV =**	**77,510,816**
												IRR =	**40%**

Source: Estimations made by The Author. See Table Notes in Table A 2.21.

Table A 2.18. Honduras: Base scenario Net Present Value (NPV) and Internal Rate of Return (IRR) calculations for improved small red bean varieties. 1991-2015.

Year	Period	Area harvested (ha)	Production (mt)	Adoption rate (%)	λ growth (%)	Kt Type I	Kt Type II	Supply Elasticity e	Real Price ($/mt)	Change in TS Type I	Change in TS Type II	Research Costs ($, real)	Net Benefit ($)
1991	-5	104,272		0.20						0	0	258,564	-258,564
1992	-4	67,996		0.23						0	0	211,207	-211,207
1993	-3	79,202		0.25						0	0	197,282	-197,282
1994	-2	111,700		0.27						0	0	171,351	-171,351
1995	-1	64,859		0.29						0	0	125,563	-125,563
1996	Base	79,043	57,718	0.31						0	0	111,262	-111,262
1997	1	78,850	57,577	0.33	0.0056	0.002	0.002	0.7	1,412	180,694	141,196	122,252	199,638
1998	2	74,881	54,679	0.35	0.0112	0.004	0.004	0.7	1,212	285,269	245,432	129,429	401,272
1999	3	106,064	77,449	0.36	0.0169	0.006	0.006	0.7	1,152	555,813	524,885	135,488	945,209
2000	4	114,671	83,734	0.38	0.0226	0.008	0.008	0.7	960	641,461	662,847	164,462	1,139,846
2001	5	72,568	52,990	0.39	0.0283	0.010	0.011	0.7	867	439,057	494,904	168,242	765,718
2002	6	132,661	96,870	0.41	0.0341	0.011	0.013	0.7	857	911,342	1,117,124	155,937	1,872,529
2003	7	99,005	72,295	0.42	0.0399	0.012	0.016	0.7	518	457,807	608,424	160,481	905,751
2004	8	98,347	71,814	0.43	0.0457	0.013	0.019	0.7	804	768,922	1,104,652	156,797	1,716,777
2005	9	111,916	81,722	0.43	0.0515	0.014	0.022	0.7	880	1,026,258	1,589,168	169,698	2,445,728
2006	10	121,600	88,794	0.44	0.0574	0.015	0.025	0.7	728	975,038	1,622,924	164,844	2,433,117
2007	11	133,000	97,118	0.45	0.0634	0.016	0.028	0.7	901	1,382,603	2,467,031	212,451	3,637,183
2008	12	133,000	97,118	0.45	0.0693	0.016	0.031	0.7	1,411	2,246,392	4,285,946	205,016	6,327,322
2009	13	98,856	72,186	0.46	0.0753	0.017	0.034	0.7	963	1,176,031	2,393,291	155,897	3,413,425
2010	14	119,674	87,388	0.46	0.0813	0.017	0.037	0.7	1,109	1,681,314	3,640,993		5,322,306
2011	15	119,674	87,388	0.46	0.0874	0.018	0.040	0.7	1,022	1,583,663	3,641,281		5,224,944
2012	16	119,674	87,388	0.47	0.0935	0.018	0.043	0.7	1,022	1,611,759	3,926,310		5,538,070
2013	17	119,674	87,388	0.47	0.0996	0.018	0.046	0.7	1,022	1,635,459	4,212,450		5,847,909
2014	18	119,674	87,388	0.47	0.1057	0.018	0.050	0.7	1,022	1,655,416	4,499,600		6,155,016
2015	19	119,674	87,388	0.47	0.1119	0.019	0.053	0.7	1,022	1,672,195	4,787,722		6,459,917
		In constant 1991 US$:			**NPV =**	**27,648,128**			***In constant 2009 US$:***			**NPV =**	**58,250,437**
												IRR =	**34%**

Source: Estimations made by The Author. See Table Notes in Table A 2.21.

Table A 2.19. Nicaragua: Base scenario Net Present Value (NPV) and Internal Rate of Return (IRR) calculations for improved small red bean varieties. 1991-2015.

Year	Period	Area harvested (ha)	Production (mt)	Adoption rate (%)	λ growth (%)	Kt Type I	Kt Type II	Supply Elasticity e	Real Price ($/mt)	Change in TS Type I	Change in TS Type II	Research Costs ($, real)	Net Benefit ($)
1991	-5	98,368		0.09						0	0	490,362	-490,362
1992	-4	88,139		0.12						0	0	476,032	-476,032
1993	-3	100,300		0.15						0	0	462,196	-462,196
1994	-2	98,786		0.19						0	0	450,657	-450,657
1995	-1	120,677		0.24						0	0	438,237	-438,237
1996	Base	104,509	67,653	0.30						0	0	425,668	-425,668
1997	1	117,694	76,187	0.36	0.0049	0.007	0.001	0.7	1,412	762,195	158,191	416,120	504,266
1998	2	165,025	106,827	0.43	0.0098	0.014	0.004	0.7	1,212	1,879,670	460,346	409,738	1,930,278
1999	3	180,351	116,748	0.49	0.0148	0.022	0.006	0.7	1,152	2,954,150	847,761	400,884	3,401,027
2000	4	194,773	126,084	0.55	0.0197	0.029	0.010	0.7	960	3,517,663	1,173,653	387,847	4,303,468
2001	5	201,338	130,333	0.61	0.0247	0.035	0.014	0.7	867	4,016,351	1,544,826	377,116	5,184,060
2002	6	218,311	141,321	0.65	0.0298	0.041	0.018	0.7	857	4,999,838	2,197,405	323,952	6,873,290
2003	7	252,934	163,733	0.69	0.0348	0.045	0.023	0.7	518	3,910,834	1,946,442	317,584	5,539,692
2004	8	202,692	131,210	0.73	0.0399	0.049	0.028	0.7	804	5,282,203	2,951,336	309,346	7,924,193
2005	9	236,473	153,078	0.75	0.0450	0.052	0.033	0.7	880	7,173,491	4,462,568	299,208	11,336,851
2006	10	199,953	129,437	0.78	0.0501	0.055	0.038	0.7	728	5,249,426	3,608,318	289,858	8,567,886
2007	11	202,613	131,159	0.79	0.0552	0.057	0.043	0.7	901	6,814,754	5,140,042	281,831	11,672,965
2008	12	209,269	135,468	0.80	0.0604	0.058	0.048	0.7	1,411	11,294,234	9,289,222	271,410	20,312,046
2009	13	217,518	140,808	0.81	0.0656	0.059	0.053	0.7	963	8,166,618	7,283,424	271,650	15,178,392
2010	14	213,165	137,990	0.82	0.0708	0.060	0.058	0.7	1,109	9,339,858	8,987,250		18,327,108
2011	15	213,165	137,990	0.83	0.0761	0.060	0.062	0.7	1,022	8,700,616	8,992,551		17,693,167
2012	16	213,165	137,990	0.83	0.0813	0.061	0.067	0.7	1,022	8,765,976	9,692,501		18,458,477
2013	17	213,165	137,990	0.83	0.0866	0.061	0.072	0.7	1,022	8,814,450	10,388,869		19,203,319
2014	18	213,165	137,990	0.83	0.0920	0.061	0.077	0.7	1,022	8,850,324	11,083,067		19,933,391
2015	19	213,165	137,990	0.84	0.0973	0.062	0.081	0.7	1,022	8,876,828	11,776,409		20,653,237
			In constant 1991 US$:		**NPV =**	**101,574,886**			***In constant 2009 US$:***			**NPV =**	**214,002,964**
												IRR =	**42%**

Source: Estimations made by The Author. See Table Notes in Table A 2.21.

Table A 2.20. Ecuador: Base scenario Net Present Value (NPV) and Internal Rate of Return (IRR) calculations for improved red mottled bean varieties in northern Ecuador. 1991-2015.

Year	Period	Area harvested (ha)	Production (mt)	Adoption rate (%)	λ growth (%)	Kt Type I	Kt Type II	Supply Elasticity e	Real Price ($/mt)	Change in TS Type I	Change in TS Type II	Research Costs ($, real)	Net Benefit ($)
1991	-5	6,983		0.03						0	0	22,827	-22,827
1992	-4	6,970		0.04						0	0	21,763	-21,763
1993	-3	7,185		0.05						0	0	28,098	-28,098
1994	-2	8,599		0.07						0	0	37,864	-37,864
1995	-1	7,759		0.09						0	0	31,751	-31,751
1996	Base	8,489	7,287	0.12						0	0	29,341	-29,341
1997	1	8,534	7,326	0.15	0.0168	0.006	0.002	0.7	600	25,598	8,868	28,903	5,562
1998	2	7,533	6,467	0.19	0.0339	0.012	0.005	0.7	600	48,464	19,965	27,246	41,183
1999	3	7,762	6,663	0.23	0.0513	0.020	0.010	0.7	600	79,158	38,566	23,406	94,318
2000	4	6,427	5,517	0.27	0.0689	0.027	0.016	0.7	600	90,857	52,038	7,480	135,415
2001	5	7,207	6,187	0.31	0.0869	0.035	0.023	0.7	600	130,154	87,051	12,295	204,910
2002	6	8,333	7,153	0.35	0.1051	0.042	0.032	0.7	600	181,461	140,667	13,626	308,501
2003	7	7,996	6,864	0.38	0.1237	0.048	0.043	0.7	600	201,042	179,159	44,755	335,446
2004	8	7,036	6,040	0.41	0.1426	0.053	0.054	0.7	659	216,854	220,264	57,762	379,355
2005	9	8,455	7,258	0.44	0.1618	0.058	0.066	0.7	740	318,152	365,169	57,749	625,572
2006	10	7,353	6,312	0.46	0.1813	0.062	0.079	0.7	753	299,596	385,360	55,944	629,012
2007	11	6,607	5,671	0.47	0.2011	0.065	0.092	0.7	626	234,840	335,885	61,120	509,605
2008	12	6,106	5,241	0.48	0.2213	0.067	0.104	0.7	566	203,029	320,610	131,810	391,828
2009	13	6,085	5,223	0.49	0.2418	0.069	0.117	0.7	839	308,033	533,634	57,375	784,292
2010	14	6,921	5,941	0.50	0.2627	0.070	0.129	0.7	1,039	442,028	835,322		1,277,350
2011	15	6,921	5,941	0.51	0.2839	0.071	0.142	0.7	765	329,964	676,782		1,006,747
2012	16	6,921	5,941	0.51	0.3055	0.072	0.154	0.7	765	333,394	738,908		1,072,302
2013	17	6,921	5,941	0.51	0.3274	0.072	0.167	0.7	765	335,929	801,361		1,137,290
2014	18	6,921	5,941	0.51	0.3497	0.073	0.179	0.7	765	337,796	864,319		1,202,115
2015	19	6,921	5,941	0.52	0.3724	0.073	0.191	0.7	765	339,168	927,959		1,267,126
		In constant 1991 US$:			**NPV =**		**5,183,118**		***In constant 2009 US$:***			**NPV =**	**10,920,047**
												IRR =	**37%**

Source: Estimations made by The Author. See Table Notes in Table A 2.21.

Table A 2.21. Notes for Table A 2.16 through Table A 2.20.

Country	Notes
Costa Rica	Area harvested is 25% of total area harvested to reflect only red bean production (i.e. excludes other market classes). Yield for 1996 estimated as the average yields of 1994-1998, using FAOSTAT data. λ=0.0049 (Type II gains); Type I gains=11.5% (from Mather *et al*. 2003). Price is the average price for Central American countries.
El Salvador	Area harvested is 97% of total area harvested to reflect only red bean production (i.e. excludes other market classes). Yield for 1996 estimated as the average yields of 1994-1998, using FAOSTAT data. λ=0.0049 (Type II gains); Type I gains=11.5% (from Mather *et al*. 2003). Price is the average price for Central American countries.
Honduras	Area harvested is 95% of total area harvested to reflect only red bean production (i.e. excludes other market classes). Yield for 1996 estimated as the average yields of 1994-1998, using FAOSTAT data. λ=0.0056 (Type II gains); Type I gains=11.5% (from Mather *et al*. 2003). Price is the average price for Central American countries.
Nicaragua	Area harvested is 87.5% of total area harvested to reflect only red bean production (i.e. excludes other market classes). Yield for 1996 estimated as the average yields of 1994-1998, using FAOSTAT data. λ=0.0049 (Type II gains); Type I gains=11.5% (from Mather *et al.* 2003). Price is the average price for Central American countries.
Ecuador	Area harvested is 13.5% of total of dry bean area harvested in the country to reflect only red mottled (i.e. excludes other market classes) bush-bean production in the provinces of Carchi and Imbabura. Yields in northern Ecuador are 35% higher (estimated from ESPAC data) than country-level yields. Thus, FAOSTAT yields data were multiplied by 1.35 to reflect yields in northern Ecuador and yield for 1996 estimated as the average of 1994-1998. λ=0.0168 (Type II gains); Type I gains=18.4% (from Mooney 2007).
For all countries	For 2010-2015, area harvested assumed as the average of the previous five years (i.e. 2005-2009). For 2011-2015, price assumed as the average of the previous five years (i.e. 2006-2010). Discount rate=4%. Production estimated by multiplying area harvested in each year times the base year (i.e. 1996) yields.

Table A 3.1. Additional demographic characteristics of farm households (HH). Central Highlands of Angola, 2009.

	Potato					Bean					Onion				
	Non-sellers		Sellers			Non-sellers		Sellers			Non-sellers		Sellers		
Demographics	Mean	S.E.	Mean	S.E.	MT[1]	Mean	S.E.	Mean	S.E.	MT[1]	Mean	S.E.	Mean	S.E.	MT[1]
Marital status of head (%):															
Married	66	0.195	87	0.113	***	79	0.184	79	0.156		79	0.183	88	0.094	
Single	2	0.016	1	0.012		1	0.012	2	0.019		2	0.016	1	0.014	
Widow	20	0.106	9	0.072	***	13	0.111	13	0.094		12	0.118	9	0.061	
Separated	12	0.082	4	0.034	***	7	0.063	6	0.046		7	0.059	2	0.022	
Household size	4.9	0.281	5.5	0.109	**	5.4	0.478	5.6	0.334		5.1	0.253	5.6	0.126	
No. males >17 yrs	0.8	0.176	1.0	0.115	**	1.0	0.254	1.0	0.119		0.9	0.168	1.2	0.056	***
No. females >17 yrs	1.1	0.026	1.1	0.035		1.1	0.017	1.1	0.027		1.1	0.011	1.1	0.017	
No. children <5 yrs	1.0	0.118	1.5	0.088	***	1.4	0.189	1.3	0.124		0.9	0.173	1.5	0.118	***
No. boys 5-17 yrs	0.9	0.077	1.1	0.135		1.1	0.104	1.2	0.196		1.3	0.328	1.0	0.035	
No. girls 5-17 yrs	1.1	0.078	0.8	0.181	**	0.9	0.110	1.0	0.099		1.0	0.100	0.9	0.090	
If HH member is in FO[2]:															
Received assistance about production (% yes)[3]	69	0.137	54	0.135		74	0.164	50	0.230		74	0.174	68	0.127	
Received assistance about marketing (% yes)[3]	23	0.165	11	0.068		6	0.052	26	0.080	*	26	0.191	14	0.092	
Family members >17 literate:[4]															
No. males >17 literate	0.7	0.169	0.5	0.051	**	0.4	0.107	0.6	0.073	**	0.5	0.053	0.7	0.060	**
No. females >17 literate	0.3	0.044	0.2	0.020		0.2	0.035	0.3	0.033	**	0.4	0.054	0.2	0.051	*
Share of all adults (%)	46	0.090	34	0.022	**	24	0.036	42	0.044	***	39	0.036	38	0.049	
Number of observations	88		183			101		223			60		134		

Table A 3.1 (cont'd).

[1] MT = test of difference between means: * significant at 10%; ** significant at 5%; *** significant at 1%. [2] FO = Farmer organization. [3] Asked to member of FO and refers to assistance over past 12 months. [4] Literacy refers to people who can read and write.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.2. Major sources of crop and non-crop household incomes by market participation. Central Highlands of Angola, 2009.

Households' (HH) heads declaring[1]	Potato					Bean					Onion				
	Non-sellers		Sellers			Non-sellers		Sellers			Non-sellers		Sellers		
	Mean	S.E.	Mean	S.E.	MT[2]	Mean	S.E.	Mean	S.E.	MT[2]	Mean	S.E.	Mean	S.E.	MT[2]
Crops below as their major source of crop income (%):															
Potatoes	18	0.046	47	0.067	***	15	0.065	14	0.015		11	0.037	31	0.026	***
Corn	30	0.046	14	0.039	***	23	0.058	14	0.067	*	11	0.027	13	0.016	
Beans	33	0.018	19	0.019	**	29	0.034	63	0.086	***	58	0.103	29	0.026	***
Onions	5	0.023	7	0.030		8	0.035	3	0.010	*	9	0.066	15	0.027	
Other crops	14	0.026	12	0.035		24	0.083	6	0.012	***	11	0.028	12	0.013	
Activities below as their major source of non-crop income (%):															
Commerce	28	0.120	18	0.060	*	25	0.043	24	0.019		19	0.012	32	0.040	
Services	3	0.028	23	0.079	***	20	0.090	13	0.054		11	0.044	17	0.068	
Farm labor	27	0.084	38	0.017	*	21	0.114	32	0.039	*	22	0.087	29	0.021	
Gifts, retirements, transfers, remittances	8	0.034	3	0.007	**	2	0.017	7	0.008	*	20	0.105	2	0.003	***
Handcrafts, processed products	4	0.025	10	0.013		12	0.030	5	0.022	*	8	0.024	7	0.015	
None	28	0.119	6	0.027	***	14	0.026	15	0.017		10	0.104	12	0.029	
Other activities	1	0.007	3	0.015		7	0.036	4	0.017		11	0.063	1	0.010	***
Number of observations	76		186			85		225			47		125		

[1] Column sum within sources may not add to 100% due to rounding.

[2] MT = test of difference between means: * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.3. Scoring factors, summary statistics, and per tercile means for asset indicators entering the computation of the first principal component (asset ownership).

Asset indicators	Total sample: Scoring Factors	Mean	Std. Dev.	Scor. Fac. / Std. Dev.	Percentage of households owning the asset: Lowest tercile	Middle tercile	Highest tercile
Own plow	0.326	0.094	0.292	1.11	0%	4%	23%
Own cart	0.121	0.004	0.065	1.87	0%	0%	1%
Own backpack sprayer	0.224	0.019	0.136	1.65	0%	0%	6%
Own motorcycle	0.434	0.069	0.254	1.71	0%	0%	23%
Own bicycle	0.297	0.153	0.360	0.82	0%	5%	58%
Own cell phone	0.299	0.059	0.235	1.27	0%	0%	21%
Have water storage at home	0.261	0.197	0.398	0.66	5%	19%	42%
Have latrine in the house	0.094	0.789	0.409	0.23	71%	93%	94%
Have lusalite or zinc roof	0.393	0.467	0.499	0.79	0%	46%	79%
Own radio	0.347	0.377	0.485	0.71	2%	55%	62%
Own television	0.335	0.029	0.169	1.98	0%	0%	6%
					Mean by tercile		
Economic Status Index		0.000	1.522		-1.259	-0.277	1.719
Number of observations		478			164	184	130

Notes: Three of the 14 indicators were dropped because they had zero variance. Scoring Factor is the "weight" assigned to each indicator or eigenvector (normalized by its mean and standard deviation) in the linear combination of the variables that constitute the first principal component. The percentage of the covariance explained by the first principal component is 21.06%. The first eigenvalue is 2.32. Data provided in the last three columns were estimated with weights to reflect population (except number of observations).

Source: ProRenda survey, Angola, 2009.

Table A 3.4. Means per market participation (seller) for asset indicators entering the computation of the first principal component (asset ownership).

	Percentage of households owning the asset								
	Potato seller			Bean seller			Onion seller		
Asset indicators	**No**	**Yes**	**MT**	**No**	**Yes**	**MT**	**No**	**Yes**	**MT**
Own plow	16%	9%	--	4%	9%	--	7%	11%	--
Own cart	0%	1%	--	0%	0%	--	2%	0%	--
Own backpack sprayer	0%	4%	--	0%	1%	--	0%	4%	--
Own motorcycle	3%	10%	--	8%	9%	--	21%	7%	--
Own bicycle	20%	27%	--	17%	19%	--	22%	25%	--
Own cell phone	7%	10%	--	5%	11%	--	10%	8%	--
Have water storage at home	19%	21%	--	23%	19%	--	44%	20%	--
Have latrine in the house	81%	90%	--	86%	89%	--	80%	91%	--
Have lusalite or zinc roof	37%	56%	--	38%	43%	--	63%	33%	--
Own radio	35%	54%	--	48%	40%	--	47%	63%	--
Own television	0%	2%	--	0%	3%	--	2%	1%	--
				Mean by group					
Economic Status Index	-0.118	0.432	***	-0.086	0.121		0.651	0.224	*
Number of observations	97	175		115	232		57	130	

Notes: Three of the 14 indicators were dropped because they had zero variance. The percentage of the covariance explained by the first principal component is 21.06%. The first eigenvalue is 2.32. Estimates weighted to reflect population (except last row). MT = Bonferroni test of difference between means: * significant at 10%; ** significant at 5%; *** significant at 1%; -- not tested.

Source: ProRenda survey, Angola, 2009.

Table A 3.5. Potato sellers: Average receipts, costs, margins and percentage of production sold, per economic status index and gender of household head (HHH).

	Economic Status Index by tercile [1]						Gender of HHH [1]			
Detail	**Lowest**		**Middle**		**Highest**		**Male**	**Female**		**Total**
					(mean values)					
Receipts (Kw)	7,705	a	12,630	ab	17,795	b	15,761	7,287	***	14,087
Price per kg sold (Kw/kg)	79	--	86	--	89	--	85	71	--	82
Total Costs (Kw)	5,544		8,864		12,796		11,379	5,388	**	10,195
Production costs per kg produced (Kw/kg)	46.5	--	43.1	--	61.3	--	51.9	43.4	--	50.2
Marketing costs per kg sold (Kw/kg)	1.8	--	2.7	--	2.9	--	2.4	2.0	--	2.4
Margins (Kw)	2,160		3,766		4,999		4,382	1,900		3,892
Share sold (% of total production)	77%		83%		83%		84%	77%	*	82%
Number of observations	39		68		67		127	74		201

NOTES: Kw = Kwanzas. Costs include purchased inputs, hired labor, and reported marketing costs. Variables are at the household level. Number of observations in Economic Status Index smaller than in last column because of missing values in this variable.

[1] Bonferroni test of difference between means: for Economic Status Index, different letters imply differences are significant at 10%; for Gender of HHH, * significant at 10%; ** significant at 5%; *** significant at 1%. -- = mean differences not tested.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.6. Bean sellers: Average receipts, costs, margins and percentage of production sold, per economic status index and gender of household head (HHH).

Detail	Economic Status Index by tercile [1]						Gender of HHH [1]			Total
	Lowest		Middle		Highest		Male	Female		
					(mean values)					
Receipts (Kw)	3,193	a	4,792	a	11,625	b	8,447	3,039	***	6,785
Price per kg sold (Kw/kg)	74	--	65	--	74	--	72	69	--	71
Total Costs (Kw)	947		987		1,867		1,443	887		1,272
Production costs per kg produced (Kw/kg)	8.8	--	9.6	--	9.3	--	8.2	11.5	--	9.2
Marketing costs per kg sold (Kw/kg)	5.0	--	3.0	--	0.8	--	3.2	2.0	--	2.8
Margins (Kw)	2,247	a	3,805	a	9,758	b	7,004	2,152	***	5,513
Share sold (% of total production)	60%		66%		61%		64%	57%	**	62%
Number of observations	87		79		64		142	113		255

NOTES: Kw = Kwanzas. Costs include purchased inputs, hired labor, and reported marketing costs. Variables are at the household level. Number of observations in Economic Status Index smaller than in last column because of missing values in this variable.

[1] Bonferroni test of difference between means: for Economic Status Index, different letters imply differences are significant at 10%; for Gender of HHH, * significant at 10%; ** significant at 5%; *** significant at 1%. -- = mean differences not tested.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.7. Onion sellers: Average receipts, costs, margins and percentage of production sold, per economic status index and gender of household head (HHH).

	Economic Status Index by tercile [1]						Gender of HHH [1]			
Detail	**Lowest**		**Middle**		**Highest**		**Male**	**Female**		**Total**
					(mean values)					
Receipts (Kw)	1,375		5,135		5,294		5,300	1,883	**	4,708
Price per kg sold (Kw/kg)	117	--	86	--	107	--	98	114	--	101
Total Costs (Kw)	1,671		2,386		5,873		4,284	1,096	**	3,732
Production costs per kg produced (Kw/kg)	95.7	--	42.7	--	114.3	--	90	43	--	82
Marketing costs per kg sold (Kw/kg)	2.9	--	3.6	--	2.4	--	2.9	3.8	--	3.0
Margins (Kw)	-296		2,750		-579		1,016	787		976
Share sold (% of total production)	74%		80%		77%		80%	77%		79%
Number of observations	34		50		45		89	52		141

NOTES: Kw = Kwanzas. Costs include purchased inputs, hired labor, and reported marketing costs. Variables are at the household level. Number of observations in Economic Status Index smaller than in last column because of missing values in this variable.

[1] Bonferroni test of difference between means: for Economic Status Index, different letters imply differences are significant at 10%; for Gender of HHH, * significant at 10%; ** significant at 5%; *** significant at 1%. -- = mean differences not tested.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.8. Descriptive statistics of factors influencing potato, bean and onion production. Central Highlands of Angola, 2009.

	Potato		Bean		Onion	
	N = 281		N = 380		N = 162	
Variables	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
Dependent Variable						
Quantity produced (kg)	169.49	29.120	89.05	17.083	46.28	7.686
Independent Variables						
Household (HH) Characteristics						
Age of HH head (Years)	39.71	0.819	43.71	0.396	43.84	0.919
Gender of HH head (% Male)	74.03	0.214	68.75	0.263	76.51	0.208
Dependency ratio[1]	0.59	0.010	0.56	0.011	0.54	0.012
HH member is in farmer organization (% yes)	9.37	0.046	2.18	0.010	6.39	0.034
No. adults (>17 yr) literate[2]	0.80	0.059	0.88	0.096	1.05	0.104
No. of Tropical Livestock Units	0.38	0.092	0.51	0.094	0.41	0.049
Home has zinc roof (% yes)	56.97	0.048	46.58	0.077	43.50	0.040
Productive Assets Ownership (% yes)						
Owns a plow	13.53	0.027	11.78	0.031	9.40	0.010
Owns a backpack sprayer	4.44	0.012	0.75	0.005	2.81	0.021
Public Assets and Quasi-fixed Factors (% yes)						
IDA office in village	26.45	0.054	19.25	0.039	19.03	0.019
Public market in village	17.33	0.045	18.97	0.032	12.79	0.043
HH in Caala Municipality	16.62	0.021	7.06	0.013	10.45	0.040
HH in Ekunha Municipality	1.60	0.013	3.35	0.023	1.27	0.011
HH in Bailundo Municipality	15.97	0.038	50.19	0.040	34.93	0.049
HH in Londuimbali Municipality	17.11	0.038	29.70	0.034	24.06	0.051
HH in Katchiungo Municipality	12.45	0.022	3.79	0.004	6.09	0.010

Table A 3.8 (cont'd).

Variables	Potato N = 281 Mean	Potato Std. Err.	Bean N = 380 Mean	Bean Std. Err.	Onion N = 162 Mean	Onion Std. Err.
HH in Tchicalachuluanga Municipality	2.83	0.018	2.36	0.013	3.52	0.019
HH in Chiguar Municipality	33.17	0.031	3.32	0.022	19.66	0.044
HH in Babaera Municipality	0.25	0.002	0.23	0.002	0.02	0.000
Production-related variables						
Total seed used (kg)	41.16	6.562	23.59	3.273	0.03	0.013
Planted in rainfed plot (% yes)	44.03	0.014	94.20	0.016	56.57	0.040
Planted intercropped (% yes)	n.a.		59.97	0.017	n.a.	
Planted local variety (% yes)	73.75	0.046	98.10	0.004	92.90	0.031
Used fertilizer (% yes)	65.62	0.028	2.55	0.006	48.57	0.072
Used pesticides (% yes)	10.66	0.054	0.11	0.001	3.57	0.014
Reported production costs (Kw/kg)	62.54	9.583	10.93	2.109	75.66	7.912
HH reported lower harvest (% yes)	66.75	0.026	57.92	0.020	54.65	0.035

Notes: n.a. = not applicable since only beans may be planted intercropped.

[1] Dependency ratio estimated by dividing No. members ≤17 yr by household size.

[2] Literacy refers to adults who can read and write.

Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.9. Unconditional average partial effects of factors influencing potato sales. Central Highlands of Angola, 2009.

Independent variables: the coefficients displayed are the unconditional average partial effects (APEs).	**Quantity sold (kg)**	
	Coefficient	p-value
Age of HH head (Years)	-0.309	0.124
Gender of HH head (1=Male)	23.994	0.353
Dependency ratio	20.491	0.702
HH member is in farmer organization (1=Yes)	19.389	*0.091
No. adults (>17 yr) literate	1.822	0.666
No. of Tropical Livestock Units	4.275	0.571
Asset Index	-6.980	*0.056
Owns motorcycle (1=Yes)	12.298	0.717
Owns bicycle (1=Yes)	28.198	***0.000
IDA office in village (1=Yes)	43.242	**0.041
Public market in village (1=Yes)	-23.283	0.111
HH in Caala Municipality (1=Yes)	49.531	0.175
HH in Ekunha Municipality (1=Yes)	65.411	**0.042
HH in Bailundo Municipality (1=Yes)	-86.079	*0.066
HH in Katchiungo Municipality (1=Yes)	36.192	**0.018
HH in Tchicalachuluanga Municipality (1=Yes)	-6.738	0.769
HH in Chiguar Municipality (1=Yes)	4.081	0.805
HH in Babaera Municipality (1=Yes)	-29.095	0.378
Distance from village to sede (km)	-0.773	0.240
Road between village and sede in poor condition (1=Yes)	-59.345	***0.000
Seller sought price information prior to sales (1=Yes)	-2.937	0.761
Reported marketing costs (Kw/kg)	-0.454	0.683
Total potato production (kg)	0.577	***0.000

Notes: *, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.
Coefficients and p-values obtained via bootstrapping at 500 repetitions.
Dependency ratio estimated by dividing No. members ≤17 yr by household (HH) size.
Literacy refers to adults who can read and write.
n.a. = not applicable because variable was not included in the regression.
Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.10. Unconditional average partial effects of factors influencing bean sales. Central Highlands of Angola, 2009.

Independent variables: the coefficients displayed are the unconditional average partial effects (APEs).	**Quantity sold (kg)** Coefficient	p-value
Age of HH head (Years)	-0.400	**0.016
Gender of HH head (1=Male)	5.296	0.502
Dependency ratio	-10.200	0.188
HH member is in farmer organization (1=Yes)	-12.154	0.127
No. adults (>17 yr) literate	5.717	*0.055
No. of Tropical Livestock Units	2.383	0.170
Asset Index	0.971	0.668
Owns motorcycle (1=Yes)	-35.318	***0.008
Owns bicycle (1=Yes)	14.703	***0.000
IDA office in village (1=Yes)	1.023	0.958
Public market in village (1=Yes)	-6.534	0.760
HH in Caala Municipality (1=Yes)	-19.680	***0.000
HH in Ekunha Municipality (1=Yes)	10.260	0.216
HH in Bailundo Municipality (1=Yes)	12.255	***0.000
HH in Katchiungo Municipality (1=Yes)	-16.531	***0.000
HH in Tchicalachuluanga Municipality (1=Yes)	-13.475	0.216
HH in Chiguar Municipality (1=Yes)	-2.358	0.910
HH in Babaera Municipality (1=Yes)	-32.637	***0.001
Distance from village to sede (km)	0.538	***0.003
Road between village and sede in poor condition (1=Yes)	2.300	0.709
Seller sought price information prior to sales (1=Yes)	-9.474	***0.002
Reported marketing costs (Kw/kg)	-0.331	0.313
Total bean production (kg)	0.483	***0.000

Notes: *, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.
Coefficients and p-values obtained via bootstrapping at 500 repetitions.
Dependency ratio estimated by dividing No. members ≤17 yr by household (HH) size. Literacy refers to adults who can read and write.
Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

Table A 3.11. Unconditional average partial effects of factors influencing onion sales. Central Highlands of Angola, 2009.

Independent variables: the coefficients displayed are the unconditional average partial effects (APEs).	**Quantity sold (kg)**	
	Coefficient	p-value
Age of HH head (Years)	0.112	0.550
Gender of HH head (1=Male)	3.530	0.211
Dependency ratio	5.954	0.147
HH member is in farmer organization (1=Yes)	0.850	0.851
No. adults (>17 yr) literate	2.795	***0.000
No. of Tropical Livestock Units	-0.201	0.961
Asset Index	-2.997	***0.000
Owns motorcycle (1=Yes)	-2.391	0.761
Owns bicycle (1=Yes)	1.157	0.788
IDA office in village (1=Yes)	2.316	0.679
Public market in village (1=Yes)	3.847	*0.065
HH in Caala Municipality (1=Yes)	0.276	0.963
HH in Ekunha Municipality (1=Yes)	-0.561	0.852
HH in Bailundo Municipality (1=Yes)	-1.466	0.702
HH in Katchiungo Municipality (1=Yes)	7.706	0.105
HH in Tchicalachuluanga Municipality (1=Yes)	-2.762	0.410
HH in Chiguar Municipality (1=Yes)	3.635	0.485
Distance from village to sede (km)	-0.681	**0.019
Road between village and sede in poor condition (1=Yes)	10.130	***0.000
Seller sought price information prior to sales (1=Yes)	1.997	0.267
Reported marketing costs (Kw/kg)	-0.147	*0.078
Total onion production (kg)	0.675	***0.000
Residual from onion production equation	-0.082	**0.028

Notes: *, **, *** indicates the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.
Coefficients and p-values obtained via bootstrapping at 500 repetitions.
Dependency ratio estimated by dividing No. members ≤17 yr by household (HH) size. Literacy refers to adults who can read and write.
Source: ProRenda survey, Angola, 2009. Estimates weighted to reflect population.

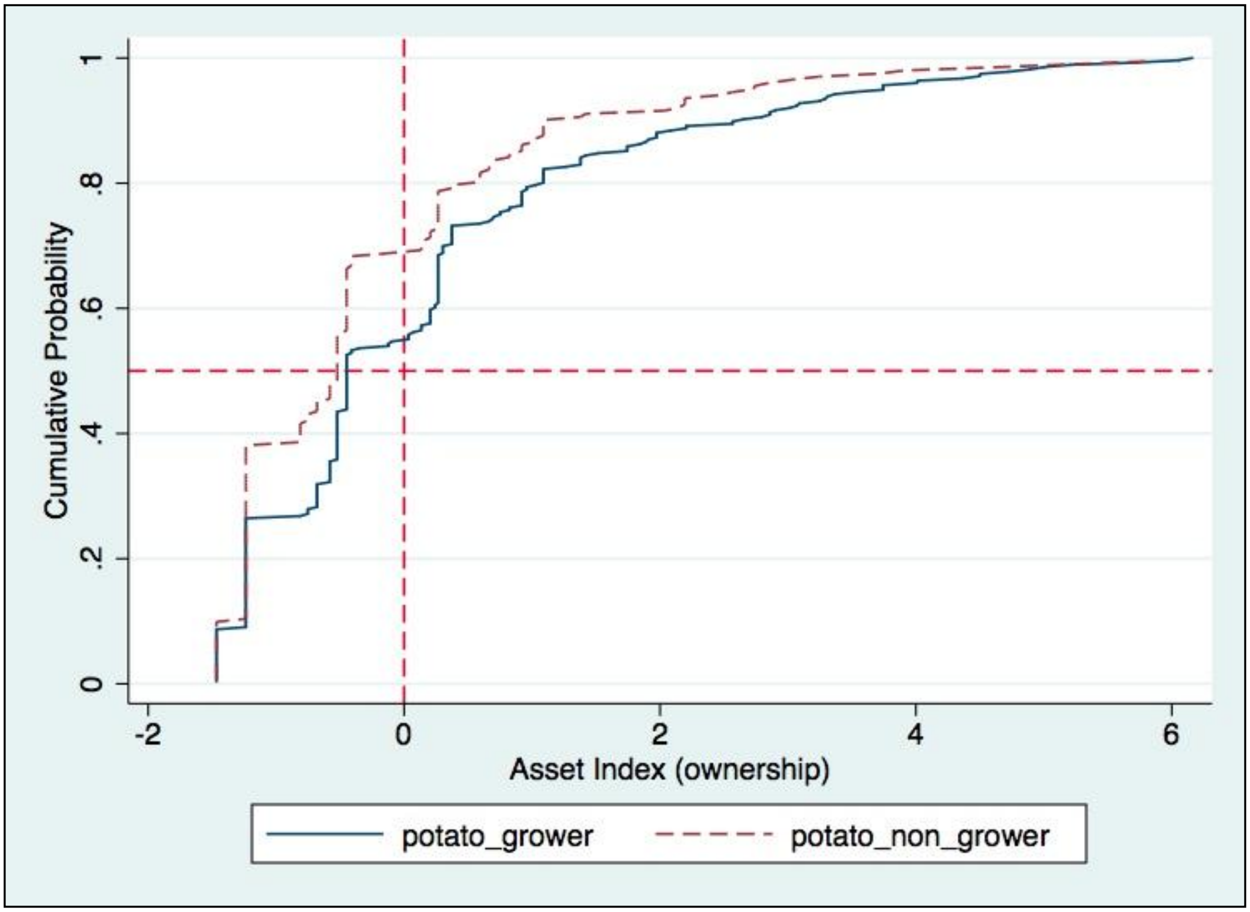

Figure A 3.1. Cumulative distribution of asset index by potato growers and non-growers. Central Highlands of Angola, 2009.

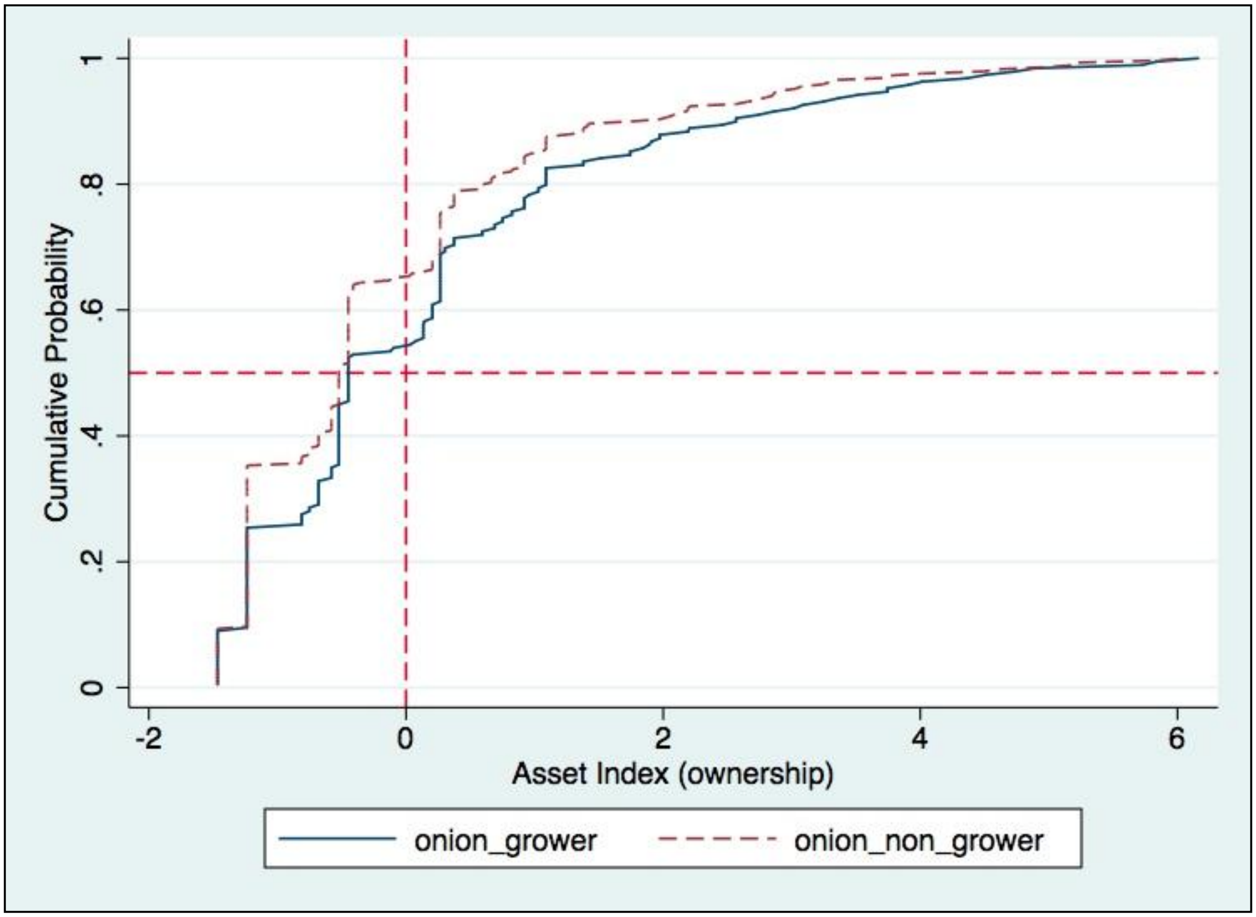

Figure A 3.2. Cumulative distribution of asset index by onion growers and non-growers. Central Highlands of Angola, 2009.

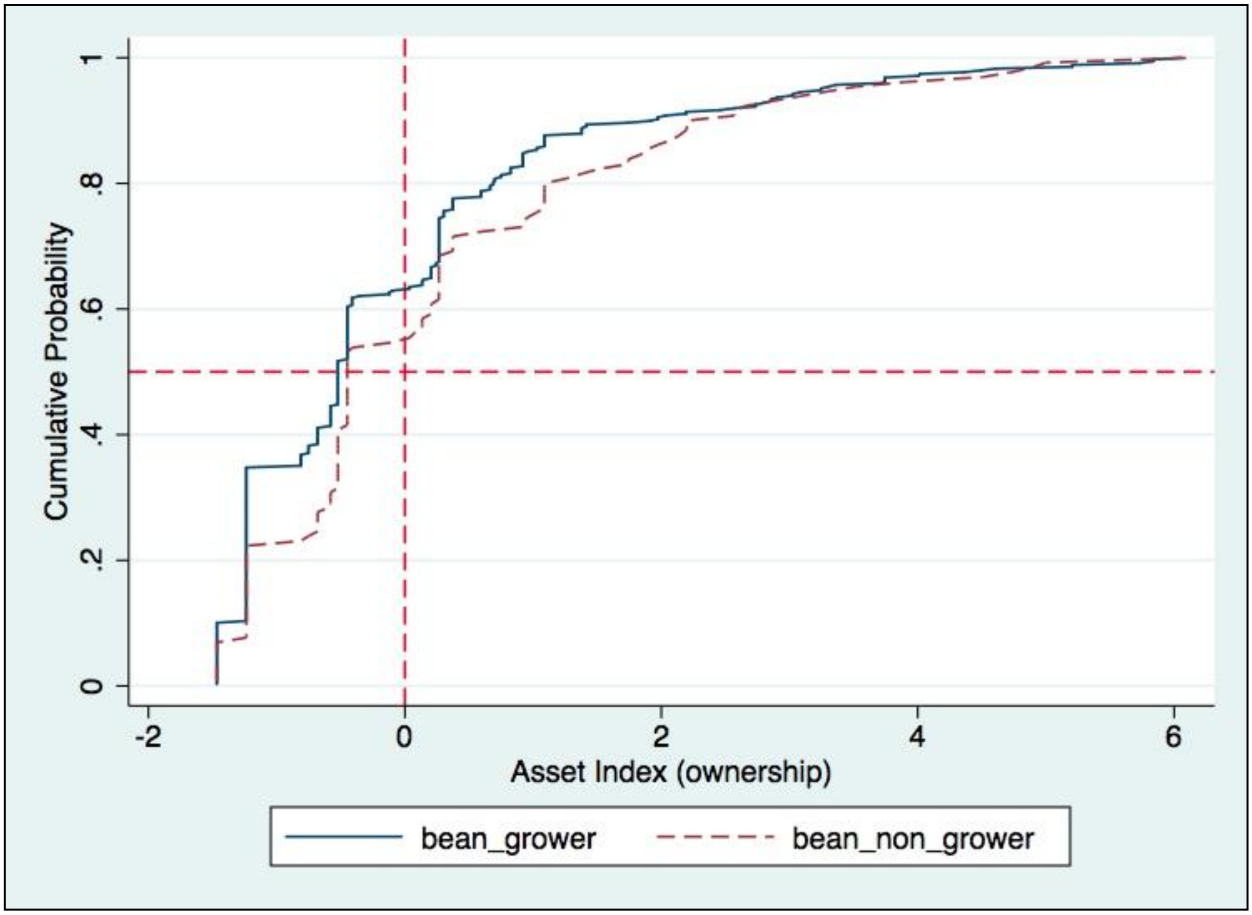

Figure A 3.3. Cumulative distribution of asset index by bean growers and non-growers. Central Highlands of Angola, 2009.

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