Small scale agriculture, marginal conditions and market access: Impacts on natural resources and farmers' welfare

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Contents

Abstract

Numerous are the obstacles and difficulties smallholder farmers from developing countries have to face to achieve food security or improve their wellbeing. Challenges and opportunities may vary dramatically from having to cope with harsh climatic and production conditions to having the option of entering the market, yet farming systems and production decisions are crucial elements to reduce poverty and improve wellbeing. This is particularly true in a time in which growing population, climate change and energy requirements pose increasing pressure on land and natural resources. In either context, the use and exploitation of natural resources is thus a key aspect to consider particularly with regard to the variety choices that can affect genetic diversity and to the use of pesticides that might be induced to achieve standards required by the market.

This thesis attempts to address these elements by analysing how small-scale farmers deal with achieving food security and improving their wellbeing through crop production choices, farming technologies and strategies adopted to access the market in marginal but market-oriented conditions as opposed to manage production in harsh agro-ecological conditions.

After analyzing in detail the role of agriculture, of Plant Genetic Resources for Food and Agriculture (PGRFA) and of agricultural markets and seed systems, the thesis is divided in two parts. The first part deals with analyzing how small-scale farmers from the Ecuadorian Sierra benefit from dynamic changes in the agricultural economy and what is the impact of their production choices on the use of pesticides and of potato varieties adopted. The second part examines how smallholder farmers from the Hararghe region of Ethiopia deal with frequent production difficulties and with production shocks mainly determined by drought through variety adoption choices and what are the impacts of these choices on production efficiency and genetic diversity. The importance of social capital, evident throughout the work presented, is specifically analyzed for the case of Ethiopia.

By using different approaches, methodologies and data, among which rigorous impact assessment plays a key role, findings show the unequivocal importance of market access, seed sources, production technologies and social capital. The analysis undertaken demonstrates that programs and policies to be effective need to be implemented throughout the entire value chain: from input use to produce commercialization, whereas social capital might dramatically facilitate the successfulness of variety adoption, seed access and program implementation. Lastly, this work demonstrates that rigorous impact evaluation can help identify aspects of programs and policies crucial to suggest the way forward on achieving sustainable economic development.

Keywords: *small-scale farmers, food security, impact evaluation, Ecuador, Ethiopia, crop choice, social capital, crop genetic diversity, pesticides.*

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Romina Cavatassi

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Chapter 1

Introduction

Feeding a growing human population, in spite of the enormous progresses in industrial and agricultural production, is a key issue on the international policy agenda. In a context of global challenges where population keeps growing, climate change poses more frequent and adverse threats and natural resources compete between energy and food needs, this challenge must be addressed undoubtedly while respecting the environment and its natural resources. In the words of Lipper et al. (2009: 3) “agricultural markets, seeds systems and crop genetic resources lie at the heart of this challenge”.

Agriculture contributes to food security and human well-being both through producing food within accessible price ranges for rural and urban consumers as well as by providing income to farmers to purchase food. However, producing in marginal areas poses challenges and opportunities different than those encountered by farmers producing in more market oriented areas.

Whilst for the former, improving farm level productivity and resilience to agricultural production shocks is essential to reducing poverty and improving household food security, for the latter agricultural production and market integration represent crucial elements to improve well-being and ensure food security.

This thesis examines how smallholder farmers achieve the objectives of food security and of improving their welfare through crop production choices, farming technology and market access. These objectives are analyzed in a marginal but market oriented versus a marginal and harsh production context. The role of crop genetic resources (CGR) and of the seed systems within the above mentioned challenges are also considered. The former context is offered by a case study conducted in the Ecuadorian Sierra while the latter is offered by a case study run in Ethiopia. The impacts that production choices have in the two different contexts not only on food security and wellbeing but also on the use of natural resources are analyzed. In particular the analysis takes into account the utilization of selected staple crops, respectively potatoes versus sorghum and wheat, for which both countries are rich in diversity, as well as the potential genetic erosion occurring as a consequence of production choices. The impacts on the environment and on human health caused by the use of pesticides are also analyzed for the case of Ecuador.

1.1 Background

Sustainable agricultural development is a process that is ecologically sound, economically viable and socially just, and one that aims to produce the food and/or the income needed to achieve food security, a state that FAO defines as: *"a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO, 2002). Agriculture not only contributes to development as an economic activity and as a source of livelihoods but it is also an important provider of environmental services (World Bank, 2007). At present, however, many agricultural production practices contribute to resource degradation, including the loss of Plant Genetic Resources for Food and Agriculture (PGRFA). The Millennium Ecosystem Assessment (2005) reported that about 60% of the ecosystems studied were being degraded or used unsustainably, while climate change, the demands of an increasing human population, and the use of biofuels are all putting additional and new pressure on land (chapter 2, this thesis).

Researchers and development practitioners are increasingly realizing the importance of livelihood diversity in poverty reduction strategies (e.g. Ellis and Freeman, 2004) as well as the crucial role of staple crop production and of crop and variety diversification strategies for farmers' food security (see Eakin, 2005; Narloch et al., 2009).

Crop diversification is a key strategy in agricultural production carried out by smallholder farmers because of the opportunities it offers for managing risk and heterogeneous production conditions, as well as because of the increased income generation it allows through market participation. The literature on motivations for crop and/or variety diversification shows that supply as well as demand factors determine diversity levels maintained at the farm and at more aggregate levels (chapter 6, this thesis). There are three main driving factors of farmers' "demand" for crop diversity: i) managing risk, ii) adapting to heterogeneous agro-ecological production conditions; and iii) diversification to meet market demands.[1] Other reasons include nutritional preferences, cultural values, managing labour bottlenecks, information flow over varieties or constraints in accessing certain cultivars (Bellon, 1996; Lipper et al., 2006).

Increasing agricultural productivity and production efficiency through modern or high yielding varieties has often been found to be an effective strategy. However, for farmers dealing with risk management or with harsh agro-ecological production conditions, these varieties might not be suitable and yield nearly nothing given that they have been developed primarily for high potential production

[1] See for example Newberry and Stiglitz (1981), Chavas and Holt (1990), Rosenzweig and Binswanger (1993) and Fafchamps (1999).

conditions, requiring a set of complementary inputs (Evenson and Gollin, 2003). On the other hand, landraces or traditional varieties show a higher stability (adaptation over time) in these environments and may contribute to farm level resilience to cope with production shocks (FAO, 1998; Ceccarelli et al., 2001). An important requirement for promoting food security and rural development strategies through a sustainable utilization of CGR[2] is gaining better insights into the adoption of Modern Varieties (MV) among farmers operating in such areas as well as gaining a better understanding of seed system functioning and seed flows within formal and informal networks.

Likewise, it is important to gain a better understanding of what are the processes and elements that generate the possibility for small farmers to access the market profitably. Moving from marginal and subsistence farming towards commercial production, farmers start to produce for the markets and adopt new crops or varieties to meet demand. In the transition from subsistence to commercial production, farms become semi-commercial characterized by mixed cropping systems frequently associated with higher levels of crop diversity than subsistence systems (Pingali and Rosegrant, 1995). As commercialization proceeds, however, farms become more specialized even though the agricultural economy may be more diversified.

The process of agro-industrialization, ongoing in many developing countries, brings about a set of changes, often referred to as *the new agricultural economy*, which create the potential to increase farm incomes and improve food security (Eaton and Shepherd, 2001; Winters et al., 2005). However, the fact that many smallholders remain on the periphery of the new agricultural economy indicates benefits to them do not accrue automatically and are by no means guaranteed (Little and Watts, 1994; Berdegué et al., 2003; Reardon et al., 2003).

The net effect of the new agricultural economy on the welfare of poor people is indeed controversial and depends on how these changes will affect the poor as producers and as consumers and on the conditions that determine their market integration. These changes, have introduced new forms of institutions imposing private grades and standards for food quality and safety, in addition to choices on new organizational arrangements within the food marketing chain (Kerallah and Kristen, 2001; Reardon and Berdegué, 2002; Dolan and Humphrey, 2004).

The increased commercialization of agricultural produce could have various opposing effects also on the environment. The orientation towards regional and farm-level specialization as well as the intensification of natural resources' use, have raised several concerns related to the loss of biodiversity and to the genetic erosion of local varieties, in addition to the intensification of chemicals used (Barrett et al., 2001; Pingali, 2001; Singh, 2002; Winters et al., 2005). The quality and uniformity requirements of agro processors may, indeed, limit the use of certain varieties, particularly traditional ones in favour of modern varieties with desirable processing characteristics (Dasgupta et al., 2001; Pingali, 2001). Moreover, the requirements of standards may lead, at least initially, to an increase in

[2] Within Crop Genetic Resources particular attention is dedicated to Plant Genetic Resources for Food and Agriculture.

the use of agricultural chemicals and thus to higher environmental and human health risks (Thrupp, 1990; Crissman et al., 1998; Pingali, 2001, Berdegué et al., 2003).

The challenge is, thus, to identify ways that allow smallholders to actively participate and benefit from the increased food-system dynamics while avoiding negative environmental externalities. Nevertheless, empirical research on farmers' choices to participate to the growing market liberalization is rather intricate, as it is analysing the consequential effects on the environment.

The present thesis represents a specific attempt to try to account for the difficulties above mentioned and to identify the types of obstacles and the difficulties farmers face in achieving food security and improving their well-being.

The thesis, after analyzing in detail the importance of CGR (and particularly PGRFA), agricultural markets and seeds systems to achieve food security and alleviate poverty (or increase wellbeing), is divided in two parts. The first part deals with analyzing how smallholder farmers in the Ecuadorian Sierra benefit from dynamic changes in the agricultural economy and what is the impact on the use of pesticides and of potato varieties. The second part examines how smallholder farmers in the Hararghe region of Ethiopia, who deal with very difficult agro-ecological conditions and frequent production shocks, make variety adoption choices and what are the impacts of these choices on production efficiency and potential genetic erosion. The importance of social capital in both contexts is rather evident throughout the thesis and is specifically analysed for the case of Ethiopia.

Ecuador and potato have been chosen for the first case study because:

- Potato is a staple crop, crucial to the food security of many Ecuadorian peoples, but also a crop that is commonly used in the processing of chips, fries and other foods. Moreover the Andes are the centre of origin and diversity for potatoes.
- Ecuador has been chosen because, despite its ongoing agro-industrialization process, it still has large indigenous populations and widespread poverty, particularly in rural areas. It is a country that presents various degrees of farmers' integration with the market, from the many small farmers who still produce under the rules of traditional farming system to those vertically integrated and oriented towards agro-industrial production.

Moreover, a relatively large scale integrated market chain intervention with small potato farmers (*Plataforma de concertación*) offered an opportunity for conducting an interesting impact evaluation study.

Ethiopia and the staple crops of sorghum and wheat have been chosen for the second study because:

- Ethiopia is centre of diversity for sorghum and wheat, among other crops.
- Sorghum and wheat are key staple crops for most of the population in the area selected.
- The country presents a very high rate of food and seed insecurity.
- There had been a seed intervention project meant to distribute clean seeds of modern and

landrace varieties which offered a potentially interesting study case.

1.2 Research objectives and questions

The specific objectives of the thesis are as follows:

- Promote the sustainable utilization of Crop Genetic Resources, and particularly of PGRFA, by discussing their role and contribution to food security and sustainable agricultural development;
- Identify the circumstances and mechanisms which promote or inhibit small farmers' entry into the new agricultural economy and the actions that can be taken to improve the benefits of such entry;
- Understand the role of social capital, transactions costs or other elements that could determine farmers' decision making and influence their choice to participate in the market and in which form;
- Ascertain conditions under which such participation influence the production function and the utilization of conventional as opposed to damage control inputs and how this might ultimately allow the conservation of crop genetic diversity and a reduced use of pesticides;
- Understand motivations and impacts of modern variety adoption for farmers facing difficult agro-ecological conditions and frequent production shocks;
- Identify and gain insights into the functioning of formal and informal seed system and the role of social capital and networks in seed flows and agrobiodiversity conservation in marginal production contexts.

The ultimate aim of the thesis is to provide information on the design of policies aimed at addressing food security and farmers' wellbeing in diverse contexts and production conditions.

To reach these objectives the following research questions are to be answered:

1. a) What is the role of CGR and particularly of Plant Genetic Resources for Food and Agriculture (PGRFA) in achieving food security and alleviate poverty within the context of some of the emerging and difficult challenges now facing agriculture? b) And what is the role of markets and seed systems within this context?
2. a) Has participating in the market through the Plataformas in Ecuador increased farmers' welfare as measured by potato yields and gross margins? b) What are the primary mechanisms through which the program has improved welfare? c) Has participation led to health or environmental degradation with respect to agrochemicals utilization and changes

in varietal use?

3. a) To what extent has participating in the Plataformas program had an impact on yield through modifying the production technology? b) To what extent has participation in the Plataforma influenced the use of yield enhancing inputs versus damage abating inputs?
4. a) Are more risk adverse farmers with climatically sensitive production systems more or less likely to adopt modern varieties? b) Does modern variety adoption reduce or increase the probability of being affected by crop failure?
5. a) How does agricultural household decision-making determine on-farm diversity? b) What is the role of social capital in determining on-farm level diversity of crops and varieties?

1.3 Methodology and approach

The best way to gain insights and provide information on the design of policies aimed at food security and farmers' well-being in diverse contexts and production conditions is looking across countries at different points in agro-technological and agro-processing development (new agricultural economy). For this purpose the countries of Ethiopia and Ecuador have been chosen for such an investigation. These two countries are ideally suited for the study because they both have large populations and widespread poverty, particularly in the rural areas of Ecuador and for the country at large in the case of Ethiopia. Andean agriculture relies on a resource base that is somewhat fragile because of its topography, whilst Ethiopia presents very diverse, difficult and marginal agro-ecological conditions. They are both the point of origin and centres of genetic diversity for a number of important crops, particularly potatoes and quinoa in Ecuador and sorghum, teff and wheat in Ethiopia.

Potato, sorghum and wheat are chosen for detailed analysis because they are staple crops in the respective countries and are crucial to the food security of smallholder farmers. In addition, potato is a crop that is suitable for agricultural industrialization being commonly used in processing of chips, fries and other processed foods.

Whilst both countries face poverty, yet the level as well as the incidence of poverty is rather different in Ethiopia than in Ecuador. Whereas Ethiopia ranks 130th in terms of Human Development Index-1 (HDI-1) and 77.9% of its population lives with less than 2 USD a day, Ecuador ranks 32nd and has 20.4% of its population living with less than 2 USD between 2004-2006 according to the UNDP Human Development Report (UNDP, 2009). Moreover, while Ethiopia is still far from agro-industrialization and farmers mainly deal with risk management and coping strategies, in Ecuador agro-industrialization is rather advanced. Frito-Lay, a multinational potato processing enterprise, has a potato chip factory in Ecuador that procures about 10,000 tons of potato annually from local farmers. In addition, there have been some public-sector policy initiatives to increase access to the processing market by small farmers. In particular, what we examine in this thesis is the case of the *Plataformas de concertación* or simply *Plataformas* (Devaux et al., 2009).

Likewise, while in Ethiopia the utilization of agro-chemicals is not an issue because of the very limited utilization, for Ecuador the issue of pesticide use is most important because of the intensification of agriculture that accompanies a shift to processing. On the other hand, with respect to agricultural biodiversity whilst in Ethiopia the mix of crops and varieties chosen represent important aspects of coping with difficult production conditions, in Ecuador they are expected to be mainly driven by the on-going process of agro-industrialization.

To address the research questions above listed, two case studies have been conducted respectively in these two countries. More in particular, a specially designed primary level survey on smallholder potato producers in Ecuador was used to collect data to measure the impacts on food security and farmers' welfare of market participation as well as the effects on the environment and the mechanisms in place to generate these impacts. The data were collected from June to August of 2007 through a detailed household questionnaire, which was specifically designed to conduct an impact evaluation. The questions were developed based on qualitative information collected through an earlier value chain analysis, key informant interviews and farmers' focus group discussions. Several revisions of the questionnaire were done during the pilot phase and through conversations with key informants to make it better targeted to potato producers from selected areas. To properly run impact evaluation communities and households were selected in such a way to ensure proper identification of program impact and divided into treatment (program participants) and control (non participants) groups. A third group of non participants, but residents in participant communities was also selected to check for spillover effects. The final sample includes a total of 1007 households of which 683 reside in beneficiary communities (324 participants and 359 non-participants) and 325 in control communities (non-eligible). Lists of households from each of these categories were provided by *Plataforma* coordinators and community leaders. Households from the lists were randomly selected to be included in the survey.

Likewise the data used for the case study run in Ethiopia was also collected to evaluate a seed system intervention carried out in the area by the Hararghe Catholic Secretariat (HCS), a local NGO. The sample was limited to woredas (counties) where HCS had been active and included peasant associations (PAs) only within the mid and highland areas, which have similar agro-ecological zones and fairly uniform cropping patterns. PAs that participated with the HCS program and those that did not were included in the sample. In the three woredas, a total of 30 PAs were selected: 15 PAs in which HCS project had been implemented and 15 similar PAs in which HCS did not distribute seeds. The principle governing the selection of non-participant PAs (i.e. the control group) was to identify those as similar as possible to the HCS project areas and households. To select the sample, a similar approach to the Ecuadorian data set was used, in that households were divided into treated and control, in addition to households that did not participate to the program but lived within communities where the program was implemented to check for spillover effects. A number of different survey instruments were used to collect data on household and community characteristics, crop production and the cropping systems. A total of 720 households were selected and interviewed over the cropping season of 2002-2003. The household survey instrument was implemented in two rounds in order to ensure sufficient detail on agricultural production. The first round was conducted towards the end of the Meher (main crop) planting season in August 2002. The second round was done after the harvest of the Meher crop in early 2003. In each of the 30 PAs surveyed, data on community characteristics was gathered through the use of a community level survey instrument administered to key informants, usually PA leaders. Agro-morphological characterization as well as farmers' focus group discussions were also run to complement the data set and information.

1.4 Outline of the thesis

The remainder of this thesis comprises six additional chapters. The next five chapters represent the core of the thesis. These chapters are written as stand-alone publications for scientific journals and some overlap between chapters is inevitable. A concluding chapter summarizes and discusses the main findings.

Chapter 2 addresses the first research question by discussing the role and contribution of PGRFA to food security and sustainable agricultural development. In the context of food security, poverty alleviation is considered as a key step for eliminating food insecurity. The chapter does not review or interpret these concepts or their inherent complexity and inter-linkages. Instead, it looks at the role of PGRFA in the context of some of the emerging and difficult challenges now facing agriculture providing a review of the current status of PGRFA and considering PGRFA not as victims of agricultural modernization but rather as a key tool for achieving broader social goals. The analysis presented is instrumental to identify some of the key gaps and needs for further research, which conclude the chapter.

Chapter 3 addresses questions 2a, 2b and 2c by looking at the experience of the Plataformas program in the Ecuadorian Sierra. Rigorous impact evaluation of participation in the market through the Plataformas is conducted by using multiple evaluation methods. These include ordinary least square (OLS) regression, Propensity Score Matching (PSM), weighted PSM and an Instrumental Variable approach. The various methods used allow to ensure identification of program impact and to attribute robustness to findings. Households were sampled in a way to ensure treatment and control effects could be soundly determined. Comparisons of impacts across the different groups allow checking for spillover effects and confirm the success of the program in achieving its objectives.

Chapter 4 addresses questions 3a and 3b. Since programs designed to improve returns to agriculture, such as the *Plataformas*, can influence crop production not only through changes in input and output indicators, but also through the production technology, the relationship between these indicators as embodied in the production technology needs to be analyzed. The chapter examines the impact of the Plataforma program on the production technology looking in particular at the use of pesticides and of potato varieties grown, as measured by a specifically constructed agro-biodiversity indicator within a damage abatement framework. In this framework pesticides and agrobiodiversity are seen in their damage reducting role rather than output enhancing. In particular, a weighted estimation, where weights are constructed through Propensity Score Matching, is employed to estimate the production function within a damage abatement framework. The function incorporates a series of interaction terms to assess the impact of the program on the production technology.

Chapter 5 addresses questions 4a and 4b by using the data set collected in the eastern Hararghe of Ethiopia in a year of extreme drought. Technology adoption decisions are particularly important in situations of high food insecurity, where the probability of complete crop failure is rather likely and where risk adverse farmers have limited capacity for ex-post consumption smoothing. In such contexts we can expect that small-scale farmers choose their production technology to minimize the probability of disaster outcomes. Whether modern varieties (MV) adoption is a risk reducing technology is very context-dependent. Thanks to early maturing traits MV may represent an effective means of coping with droughts on one hand, but landraces may show to be better adapted to marginal production conditions and be more drought-tolerant on the other hand. To analyze the adoption of MV, considered a technology choice, as well as the probability of experiencing crop failure for MV adopters, the chapter presents a maximum likelihood bivariate probit model rooted in the standard household model.

Chapter 6 focuses on how seed supply limitations influence crop diversity and the role that social networks play in overcoming this barrier so addressing question 5a and 5b. Social capital is considered an important feature of informal seed systems, which involve seed exchanges in the context of social interactions. Different forms of social capital are, thus, hypothesized to influence access and have differential impacts on the farm level choice of crops and varieties to plant, and thus on-farm crop diversity. To evaluate the factors influencing diversity, as measured by indicators adapted from the ecological literature and going from the count to the left censored Shannon and Berger-Parker indexes, respectively a poisson and two tobit regressions within the agricultural households model are applied. The model used is innovative in that it takes specific account of various forms of social capital within the agricultural household model.

Finally chapter 7 concludes by summarising the main findings of the thesis. Research questions presented above are synthetically answered and discussed. Implications for policy advice are discussed as well as recommendations for further research.

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Chapter 2

The contribution of Plant Genetic Resources for Food and Agriculture to food security and sustainable agricultural development[3]

Abstract: *This chapter considers plant genetic resources for food and agriculture (PGRFA) as important tools for achieving broader social goals of food security and sustainable agricultural development. We summarize evidence of the importance of genetic diversity for sustainable agriculture, and present an analysis of the three main elements through which agriculture and PGRFA contribute to food security: agricultural yields, market values and nutritional value of agricultural produce. Based on these three elements, we discuss on-farm management of PGRFA including drivers of variety choices, adoption of improved crop varieties and access to seeds. Particularly in light of new and emerging challenges, including population growth, climate change, and increased competition among agricultural land uses, we argue that wise use and management of PGRFA is ever more important. We conclude with an assessment of some major challenges and priorities for enhancing the contribution of PGRFA to food security and sustainable agricultural development.*

[3] This chapter is based on the article *The contribution of PGRFA to food security and sustainable agricultural development* by R. Cavatassi, L. Lipper and A. Keleman prepared for journal submission. It is based on a chapter contribution written by L. Lipper, R. Cavatassi and A. Keleman, (2010) for the 2nd State of the World on Plant Genetic Resources for Food and Agriculture, FAO, Rome, Italy. The authors would like to acknowledge constructive and valuable comments from P. Hazell, G. Hawtin, P. McGuire, E. Guimares, G. K. Ghosh, G. Guei and two anonymous referees. The usual disclaimer applies.

2.1 Introduction

In this chapter, we build an argument for considering the use of plant genetic resources for food and agriculture (PGRFA) as a key tool to support the broader social goals of food security and sustainable agricultural development. We also address how some recent trends and advances are making the conservation and wise use of PGRFA more important than ever.

The linked challenges of food security and sustainable agricultural development have recently re-emerged at the forefront of international concern following the food and economic crises. The latest FAO report estimated that the number of chronically hungry people in the world has reached a total of 1.02 billion people (FAO, 2009). About 75% of the worst-affected people reside in rural areas of developing countries, their livelihoods depending directly or indirectly on agriculture (FAO, 2009). Meanwhile, with the world population expected to reach about 9.2 billion by 2050, estimates suggest that between 70% and 100% increase in world agricultural production will be necessary to meet food demands (World Bank, 2007; Bruinsma, 2009; Royal Society of London, 2009).

Reaching this goal will require major improvements in crop production. Greater demand for processed food will put additional pressure on food supply systems, which will intensify the need to curb the increasingly recognized negative effects of agriculture on the environment (Godfray et al., 2010). Moreover, much of the projected growth will have to come from rainfed production outside areas of high agricultural potential, given competition for land-use among food, water and energy needs (Bruinsma, 2009). Last but not least, overarching all these issues is the threat that climate change poses to yield potential and the resilience of agricultural systems (Schmidhuber and Tubiello, 2007; VonBraun, 2007; Godfray et al., 2010).

PGRFA have the potential to contribute both directly and indirectly to meeting these challenges. Yields, productivity, nutrition, and marketability are directly linked to the type of crops and varieties grown. Meanwhile, increasing pest and disease resistance and resilience to production shocks, and providing breeding material for adaptation purposes in the present and in the future, are indispensable, though less direct, ways of addressing these challenges.

For the purposes of this chapter, we follow the definition provided in the International Treaty on Plant Genetic Resources for Food and Agriculture, which considers PGRFA to include “any genetic material of plant origin of actual or potential value for food and agriculture” (ITPGRFA, 2009: 11). This definition is useful because it comprises PGRFA of many different types, including agricultural biodiversity that is locally managed by farmers as well as modern varieties bred and deployed in larger-scale agricultural systems. This definition also encompasses the value of diversity in agricultural systems which, as discussed below, may be different from the value of a single crop or crop variety.

Much of the literature on PGRFA is framed by the real or perceived threat of genetic erosion, responding to the question of whether PGRFA conservation is best achieved with in-situ or ex-situ management (see Brush, 1991, 2004, for useful summaries of this debate). In this chapter, however, our aim is to take a different approach; while we acknowledge concerns about genetic erosion, we consider PGRFA not as "victims" of agricultural modernization, but rather as important tools for achieving broader social goals. To this end, we explore the importance of genetic diversity for sustainable agriculture (section 2.2), and offer an analysis of the three main pathways through which agriculture and PGRFA contribute to food security (section 2.3): agricultural yields, market values and nutritional value of agricultural produce. In section 2.4, we discuss the relationship between on-farm management of PGRFA, including the demand for crop variety traits, adoption of improved crop varieties, and access to seeds. The section concludes by addressing challenges and opportunities in the management of PGRFA under the threat of climate change coupled, with population growth and competition for land. Finally, section 2.5 concludes with an assessment of some major challenges and priorities for enhancing the contribution of PGRFA to food security and sustainable agricultural development.

2.2 Food security and sustainable agricultural development: the basis

A widely adopted and comprehensive definition of sustainable agricultural development describes it a process that is ecologically sound, economically viable and socially just, and one that aims to produce the food, and/or the income needed to achieve food security. FAO defines food security as: "*a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" (FAO, 2002).

Attaining food security through sustainable agricultural development thus requires ecologically sound production systems among the other requirements. At present however, many agricultural production practices contribute to resource degradation, including the loss of PGRFA. The Millennium Ecosystem Assessment (2005) reported that about 60% of the ecosystems studied were being degraded or used unsustainably, with pressure on land resources being intensified by continued human population growth, climate change, and increasing demand for biofuels.

Agriculture not only contributes to development as an economic activity and as a source of livelihoods but is also an important provider of environmental services (World Bank, 2007; FAO, 2009). Plant genetic resources represent a strategic resource and a tool for sustainable agriculture particularly in light of the two main dimensions that link genetic diversity and sustainability. Firstly the deployment of different crops and varieties, and the use of genetically heterogeneous varieties and populations, can be a mechanism to reduce risk and increase overall production stability. Secondly, genetic diversity is the basis on which new crop varieties can be bred to meet a number of environmental challenges.

The development and production of appropriate crop varieties provides one of the best mechanisms for addressing many of the most important agricultural challenges related to sustainability. Varieties that are pest and disease resistant require fewer fungicide and insecticide applications; varieties that compete better with weeds require less herbicide; varieties that use water more efficiently can produce higher yields with less water; and varieties that use nitrogen more efficiently require less nitrogenous fertilizer, with a concomitant saving in fossil fuel (FAO, 2010).

There are countless examples of the use of PGRFA to improve pest and disease resistance, and the success of such efforts depends on the existence of PGRFA and the ability to access and utilize it. In Pakistan, for example, 2 million cotton bales were lost from 1991 to 1993 due to a crop failure caused by Cotton Leaf Curl Virus. Resistant cotton types were subsequently identified and were used to develop new virus resistant cotton varieties, adapted to the growing conditions in Pakistan. Similarly, Moroccan breeders were able to release the first Hessian fly-resistant durum wheat varieties, derived from inter-specific crosses with wild relatives (FAO, 2010).

Agricultural environments are dynamic systems; new pests and diseases arise and the demand for specific products is constantly shifting. The result is that there is a continual need for new varieties. A variety that performs well in one location may not do so in another, and a variety that produces a good yield this year may disappear because of a new pest the following year. In order to be able to continually adapt agriculture to ever-changing conditions, plant breeders will need to develop and maintain a constant pipeline of new varieties. Genetic diversity of PGRFA underpins the process of producing new varieties representing the reservoir that enables breeders to keep the pipeline full.

2.3 Genetic diversity for Food security

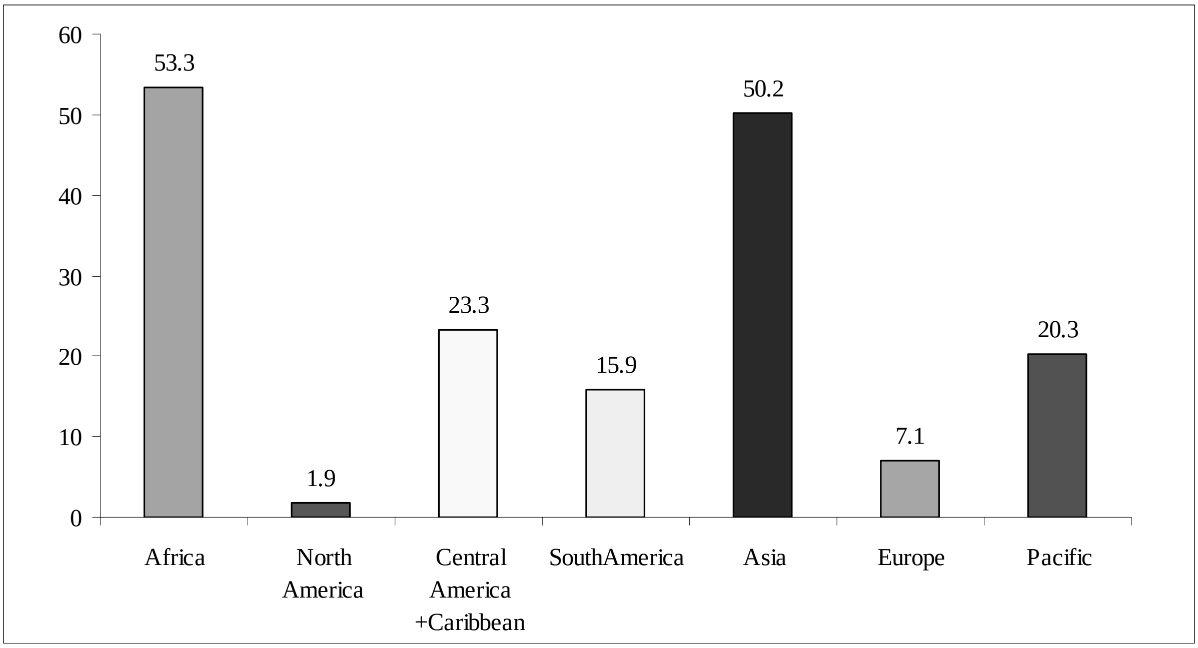
PGRFA contribute to what are frequently known as the “three pillars” of food security (availability, access, and utilization) through a few key pathways. First, PGRFA directly underpin the production (e.g. availability) of food for both rural and urban consumers. Second, PGRFA in the form of marketable crops and crop varieties have the potential to enhance income, increasing households’ access to purchased food. Third, they may also offer healthier consumption options, providing more or better quality nutrients for the body to utilize. Particularly at the level of the individual farm, PGRFA also contribute to a fourth, less frequently cited aspect of food security – e.g. the constancy of food supply – by providing farmers with options for distributing labor, risk, and the availability of the harvest over time.

In this section, we review the contributions of PGRFA to the agricultural conditions affecting food security, including production and yield increases; poverty reduction; access to markets; and nutrition. In particular we emphasize the link between agriculture and poverty reduction, which we consider to be a key step for eliminating food insecurity.

2.3.1 Crop production, yields and PGRFA

The importance of agriculture varies regionally, from only 1.9% of the population dependent on agriculture in North America to over 50% in Africa and Asia (see figure 2.1). Taken overall, agricultural production is the main source of income for about half of the world's population. In 2005, the world's rural population was estimated to be approximately 3.3 billion, of which some 2.6 billion, or about 40% of the total world population, depended in some way on agriculture.

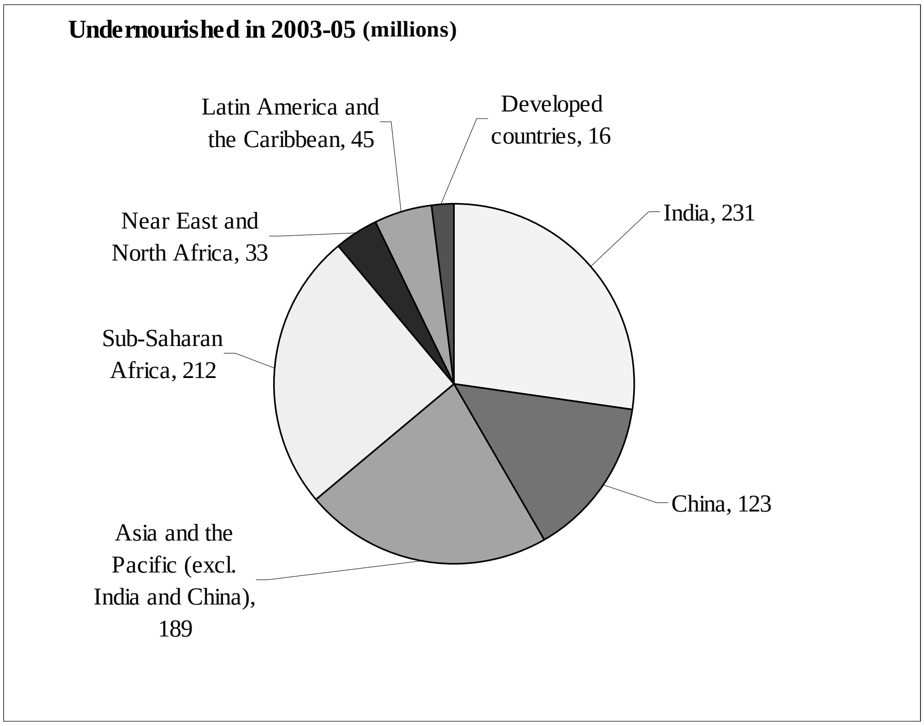
Figure 2.1: Distribution of the world's agricultural population as percentage of regional total population



Source: FAOSTAT (http://faostat.fao.org)

Most of the food-insecure people of the world live in rural areas, mainly in Asia or Sub-Saharan Africa (see figure 2.2). Just seven countries: India, China, Democratic Republic of Congo, Bangladesh, Indonesia, Pakistan, and Ethiopia account for 65% of the world's food insecure people with the proportion reaching its highest level in Sub-Saharan Africa, where one in three people is food insecure (FAO, 2008).

Figure 2.2: Number of undernourished people in the world, 2003-2005 (millions)



Source: FAO, 2008

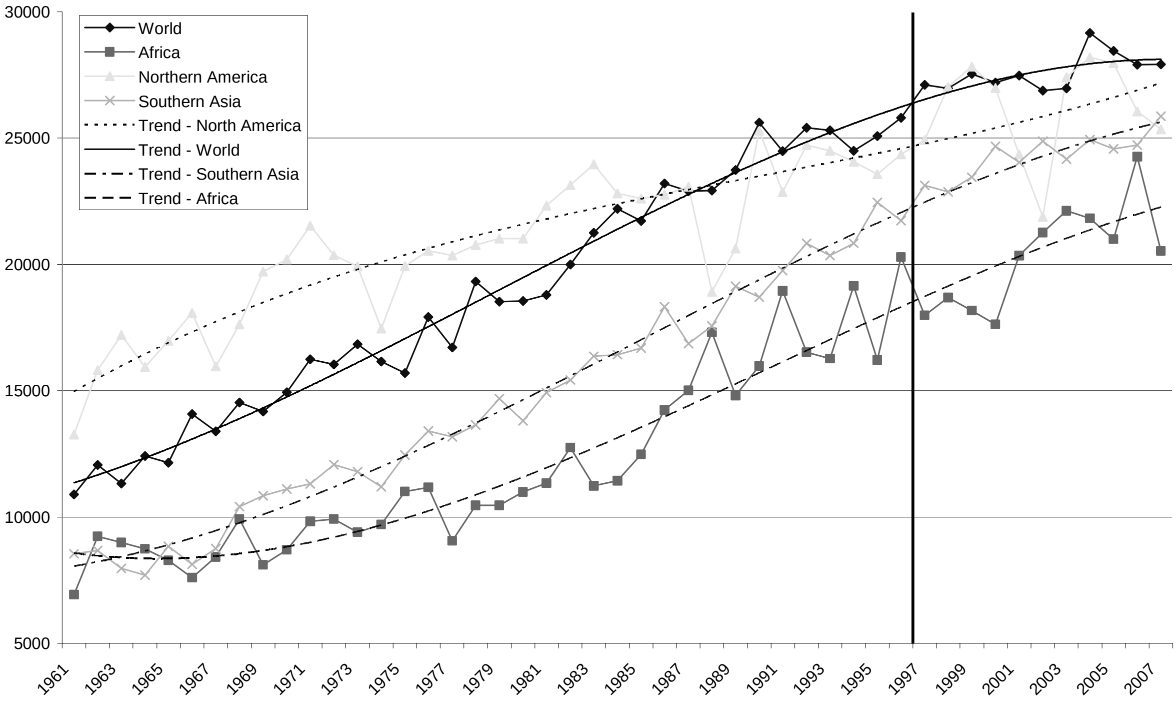
Agricultural production in general and crop production in particular, must increase substantially in order to meet the food demands of a population that is projected to expand by some 40% by 2050. According to one projection by FAO, one additional billion tonnes of cereals will be needed annually by 2050 (Bruinsma, 2009). PGRFA management is a key driver of crop productivity growth, particularly through the introduction of improved genetic materials: approximately 50% of the yield growth seen in developing countries in the latter part of the Green Revolution (1981-2000) has been attributed to the development of PGRFA resources in the form of modern varieties (Evenson and Gollin, 2003: 760).

The choice of crops, varieties, planting material and associated production methods has a significant influence on productivity and livelihoods. In China, for example, varieties of rice, cotton and oil seed crops have all been replaced 4 to 6 times throughout the country since 1978, each replacement representing the introduction of a new, improved version of previous varieties. This led to an increase in yields of more than 10% with each replacement, which in turn implied a reduction in the level of poverty by 6 to 8% (FAO, 2010).

Similarly, in Malawi the adoption of improved varieties of sorghum and cassava has led to higher yields and greater food security at both the household and national levels. The increased use of improved varieties has also triggered new business opportunities for farmers, such as marketing cash crops and cassava snacks. The extra income derived from these new business opportunities has, over time, helped to boost local industry, led to the fabrication of local cassava processing equipment, increased the use of cassava in livestock feed and provided funds for the development of local on-farm seed programmes (FAO, 2010).

Recent experience with crop productivity growth gives reason for both optimism and concern. When growth in yield-per-hectare is assessed for key staple crops over the past several decades, it is apparent, particularly for wheat, that the highest growth rates occurred during the first two or three decades of the Green Revolution, while productivity growth has levelled off more recently (figure 2.3). Maize and rice productivity growth, although less dramatic than increases in wheat yields during the Green Revolution, have remained steady in recent years on a world scale, although rice yield increases have also leveled off in East and Southeast Asia. Yield increases were slowest to take off in Africa, which experienced slow or even negative yield growth early in the Green-Revolution period. This trend has improved in recent years, but yields of the three major crops in Africa still remain far below those typically seen in other regions.

Figure 2.3: Average yields (hg/ha) for wheat by major regions: 1961-2007 (The vertical bar marks the last decade of data available)

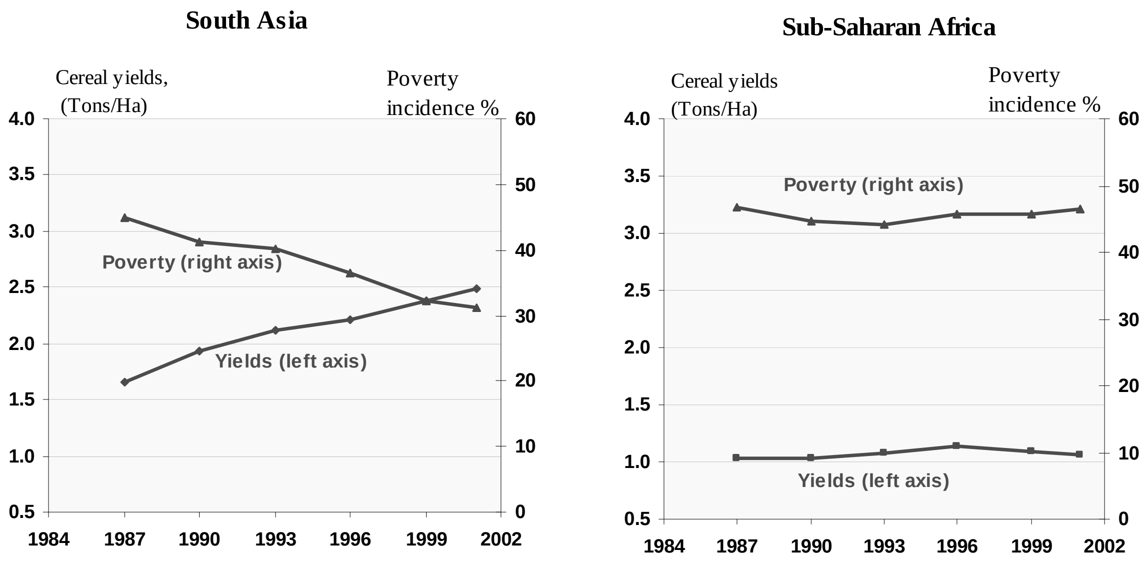


Source : Faostat (http://faostat.fao.org)

Much of the yield increase is attributable to a combination of factors including an increased use of appropriate inputs and good weather conditions. However, one key factor has undoubtedly been the development and dissemination of improved crop varieties.

Several studies have indicated that agricultural productivity growth has had an important poverty reduction effect (Thirtle et al., 2003; World Bank, 2007) and plant breeding has had an important role in this. Nonetheless, while this is certainly the case for Asia and Latin America, the relationship is less clear in Sub-Saharan Africa where agricultural yields have generally stagnated, making it more difficult to clearly establish a relationship with poverty reduction (see figure 2.4). We explore this topic further in the next section.

Figure 2.4: Relationship between cereal yield and poverty[4] in South Asia and Sub-Saharan Africa



Source: World Bank, 2007

2.3.2 Modern varieties and poverty reduction

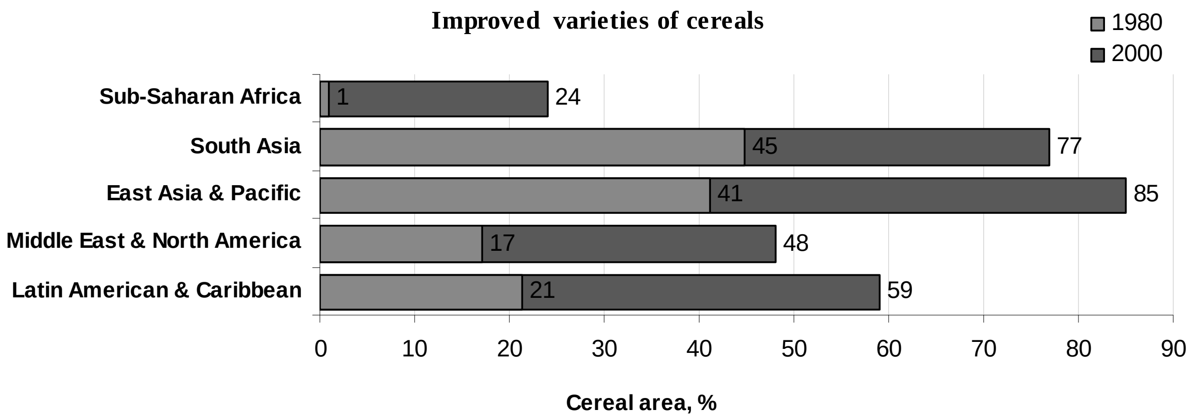
A number of studies claim the significant contribution of modern varieties to agricultural growth and poverty reduction (Thirtle et al., 2003; Hazell, 2008). The impact has been both direct and indirect: high yields lead to higher incomes, while also generating employment opportunities and lower food prices (Gollin et al., 2005; Hazell, 2008). Beginning in the early 1960s, the Green Revolution initially brought about yield increases in the major cereals (wheat, maize, and rice) in high potential agricultural production areas (Gollin et al., 2005; Hazell, 2008). In later phases, the focus has shifted to reducing input costs and increasing efficiency in more knowledge-intensive production systems (Gollin et al., 2005).

However, within these broad successes, location-specific outcomes have varied; thus Evenson and Gollin have concluded that the contribution of modern varieties to productivity increases was a “global success, but for a number of countries a local failure” (2003). Many of these countries are located in Sub-Saharan Africa, where adoption of improved varieties of cereal crops was very low during initial

[4] Poverty headcount ratio at $1 a day (PPP) (% of population).

phases of the Green Revolution, and only began to reach significant levels in the late 1990s (see figure 2.5). Notably, the yield growth experienced by Sub-Saharan Africa, although relatively small, has been almost completely attributable to modern varieties, with little contribution from fertilizers and other inputs (Evenson and Gollin, 2003).

Figure 2.5: Percentage in arable land under improved cereal varieties between 1980 and 2000



Source: World Development Report: World Bank, 2007.

There is considerable variability in adoption patterns of modern varieties within regions as well as across crops. Some national-level datasets (Aquino et al. 1999) illustrate the lack of uniformity of improved-variety use, even within a single country. Several factors help to explain these trends. One is environmental heterogeneity. Another factor may be the availability of a large range of alternative crop and variety types beyond the formally bred improved seed system.

While modern varieties contribute significantly to poverty reduction, they have arguably been less successful in sustainable agricultural development. Key shortcomings cited have been a lack of adaptation to heterogeneous and marginal production areas (Lipper and Cooper, 2009), emphasis on wide rather than local adaptation (e.g. Cecarelli 1989) and the failure of many centralized plant breeding programs to breed for traits of concern to small-scale and resource poor farmers (Bellon, 2006; FAO, 2010). On the environmental side, increases in pesticide and fertilizer use accompanying high-yielding varieties have, in some cases, generated serious damage to land, water and even human health, the high economic cost of which is only now becoming apparent (Tilman et al., 2002). For example, a study of the Pakistani Punjab estimates that the environmental costs equal to approximately one third of the total benefits generated by agricultural intensification (Ali and Byerlee, 2002).

2.3.3 Markets, poverty and PGRFA

In many countries, the growth of a dynamic food-marketing sector has created high-value potential market outlets, representing important means of increasing farm incomes and achieving food security.

Nevertheless, small farmers often experience difficulty in accessing both input and output markets, remaining at the periphery of new agricultural economy. Numerous studies have documented that the agro-industrialization process may even exacerbate poverty levels through marginalization of small farmers and the rural poor (Little and Watts, 1994; Berdegué et al., 2003; Reardon et al., 2003; Johnson and Berdegué, 2004). One of the most serious constraints to diversifying crop production and increasing genetic diversity is related to barriers in marketing and commerce in both input and output markets (Cavatassi et al., 2009; Lipper et al., 2009; FAO, 2010).

Lack of access to good quality seed of appropriate varieties can prevent farmers from entering specific output markets. Likewise, it is difficult to establish links with purchasers, and to guarantee sale at a price providing a positive net return to producers. Overcoming input and output bottlenecks and inequalities in the value chain is a key strategy for increasing the market value of crops – a strategy that has important implications for the management of PGRFA. In Ecuador, for example, a project to link smallholders to high-value potato markets resulted in participating farmers achieving higher yields and larger gross margins through selling more of their harvest at a price about 30% higher than that earned by non-participating farmers. This success was attributed both to their ability to access good quality seed of new varieties as well as to having direct links to output markets (chapter 3, this thesis; Cavatassi et al., 2009). This program is also noteworthy for its design and implementation of a seed system combining formal and informal elements (Thiele, 1999).

Negative environmental impacts have often resulted from techniques associated with crop productivity growth and farmers' integration in commercial markets, and these patterns are challenging for the design of sustainable agricultural development strategies. In particular, there are concerns over increased intensity of natural resource use, biodiversity loss through the genetic erosion of local varieties and the intensification of chemicals used for agricultural production (Barrett et al., 2001; Pingali, 2001; Singh, 2002; Winters et al., 2005). The quality and standards required by agro-processors may induce farmers to limit the use of certain varieties, particularly traditional varieties, in favour of modern varieties with certain desirable processing characteristics (Dasgupta et al., 2001; Pingali, 2001; Hendrickson and James 2005) possibly leading to a reduction of genetic variability. Furthermore, a higher opportunity cost of labour can boost farmers' reliance on herbicides for weed control, and the need to meet stringent quality and innocuity standards can drive increased use of insecticides and fungicides. The human health risks occasioned by the increased use of agricultural chemicals may be difficult to perceive in the short run (Pingali, 2001). The challenge facing policy makers, then, is to develop programs and policies that allow smallholders to actively participate and benefit from the increased market integration while trying to avoid, or at least minimise, negative environmental externalities.

There are, however, agricultural diversification strategies that could support the conservation of PGRFA. The availability of high-value niche markets, for example, is one way for farmers to realize value from their traditional crops and varieties, and hence promote their conservation. For example, in the central highlands of Mexico, markets for specialty maize products, derived primarily from landraces, appear to provide an incentive for farmers to continue planting these varieties. In contrast, in mainstream commodity marketing chains farmers may be penalized for selling landrace maize, which is often considered less suitable for industrial processing than improved maize varieties (Keleman et al., 2008, 2009). However the opportunities for the development of such markets are somewhat limited; they are unlikely to be a panacea for sustainable agricultural development.

2.3.4 Nutrition, health and PGRFA

PGRFA support the achievement of food security, as previously defined, not only in terms of total quantity of food produced but also in terms of nutritional wellbeing**.** One of the challenges of nutritional adequacy faced by many poor people is the lack of access to a diversified diet, relying instead on a few staple food crops (frequently starches). These consumption patterns may result in an inadequate consumption of micronutrients, even when caloric intake is sufficient. A number of breeding efforts are underway to improve the nutritional quality of staple crops, for example, by producing rice, maize, cassava and sweet potato with higher levels of beta–carotene (the precursor of vitamin A); pearl millet and beans with higher levels of available iron; and rice, wheat and beans with higher levels of zinc[5] (FAO, 2010).

In some cases local, indigenous, neglected or minor crops may also play key roles in providing healthy and adequate diets. For example, roselle is important in Senegal and Mali as a multi-purpose crop that provides ecological, dietary, medicinal, and income benefits (McClintock, 2004); and locally important leafy vegetables that have multiple values in many parts of Africa (Chewya and Eyzaguirre, 1999). Similarly, native greens in Guatemala have been shown to have a higher nutritional content than other introduced species more frequently found in the market (Molina et al. 1997, cited in Azurdia, 2008). Many countries have reported efforts over the past decade to collect, characterize, evaluate, and conserve samples of under-utilized species in their national plant germplasm systems, as well as efforts to promote and market them (FAO, 2010). However, the area sown to these crops world-wide is relatively small (Padulosi et al., 2002) and in many cases no national breeding efforts or major commodity markets have been established.

Notably, the consumption of a diverse diet plays an important role in boosting the human immune system. Consequently, the potential of PGRFA to be utilized to improve nutritional intake in areas facing high prevalence of HIV/AIDS may prove particularly important (IPGRI, 2005; Oniago et al., 2005).

[5] See harvest plus at: http://www.harvestplus.org

2.4 Farm management of PGRFA

Farmers' choice of agricultural technology – e.g. crops, varieties, planting material and associated production methods - has a significant influence on productivity and livelihoods. These outcomes are further driven by a range of economic, social and agronomic factors, including marketing outlets and prices, familiarity and social acceptance, cost of production, need for and availability of production inputs (including seed[6], water, fertilizer, pesticides, labour etc), climate, soils and topography.

Generally, farmers choose crop species and intra-specific varieties based on the benefits they provide in the form of income, food, and other products. Benefits may arise from the overall portfolio of crops and varieties, including nitrogen fixation and organic matter in the soil, mitigation against the effects of failure of any one crop or variety, spreading production through the year (and hence avoiding labour bottlenecks), achieving a greater intensity of land use, and satisfying nutritional and/or cultural values.

While farmers may be seeking multiple benefits from their choice of variety, most genetic improvement efforts concentrate almost exclusively on yield per unit area and factors that directly relate to it, characteristics that may not always be small-scale farmers' primary concerns. Hence while modern and improved varieties have historically played a major role in increasing agricultural production and food security at an aggregate level, their adoption by food insecure farmers themselves is not guaranteed. The decision to adopt (or not) may be driven by such diverse factors as farmers' risk-management strategies, their nutritional and consumption preferences, the agro-ecological conditions in which they farm, their endowments of physical and natural capital, and their socio-demographic characteristics. We explore these in greater depth below.

2.4.1 The main drivers of variety choices and diversification strategies

Studies of variety adoption at the household level paint a multifaceted picture, with the likelihood of smallholder households to adopt modern varieties varying by crop, or by household endowments, or by other household characteristics. In an analysis of modern variety adoption of sorghum and bread wheat in low-income farming communities of Eastern Ethiopia (Lipper et al., 2006) it was found that the poorest farmers were less likely to adopt modern varieties of either crop, although higher adoption levels were found for bread wheat than sorghum.

Explanations for this difference may be inferred from the differences in local seed systems for these two crops. In sorghum considerable local diversity is available through informal seed systems; it is grown for multiple purposes, and on-farm seed-storage techniques are well developed. In contrast,

[6] For the remainder of the paper the term 'seed' will refer to planting material in general, including cuttings, bulbs, tubers, etc.

bread wheat, unlike durum wheat, is a relatively recently introduced crop in this area of Ethiopia, and as a result the genetic diversity available locally is quite limited. A deeper look at adoption of modern sorghum varieties through the same data set showed that climatic variability and being most affected by production shocks were major adoption determinant at household level (chapter 5, this thesis).

In an assessment of the adoption of modern varieties of rice in Bangladesh, Hossain et al. (2007) found that smallholders were more likely to adopt than large farmers, but technical factors such as access to irrigation and elevation of the land parcel were more important determinants. In addition, in the fallow and salinity-prone coastal regions for which appropriate modern varieties have not yet been developed, farmers continue to grow traditional varieties. For poor farmers, the impacts of modern varieties on employment creation, reduced food prices, reduction in the drudgery of women's labour, and reduction in vulnerability to natural disasters were found to have been more important than impacts on yields (Hossain et al., 2007).

Such research underscores the fact that the adoption of modern varieties at the household level is driven by a number of factors, including but not limited to yields. While more market-oriented producers' choice of variety is largely driven by yield and market demand, for most food insecure farmers, this is not the case. The seminal work of Griliches (1957) on the diffusion of hybrid maize in the U.S. was followed by a number of other studies clearly demonstrating that household farms in most developing countries produce both for their own consumption and for the market (see for example: Edmeades et al., 2003; Horna et al., 2007). When farmers are both consumers and producers of food, this has a major impact on the crops and varieties they select.

Crop varietal characteristics can be grouped into three main benefit categories: risk minimization, yield maximization and consumption preferences (Lipper et al., 2006). Yield, discussed in the previous section, is typically the primary advantage of improved varieties over local ones. However, breeding programs emphasizing "wide adaptation" across many farvorable environments, rather than specific adaptations to marginal environments, may result in "yield crossover," e.g. the under-performance of improved varieties as compared to local materials when subjected to extreme environmental stress (Cecarelli, 1989). Since farmers, and particularly poor farmers, often seek greater stability of yield and production in their management of PGRFA, the real or perceived riskiness of adopting improved materials may be a deterrent for farmers in marginal environments.

Diversification across crops, varieties and farming activities is an important risk management strategy – often one of the very few available to poor farmers. At the crop level, farmers can diversify with respect to the crops and varieties they grow. At the farm level, a diversity of enterprises can be undertaken in addition to cropping, e.g. food processing, meat or egg production, agroforestry or agrotourism; and many of these have important implications for genetic diversity and the crops and varieties grown. Households may also rely on off-farm employment, often with one or more family members taking on paid employment away from the farm and remitting money back home. These income diversification strategies, within and outside the agricultural sector, have different implications for PGRFA management, depending on the type and degree of diversification applied, as well as on labour availability.

Variety traits associated with consumption, such as taste and cooking quality are also very important characteristics in variety choices particularly to the poor. In an analysis of maize landraces in Mexico (Bellon, 1996) it was found that even though new high yielding varieties were available and supported by the government, farmers maintained complex populations of landraces. These mixes of landraces were intended to satisfy their main household concerns: coping with the effects of environmental heterogeneity, resistance to pests and diseases, cultural and ritual needs, and dietary and food preferences.

Last but not least, the choice of varieties with regard to certain traits, sometimes associated with nutritional values or cultural needs, are also largely driven by gender that is an important determinant of the extent and nature of the diversity of crops and varieties grown and a key for sustainable crop production and food security.

Rural women are responsible for half of the world's food production and produce between 60 and 80% of the food in many developing countries (FAO-ESW, 2009). Women are often described as the guardians of local agro-biodiversity (Howard, 2003), a role primarily originating with their responsibilities as food providers and care-givers, but which can also be enhanced in regions where women are directly involved in farming. Some evidence suggests that women tend to have better knowledge about and better access to local, indigenous, medicinal, and wild plants than do men (e.g., Voeks, 2007). Likewise, culinary knowledge and traditions regarding indigenous or locally available crops and vegetables are often a prerogative of women, who also take care of processing, storing, and exchanging plants.

In addition to the importance of women's role in selecting staple-crops that are, in many regions, primarily tended by men, observers have also noted the existence of "gendered production spaces," or "gendered crops." For example, in Ghana, women are considered primarily responsible for the provision of ingredients for soups (considered a "female" dish), whereas men are responsible for the provision of starches (a "male" dish). In home-gardens in the Yucatan region of Mexico, and in Bangladesh, women are primarily responsible for the decisions about production, harvesting, and seed-saving, although they may share decision-making about both these spaces and larger fields with their husbands (Lope-Alzina, 2007; Oakley and Henshall-Momsen 2007). Gender differences are further evident in varietal choices and the importance placed on different traits. Research in Tanzania, for example, showed differences between male and female farmers in the importance and ranking they gave to various traits in sorghum.[7]

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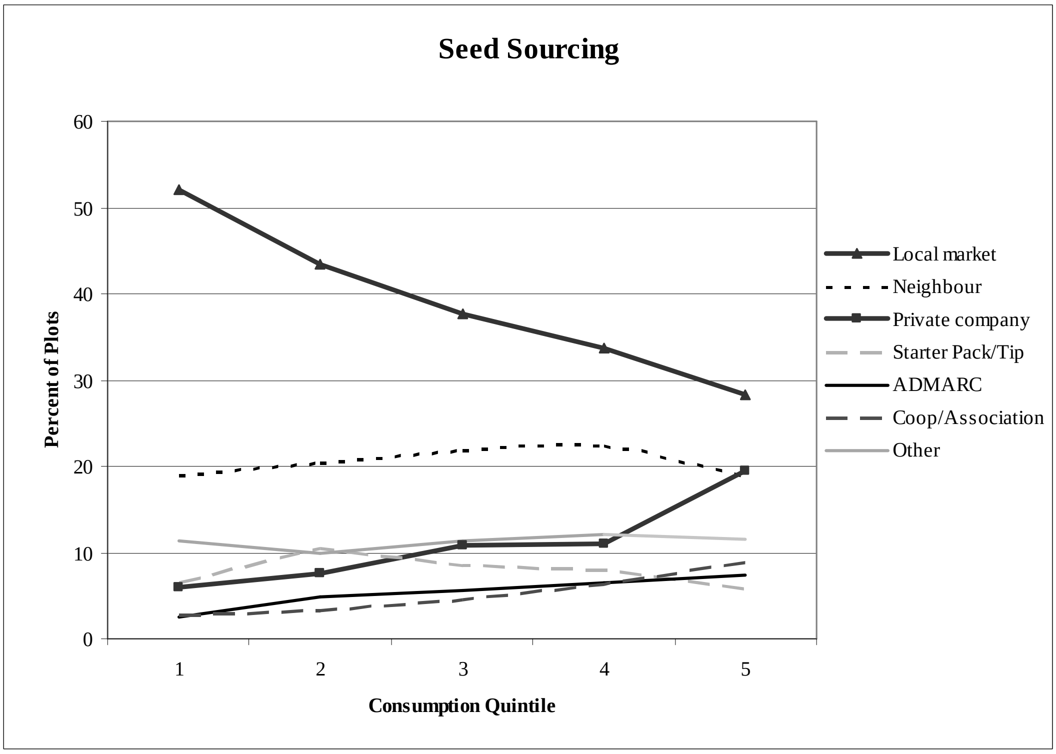
[7] FAO Links Project, data source: 2003.

2.4.2 Cropping options and access to seeds

Numerous country reports underpinning the second report on the State of the World's PGRFA (FAO, 2010), particularly from Africa, referenced the sub-optimal state of seed production and distribution systems. These observations cited insufficient availability of seeds of new and appropriate varieties, and stressed the importance of making good quality seeds available and accessible to farmers at the right time and at the right price.

Markets are important for smallholder farmers' access to seed, as demonstrated by an analysis of survey data from Malawi, Nigeria, and Ghana[8]. In Malawi, for example, purchased seed was used on 30% of plots surveyed, a percentage that was essentially the same across all income groups (see figure 2.6). However, the source of purchased seed varied significantly. While local markets were the most important source of seed for all groups, their relative importance diminished as farmers' wealth status increased, and private companies played an increasingly important role in providing seeds to better-off farmers.

Figure 2.6: Seed sources by consumption group in Malawi (1=poor; 5=rich)



Source: FAO-RIGA database (elaborated by S. Nordhagen)

Access to seed can also vary with household income status. Poor farmers in the eastern Hararghe region of Ethiopia reported having more difficulty than better-off farmers in accessing seed of either

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[8] FAO Rural Income Generation Activity (RIGA) project: www.fao.org/es/ESA/riga/english/index_en.htm

wheat or sorghum (Lipper et al., 2006). In general, poorer people found it relatively easier to access sorghum seed compared to wheat. While this is due to a stronger informal system for sorghum, the importance of local markets can also vary greatly depending on the situation. In the same study it was found that markets played a crucial role in supplying farmers with seed particularly in times of stress – a finding that is consistent with a study from Sperling and Cooper (2004) who found that local markets are a key source of seed when farmers have lost their own due to natural or human-caused disasters.

Many recent studies have explored possibilities for overcoming market inefficiencies and inequalities in the value chain in order to increase smallholder participation and food security (Barrett et al. 2001; Pingali, 2001; Reardon et al., 2002, DeHaen et al., 2003). A recent cross-country study on seed systems, markets and crop genetic diversity argues that increasing the diversity of genetic resources accessible to farmers by improving the informal seed system while simultaneously supporting greater diversity in formal seed systems is a key way to improve the sustainable use of crop genetic resources on farm and, in turn, to achieve food security for smallholder farmers (Lipper et al., 2009). These studies have contributed to increasing recognition that production-oriented interventions may be insufficient to resolve poor smallholder farmers' problems in the absence of policies and programs targeted to other parts of the production-distribution-retail chain. Such policies will also be key to maximizing the potential benefits of PGRFA for food security and poverty reduction.

2.4.3 PGRFA and current challenges: climate change and biofuels

Climate change has come to be recognized as a major challenge for agriculture broadly, and for PGRFA management specifically, with uncertain but highly significant impacts on agricultural production projected for many areas and a serious threat to food security. Prediction models of the International Panel on Climate Change[9] as well as other reports (World Bank, 2008; Burke et al., 2009) indicate that there will be severe effects on agricultural productivity in various parts of the world. Nevertheless, for how worrying the prediction might sound, some regions, especially those further away from the equator, are expected to have longer growing seasons and become more productive. Yet, expected changes will have a major impact on the poorest, most vulnerable, and least food secure people, and on countries least able to cope with the impacts of climate change, particularly those tropical and sub-tropical regions, such as parts of southern Africa (Lobell et al., 2008). In addition, there will be greater risks to the natural resource base, including soil erosion, land degradation and loss of wild biodiversity.

Management and use of PGRFA represent important tools for adaptation to these changes. In many regions adaptation will require a shift to more drought-tolerant or heat-tolerant varieties or even a shift to other crops. This is the case for Africa, where the majority of countries are projected to have

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[9] http://www.ipcc.ch/

"novel" climates outside current norms on at least 50% of the current growing areas for their major cereal crops (maize, millet, and sorghum). In many cases, such changes will necessitate the movement of germplasm either within the country or internationally to maintain production on current growing areas (Burke et al., 2009). Increased spread or shifts in pest and disease patterns seem to be taking place already, and new resistant or tolerant varieties will be needed, in order to maintain productivity (FAO, 2010). Less predictable weather patterns may also require the development of new varieties that are adapted to a wider range of more extreme conditions.

Overall the effects of climate change are likely to make it considerably more difficult to meet the increased demand for food, and the challenge will be exacerbated by competition for land for other uses, such as urban development or for growing new crops such as those for biofuel. There have already been significant moves to increase the production of biofuels in many countries, in response to growing concerns about climate change and in the face of fossil fuel scarcity. Aside from the potential food security implications of such large-scale land-use shifts, there is also concern that these could result in the loss of local crop varieties and bring pressure for crop production to spread into forests and other environmentally sensitive areas.

2.5 Conclusions: main findings, gaps and needs for the future

The last decade has seen the emergence of a number of trends in the agricultural sector which call to the forefront the importance of PGRFA management for achieving food security and agricultural sustainability. Despite the enormous advances in agriculture over the last few decades, a substantial increase in agricultural production is required to meet food demand and eradicate poverty. The difficulty of meeting these objectives is exacerbated by increased population growth, changing preferences for food patterns and threats posed by climate change and competing land uses.

Given the pressure on land resources, most of the necessary increase in food production must come from enhancing crop yields and sustainable intensification, rather than expansion of cultivated area. The production of staple food crops remains the largest agricultural sub-sector in most countries and will continue to play an important role in meeting food security and agricultural development objectives. Sustaining productivity growth in 'breadbasket' zones, where new, high-yielding varieties and associated practices have already been widely adopted, will remain an important strategy for meeting future food needs, particularly for rapidly growing urban populations. This will require a continual stream of new varieties to meet changing needs and environments. A significant share of the increase in staple foods, however, must also come from more marginal environments, home to many of the world's poorest people. For these areas as well, a pipeline of new varieties will, thus, be needed.

Functional markets offering positive net returns to small-scale agricultural producers have the potential to play a key role in achieving food security and eradicating poverty. In many countries the expansion and emergence of a new agricultural economics paradigm dominated by food-marketing, agro-industrialization and commercialization has created an important means of increasing farm incomes and achieving food security. However, small farmers often face enormous barriers in benefiting from this new paradigm. Stimulating programs and policies that address the whole value chain from input to output markets removing barriers and obstacles small farmers face would, thus represent, a key element to help small-scale farmers enter the market profitably and benefit from the new agricultural economy.

Although genetic diversity represents a ‘treasure chest’ of potentially valuable traits, it is, under threat, and special efforts are needed to conserve it both *in situ* and *ex situ*. To this purpose country capacity to utilize crop genetic diversity must be further developed, especially in the developing world. Plant breeding efforts need to be strengthened to ensure the availability of a wider diversity of improved varieties for a larger range of crops, across more environments and at prices that farmers can readily afford. Furthermore, there is a need for more accurate and reliable baseline data on sustainability and food security, which will underpin better measures, standards, indicators for the monitoring and assessment of efforts made in these areas. Of particular need are standards and indicators that will enable the monitoring of the specific role played by PGRFA.

In light of the environmental pitfalls historically associated with increasing crop productivity and farmers’ market integration efforts must include a sustainability component. Concerns to address include not only crop genetic erosion, but also the increased use of pesticides and agro-chemicals, and the potential impacts of climate change. These latter concerns have increased substantially over the past decade, with the recognition that agriculture is both a source and a sink for atmospheric carbon. PGFRA promise to be critically important for the development of farming systems that capture more carbon and emit fewer greenhouse gasses as well as for underpinning the breeding of new varieties adapted to future environmental conditions (FAO, 2010). Given the highly heterogeneous conditions prevailing in most of the more marginal production environments, and the expected shifts and increase in variability due to climate change, farmers and plant breeders alike must have ready access to a wide range of genetic diversity, so to be able to adapt crops to new conditions. While some progress has been made in facilitating this access, more is needed, particularly at the farmer level.

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Chapter 3

Linking Smallholders to the New Agricultural Economy: the case of the *Plataformas de Concertación* in Ecuador[10]

Abstract: *This chapter examines the challenges of linking smallholders to high-value food markets by looking at the experience of the Plataformas program in the Ecuadorian Sierra. Multiple evaluation methods are employed to ensure identification of program impact. The findings suggest that the program successfully improved the welfare of beneficiary farmers, as measured by yields and gross margins. These benefits are achieved through improving the efficiency of agricultural production and through selling at higher prices. No significant secondary health or environmental effects were found. Overall, the program provides clear evidence that combining improved agricultural service provision with facilitating market access can be successful.*

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3.1 Smallholders and the new agricultural economy

Agricultural producers in developing countries, including smallholders, are increasingly relying on market transactions to procure agricultural inputs and concomitantly linking to long and complex value chains for high-value fresh and processed products. In these high-value markets, greater emphasis is being placed on private grades and standards for food quality and safety leading to new organizational and institutional arrangements within the food marketing chain (Reardon and Berdegué, 2002; Dolan and Humphrey, 2004). The growth of a dynamic food marketing sector and the changes it implies for agriculture and related systems has the potential to increase farm income and improve food security, particularly among smallholders (Eaton and Shepherd, 2001; Winters et al., 2005). Yet, access to input and output markets has proven difficult for many smallholders who often remain at the margin of this new agricultural economy (Little and Watts, 1994; Berdegué et al., 2003; Reardon et al., 2003; Johnson and Berdegué, 2004). The process may in fact exacerbate poverty if smallholders are unable to take advantage of new market opportunities or benefit from increased labour demand. Additionally, agricultural market integration has been associated with negative environmental and health impacts, due to increased pesticide use and a deterioration of the crop genetic resource base (Barrett et al., 2001; Dasgupta, 2001; Pingali, 2001; Singh, 2002; Winters et al., 2005).

In seeking ways for smallholders to access high-value markets while minimizing negative consequences, there has been a growing recognition that standard production-oriented interventions designed to enhance productivity are insufficient unless they are accompanied by actions that target other parts of the production-distribution-retail chain. One intervention that has used this broader approach in the Andes is the *Plataformas de concertación* (multi-stakeholder platforms, or Plataformas) which seeks to link smallholders to high-value agricultural markets (Devaux et al., 2009). The Plataformas are alliances between small scale farmers and a range of agricultural support service providers. The main objectives of the Plataformas are to increase yields and profits of potato-producing smallholders in order to reduce poverty and improve food security (Pico, 2006). The program provides participants with new technologies and high quality seeds in addition to facilitating access to high-value potato markets. Through the Plataformas, smallholder potato producers are directly linked to restaurants, supermarkets and processors who are willing to pay a premium for potatoes that meet their grades and standards. By establishing direct linkages between farmer organizations and purchasers, the number of intermediaries within the value chain is reduced so providing smallholders with the opportunity to benefit from the changes in agricultural marketing systems. In a span of four years, from the initiation of the intervention in 2003 to 2007, when this study was conducted, participant farmers have gone from marketing 420 metric tonnes (MT) of potato produced on 10 hectares of land to 1,483 MT of potato from 260 hectares of land (CONPAPA, 2008).

The objective of this chapter is to understand whether and to what extent, participating in the

Plataformas impacts farmers' wellbeing through increasing the earnings from potato production in poor areas of Ecuador where potatoes are a key staple crop. The mechanisms by which program objectives have been achieved and secondary environmental and health effects are also analyzed. The results, although context specific, provide insights about meeting the challenges of linking smallholders to high-value markets. The remainder of the chapter is organized as follows. Section 3.2 presents the logic of the Plataformas intervention. The methodological approach used is described in section 3.3, whilst section 3.4 provides a description of the context and the data. Section 3.5 presents the results followed by a discussion of lessons learned and conclusions in section 3.6.

3.2 Linking farmers to markets: the logic of the *Plataformas* approach

While there are multiple structures for organizing production, the new institutional economics literature posits that the one that emerges is that which minimizes overall costs including transaction costs (Williamson, 1985). Such costs include standard production costs but also the ex ante costs of drafting, negotiating and safeguarding agreements as well as ex post costs of maladaption, setup and running of governance systems and bonding costs of securing commitments (Dietrich, 1994). For agricultural industries where crops are sold in high-value markets or for processing, timely delivery and quality standards are often crucial to the decision of how to organize production. Using the open market for obtaining these commodities may involve high transaction costs and so have limited appeal (Winters et al., 2005). Agribusinesses may then seek alternative structures for organizing production, such as through vertical integration or contract farming if they view creating such a relationship as the least cost alternative option.

The manner in which smallholders fit into a specific agricultural value chain depends on the underlying cost structures. The primary cost advantage of smallholders is their ability to supply cheap labour for labour-intensive crops. In such cases, it may be worthwhile for an agribusiness to deal with numerous smallholders since labour is a large share of labour costs. To minimize transaction costs, the agribusiness may choose to contract smallholders or groups of smallholders directly. To ensure smallholder participation, a cost advantage or price premium must be paid to contracted smallholders. If the crop is not labour intensive and it is possible to contract a smaller number of largeholders thereby minimizing transactions costs, this is a more likely outcome. Alternatively, if the agribusiness chooses to purchase the commodity in the open market since it is the lowest cost option and meets quality and timing needs, intermediaries are likely to play the role of bulking up the necessary product and providing it to the agribusiness. While these intermediaries may purchase the crop from smallholders, it will be at going market rates and provide no price premium or cost benefit to smallholders unless they are large enough suppliers that they can influence overall price.

The motivation for linking smallholders to agribusinesses is the presumed price premium for selling in these markets and thus overall income gains. When smallholders have no apparent comparative advantage in production, the challenge is to create that advantage or to reduce the transaction costs associated with purchasing from large numbers of farmers producing small quantities. Linking smallholders to high-value purchasers is likely to require organizing smallholders to overcome transaction costs as well as providing them with the necessary information to meet market requirements. While this adds costs for smallholders since they must take the time to organize and obtain information, it lowers the costs to industry.

This is exactly the logic of the intervention undertaken through the creation of the Plataformas; namely, reducing transaction and production costs so smallholders can be a low cost option for high-value purchasers, and providing smallholders with the necessary tools to meet quality and quantity demanded.

The primary mechanism by which the Plataformas reduce transaction costs is through providing support for smallholders from a range of agricultural support service providers including the National Autonomous Institute for Agricultural Research (INIAP), nongovernmental organizations, researchers, universities, local governments and international donors, and through fostering organization among smallholders. This support network comprises the Plataformas. The support and organization enables smallholders to generally improve production and meet the needs of high-value markets allowing them to sell directly to restaurants, processors and supermarkets. The Plataformas, therefore, reduces costs for two types of transactions: *a)* between farmers and final purchasers; and *b)* between farmers and suppliers of services (inputs, seeds, and technical assistance).

More specially, the Plataformas ensure seed provision and seed inventories are matched to detailed production plans established during regular meetings held among farmers, coordinating NGOs, and other stakeholders in order to achieve monthly quotas for delivery to clients. Further, the Plataformas provide training through Farmer Field Schools (FFS) to enhance productivity and promote Integrated Pest Management (IPM) techniques with the aim of improving quality and quantity of production through reduced use of pesticides (or at least limited increases). Farmers are also trained to oversee quality control during harvesting and commercialization, and to identify potential clients who can make a verbal commitment to buy their produce as long as the required standards are met.

Our main interest in evaluating the Plataformas project is to determine the feasibility of linking smallholders to the new agricultural economy in a context in which they have little obvious comparative advantage. The approach seeks to lower transaction costs and to improve overall cost effectiveness through creating a support system to facilitate smallholder entry into this market. The three hypotheses we wish to test are: 1) participating in the Plataformas has increased farmers' welfare as measured by potato yields and gross margins; 2) greater potato sales and higher prices are the primary mechanisms through which the program has improved welfare; 3) although high-value markets require high product quality, participation has not led to health or environmental degradation as measured by levels of agrochemicals used, their toxicity, precautions taken in their applications and changes in varietal use. The methods for testing these hypotheses are discussed in the next section.

3.3 Empirical approach and the search for a counterfactual

The key to identifying and measuring the impact of Plataformas participation is to have a proper counterfactual—that is, a comparison (control) group that is similar to the intervention (treatment) group in all ways except that it did not receive the intervention. The empirical problem faced in this analysis is thus the typical one of missing data for the counterfactual; that is, it is not known what the outcomes for participants would have been had they not participated. In experimental studies, households are randomly assigned to treatment and control ex ante and, given a sufficiently large sample size, it is reasonable to assume that the treatment and control are alike in all ways except in receiving the intervention. When assessment studies are set up ex post (after project implementation) and not as part of project design, experiments are not possible and non-experimental methods must be used to identify impact. This section describes the steps taken to collect quality data to construct a proper counterfactual, followed by a description of the empirical approach used in the analysis.

3.3.1 The data collection

The data used in this analysis comes from household and community level surveys that were administered from June to August of 2007 in the Ecuadorian provinces of Chimborazo and Tungurahua. Prior to administering the surveys, a series of steps were taken to facilitate an evaluation of the program. First, participating communities (treatment communities) were identified in each province and information on these communities was obtained. Second, using the 2001 Ecuador census data (INEC, 2001), the treatment communities and a set of potential control communities with similar geographic, agro-ecological and socio-demographic characteristics were identified. This provided a list of all possible treatment and control communities to be included in the survey. Third, using propensity score matching (PSM), (described more fully below), control communities that were most comparable to treatment communities were identified—that is, control communities with similar propensity scores to the treatment communities were kept as the potential set of communities for the sample. Fourth, the resulting list of potential control communities was discussed and fine tuned with key local organizations from the Plataformas to determine if they were indeed comparable to the treatment communities. Some of the key characteristics considered were similarities in agricultural production, agro-ecological traits and levels of community and farmer organization. Further, treatment communities with distinct characteristics and no comparable control communities were excluded from the sample. The final community list contained 35 communities (18 treatment and 17 controls).

Within each treated community, there are community members who participate in the program and others that do not (non-participants). There are two concerns about including non-participants in the treatment communities as part of the counterfactual. First, the fact that participants self select to join the program can lead to a potential bias in estimates of impact since the estimates may reflect fundamental differences between the two groups rather than the impact of the program. Secondly, since they live in close proximity to beneficiaries they may obtain indirect benefits from the program (spillover effects). For both these reasons, using solely these households as a control group is potentially problematic. Yet, this is a potentially useful group because their observable characteristics are likely to be similar to participants. The final sample, therefore, includes three sets of households: *i) beneficiaries* of the program, *ii)* non-beneficiaries in the treatment communities (referred to as *non-participants*), and *iii)* non-beneficiary households in the control communities (referred to as *non-eligible*). Lists of households from each of these subgroups were provided by Plataformas coordinators and community leaders. Households were randomly selected to be included in the sample. The final sample includes a total of 1007 households of which 683 reside in treatment communities (324 beneficiaries and 359 non-participants) and 325 in control communities (non-eligible). Of those, full information on the potato production cycle is available for 660 households.[11]

This sampling strategy allows for different comparison groups, each offering interesting insights. The ideal comparison group partly depends on whether there are spillover effects on non-participants. If there are such effects, including non-participants in the counterfactual would lead to an underestimation of program impact (Angelucci and Attanasio, 2006). If spillover effects are substantial it may be desirable to include non-participants as treated households (Intent to Treat group: ITT) to get the total effect (direct and spillover effect) of the program and use only non-eligible households as a counterfactual. These different options are considered below.

3.3.2 Empirical approach

With the available data, four methods are used to identify impact: ordinary least squares (OLS), propensity score matching (PSM), propensity score weighted least squares (WLS) and instrumental variable (IV) regression. The reason for these multiple methods is to ensure a reasonable level of confidence in our impact estimates. The methods and underlying assumptions are presented below. The approach also includes exploring alternative counterfactual groupings to determine the role of spillover effects. Ultimately, we argue that results are consistent when using approaches based on selection on observables (PSM and WLS) as well as when using an approach that deals with unobservables (IV). Further, we argue that spillover effects are minimal and that the main source of potential bias is related to program selection of beneficiaries.

The first approach is a standard OLS regression framework where the program impact on outcome variable Y_i can be determined by:

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[11] In this region, potato production can be conducted year round. Treated and non-beneficiary households appear to be equally likely to have completed the production cycle and there are no systematic differences found between households that have completed the production cycle versus those that had not yet completed the production cycle suggesting this should not influence results.

$$Y_i = \beta X_i + \alpha d_i + \varepsilon_i \tag{3.1}$$

where

d_i=1 if households participate, 0 otherwise,

X_i is a set of exogenous variables including socio-economic characteristics of the households, agroecological conditions, geographic and location effects, and so forth,

α measures the treatment effect for household *i*,

β defines the relationship between X_i variables and Y_i, and

ε_i is the error term.

This formulation assumes that the outcomes are linear in parameters and that the error term is uncorrelated with the exogenous variables X_i and with treatment. Conditional on these X variables, if the control group is like the treatment group in all characteristics except for having received the program, α, the measure of treatment's effects provides an unbiased estimate of the program effect. However, d_i may be correlated with the error term ε_i leading to a biased estimate of the treatment effect α since it may capture not just the impact of the program but differences between treated and control households (Ravallion, 2005). If the source of the problem is program placement bias—differences due to characteristics of the household the program deemed desirable—the differences are more likely to be observable. If self-selection bias is the issue—certain types of households chose to enter into the program—the differences are more likely to be unobservable.

Assuming the source of bias is observable, PSM is a way to obviate the problems outlined above. The main contribution of PSM[12] is to construct a control group that has similar observable characteristics (X_i) to the treated group, through a predicted probability of group membership calculated through a logit or probit regression, and then compare the outcomes. Given the unconfoundness assumption (Rosenbaum and Rubin, 1983) or selection on observables assumption (Heckman and Robb, 1985), if we call $Y_{Ti,}$ the value of the outcome for the treated household and $Y_{Ci,}$ the value of the outcome for the control, these are independent of the treatment (d_i) but conditional on a set of observable characteristics X_i.

$$(Y_{Ti}, Y_{Ci} \perp d_i) \mid X_i \tag{3.2}$$

Since matching on X_i is the same as matching on the probability of being treated $P(X_i)$ (Rosebaum and Rubin, 1983), all dimensions of X_i can be summarized into a predicted probability of being treated:

$$P(X_i) = P(d_i = 1 \mid X_i) = h(x_i^{'} * b) \tag{3.3}$$

where *h* is the standard normal distribution function.

Households in the untreated group that have a very similar probability of participating would be used as controls for their treated counterparts. So the effect of the treatment on the treated α can be

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[12] See for example: Heckman et al. (1998); Imbens (2004); Ryan and Meng (2004); Ravallion (2005).

defined as:

$$\alpha = E(Y_{Ti} - Y_{Ci} \mid P(X), d = 1) \tag{3.4}$$

Conditioning on the propensity score, results in the balancing of covariates across treatment and control groups, thus focuses the analysis on the area of common support by dropping those observations without a clear match. Further, PSM avoids the arbitrary linear-in-parameters form of an OLS approach (Ravallion, 2005). Heckman et al. (1996, 1998) and Dehejia and Wahba (1999, 2002) show that PSM does well in replicating experimental results provided researchers have access to a rich set of covariates or control variables and use the same survey instruments. These two requirements are fulfilled in this case since the collected data, as described in the next section, are rich in information, and were obtained using the same survey for treatment and control households. In the PSM approach, a common method of determining statistical significance of results is to use bootstrapped standard errors since it provides reliable standard errors for all of the matching estimators and also accounts for the fact that the balancing score is estimated (Diaz and Handa, 2006). Bootstrapped standard errors are therefore used to test the significance of the PSM estimates of impact.

An alternative to PSM, particularly when control and treatment, although not randomly assigned, are reasonably comparable, is a weighted least squares method using weights calculated by the inverse of the propensity score (Sacerdote, 2004; Todd et al., 2010). Weighting by the inverse of the estimated propensity score has demonstrated to achieve covariate balance and, in contrast to matching and stratification/blocking, uses all observations in the sample (Sacerdote, 2004). Following Hirano and Imbens (2001), weights are calculated as follows:

$$\omega_{(T,C)} = \left[\frac{d_i}{p(X_i)} - \frac{(1-d_i)}{1-p(X_i)} \right] \tag{3.5}$$

where $p(X_i)$ are the estimated propensity scores calculated as in equation (3.3), above.

Intuitively, the weights imply a greater emphasis on those treated households with lower scores and control households with higher scores—that is, the area of greatest common support. Using equations (3.5) the weights created can be used in a regression framework where X_i is included as a set of covariates and where standard tests of significance can be used (Robins and Rotnitzky, 1995; Hirano and Imbens, 2001). Further, the approach retains full information from all households. Using weights ensures no correlation between treatment and covariates leading to a consistent estimate of the average treatment effect (Imbens, 2004). Impacts are thus measured as follows:

$$Y_i = \beta X_i + \alpha d_i + \omega_i + \varepsilon_i \tag{3.6}$$

where:

ω_i are the weights used in the regression and calculated as per equation (3.5), above,

α, β, X_i, d_i and ε_i are defined as in equation (3.1), above.

Each of these three approaches relies on an assumption of exogeneity, namely that program participation is exogenous to outcomes given a rich set of observable covariates X_i. When this assumption holds, treatment effects can be estimated without bias using observed estimands. Although we are reasonably confident that this assumption holds, to explore the possibility of estimates being biased by unobservable differences between treatment and control groups an IV approach is also used. An IV approach allows relaxing the exogeneity assumption, but requires identifying an instrument, Z_i, which is correlated with program participation but uncorrelated with the error term (that is, would not capture the bias associated with unobservable differences between treatment and control). In an IV approach, two stages are estimated as follows:

Stage 1: $d_i = \delta Z_i + \varphi X_i + \nu_i$

Stage 2: $Y_i = \beta X_i + \alpha \bar{d}_i + \varepsilon_i$ (3.7)

where

δ defines the relationship between instrument Z_i and Plataformas participation,

φ defines the relationship between instrument X_i and Plataformas participation,

$\bar{d}_i$ is predicted participation in the Plataformas as estimated from the first stage,

ν_i is the error term in the first stage, and

remaining variables are as previously defined.

The first stage is estimated as a linear probability model. Angrist (2000) suggests this approach when the first stage is a limited dependent variable model and argues that it is consistent and safer since predicting using a probit in the first stage is only consistent if the model is exactly correct. The main advantage of using an IV approach, when a valid instrument can be found, is that it deals with potential bias from observable and unobservable differences in control and treatment. In addition, the method can be used to test the exogeneity assumption used in PSM and OLS (Ravallion, 2005).

To summarize, for the indicators analyzed (Y_i) that tests the hypotheses noted in section 3.2, these four empirical approaches are employed. This allows for a clear assessment of the impact of the program. The next section presents the data used to conduct these analyses.

3.4 Data

Two survey instruments (household and community) administered in the field were developed using qualitative information gathered by means of value chain analysis, stakeholder consultations and focus group discussions. Several revisions of the survey instruments were done based on field testing and conversations with key informants from the two study regions. The household survey included demographic information, economic and financial conditions of the households, social capital information and agricultural production data, including detailed information on potato production. The community survey included information on the overall community population characteristics, access to infrastructure and community organization.

3.4.1 Household characteristics

Table 3.1 presents descriptive statistics of household characteristics along with t-test of difference for equality of means for the various counterfactual groups. Beneficiaries are contrasted to non-participants and non-eligible households as well as to the whole group of non-beneficiaries (that is non-participants plus non-eligibles). The t-test of difference for equality of means provides evidence of significant differences among the groups offering an initial assessment of which group may represent a better counterfactual. The table presents statistics for 660 households used in the analysis for which full information on an entire production cycle is available.[13] In the interest of space, the details of the descriptive statistics are not discussed and we focus only on a few key characteristics and overall on the evidence regarding whether the survey design and data collection created a reasonable counterfactual. The exception is the social capital variables which played a key role in the formation of the Plataformas and are therefore discussed in more detail.

Examining the first three sections of the table, the results suggest that households in the sample have many of the characteristics of smallholders in the Andes. They have limited amounts of land (2.58 hectares of land with less than half dedicated to potato cultivation), which tend to be spread across a few (about 3), often steep plots. Household heads tend to be indigenous (62%) and have limited levels of education (around five years) with an average family size of nearly five members. Asset ownership is generally limited and diverse so a principal component analysis has been conducted to construct variables for assets ownership, grouped as durable assets, agricultural assets and livestock. Although households tend to own their own homes and have access to a water system (95%), many have limited sewage access (7%) and modern methods of cooking (54% cook with electricity or gas). Among the land, socio-demographic and welfare variables, most do not show statistically significant differences between the beneficiary group and any of the non-beneficiary groupings. The few variables that are significantly different have similar magnitudes and could potentially be controlled for in the analysis. In general, the first part of table 3.1 shows that the most similar possible control group would be the group of non-participants, since they have the fewest differences with beneficiaries. However, even the non-eligible group seems to be reasonably comparable to the beneficiaries. The entire group of non beneficiaries thus is a reasonable counterfactual and it offers a higher number of farmers highly comparable to the beneficiaries.

[13] See footnote 2.

Table 3.1: Description statistics

Variable name	*Whole Sample*	*Benef.*	*Non-part.*	*Pr(|T| > |t|)*		*Non-elig.*	*Pr(|T| > |t|)*		*All non-benef.*	*Pr(|T| > |t|)*	
Land											
Altitud (m.a.s.l)	3458	3448	3461	0.701		3466	0.617		3463	0.613	
Land Owned (ha)	2.58	2.55	2.04	0.106		3.14	0.115		2.59	0.891	
Owned Plots (#)	2.97	3.25	2.55	0.001	***	3.11	0.502		2.83	0.016	**
Black Soil (%)	79%	77%	80%	0.407		81%	0.240		81%	0.242	
Flat Land (%)	39%	38%	40%	0.446		40%	0.516		40%	0.420	
Irrigated Land (%)	57%	54%	57%	0.499		61%	0.135		59%	0.214	
Socio-Demographic											
Family Size	4.71	4.79	4.77	0.905		4.57	0.241		4.67	0.448	
Average Educ. Of Head	4.96	5.24	4.91	0.342		4.74	0.169		4.82	0.176	
Indigenous Head	62%	58%	59%	0.766		68%	0.020	**	64%	0.133	
Female Head	12%	12%	12%	0.766		13%	0.827		12%	0.939	
Age of Head	42.3	42.2	40.33	0.143		44.38	0.105		42.35	0.901	
Dependency Share	29%	29%	31%	0.332		27%	0.399		29%	0.929	
Welfare											
Durable assets	0.013	0.040	-0.025	0.474		0.025	0.874		0.00	0.623	
Agricultural Assets	-0.005	0.129	-0.095	0.033	**	-0.048	0.125		-0.07	0.014	**
Livestock	0.067	0.063	-0.036	0.297		0.174	0.300		0.07	0.950	
Own House	86%	84%	88%	0.234		87%	0.374		87%	0.223	
Concrete/brick House	87%	83%	90%	0.041	**	90%	0.043	**	90%	0.015	**
Access to Water System	95%	92%	94%	0.413		97%	0.016	**	96%	0.060	*
Sewage	7%	6%	7%	0.743		7%	0.600		7%	0.627	
Cook with Electricity/Gas	54%	57%	54%	0.518		52%	0.285		53%	0.323	
Dist. to Closest City (km)	29.38	27.13	25.46	0.171		35.53	0.000	***	30.49	0.025	**
Social Capital											
Participate in Non-Ag. Ass. in comm.	83%	82%	83%	0.815		84%	0.639		84%	0.684	
Participate in Ag. Ass. in comm.	23%	43%	14%	0.000	***	14%	0.000	***	14%	0.000	***
Non-Ag. Associations in Comm.											
Membership (Max # of yrs.)	9.54	9.97	8.60	0.129		10.06	0.921		9.33	0.405	
Meetings (#/yr)	32.46	32.32	33.18	0.808		31.88	0.892		32.53	0.944	
Agricultural Ass. in Comm.											
Membership (Max # of yrs.)	6.57	3.96	10.03	0.000	***	11.06	0.000	***	10.56	0.000	***
Meetings (#/yr)	16.56	16.82	12.77	0.189		19.45	0.433		16.16	0.794	
Before *Plataformas* (5 yrs. Prior to surveys)											
Agricultural Ass. in Comm.	8%	7%	8%	0.938		8%	0.918		8%	0.920	
Membership (Max # of yrs.)	17.29	15.20	17.00	0.585		18.88	0.311		17.94	0.404	
Meetings (#/yr)	14.74	21.30	12.69	0.144		12.69	0.167		12.69	0.084	*
Outside Associations											
Non-Ag.Associations	17%	17%	18%	0.887		16%	0.782		17%	0.969	
Agricultural Associations	7%	4%	5%	0.512		7%	0.231		6%	0.773	
Observations	660	217	222			221			443		

* Significant at the 10% level, ** = 5% ; and *** = 1%

Source: authors' calculation using Linking smallfarmers to the new agricultural economy data set

Moving to the social capital section of table 3.1, a broad set of variables is presented since social capital was a key element in the Plataformas program. These show that participation in non-agricultural community associations is quite high (83%) and over three times the membership in agricultural community associations. While membership in non-agricultural associations is not different across the groupings, the membership in an agricultural association does show statistically significant differences: while 43% of beneficiaries belong to an agricultural association, the percentage adds up to 14% for both non-participants and non-eligibles. At first glance, these results indicate that there is something fundamentally different about the group of beneficiaries who participate in an agricultural association at higher rates than the possible control groups. However, while the Plataformas allowed all individuals and households to participate in the program, the program gave preference to those in associations. Thus, prior to joining the Plataformas, farmers may have been members in existing associations, may have joined existing ones or may have formed new groups. This could explain the differences in the percentages of those that belong to an agricultural association across the three groups compared in table 3.1.

A way to corroborate this hypothesis is to use data on the number of years that farmers have belonged to an agricultural association. If beneficiaries joined, or formed an agricultural association to qualify for the Plataformas, the maximum number of years belonging to such an association would be expected to be less than five years prior to the implementation of the surveys, which is when the Plataformas began. We would expect then that beyond five years prior the survey, the levels of social capital would be very similar across groups.

To this end, the final rows of table 3.1 present an additional set of social capital variables. First, there are no statistically significant differences in the number of years of membership and frequency of meetings for participation in non-agricultural associations. However, for agricultural associations, whilst the number of meetings per year is not significantly different, membership is a relatively new event for beneficiaries who have been members for 3.96 years on average, as opposed to 10.03 for non-participants, and 11.06 years for non-eligibles. This seems to confirm that many beneficiaries recently joined an agricultural association. Another way to corroborate this is by looking at the rate of participation for those that have been part of an agricultural association for more than five years. The next set of variables confirms this as 7% of beneficiaries belonged to an agricultural association for more than five years versus 8% for non-participants and for non-eligible with all differences being statistically insignificant. Looking at the maximum number of years of membership for this subgroup, the data show that there are no differences across groups. Lastly, the final set of variables show no statistically significant differences between beneficiaries and possible control groups in the rate of participation with outside agricultural and or non-agricultural associations. Based on this information it is reasonable to assume that the differences that exist today across the groups are likely due to joining the Plataformas which implies the willingness to create or strengthen social capital. Hence, potential unobservable differences, if existing, are likely to be captured by the social capital variables that best proxy this selection criterion.

3.4.2 Indicator variables

To test the hypotheses noted in section 3.2, the following three sets of indicators are analyzed: *(i) primary indicators,* expressed by log of total harvest per hectare and gross margins per hectare; *(ii) mechanisms* through which primary objectives were reached, or why they were not reached; and *(iii) secondary indicators* arising from participation, particularly related to use, knowledge and practice of precautionary measures in agrochemical applications, and other environmental impacts. Table 3.2 presents these indicators.

Table 3.2: Program Impact Indicators

Indicator	***Whole Sample***	
Primary Indicators		
Log of Total Harvest (Kg/Ha)	7.94	***
Gross Margins ($/ha)	112.72	***
Mechanisms		
Total Potatoes Sold (% of harvest)	0.45	**
Value of Potatoes Harvested ($/ha)	763.49	***
Price of Potatoes Sold ($/kg)	0.11	***
Time of Transaction (hr)	1.29	
Input Costs ($/ha)	650.77	**
Cost of Paid Labor ($/ha)	97.48	***
Cost of Seeds Purchased ($/ha)	48.55	***
Value of Seeds Planted ($/ha)	181.45	***
Secondary Indicators		
Preventive Fung. Applied (kg or l/ha)	3.15	
Curative Fung. Applied (kg or l/ha)	4.16	
Insecticides Applied (kg or l/ha)	2.22	**
Cost of Chemical Fertilizer ($/ha)	124.68	***
Cost of Organic Fertilizer ($/ha)	46.04	***
Applies Traps (%)	26.7%	***
Environmental Impact Quotient	95.24	
Can Identify Most Toxic Prdcts.	34.1%	***
Always Use Plastic Poncho	13.0%	**
Always Use Mask	6.4%	***
Berger Index of Diversity	1.45	
Most Used Variety - Fripapa	29.0%	***
Observations	660	

* Significant at the 10% level, ** = 5% ; and *** = 1%

Source: authors' calculation

Among the primary indicators, the amount of potato produce harvested per hectare is the most direct indicator of productivity. The log of the quantity harvested is used and analyzed due to the expectation the data is log normal. On average, the harvest per hectare is 7,006 kg or 7.94 in logarithms. Gross margins express returns to fixed factors of production, which provide a good indication of profitability, and are calculated as the total value of harvest minus the total variable costs incurred for their production. On average farmers earn $112 per hectare of potatoes harvested.[14]

There are multiple mechanisms through which farmers could increase yields and the income they generate from potato production. One key mechanism is through increased revenue by selling more potatoes, getting a higher price for those potatoes or reducing transaction costs in sale. Four indicators for this mechanism are presented: (i) percentage of potato sold per hectare, (ii) value of potato production, (iii) price of sale, and (iv) time required for sales transactions. Households on average sell almost half of their potato harvest (45%) which has a total value of $763 per hectare and sells at a price of about $0.11 per kg. On average, it takes 1.29 hours to sell their potatoes. The Plataformas also worked on the input side of the supply chain introducing and supplying seed of the most market-demanded varieties, principally Fripapa. Changes in gross margins could reflect a change in input costs while changes in yields could be due to additional input use and/or better farming practices. Four cost indicators are used to explore this mechanism. The average total input cost for households is $650 per hectare, of which $97 is paid labour costs per hectare, and $49 purchased seeds per hectare. The average value of seeds planted, however, is over three times higher at $181 per hectare suggesting much of the seed is not purchased.

The secondary indicators capture the possible side effects of participation. The first set, which incorporates both health and environmental impacts, is the use of agrochemicals. To avoid increased agrochemical use and minimize their negative effects, FFS introduced an integrated pest management (IPM) approach. This included the use of insect traps with low-toxicity pesticides for the control of Andean weevil, one of the principal pests which can cause extensive tuber damage. The FFS also improved farmers knowledge for managing late blight which can severely lower yields if not properly controlled; this included training about the causes of late blight, the types and mode of action of fungicides available to control it and improved spraying practices. Nevertheless, in order to comply with standards required, farmers might be inclined to use more pesticides and chemical fertilizers to make sure harvested output is of a required physical quality and to improve yields (Orozco et al., 2007). To explore these possibilities, the amount of preventive and curative fungicides, the amount of insecticides and the costs of chemical fertilizers are considered. Further, alternatives to chemical inputs, namely the cost of organic fertilizer and use of traps, are also examined.

FFSs teach the different risks associated with the toxicity of agrochemicals, how to recognize toxicity levels of a product and what precautions to use. The expectation is that as a result of training participants use less toxic pesticides, that farmers recognize toxicity levels and take more precautions when applying agrochemicals. To assess this effect, the Total Environmental Impact (TEI) is used, which accounts for the toxicity level of the active ingredients of each agrochemical in a growing

[14] All monetary indicators are in U.S. dollars.

season (Kovach et al., 1992). Environmental Impact Quotient (EIQ) for each active ingredient were gathered and aggregated according to the rate and concentration of each, obtaining the EIQ Field Use Rating for each agrochemical, and the TEI for all the agrochemicals used in a growing season (per ha). The average value of the TEI is 95. An indicator of knowledge of toxicity level is also included, and on average 34% of farmers can identify the most toxic products. A selected set of indicators for the use of protective gears is also reported. Data shows that the percentage of households that use protective measures is in general very low, with 13% of farmers interviewed using plastic ponchos and only 6% using masks.

The final secondary indicators are related to the level of agrobiodiversity maintained at the household level—that is, how the composition and share of potato varieties changes due to market participation. The Plataformas focus on commercial varieties and theory suggests that as farmers shift to market varieties and begin to specialize, the overall number of varieties cultivated is reduced (Pingali and Rosengrant, 1995; Pingali, 2001) even though this does not necessarily imply genetic erosion (Smale, 1997). The Berger-Parker index of inverse dominance, which expresses the relative abundance of the most common species (Magurran, 1988; Baumgärtner, 2006) is reported.[15] Also included is the share of potato area planted with the Fripapa variety, a key variety promoted through the Plataformas, which at the time of the survey was the dominant variety in 29% of cases.

3.5 Analysis and results

As noted, the approach used to select communities for inclusion in the sample focused on establishing a good counterfactual. To avoid remaining biases requires controlling for any further differences between treatment and control groups. Discussions with key informants and program leaders suggest that social capital is the key factor of program participation and the data presented earlier supports this. In particular, whether a household participated in an agricultural association for more than one year appears to capture the differences between treatment and control households. Since this is closely related to participation in the Plataforma, controlling for this variable in the regression model or using it in PSM should ensure controlling for those unobservables that may have driven certain households to participate. The assumption is that this variable is correlated with unobservables related to being an “organization joiner”, which compels households to join the program, and thus any bias associated with self-selection should be eliminated. This variable is included in each of the regressions.

Since there remains the possibility of potential unobservable differences and, therefore, biased impact estimates, an IV approach is also employed as per equations (3.7). Finding a suitable and valid instrument is often a challenge, but a common solution used in impact evaluation is to use the intent-

[15] Additional diversity indices were used (Shannon and Margalef) with similar results; these are not presented here.

to-treat (ITT) since all households in the treated communities had the option to enter the program but not everybody participated (Galasso et al., 2001; Ravallion, 2005; Oosterbeek et al., 2008). Provided that we control for location-specific effects which might have a direct effect on outcomes, this should be a good predictor of participation. The eligibility criteria are shown to be, indeed, a valid instrument in our case being the instrument (ITT) highly significant in the first stage and the instrumented variable highly significant in the second stage. We also checked the null hypothesis that the instrument is weak and reject this hypothesis as it passes the rule of thumb that the F statistics for excluded instruments is higher than 10. Lastly, the endogeneity test accepts the null hypothesis that Plataformas can be treated as exogenous to our specification thus supporting the exogeneity assumption needed in the PSM and WLS.[16]

For each of the four specifications presented, all non-beneficiaries are used as the potential counterfactual group and results are reported in table 3.4. In general, the four approaches provide robust results suggesting impact estimates are accurate. Since all non-beneficiaries are used for this first set of results, they may be lower bound estimates due to the possibility of spillover effects of the program on non-participants in the treatment communities. Even if there are spillover effects, they are likely to be small since non-participants would not have obtained the benefits of market access, which appear substantial, and instead are only likely to receive indirect benefits from improved access to seed and transmission of new production technologies. Nonetheless, to make sure no spillover effects are found we consider additional counterfactual groups within the WLS framework. These include non-eligibles, non-participants as well as the ITT group (beneficiaries and non-participants) contrasted to the non-eligibles. The benefit of this last approach is that it potentially captures both direct and spillover effects. These results are presented in table 3.5. Before proceeding with a discussion of these two sets of results, the probit on participation is first examined.

3.5.1 Participation in the Plataformas

Table 3.3 reports the results of the probit on Plataformas participation with marginal effects calculated at the sample mean. The model accurately predicts 71.8% of outcomes and shows the importance of a number of variables. The differences are as expected and reflect those reported in table 3.1. Membership in an agricultural association within the community for more than a year is significant and has the expected sign.

[16] With regard to the identification strategy, no tests for over-identification can be run since given one instrument, the equation is exactly identified. To verify the endogeneity assumption a test under the null hypothesis that the specified endogenous regressors (participation to the Plataforma) can actually be treated as exogenous has been run. The test statistic is distributed as chi-squared with degrees of freedom equal to the number of regressors tested and defined as the difference of two Sargan-Hansen statistics: one for the equation with the smaller set of instruments, where Plataformas is treated as endogenous, and one for the equation with the larger set of instruments, where Palataformas is treated as exogenous.

Table 3.3: Probit on Plataforma Participation

LR chi2(26) =84.37
Prob > chi2 = 0.0000
Log likelihood =-375.80489 Pseudo R2 = 0.1009

	dF/dx	P>|z|	
Land Owned (ha)	-0.004	0.506	
Owned Plots (#)	0.031	0.003	***
Black Soil (%)	-0.048	0.451	
Flat Land (%)	-0.068	0.216	
Irrigated Land (%)	-0.076	0.156	
Family Size	0.010	0.369	
Average Educ. Of Head	0.006	0.338	
Indigenous Head	-0.027	0.549	
Female Head	0.011	0.860	
Age of Head	0.000	0.964	
Dependency Share	0.056	0.631	
Livestock	-0.015	0.488	
Agricultural Assets	0.041	0.068	*
Durable assets	-0.004	0.876	
House	-0.043	0.500	
Concrete/brick House	-0.131	0.051	*
Access to Water System	-0.200	0.025	**
Sewage	-0.087	0.258	
Cook with Electricity/Gas	0.076	0.084	*
Dist. to Closest City (km)	-0.003	0.049	**
Altitude	0.000	0.846	
Chimborazo	-0.065	0.307	
Ag. Association (>1 year)	0.327	0.000	***
Non Ag. Association	-0.015	0.774	
External ag. Associations	-0.021	0.786	
External non ag. Associations	-0.007	0.901	

Notes: * Significant at the 10% level, ** = 5% ; and *** = 1%

Source: authors' calculation

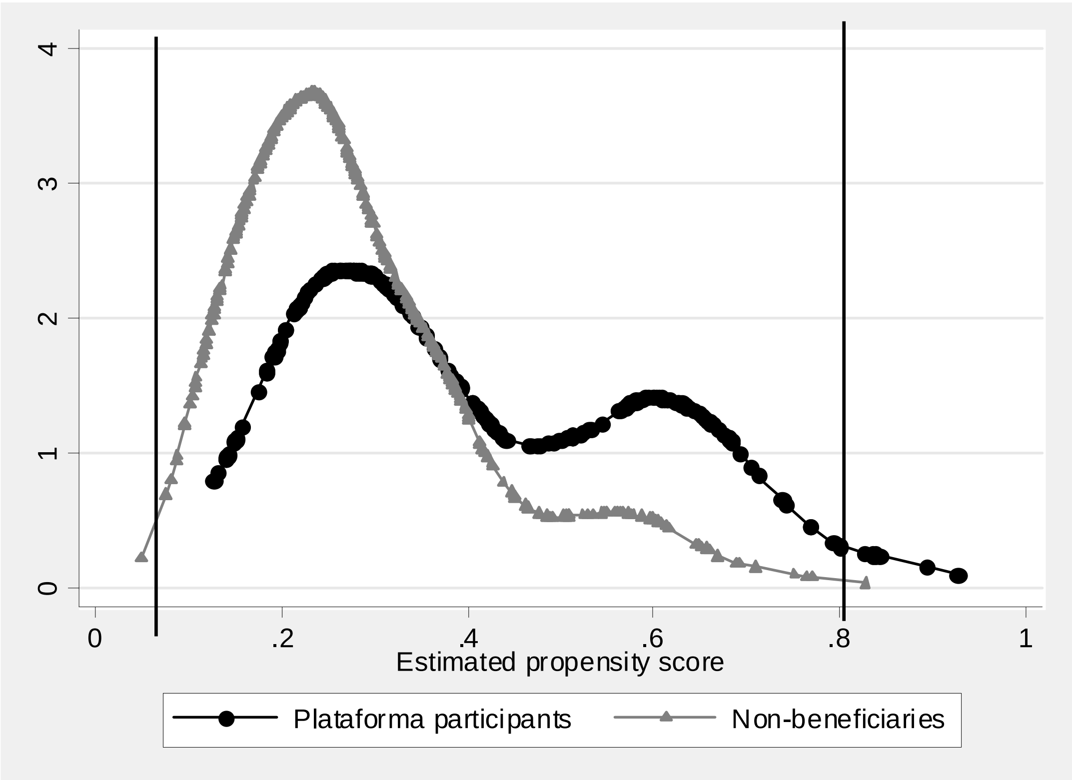
Observations	660
Sensitivity	34.56%
Specificity	90.07%
Positive predictive value	63.03%
Negative predictive value	73.75%
Correctly classified	71.82%

Using the probit results, propensity scores are calculated for the treatment and control group. Figure 3.1 shows the kernel density estimates of the distribution of estimated propensity scores for each group. The scores obtained are almost entirely in the area of common support suggesting that non-beneficiaries represent a reasonable counterfactual to the treated population.[17] Furthermore, Annex 3.I reports the punctual test of means showing a drastic reduction of significant differences across the two groups and demonstrating the capability of the method to balance the baseline

[17] Figures assessing the common support for all possible counterfactual options were also constructed but are not reported as they all consistently suggested a similar area of common support indicating high similarity across groups. For simplicity, only one figure is presented. The consistency of the common support across potential control groups is corroborated in the results of the various analyses presented in this section.

covariates and to make the two groups highly comparable. Nevertheless, the difference in mean propensity score across the treatment and control groups (mean of 0.37 in the treatment group versus 0.29 in the control group, $p < 0.000$) implies that simply conditioning on X through an OLS specification might not yield the correct average treatment effect if this effect is in fact heterogeneous. Given these results, PSM, WLS and IV estimates are considered to ensure an unbiased estimate of impacts.

Figure 3.1: Kernel distribution and common support area across the two groups



Notes: The common support area is marked within the black vertical lines

3.5.2 Assessing Results

Table 3.4 presents the results of the analysis using the OLS, PSM, WLS and IV approaches reporting the impact estimate of Plataformas participation (α) on the indicator of interest (Y_i). Table 3.5 reports results using the WLS, which we think best represents and approximates impacts, for the alternative counterfactual groups. The results are remarkably consistent across specifications (table 3.4) and make sense for the different counterfactual groupings (table 3.5) indicating that the program effects are well identified.

Table 3.4 shows that both primary indicators, log of yields and gross margins, are positively and significantly influenced by participation in the program with the estimated differences being very similar and significant across specifications. Gross margins per hectare are around $200 higher for participants which are substantial given average margins are only around $100 per hectare (see table 3.2). The findings in table 3.5 suggest results are similar even when using different counterfactual groupings. The results using the non-participants suggests there are little or no spillover effects and indicates that participating in the Plataformas program is associated with a successful welfare improvement for beneficiary farmers.

Table 3.4: Impact of Plataformas

	OLS			PSM, Kernel			PS Weighted LS			IV		
	Diff.	**P>|z|**		**Diff.**	**P>|z|**		**Diff.**	**P>|z|**		**Diff.**	**P>|z|**	
Primary Indicators												
Log of Total Harvest (Kg/Ha)	0.55	0.000	***	0.55	0.000	***	0.58	0.000	***	0.85	0.003	***
Gross Margins ($/ha)	215.19	0.008	***	237.56	0.002	***	184.82	0.010	***	243.33	0.069	*
Mechanisms												
Total Potatoes Sold (% of harvest)	0.08	0.002	***	0.09	0.005	***	0.09	0.001	***	0.10	0.070	*
Value of Potatoes Harvested ($/ha)	362.50	0.010	***	419.47	0.001	***	368.07	0.001	***	365.62	0.111	
Price of Potatoes Sold ($/kg)	0.03	0.000	***	0.03	0.000	***	0.03	0.000	***	0.04	0.000	***
Time of Transaction (hr)	0.02	0.909		0.011	0.947		-0.02	0.876		-0.62	0.041	**
Input Costs ($/ha)	147.31	0.272		181.91	0.250		183.25	0.075	*	122.29	0.562	
Cost of Paid Labor ($/ha)	49.30	0.028	**	72.25	0.008	***	44.10	0.039	**	-11.36	0.823	
Cost of Seeds Purchased ($/ha)	45.51	0.008	***	51.45	0.003	***	37.86	0.022	**	71.62	0.016	**
Value of Seeds Planted ($/ha)	87.59	0.009	***	93.04	0.007	***	91.44	0.008	***	117.24	0.058	*
Secondary Indicators												
Preventive Fung. Applied (kg or l/ha)	-0.50	0.485		-0.36	0.588		-0.28	0.636		-2.16	0.172	
Curative Fung. Applied (kg or l/ha)	-0.25	0.802		0.10	0.905		-0.51	0.651		-5.41	0.147	
Insecticides Applied (kg or l/ha)	1.00	0.098	*	0.92	0.120		1.21	0.051	*	0.52	0.538	
Cost of Chemical Fertilizer ($/ha)	38.50	0.033	**	44.66	0.011	**	40.67	0.020	**	63.33	0.063	*
Cost of Organic Fertilizer ($/ha)	15.50	0.262		18.45	0.352		16.50	0.162		51.30	0.016	**
Applies Traps (%)	0.50	0.000	***	0.50	0.000	***	0.51	0.000	***	0.57	0.000	***
Total Environmental Impact Quotient (EIQ/ha)	-31.03	0.343		-28.45	0.401		-22.71	0.356		-116.69	0.081	*
Can Identify Most Toxic Prdcts. (label color)	37%	0.000	***	39%	0.000	***	36%	0.000	***	46%	0.000	***
Always Use Plastic Poncho	7%	0.026	**	7%	0.044	**	7%	0.035	**	7%	0.218	
Always Use Mask	4%	0.059	*	5%	0.055	**	4%	0.085	*	2%	0.560	
Berger Index of Diversity	0.00	0.969		0.01	0.909		0.00	0.933		0.04	0.724	
Most Used Variety - Fripapa	35%	0.000	***	36%	0.000	***	35%	0.000	***	30%	0.000	***
Observations	660			660			660			660		

Notes: * Significant at the 10% level, ** = 5% ; and *** = 1%

Source: authors' calculation using Linking smallfarmers to the new agricultural economy data set

The mechanisms leading to these results show that beneficiaries sell more of their harvest compared to non-beneficiaries and at a significantly higher price thus obtaining a greater value. Prices obtained are indeed about three USD per metric quintal more than non beneficiaries, corresponding approximately to 30% higher price if looking at the differences in prices (table 3.2). The results on the time taken for the transaction are mostly insignificant although the IV results suggest they are lower for participants. Table 3.4 shows that, overall, total input costs do not appear to be significantly higher for the beneficiaries, however, seeds purchased and used are significantly higher for treated households and for most specifications so are labour costs (the exception being the IV results).

Moving to the secondary indicators of table 3.4, the increased use of some inputs suggest possible environmental and health problems if it is linked to increased use of agrochemicals. The evidence is somewhat mixed, but does not seem to imply a widespread problem. Beneficiaries do not use significantly more fungicides, but do use more insecticides (although not according to the IV results) and chemical fertilizers. Findings suggest, however, that farmers are using less toxic chemicals given that they are using more chemicals and the TEI ratio is not significantly different from zero in any of the specifications except for the IV where it is negative and moderately significant. The finding is also supported by the evidence that beneficiaries can identify toxic products better than non-beneficiaries. This is most likely due to the training participants received in FFS. Additionally, traps for the Andean weevil are more commonly used by beneficiaries than non-beneficiaries. Lastly, program participants are generally more likely to use protective gear as evidenced by a greater use of a plastic ponchos and masks (this result, however, does not hold for the IV results which is insignificant).

With respect to the potential losses of agricultural biodiversity as market demand pressures farmers to abandon traditional varieties, the evidence does not support this hypothesis as indicated by the insignificant impact on the agrobiodiversity indicator reported. Participants do seem to have switched to the Fripapa variety. Thus, Plataformas farmers seem to maintain the same diversity level although changing the primary market variety grown.

Table 3.5: Comparison of Alternative Control Groups (Using PS Weighted LS)

	Plata vs Non-benef.			Plata vs Non-eligible			Plata vs Non-part.			ITT vs Non-eligible		
	Diff.	P>|t|		Diff.	P>|t|		Diff.	P>|t|		Diff.	P>|t|	
Primary Indicators												
Log of Total Harvest (Kg/Ha)	0.58	0.000	***	0.73	0.000	***	0.47	0.002	***	0.47	0.005	***
Gross Margins ($/ha)	184.82	0.010	***	170.68	0.034	**	186.11	0.028	**	110.69	0.077	*
Mechanisms												
Total Potatoes Sold (% of harvest)	0.09	0.001	***	0.10	0.003	***	0.09	0.004	***	0.07	0.014	***
Value of Potatoes Harvested ($/ha)	368.07	0.001	***	417.54	0.001	***	414.76	0.000	***	232.51	0.019	**
Price of Potatoes Sold ($/kg)	0.03	0.000	***	0.03	0.000	***	0.03	0.000	***	0.02	0.019	**
Time of Transaction (hr)	-0.02	0.876		-0.15	0.404		0.13	0.462		-0.28	0.049	**
Input Costs ($/ha)	183.25	0.075	*	246.86	0.020	**	228.65	0.002	***	121.82	0.124	
Cost of Paid Labor ($/ha)	44.10	0.039	**	38.90	0.164		66.03	0.001	***	8.71	0.688	
Cost of Seeds Purchased ($/ha)	37.86	0.022	**	49.76	0.002	***	39.80	0.064	*	34.88	0.005	***
Value of Seeds Planted ($/ha)	91.44	0.008	***	108.84	0.004	***	85.80	0.007	***	59.68	0.026	**
Secondary Indicators												
Preventive Fung. Applied (kg or l/ha)	-0.28	0.636		-0.40	0.551		0.31	0.582		-0.68	0.271	
Curative Fung. Applied (kg or l/ha)	-0.51	0.651		-1.33	0.408		1.04	0.066	*	-1.71	0.227	
Insecticides Applied (kg or l/ha)	1.21	0.051	*	1.15	0.052	*	1.36	0.031	**	0.47	0.196	
Cost of Chemical Fertilizer ($/ha)	40.67	0.020	**	53.07	0.008	***	34.68	0.075	*	37.12	0.018	**
Cost of Organic Fertilizer ($/ha)	16.50	0.162		36.52	0.001	***	2.82	0.855		29.11	0.010	***
Applies Traps (%)	0.51	0.000	***	0.54	0.000	***	0.49	0.000	***	0.29	0.000	***
Total Environmental Impact Quotient (EIQ/ha)	-22.71	0.356		-29.67	0.277		16.98	0.176		-35.30	0.135	
Can Identify Most Toxic Prdcts. (label color)	36%	0.000	***	39%	0.000	***	34%	0.000	***	24%	0.000	***
Always Use Plastic Poncho	7%	0.035	**	5%	0.159		7%	0.073	*	3%	0.280	
Always Use Mask	4%	0.085	*	3%	0.295		5%	0.049	**	1%	0.576	
Berger Index of Diversity	0.00	0.933		-0.02	0.752		-0.02	0.735		-0.02	0.751	
Most Used Variety - Fripapa	35%	0.000	***	32%	0.000	***	36%	0.000	***	14%	0.000	***
Observations	**660**			**438**			**439**			**660**		

Notes: * Significant at the 10% level, ** = 5% , and *** = 1%
Source: authors' calculation

3.5.3 Linking different farmers to market

Different organizations implemented the field training in the FFS in the two regions of Chimborazo and Tungurahua, however all trainers used the same methodology and curriculum. Likewise the process of incorporating farmers to the Plataformas was the same in both regions. Although Chimborazo and Tungurahua are both relatively poor areas, it is important to note that there are significant differences between the two. Data from the Ecuadorian National Institute of Statistics and Census shows that about 54.1% of the population in Chimborazo lived in consumption poverty in 2006, while only 36.2% lived in poverty in Tungurahua (INEC, 2005-2006).[18] These differences are reflected in our own data where land variables as well as socio-demographic indicators suggest that, although both provinces are rather poor, farmers in Tungurahua are, on average, better off than their counterparts in Chimborazo owning more land and generally having higher socioeconomic indicators. It is reasonable to assume that these differences may be reflected in divergent results in the two regions.

To determine how well the Plataformas perform in each area, the analysis is done for each region. Table 3.6 shows results for the two provinces and seems to suggest that the effects of the Plataformas participation are stronger for farmers in Chimborazo who have clearer direct impacts: larger and strongly significant gross margins and a higher impact on harvest. In Tungurahua, on the other hand, while the signs for these indicators are positive, only the log of harvest per hectare is significantly (at 10% level of confidence) larger for participants. However, this difference does not translate into significantly higher gross margins. This is likely due to a combination of factors led by a smaller difference in productivity between beneficiaries and non-beneficiaries but also by smaller differences in price of potato sold, in the percentage of produce sold and in the value of produce harvested, although for both the former indicators differences are significantly higher for beneficiaries in both regions. It is interesting to note that beneficiary farmers in Tungurahua, purchased a greater amount of seeds spending more than the control group, while the remaining input costs are not significantly different as opposed to Chimborazo where participant farmers spent significantly higher amounts for inputs particularly in terms of hired labour. For the secondary indicators, the differences between the two groups are similar in both regions with the only exception of costs of chemical fertilizers that are significantly greater for participants in Chimborazo. Overall, Plataformas farmers are successfully adopting the new production approach in both regions, even though participation seems to be having a greater effect on participants in Chimborazo. These differences may suggest that poverty levels and/or financial constraints are more of an issue for farmers in Chimborazo. If this is the case, we might conclude that program participation is more effective for less endowed and more financially constrained farmers. However, it may be that other regional factors are playing a role.

[18] Using INEC, Base de Datos de la Encuesta Condiciones de Vida ECV, Quinta ronda (2005-2006), by DISUR.

Table 3.6: Impact by Region (Using PS Weighted LS)

	Tungurahua			Chimborazo		
	Diff.	P>|t|		Diff.	P>|t|	
Primary Indicators						
Log of Total Harvest (Kg/Ha)	0.30	0.060	*	0.86	0.000	***
Gross Margins ($/ha)	25.53	0.686		366.47	0.004	***
Mechanisms						
Total Potatoes Sold (% of harvest)	7%	0.034	**	9%	0.027	**
Value of Potatoes Harvested ($/ha)	116.98	0.151		672.28	0.000	***
Price of Potatoes Sold ($/kg)	0.02	0.006	***	0.04	0.001	***
Time of Transaction (hr)	-0.14	0.391		0.03	0.925	
Input Costs ($/ha)	91.45	0.109		305.80	0.043	**
Cost of Paid Labor ($/ha)	3.26	0.776		95.31	0.027	**
Cost of Seeds Purchased ($/ha)	29.85	0.021	**	24.52	0.375	
Value of Seeds Planted ($/ha)	55.72	0.001	***	110.23	0.032	**
Secondary Indicators						
Preventive Fung. Applied (kg or l/ha)	0.20	0.831		-0.51	0.462	
Curative Fung. Applied (kg or l/ha)	-1.56	0.363		-0.10	0.949	
Insecticides Applied (kg or l/ha)	1.21	0.107		1.23	0.150	
Cost of Chemical Fertilizer ($/ha)	29.51	0.173		68.09	0.022	**
Cost of Organic Fertilizer ($/ha)	4.78	0.445		22.21	0.339	
Applies Traps (%)	0.55	0.000	***	0.46	0.000	***
Total Environmental Impact Quotient (EIQ/ha)	2.35	0.944		-30.14	0.310	
Can Identify Most Toxic Prdcts. (label color)	36%	0.000	***	43%	0.000	***
Always Use Plastic Poncho	10%	0.047	**	8%	0.054	**
Always Use Mask	6%	0.056	*	3%	0.415	
Berger Index of Diversity	-0.07	0.332		0.09	0.132	
Most Used Variety - Fripapa	31%	0.000	***	34%	0.000	***
Observations	**314**			**329**		

Notes: * Significant at the 10% level, ** = 5% ; and *** = 1%
Source: authors' calculation

To explore better whether the differences in results are due to greater benefits going to smallholders and less endowed participants, additional analyses by land holding size is included. Keeping in mind that generally all farmers have relatively small land holdings, we divide land holdings into small (less than 1 hectare), medium (1 to 5 hectares) and large (more than 5 hectares) landholdings. The results presented in table 3.7 show that medium farms have been able to gain the largest benefits of the program obtaining significantly higher yields and productivity which translates into higher gross margins. These have been achieved through a larger percentage of potato sold as well as through higher price gains of the produce sold, even though higher input costs, both for seeds and fertilizers have been afforded. Beneficiaries with very small farms managed to harvest more than their control group and sold a significantly higher amount and share of potatoes, however these did not translate into higher gross margins. This is due to significantly higher input costs which did not lead to a high enough productivity increase suggesting that land holding, and thus smaller total amounts harvested and sold, are insufficient to compensate the sunk costs participant farmers incur in production. To achieve higher benefits they would need to either further increase productivity or to cut costs. Importantly, it should be noted that small farmers experienced a significantly shorter time to sell their produce. Looking at relatively larger farmers significantly higher gross margins seem to be due mostly to economies of scale. What seems to have played a major role for larger farms are the reduced per unit costs supported for each type of input and particularly for significantly smaller labour costs. Larger farmers are also not increasing other costs compared to those with smaller landholdings. This may be due to the fact larger farmers are already relatively efficient and do not get the level gains that medium farmers experience. In sum while for larger farmers, economies of scale are sufficient to outweigh the costs and guarantee higher gross margins, in the case of smallholders an intensification of technology adoption combined with a reduction of direct and transaction costs would be needed to guarantee that higher productivity translates into higher gross margins.

Table 3.7: Impact by land size (Using PS Weighted LS)

	Small Farms (less than 1 ha)			**Medium Farms (btwn 1 and 5 has)**			**Large Farms (more than 5 has)**		
	Diff.	**P>|t|**		**Diff.**	**P>|t|**		**Diff.**	**P>|t|**	
Primary Indicators									
Log of Total Harvest (Kg/Ha)	0.45	0.004	***	0.67	0.005	***	0.06	0.799	
Gross Margins ($/ha)	-23.16	0.844		318.68	0.004	***	111.81	0.068	*
Mechanisms									
Total Potatoes Sold (% of harvest)	13%	0.001	***	4%	0.353		1%	0.912	
Value of Potatoes Harvested ($/ha)	375.79	0.012	**	442.69	0.009	***	43.34	0.646	
Price of Potatoes Sold ($/kg)	0.03		***	0.03	0.000	***	-0.02	0.119	
Time of Transaction (hr)	-0.40	0.010	***	0.19	0.559		0.16	0.694	
Input Costs ($/ha)	398.95	0.002	***	124.01	0.299		-68.48	0.202	
Cost of Paid Labor ($/ha)	100.05	0.042	**	16.18	0.608		-52.33	0.005	***
Cost of Seeds Purchased ($/ha)	78.42	0.097	*	49.93	0.012	***	-6.67	0.636	
Value of Seeds Planted ($/ha)	137.63	0.017	**	92.34	0.000	***	-7.88	0.663	
Secondary Indicators									
Preventive Fung. Applied (kg or l/ha)	-0.20	0.827		0.19	0.745		-0.52	0.574	
Curative Fung. Applied (kg or l/ha)	-1.23	0.630		0.25	0.689		-0.71	0.220	
Insecticides Applied (kg or l/ha)	3.31	0.032	**	0.23	0.546		-0.13	0.423	
Cost of Chemical Fertilizer ($/ha)	83.33	0.027	**	22.99	0.123		-1.42	0.930	
Cost of Organic Fertilizer ($/ha)	-2.41	0.907		43.63	0.005	***	11.46	0.011	**
Applies traps (%)	0.55	0.000	***	0.49	0.000	***	0.32	0.007	***
Total Env.tal Impact Quotient (EIQ/ha)	-11.93	0.733		-8.69	0.745		-18.10	0.538	
Can Identify Most Toxic Prdcts. (label color)	35%	0.000	***	41%	0.000	***	20%	0.124	
Always Use Plastic Poncho	3%	0.613		7%	0.136		11%	0.050	**
Always Use Mask	0%	0.888		2%	0.669		14%	0.120	
Berger Index of Diversity	0.14	0.108		-0.05	0.422		-0.11	0.478	
Most Used Variety - Fripapa	34%	0.000	***	41%	0.000	***	11%	0.262	
Observations	302			263			88		

Notes: * Significant at the 10% level, ** = 5% ; and *** = 1%
Source: authors' calculation

3.6 Conclusions

In this chapter, the challenges of linking smallholder potato farmers to high-value markets is examined by looking at the experience of the multistakeholder Plataformas program in the provinces of Chimborazo and Tungurahua in the Ecuadorian Sierra. An empirical analysis to assess whether the program has been successful in increasing yields and profits of potato producing smallholders while protecting farmers' health and the environment has been conducted. Mechanisms by which these objectives have been achieved were also analyzed.

To ensure a proper and sound empirical analysis the data was collected in a way that it was possible to create a reasonable counterfactual for comparing Plataformas participants. Additionally, multiple econometric methods were employed to ensure results were not driven by a specific methodology. Spillover effects are also considered using different counterfactual groupings. The results are strongly consistent across the different specifications and the use of different types of counterfactuals suggesting that the success of the Plataformas is well identified. Our findings show that the Plataformas program successfully improved the welfare of beneficiary farmers and that the benefits were limited to farmers that directly participated since there appear to be little spillover effects on non-participants.

Both primary indicators, namely yields and gross margins, are positive and significant for beneficiaries with estimated differences very similar across specifications. The mechanisms through which the Plataformas achieve these primary benefits are through selling higher percentages and amounts of potato harvest than non-beneficiaries in addition to selling at a 30% higher price. Although participant farmers incur higher input costs, particularly for seeds but also for hired labour and fertilizers, benefits are enough to outweigh these added costs. The regional analysis has shown that farmers in Chimborazo, which are on average poorer than farmers in Tungurahua, have achieved higher and better results through participating in the Plataformas. Clear benefits are, in particular, achieved by medium farmers while large farmers achieve benefits mainly due to economies of scale. On the other hand, smallholders need to intensify technology and reduce direct as well as transaction costs to be able to achieve higher returns.

Results for secondary indicators are somewhat mixed. With respect to the use of agrochemicals, beneficiaries do use slightly more insecticides and chemical fertilizers, but most of the other indicators are not significantly different and products utilized are likely to be less toxic given the Total Environmental Impact (TEI) is not significantly different from non-beneficiaries and in general has a negative sign. The Plataformas is clearly having an impact on the utilization of traps for Andean weevil and in diffusing knowledge: a significantly higher percentage of participant farmers apply traps while a significantly higher percentage of farmers are able to recognise the toxicity of agrochemicals. This latter translates into a higher utilization of protective gear although percentages are generally relatively low.

The concerns about negative impacts on agricultural biodiversity of the Platforms are unfounded since results suggest that participants and non-beneficiaries maintain the same level of diversity. Given that most of the varieties cultivated are modern it appears that genetic erosion, if any, happened in the past due to a combination of natural causes (El Niño), agroindustrialization and farmers' preferences in response to changing market opportunities.

Overall, participation in the Plataformas suggests a successful way of linking smallholder potato farmers to the markets. The success of the Plataformas can be first explained by its intervention along the value chain. On the output side, direct linkages with restaurants led to reduced transaction costs that resulted from circumventing intermediaries and making sure farmers obtain a greater share of the returns from their production. On the input side linkages with seed producers led to the provision of high quality seeds of market-demanded varieties, particularly of Fripapa with its good frying quality, and taught efficient farming techniques. Secondly, the success of the Plataformas highlights the importance of social capital in identifying and organizing beneficiaries in a manner that effectively overcomes entrance barriers.

While this chapter has, overall, found important positive and significant impacts of the Plataformas on the welfare of farmers and no negative effects on farmers' health and the environment, there still remains a question of cost-effectiveness and the potential effect on efficiency. For example, Thiele et al. (2009) note that one question that has not so far been addressed because of data limitations is whether there is sufficient value added in the new market opportunities to cover the costs of the Plataformas and still provide farmers with a sufficient income increment to justify program participation. The authors also observe that while the program received substantial subsidies through project funding, this was likely a reasonable investment given the sizeable level of benefits obtained. In the long run and for scaling up the program, however, other funding mechanisms would need to be explored to achieve financial sustainability for the Plataformas (Thiele et al., 2009). Although we recognise the importance of assessing costs and shedding light on the sustainability of the Plataformas, it is not possible with the current available data. The total investments in the program have not been sufficiently identified since they came from multiple sources. Further, sustainability would need to be assessed with a new round of data collection that would examine how the program is currently operating now that much of the external support has been withdrawn. New initiatives are underway to gather the necessary information to arrive at a more accurate answer to these important questions, presenting a clear direction for future research.

Annex 3.I: Punctual Test of Means comparing beneficiaries to all non-beneficiaries

Variable	Mean Treated	Mean Control	% reduction |bias|	p>|t|
Land Owned (ha)	2.55	2.41	-230.7	0.622
Owned Plots (#)	3.25	3.11	68.2	0.617
Black Soil (%)	0.77	0.78	60.3	0.884
Flat Land (%)	0.38	0.36	48.6	0.857
Irrigated Land (%)	0.54	0.52	49.1	0.659
Family Size	4.79	4.82	75	0.930
Average Educ. Of Head	5.24	4.96	32.3	0.462
Indigenous Head	0.58	0.61	43.6	0.532
Female Head	0.12	0.11	-155.5	0.913
Age of Head	42.20	42.38	-22.7	0.953
Dependency Share	0.29	0.29	64	0.958
Livestock	0.06	0.05	-113.1	0.893
Agricultural Assets	0.13	0.00	33.6	0.788
Durable Assets	0.04	0.01	30.5	0.870
House	0.84	0.86	27.8	0.570
Concrete/brick House	0.83	0.85	73.6	0.732
Access to Water System	0.92	0.93	70.1	0.759
Sewage	0.06	0.06	72.5	0.954
Cook with Electricity/Gas	0.57	0.55	60.5	0.751
Dist. to Closest City (km)	27.13	26.14	70.4	0.362
Altitude	3447.50	3446.00	90.4	0.918
Chimborazo	0.50	0.50	-20.8	0.849
Ag. Association (>1 year)	0.34	0.33	98.7	0.943
External non ag. Association	0.17	0.17	-221.9	0.930
External ag. Association	0.07	0.06	3	0.763
Non Agricultural ass. in Community	0.82	0.85	-93.5	0.595

Notes: Tests are for differences in means * Significant at the 10% level, ** = 5% ; and *** = 1%
Source: authors' calculation using Linking smallfarmers to the new agricultural economy data set

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Chapter 4

Do Agricultural Projects Alter Crop Production Technologies? Evidence from Ecuador [19]

Abstract: *Programs designed to improve returns to agriculture can influence crop production not only through changes in input and output indicators, but also through the production technology. Evaluating agricultural programs then requires considering not only their influence on these indicators, but also on the relationship between them as embodied in the production technology. This chapter examines the impact of a program intervention in the Ecuadorian Sierra designed to improve potato production, shifts towards integrated pest management and linking smallholders to high-value markets focusing on the production technology. In particular, a weighted estimation, where weights are constructed through propensity score matching, is employed to estimate a production function within a damage abatement framework. The function incorporates a series of interaction terms to assess the impact of the program on the production technology. The findings provide evidence that the program enhances yields both through shifts in technology as well as increased input use. The results suggest that the use of effective farming techniques that are learned through farmer field schools induce this technological shift.*

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4.1 Introduction

Programs designed to improve returns to agriculture are increasingly comprised by a series of interventions that are likely to influence crop production not only through changes in input types and quantities utilized but also through the manner in which the production technology is implemented. While this is the case, impact evaluations of agriculture programs often focus on sets of indicators, including input and labour use, as well as production indicators like yields per hectare and those linked to profitability, such as output sold, price of output and value of production per hectare. Failing to recognize that the program may influence the production technology assumes that the only impact of a program is through the increased use of inputs and labour. If the manner of using inputs and labour is altered, evaluating agricultural programs requires considering not only their influence on input and output indicators, but also on the relationship between these as embodied in the production technology. In this chapter, we incorporate this type of technology change in an evaluation of an agricultural intervention in the Ecuadorian Sierra designed to link small-scale and low-income potato farmers with higher-value markets.

The standard impact evaluation challenge is to determine what would have happened in the absence of a program. While program participants are observed receiving the "treatment", they are not observed in the absence of the program (Ravallion, 2005). Given this is the case, it is necessary to identify a group that did not receive the program, but that could act as a reasonable counterfactual in the sense that they have a similar range of characteristics as program participants, but that did not participate. Ideally, through randomly assigning eligible individuals to a treatment group who receive the program and a control group that does not, a reasonable counterfactual can be established. Using this experimental approach helps to identify the program impact. If such an approach is not possible, non-experimental methods for identifying impact need to be employed; such approaches help to avoid any potential bias in the impact estimates. In either case, it is necessary to adapt these techniques to a structural model to assess changes in the production technology that may have been induced by an agricultural program. In this chapter, our interest is in determining whether the Plataformas intervention in Ecuador altered not only input and labour use, but the manner in which these inputs influence production through both increasing yields and altering the way farmers control for risks. As such, a damage abatement framework is used and adjusted accordingly to determine the impact of the program on the production technology.

The *Plataformas de Concertación*, or simply Plataformas, were initiated in the central Sierra of Ecuador in 2003 and are alliances between small-scale farmers and a range of agricultural support service providers.[20] The main objectives of the Plataformas are to increase yields and profits of potato-producing smallholders in order to reduce poverty and improve food security (Pico, 2006). The program provides participants with new technologies and high quality seeds in addition to promoting farmer organization that helps facilitate access to high-value potato markets. It operates through the entire potato supply chain to reduce inefficiencies, to overcome barriers to market entry, and to reduce costs in each link of the chain (Devaux et al., 2009). Through the activities of the Plataformas, smallholder potato producers are directly linked to restaurants, supermarkets and processors who are willing to pay a premium for potatoes that meet their grades and standards. The Plataformas provide training through Farmer Field Schools (FFS) which focuses on helping producers meet the demands of high-value markets and generally assists with potato production. The FFS emphasise an Integrated Pest Management (IPM) approach designed to use a variety of complementary pest control strategies to reduce the use of pesticides while managing pest populations at an acceptable level. The IPM component is included partially due to a concern that in order to reach market quality standards participating farmers may increase the use of pesticides to avoid the risk of their product not being accepted in higher-value markets. The Plataformas can therefore have two effects on potato production. First, by increasing the profitability of potato production, it may induce an increase in the use of inputs and thus yields. Second, through farmer training in managing production, and pesticides in particular, the program may lead to changes in the production technology.

The purpose of this chapter is to understand to what extent participating in the Plataformas influences the productivity of potato cultivation determined by the use of conventional inputs as well as damage control inputs as embedded in the production technology. Towards this end, the remainder of the chapter is structured as follow. Section 4.2 provides a description of the model used in the analysis. Section 4.3 describes the context in which the model was applied and the data used for the analysis, differentiating Plataformas participating households from households that did not participate. The identification strategy is presented in section 4.4 while the estimation results are presented in section 4.5. Section 4.6 provides conclusions.

4.2 Impact Evaluation in a Damage Abatement Framework

Most agricultural risk is governed by nature, which is very difficult to predict, making management of risks key to agricultural production. As such, some production inputs primarily seek to control the potential nature-induced damage. A clear example is pesticides, which are used to minimize the risk of damage from pests or diseases. Damage control agents, like pesticides, are not necessarily directly productivity enhancing and, in fact, if overused they might even reduce productivity (Lichtenberg and

[20] These include the National Institute of Agricultural Research (INIAP), the International Potato Center (CIP), various NGOs, researchers, universities and local governments. The alliances are also supported by international donors, such as the Swiss Agency for Development and Cooperation (SDC).

Zilberman, 1986; Zhengfei et al., 2005). The role of damage control agents should rather be defined in terms of their contribution to decrease or abate the potential damage. In other words, realized output should be considered as a combination of potential output and loss from damage. Damage control agents, thus, should be considered with respect to the services they offer keeping in mind that the benefits of these agents cannot be greater than the destructive capability of the pest, which is of course limited by the maximum potential output (Lichtenberg and Zilberman, 1986).

Given that the primary goal of these inputs is to control or abate potential crop damage, using standard functional forms may not provide correct estimates of their importance. In particular, evidence suggests that a Cobb-Douglas approach to estimating production functions predicts an under use of pesticide application in developed countries (Chambers and Lichtenberg, 1994; Shankar and Thirtle, 2005). Additionally, the approach can lead to upward biased estimates of marginal productivity as the assumption of constant elasticity makes it decline more slowly than the true marginal productivity (Lichtenberg and Zilberman, 1986).

Functional forms that better represent the damage control nature of inputs have been well studied in the literature[21]. In these, control or damage abatement inputs are assumed to be employed to prevent damage and to maximize potential output rather than to increase yields. In order to capture both yield enhancing and damage control inputs, we use a combined function which includes a production function $F(Z)$ for common inputs and a damage abatement function $G(X)$ for damage abating inputs. The latter represents the reduction in lost output caused by the utilization of damage abatement inputs.

The damage abatement function $G(X)$ is defined in the interval $[0,1]$. The function gives a proportion of the destructive capacity of the pests eliminated by the application of the damage control agent at level X and it looks like a cumulative distribution function. Specifically, following Lichtenberg and Zilberman (1986):

$G(X) =1$ when the damage abatement inputs (X) completely eliminate the destructive effects of the damaging agents;

$G(X) =0$ when the damage abatement inputs do not have any effects on eradicating the damaging capacity of the hazard agents;

$G(X)$ is monotonically increasing;

X is a vector of damage control agents such as curative or preventative fungicides, insecticides, use of traps and agrobiodiversity[22];

$G(.)$ may also include exogenous variables such as the state of nature that interacts with pest prevalence (for example the humidity level or amount of rainfall if these data are available);

$G'(X)>0$; $G(X)\rightarrow 1$ as $X\rightarrow \infty$; $G(X)\rightarrow 0$ as $X\rightarrow 0$. This means that the adopted technology (X) has a

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[21] For further reference see for example: Lichtenberg and Zilberman (1986), Chambers and Lichtenberg (1994), Lansking and Carpentier, (2001), Shankar and Thirtle (2005), and Qaim and de Janvry (2005).

[22] As explained later, there are a series of reasons for which one can maintain a certain level of potato genetic diversity. One of these reasons is to reduce the probable incidence of pests and disease, a hypothesis we are testing here.

positive effect on the damage abatement function. Hence, as X increases the damage abatement function will be closer to one (total control of the damaging agent). On the other hand, while X decreases the damage abatement function will be closer to zero (deficient control of the damaging agent);

$G'(x)= \delta G(X)/ \delta X$ expresses the marginal damage control effectiveness.

A general definition of the production function in a damage abatement framework is then given by:

$$Y = F(Z) * G(X) \qquad (4.1)$$

where

Y is the total potato yield per hectare;

$[F (Z), 1]$ is the potential output;

$[F (Z), 0]$ is the maximum output obtainable under maximum destructive capacity;

Z includes the usual production inputs such as seeds, labour, land, fertilizers, etc. as well as other farm-specific factors that might affect yields, such as human capital characteristics, assets ownership, social capital, access to infrastructure and roads, soil characteristics, time-specific factors and location-specific factors.

To incorporate the impact of an agricultural intervention, such as the Plataformas, into this framework requires considering how the program would influence the production process. In this study, three possible channels in which the Plataformas could have influenced agricultural productivity are tested. First, participation in the Plataformas could have a direct effect on overall yields by providing training to farmers regarding soil management, crop rotation, etc. Second, participation in the Plataformas could have influenced production practices and yield enhancement input utilization. For instance, training through the farming field schools may influence production practices such as seed planting or fertilizer application which would influence the production function $F(Z)$. Finally, the Plataformas could have an effect on reducing yield losses through changes in damage control inputs use. For example, the training provided through the Plataformas might lead to an alteration not just of the quantity of pesticide used, but the manner in which it is applied which could enhance damage control. This would imply an influence on the damage abatement function $G(X)$. In sum, the Plataformas intervention could have a direct effect on overall yields, but also specific effects on the manner of input use on production and damage abatement. Below, these elements are incorporated into the model specification.

4.2.1 Model specification

The empirical application of model 4.1 requires the specification of functional forms for both the production function $F(Z)$ and for the damage abatement function $G(X)$. Although we acknowledge the main limitation of using a standard Cobb-Douglas approach in imposing inputs' unitary elasticities of substitution, we follow standard practice and assume *F(Z)* to be a classical Cobb-Douglas production function given the numerous advantages related to using a Cobb-Douglas function (Lansink and Carpentier, 2001; Zhengfei et al., 2005; Horna et al., 2007). The main advantages of a Cobb-Douglas approach are that it allows for decreasing marginal returns, rather typical in agriculture. Additionally, and of great importance, it allows a log-linear transformation, particularly appropriate in this analysis given that production inputs are distributed following a log normal function. The Cobb-Douglas[23] function to model potato production can be represented as follows:

$$Y = A\prod_{i=1}^{I} Z_i^{\alpha_i} \tag{4.2}$$

Where:

$F_z > 0$ and $F_{z_i z_i} < 0$

$A > 0$; $Z_i \geq 0, \forall i = 1,....,I$ and $0 < \alpha_i < 1$

Y represents potato yields per hectare at the plot level;

A indicates the degree of effectiveness in using the adopted technology and depends on a set of household and farm specific characteristics (farm characteristics: land type, soil type, irrigation, etc; household characteristics: age, education and gender of head of the household, dependency share, access to infrastructure, distance to paved road, access to social capital, altitude, community fixed effects; and time-fixed effects – dummy for month of planting) that might have an effect on total output;

Z_i is the vector of conventional yield enhancement inputs (e.g. seeds, fertilizers, labour and land).

For the damage abatement function we follow Qaim and de Janvry (2005), Shankar and Thirtle (2005) and Salazar et al. (2010) and assume a logistic specification of the type:

$$G(X) = \left[1 + \exp(\mu_i - \psi X_i)\right]^{-1} \tag{4.3}$$

where

X_i is a vector of damage control inputs that includes quantities of insecticides and fungicides used per hectare (preventative and curative), an indicator for biodiversity (which may reduce the effect of a pesticide attack), and the number of traps used (again a preventative measure against yield losses).

While this framework has been used by others for the case of adoption of Bt cotton in China (Huang et al., 2001), South Africa (Shankar and Thirtle, 2005), and Argentina (Qaim and de Janvry, 2005), and for the case of Amarillis adoption in Peru (Salazar et al., 2010), our innovation is to apply the same framework for analyzing the effects of participating in an agricultural program on yields and input use. Following the argument presented above for inclusion of the Plataformas into the model, the

[23] To obviate potential biased results we also applied a translog production function, which does not impose a priori all elasticities of substitution to have a value of one and obtained substantially the same results as the Cobb-Douglas function.

overall model specification for the production in the damage abatement framework defined in section 4.2 is as follows:

$$Y = AC\prod_{i=1}^{I} Z_i^{bi+ciC}\left[1+\exp\left(\mu_1 - (\psi_i + \phi_i C)X_i\right)\right]^{-1} \tag{4.4}$$

In its log-linear form it becomes:

$$\ln Y = \ln A_0 + \rho C + (b_i + c_i C)\ln Z_i - \ln\left[1+\exp(\mu_i - (\psi_i + \phi_i C)X_i)\right] + \xi \tag{4.5}$$

where,

C is a dummy variable that takes the value of 1 if the household participates in the Plataformas and 0 otherwise;

ξ is the error term;

b_i, c_i, ρ, ψ_i, ϕ_i are the parameters to estimate such that ρ, is the general effect of participation on yields, c_i are the estimates of the interaction between Plataformas participation and the conventional inputs, and ϕ_i , are the estimates of the interaction between Plataformas participation and the damage control inputs.

This allows a test of the hypotheses that i) participating in the Plataformas program has an impact on overall yields controlling for other factors (if ρ is significant), ii) that participating influences the use of yield enhancing inputs (if any c_i are significant), and iii) that participants achieve greater reduction of yield losses through the use of damage abatement inputs (if any ϕ_i are significant).

4.3 Data and Context

The data used in this study was collected in the provinces of Tungurahua and Chimborazo in Ecuador from June to August 2007 for the year prior to the initiation of the survey. Data was collected at the plot, household and community levels. The survey instruments were designed following qualitative methods consisting of value chain analysis, stakeholder consultations and focus group discussions. The household survey included information regarding socio-demographic characteristics, sources of household income, asset ownership, access to credit, social capital variables and multiple sections focusing on potato production and sale. The community survey collected information related to infrastructure, access to services, community organizations and population characteristics.

The data was collected with the purpose of evaluating the effects of market participation through the Plataformas program on smallholder potato farmers. For this purpose, information from Plataformas participants and non-participants was collected. To ensure that a reasonable counterfactual would be identified careful sampling procedures were implemented, which are discussed in more detail in section 4.4 as part of the identification strategy. The final sample includes a total of 35 communities (18 treatment and 17 controls) and contains 1,007 households that were randomly selected from control communities and among participants and non-participants in treated communities. Full information on complete potato production cycles (from planting, to harvesting) are available for 660 households, corresponding to 845 plots[24]. An initial analysis of the data by Cavatassi et al. (2009) show that the sample selected allows the identification of a proper counterfactual. Further, they conclude that treated and control groups are almost entirely in the area of common support and that spillover effects on non-participants in treatment communities are minimal. The lack of spillover effects is not surprising given the focus of the program is on linking smallholders to high-value markets, which is not likely to occur without having access to the program.

Table 4.1 presents descriptive statistics on plot characteristics, input use and production for the 845 plots that have completed an entire production cycle. Data is presented at the plot level to be consistent with the production analysis. On average, the households in this sample own 2.56 hectares of land and allocate three plots of about 0.9 hectares each to potato production. The cultivated land is usually steep (less than 40% of the plots are flat or slightly steep), and a substantial amount of the land is irrigated (61%). The average potato yield obtained per plot is about 7.7 tons per hectare which is similar to the national average yield in Ecuador, which equals 8 tons per hectare (CIP, 2008)[25], but it is about 1.7 MT above the average of the focus region (6 MT per ha on average in the area) (INEC, 2007).

With respect to yield enhancement inputs (all standardized by hectare), farmers use about 1.1 tons of seeds, 123 days of family labour and 19 days of hired labour as well as 4 hours of tractor and 2 days of animal traction. Organic and chemical fertilizers are applied in 56% and 93% of the plots, respectively. In the case of damage abatement inputs, farmers apply about 4.31 kg per hectare of curative fungicides, 3.38 kg of preventative fungicides and 2.37 kg of insecticides per hectare. Also, farmers use about 33 traps per hectare to control damaging agents. To analyze the level of intra-crop biodiversity as a damage abatement input, the Shannon index was calculated. This indicator accounts for the number of varieties planted (richness) and the share of land allocated to each variety (evenness) (Magurran, 1988; Baumgärtner, 2002; Winters et al., 2006). The index shows the lowest level of intracrop biodiversity at zero which suggests that plots in this sample exhibit a low level of intracrop biodiversity at 0.17.

[24] In this region, potato production can be conducted year round. Treated and non-beneficiary households appear to be equally likely to have completed the production cycle and no systematic differences were found between plots and households that have completed the production cycle versus those that had not yet completed the production cycle, suggesting this should not influence results.

[25] https://research.cip.cgiar.org/confluence/display/wpa/Ecuador

Table 4.1: Description of agricultural production

Variable name	
Plot Characteristics	
Altitude (m.a.s.l)	3457
Black Soil (%)	77%
Flat Land (%)	38%
Irrigated Land (%)	61%
Potato land area (ha)	0.9
Potato production	
Yield per plot (kg/ha)	7686
Seeds planted (kg/ha)	1174
Input/output ratio	7.01
Inputs	
Curative (kg or l/ha)	4.31
Preventive (kg or l/ha)	3.38
Insecticides (kg or l/hec)	2.37
Number of Traps (nr of traps/ha)	33.76
Organic fertilizer (%)	56%
Chemical fertilizer (%)	93%
Family labour (nr of days/ha)	123.45
Total labour (nr of days/ha)	142.18
Total paid labour (nr of days/ha)	18.72
Tractor (nr of hrs/ha)	3.88
Animal (nr of days/ha)	2.1
Shannon index of diversity	0.179
Observations	845

Table 4.2 presents descriptive statistics of household variables used in this analysis along with t-test of difference in means to compare Plataforma participants and non participants. On average, head of households are mainly indigenous, middle-age men with low levels of education, and limited access to credit and assets (household, agricultural and livestock). Overall, no important statistical significant differences between participants and non-participants are found. In the case of household characteristics, only the average number of years of education (slightly higher for participants) and the percentage of indigenous headed households (higher in control group) are statistically significant. With respect to household welfare indicators, the control group is more likely to own household assets and have access to sanitary services. On the other hand, participants are less likely to be credit constrained and more likely to own agricultural equipment.26 As for average distance to an input shop or a paved road, participants are located farther away from an input source but closer to a paved road.

Access to social capital was crucial in initiating the Plataformas. In fact, although all individuals and families were encouraged to participate, the program required potential participants to be members

[26] Notice, however, that differences in the magnitudes are rather small and not statistically significant when using weighted t-tests (weighting method is presented in the next section).

of an association, to join existing associations or to form new associations27. For this reason, a set of proxies for social capital is included. On average, 84% of households in the sample belong to a non-agricultural association in the community, with an average period of participation of about 9.6 years. No statistically significant differences are found between the two groups. Contrastingly, participants are 28% more likely to have participated in an agricultural association within the community than the control households. This can be explained by the fact that farmers may have joined existing agricultural associations or formed new ones specifically to participate in the Plataformas.

In order to understand whether farmers' access to social capital differs between participants and non-participants due to the Plataformas, we have included a set of social capital variables that capture farmers' participation in agricultural associations five years prior to data collection. The reason for this is because the implementation of the Plataformas started four years before the survey was administered. Hence, if beneficiaries joined or formed an agricultural association exclusively to qualify in the Plataformas the variables for participation in any agricultural association prior to the initiation of the program (4 to 5 years ago) between the two groups should be very similar. This is corroborated by the fact that participants and non-participants were equally likely to belong to a non-agricultural or an agricultural association prior to the implementation of the Plataformas. Moreover, farmers in the control group who belonged to an agricultural association within the community have been participating for a higher number of years, although the frequency of their group meetings is significantly lower. This suggests that any unobservable characteristics that affect both program participation and productivity are likely to be related to their willingness to join an association, which should be captured by participation in agricultural or non agricultural associations. A more detailed discussion regarding the importance of including access to social capital in the estimations is presented in section 4.4.

Although the reported descriptive statistics suggest that the process of selecting control communities with similar characteristics to treatment communities was relatively successful, a more careful identification strategy is needed to assure comparability between participants and the control group as well as to obtain unbiased estimations. The following section will describe the identification strategy implemented in this analysis.

[27] It is important to note that the associations did not have to be related to agriculture.

Table 4.2: Descriptive Statistics: Household, Welfare and Social Capital Variables

Variable name	*Whole Sample*	*Treated*	*Control*	*t-test*	*t-test wghts.*
Household characteristics					
Family Size (#)	4.7	4.75	4.67		
Education of Head (years)	5.3	5.7	5.1	***	
Indigenous Head (dummy)	62%	58%	65%	**	
Female Head (dummy)	11%	11%	10%		
Dependency ratio	0.28	0.28	0.28		
Age of Head (Years)	42.2	42.2	42.2		
Welfare and geographic indicators					
Home Audio Systems (dummy)	32%	30%	34%		
Refrigerator (dummy)	19%	14%	22%	***	
Agricultural Equipment (factor value)	5%	11%	1%	***	
Cows (#)	1.86	1.71	1.95		
Bulls (#)	0.87	0.95	0.82		
Oxen (#)	0.18	0.26	0.14	***	
House	87%	85%	87%		
Concrete/brick House (dummy)	88%	86%	89%	**	
Access to Water System (dummy)	95%	92%	96%	**	
Sewage (dummy)	7%	6%	7%		
Cook with Electricity/Gas (dummy)	53%	55%	53%		
Credit Constrained (dummy)	21%	17%	22%	*	
Remittances (dummy)	9%	8%	10%		
Migrants (dummy)	22%	23%	21%		
Microenterprise (dummy)	17%	17%	17%		
Distance to input source (km)	11.6	12.6	11.1	*	*
Distance to Paved road (km)	4.7	2.9	5.7	***	*
Social Capital (all dummy vars)					
Participate in Comm. Non-Ag. Assoc.	84%	83%	84%		
Max Time in Comm. Non-Ag. Assoc.	9.6	10	9.3		
Participate in Comm. Ag. Assoc.	23%	41%	13%	***	**
Max Time in Comm. Ag. Assoc. nr year	1.50	1.58	1.45		
External Non-Ag. Association	17%	18%	17%		
External Agricultural Association	7%	6%	7%		
Within community before *Plataformas* (5 yrs. Prior) (53 obs)					
Membership (Max # of yrs.)	17.1	13.8	18.2		*
Meetings (#/yr)	16.9	28.4	13.2	***	**
Observations	845	293	552		

Notes: Tests are differences in means * = significant at the 10% level, ** = 5% ; and *** = 1%

4.4 Impact Identification Strategy

To make sure that the effect of the Plataformas is being captured in any estimation procedure, our impact identification strategy includes three components: first, a careful data collection strategy ensured the construction of the best counterfactual possible for an ex post evaluation. Second, weighted regressions, where weights are created by using the inverse predicted probability of membership, are estimated. And third, social capital proxies are included to control for possible unobservable characteristics related to participation in the Plataformas. In this section, we will describe the rationale behind using these components as part of the impact identification.

4.4.1 Construction of an appropriate counterfactual

Counterfactual identification was conducted by implementing a careful data collection strategy. Prior to administering the survey, several key steps were taken to ensure that data collection facilitated an evaluation of the Plataformas. First, a list of all treatment and potential control communities in the region were identified using information from local and program informants. For each of these initially identified communities, Ecuadorian population and agricultural census data were obtained (from INEC 2000). Using this data (which was collected prior to the program implementation), a propensity score matching (PSM) procedure[28] was used to allow the identification of all the non-participant communities that were considerably similar[29] to those treated communities prior to sample design. This provided a reduced list of potential control and treatment communities. Finally, this list was discussed with program informants to ensure that all potential controls would have met the criteria for inclusion in the program. The final list of treatment and control communities then reflected communities that were similar from a data standpoint prior to the program and met the criteria of program leaders for potential inclusion. Once the communities for inclusion in the sample were determined, lists of households from treatment and control communities were obtained by Plataformas coordinators and community leaders in order to randomly select those to be included in the final sample.

Data analysis presented in section 4.3 provides evidence regarding the similarities between treated and control groups and therefore, the success of the data collection strategy. To corroborate these findings, results obtained from estimating a probit regression on Plataformas participation are analysed. This approach not only provides an indication of what observable variables might influence the decision to participate, but also allows an assessment of whether the control and treated groups are comparable by analysing the propensity scores or predicted probabilities of participation. Table 4.3 reports the marginal effects at the plot level, calculated at the sample mean, of the probit on Plataformas participation using robust standard errors. The probit correctly predicts 72.3% of the observations—74% of the non-participants and 66% of the participants are correctly classified.

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[28] A PSM procedure consists in constructing a control group that has similar observable characteristics to the treated group, by comparing matching scores obtained calculating a predicted probability of group membership via a logit or probit regression. See for example: Heckman et al. (1998); Imbens (2004) and Ravallion (2005).

[29] "Similar" was defined as the potential control community having a propensity score near the score found for the treatment community. In one case, there were no similar scores among the non-participant communities for the treatment community and that community was dropped.

Table 4.3: Probit on Plataformas

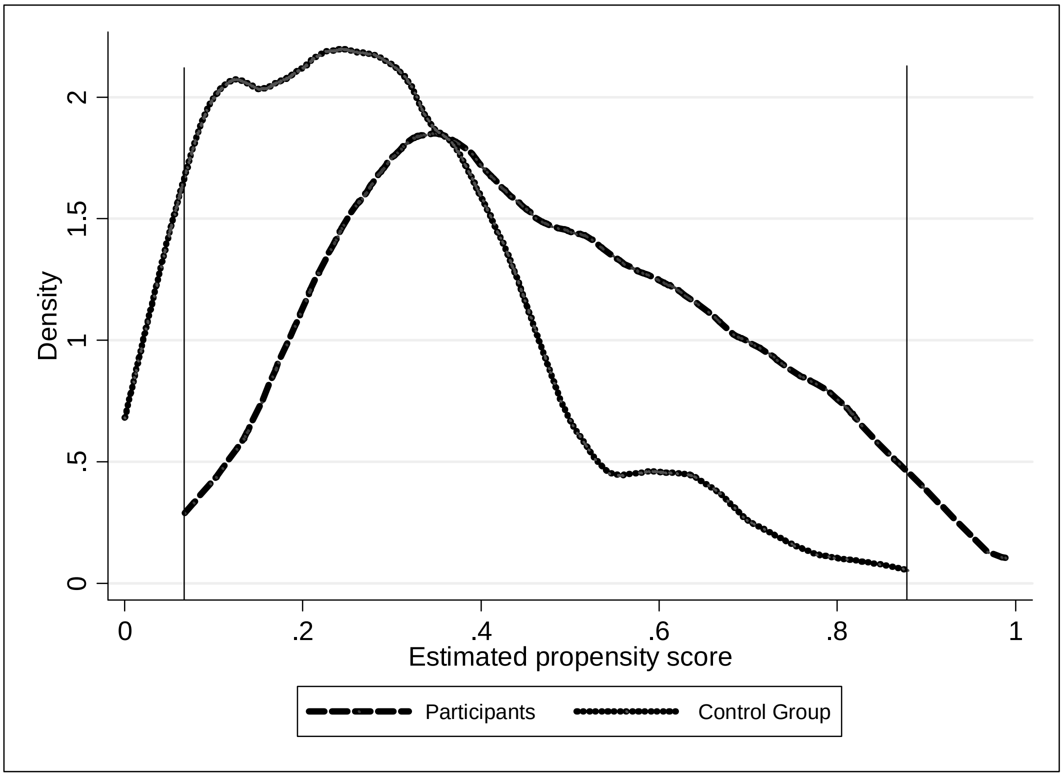
Variable name	dF/dx	P>|z|
Plot Characteristics		
Altitude (m.a.s.l)	0.000	0.02 **
Black Soil (dummy)	-0.021	0.68
Flat plot (dummy)	-0.002	0.99
Irrigation (dummy)	-0.417	0.01 **
Plot area (ha)	-0.030	0.04 **
Household Characteristics		
Family size (#)	0.011	0.30
Educ. Of Head (# yrs)	-0.004	0.69
Indigenous Head (dummy)	0.021	0.62
Female Head (dummy)	0.038	0.53
Age of Head (# yrs)	-0.004	0.19
Dependency ratio	-0.053	0.61
Education*Flat	0.004	0.70
Education*Irrigation	0.013	0.28
Age of Head*Flat	-0.001	0.72
Age of Head * Irrigation	0.007	0.02 **
Welfare and geographic indicators		
Home Audio Systems (dummy)	-0.041	0.30
Refrigerator (dummy)	-0.158	0.00 ***
Agricultural Equipment (factor value)	0.173	0.01 ***
Cows (#)	-0.011	0.20
Bulls (#)	0.023	0.06 *
Oxen (#)	0.066	0.02 **
House (dummy)	0.011	0.84
Concrete/brick House (dummy)	-0.053	0.38
Access to Water System (dummy)	-0.173	0.04 **
Sewage (dummy)	-0.070	0.35
Cook with Electricity/Gas (dummy)	0.040	0.31
Credit Constrained (dummy)	-0.060	0.18
Log Dist. to paved road (km)	-0.182	0.00 ***
Log Dist. to inputs (km)	0.087	0.00 ***
Chimborazo (dummy)	-0.025	0.68
Social Capital (all dummy vars)		
Ag. Association (>1 year)	0.359	0.00 ***
Non Ag. Association	-0.011	0.81
External Ag. Associations	-0.050	0.50 *
External Non Ag. Associations	0.036	0.46
Constant		0.91
Observations	845	
Sensitivity	40.61%	
Specificity	89.13%	
Positive predictive value	66.48%	
Negative predictive value	73.87%	
Correctly classified	72.31%	

Notes: * = significant at the 10% level, ** = 5% ; and *** = 1%

Overall, the results provide some evidence to suggest that participants are to some extent poorer than non participants. Specifically, participation is negatively related to plot area, access to irrigation and owning household assets, such as refrigerator or water system. On the other hand, having access to agricultural equipment is positively related to participation in the Plataformas. With respect to the variables that capture access to social networks, the results show that being a member of an agricultural association within the community for more than one year is positively related to program participation. This is expected due to program requirements.

To examine the degree of common support across the treatment and control groups, the kernel distributions of the propensity scores for the two groups are presented in Figure 4.1. The common support, which is the area between the vertical lines, clearly shows a large degree of overlapping which means that both groups are highly comparable. Further, the calculated propensity scores fulfil the balancing property, which indicates that characteristics of the treatment and control groups are similar even within the subsets (quartiles of propensity scores) of the area of common support. Taken together, the results indicate that the data collection was largely successful in creating a counterfactual in terms of observable characteristics of the two groups although some adjustment could be made to make them more comparable.

Figure 4.1: Common Support for Plataforma Participants and Control Group



Source: authors' calculation

4.4.2 Weighted least squares

The second component in the identification strategy is the implementation of a weighted least squares regression. This method, first suggested by Rosenbaum (1987) and followed by others such as Hirano and Imbens (2001), is particularly useful in this case because, although the treatment and control groups are not randomly assigned, these are reasonably comparable (Sacerdote, 2004; Todd et al., 2010). This applies assuming that treatment assignment is unconfounded with potential outcome based on a large set of covariates, which is a reasonable and commonly agreed assumption (Hirano and Imbens, 2001; Curtis et al., 2007).

The weighted least squares method offers many advantages to our impact identification strategy. First, it achieves covariate balance and uses all the observations (Imbens, 2004). Also, it allows us to estimate the structural form of a production function, which in turn permits the identification of the Plataformas' impact on the production technology. Importantly, this is not possible to accomplish by implementing a standard propensity score matching procedure since this method uses a non-parametric approach (Ravallion, 2005). Finally, a regression framework provides standard tests of significance unlike other quasi-experimental approaches (Robins and Rotnitzky, 1995; Hirano and Imbens, 2001). The weights for plot *i* are calculated as follows:

$$\omega_{i=}\left[\frac{C_i}{p(C_i)}-\frac{(1-C_i)}{1-p(C_i)}\right] \tag{4.6}$$

where

$p(C_i)$ are the estimated propensity scores and depend on if the household participates in the Plataformas program ($C_i = 1$) or does not ($C_i = 0$).

This weighting scheme, allows for a better representation of the population of interest by giving higher weights to participant households with lower probability of participation and non-participants with higher probability of participation as well as lower weights to participants with higher probability of participation and non-participants with lower probability of participation (Hirano and Imbens, 2001; Sacerdote, 2004: Todd et al., 2010). In effect, it adjusts the two distributions to put a stronger emphasis on areas of overlap. As can be seen in table 4.2, when tests of difference in means are done using the weights associated with each observation most remaining differences in the control and treatment disappear. The few remaining differences are primarily linked to social capital variables.

4.4.3 Access to social capital

The careful creation of the counterfactual through the sample design helps to ensure that participants and non-participants are similar in observable and unobservable characteristics. The weighted least squares approach helps to further adjust for any observable differences. There remains, however, a concern over remaining differences in unobservable characteristics of treatment and control households.

As mentioned in section 4.3, one of the prerequisites for Plataformas participation was to be a member, to join or to form an association, agricultural or non-agricultural. Hence, it is expected that farmers who already belonged to an association prior to the Plataformas' implementation are more likely to participate because they can build upon their already existent stock of social capital.[30] Also, it is expected that farmers with greater social skills or leadership capabilities would have been more willing to create their own associations or search for memberships in already existing ones in order to participate in the Plataformas. These leadership and social skills, although unobservable, can be controlled for by using a proxy for access to this type of social capital which is participation in associations, particularly of an agricultural type for one year (after the Plataformas started) or more. This variable then captures the type of person that joined the association just to be in the Plataformas. In other words, an intrinsic unobservable characteristic that might affect participation in the Plataformas can be controlled for by using an observable variable. By controlling for the type of person likely to join the Plataformas, we can ensure that estimates of the effects of the Plataformas do not capture the characteristics of the type of person and only capture program effects.

This approach is feasible to implement because some farmers in the control group are also members of agricultural and non-agricultural associations, therefore, there is enough variability. In fact, 13% and 84% of the non-participants in the Plataformas belong to an agricultural or non-agricultural association within the community, respectively. The relationship between social capital access and participation in the Plataformas is also confirmed by the positive and significant sign of participation in agricultural associations in the probit model presented in Section 4.4.1. Therefore, variables to control for access to social capital are also included in the production function in order to improve the identification of the Plataformas' impact.

4.5 Results

The weighted damage abatement production function described in equation (4.5) requires the use of non-linear least square methods (NLSQ). The results of the estimations are reported in table 4.4. In all estimations, plot characteristics, household characteristics, social capital variables, location specific (village level) fixed effects and time of planting fixed effects (month) are included through a series of dummies[31].

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[30] Social capital is a broad term that encompasses a number of forms of social relationships. Here we use the term to mean formal, horizontal social capital—that is, the forming of organizations with individuals with a similar socioeconomic background.

[31] The full results are available in the Appendix 4.A1.

Table 4.4: Impact of Plataformas Participation on Yields

Dependent Variable: Yields (log kg per ha)	**Weighted Damage abatement**	
Variable name	**Coef.**	**P>|t|**
Plataformas participation (dummy)	1.469	0.01 **
Conventional Inputs		
Land area (log ha)	0.214	0.16
Land area *Plataformas	-0.476	0.01 ***
Seed (log kg /ha)	0.609	0.00 ***
Seed *Plataformas	0.055	0.69
Family labour (log nr of days/ ha)	0.512	0.02 **
Family labour*Plataformas	-0.492	0.03 **
Paid labour (log nr of days/ ha)	0.062	0.37
Paid labour*Plataformas	0.001	0.99
Tractor (log nr of hours/ha)	0.042	0.57
Tractor *Plataformas	0.130	0.16
Animal labour (log nr of days/ ha)	-0.047	0.67
Animal *Plataformas	-0.019	0.88
Chemical fertilizer (1 if applied)	0.150	0.59
Chemical fert *Plataformas	0.173	0.61
Organic fertilizer (1 if applied)	-0.053	0.62
Organic fertilizer *Plataformas	0.040	0.81
Damage Control Function		
μ1	-0.425	0.33
Curative fungicide (kg or l /ha)	1.393	0.33
Curative*Plataformas	-1.368	0.34
Preventive fungicide (kg or l /ha)	-0.037	0.29
Preventive*Plataformas	0.122	0.06 *
Insecticide (kg or l /ha)	0.059	0.51
Insecticide*Plataformas	-0.097	0.30
Shannon index of diversity	0.666	0.42
Shannon index*Plataformas	-0.734	0.41
Number of traps (nr of traps/ ha)	0.363	0.77
Number of traps*Plataformas	-0.364	0.77
Plot characteristics	**yes**	
Household charactersistics	**yes**	
Social capital variables	**yes**	
Location specific effects	**yes**	
Time specific effects	**yes**	
Constant	12.594	0.16
Observations	845	
Adj. R2	0.61	

Notes: * = significant at the 10% level, ** = 5% ; and *** = 1%

The results of table 4.4 show that participation in the Plataformas has a significant and positive effect on yields. Specifically, simulation results run (results not shown)[32] show that participation in the Plataformas increases potato yields by about 2 tons per hectare and would have increased yields for

[32] Simulation is conducted by predicting yields with and without participation in the Plataformas, using the damage abatement function. Notice that results are very similar to the ones presented in table 4.5 which are obtained by implementing PSM on yields.

non-participants by 2.3 tons per hectare. Given that the average potato yields for the sample are 7.7 metric tons per hectare (see table 4.1), this is a non-trivial increase in yields. This suggests that there are some synergies likely embedded in the technology adopted, which make the overall yields significantly higher for participants. For instance, recommendations from FFS, such as soil sanitation, monitoring activities and crop rotation are some of the techniques adopted by farmers that are likely to increase yields without undertaking changes in input use. In other words, this coefficient is likely to be capturing the importance of farming knowledge transmission through the Plataformas. Interestingly, only three of the interaction terms between Plataformas and inputs (yield enhancing or damage abating), and precisely family labour, land and preventive fungicides, are significant. This suggests that further potential increments on yields may have been attained by participants mainly through the implementation of farming techniques learnt in the Plataformas rather than by increases in the returns to input use.

With respect to yield enhancement inputs, we find that family labour and seeds have positive significant effects on yields. For instance, 1% increase in seeds utilization would increase output by 0.6%. On the other hand, a 1% increase in family labour would increase output by 0.5%. However, Plataformas participants obtain lower net yield increases than other farmers through increments in family labour because the interaction term is negative and significant suggesting an optimal utilization of family labor for participants. Likewise the net effect of a marginal increase in the quantity of seeds used by participants is lower than for non-participants, indicating that potential for increasing yields from seed use is not very large for participants who already implement efficient seed utilization. Cultivated land provides increasing returns for non-participants (one additional ha of land increases yields by 21%) but net decreasing returns for non-participants possibly suggesting its maximum intensive utilization for participants. For all the other conventional inputs, the signs are mainly as expected.

In the case of damage abatement inputs, none of the coefficients, with the exception of preventive fungicides for participants, are significant. These results imply that additional reduction on yield losses are not likely to take place by augmenting the amount of damage control inputs generally used by farmers and that only in the case of preventive fungicide an increase on yield losses would be possible for participants.

The damage abatement framework then indicates that gains from the Plataformas come mainly from the overall farming techniques adopted and not from specific changes in the utilization of certain inputs to improve yields or abate damaging agents. Thus, overall the Plataformas lead to a general technological shift and not a specific one linked to inputs or damage control agents.

Table 4.5 presents estimated impacts of Plataforma participation on input and output indicators. These are determined using the same weighted least squares approach described previously, but focusing on each individual indicator rather than using a structural model. Thus, the dependent variable in each case is the indicator of interest in table 4.5 and the reported coefficient is the impact estimate of the Plataformas (with the same series of conditioning variables included to help identify the impact). The results point to an increase in the use of both yield-enhancing and damage-abating inputs that lead to a higher output (and thus higher gross margins) [33].

Table 4.5: Impact on Inputs and Output Indicators

Variable name	PS Weighted LS Diff.	P>|t|
Outputs		
Gross Margins ($/ha)	277.10	0.00 ***
Log of Total Harvest (kg/ha)	0.56	0.00 ***
Conventional Inputs		
Land area (log ha)	0.05	0.58
Seeds planted (log kg /ha)	0.15	0.03 **
Family labour (log nr of days/ ha)	-0.10	0.25
Paid labour (log nr of days / ha)	0.36	0.00 ***
Tractor (log nr of hours /ha)	-0.01	0.85
Animal (log nr of days /ha)	0.14	0.02 **
Organic Fertilizer use (dummy)	0.05	0.01 ***
Chemical Fertilizer use (dummy)	0.07	0.08 *
Damage Control Inputs		
Preventive Fung. Applied (log kg or l/ha)	0.10	0.09 *
Curative Fung. Applied (log kg or l/ha)	0.10	0.20
Insecticides Applied (log kg or l/ha)	0.10	0.02 **
Total Traps Used (log nr of traps/ha)	2.00	0.00 ***
Shannon Index of Diversity (per ha)	0.00	0.37
Observations	845	

Notes: * = significant at the 10% level, ** = 5% ; and *** = 1%. The above results only include the impact of the Plataformas on the impact indicator of interest. In each weighted least squares regression a standard set of controls is included in the regression.

4.6 Conclusions

For many smallholders, like the ones analysed here in the Andean highlands, staple crop production is an important source of food and a primary source of income. The ability to expand the income from staple production through linking to higher-value markets has the potential to improve the well being of smallholders. However, competing in high-value markets, which requires high quality standards, might be difficult for small-scale farmers without prior training. In fact, many smallholders would be unlikely to do so without some sort of intervention. The purpose of the multi-stakeholder Plataformas

[33] It is interesting to note here that although Plataforma participants seem to be using a larger amount of damage control agents (likely triggered by the need to achieve market quality standards) the toxicity of products used is evidently lower given that the Environmental Impact Quotient (EIQ) calculated following Kovach et al. (1992) on the basis of doses and number of application of active ingredients applied is about the same among treated and control groups.

program was to organize and link farmers to these markets and to provide potato producers with the training needed to implement alternative farmer practices, which allows an increase in potato productivity and higher returns to potato production.

In this chapter, the impact of the Plataformas program is empirically analysed through the estimation of a production function in a damage abatement framework, with a series of interaction terms to assess the impact of the program on the production technology. Such an approach moves beyond standard impact evaluation by using a structural model which allows the identification of the elements which, within an agricultural development program, are the most effective. To ensure identification of program impact, the data set was carefully constructed in order to have a reasonable counterfactual for comparing treated and control farmers. Additionally, a weighted least squares approach is used with weights calculated using the inverse of propensity scores based on the estimation of the probability of participation. This further avoids biased estimation results by controlling for remaining differences in observable characteristics of the treatment and control groups. Finally, to control for the “type of farmer” that would join the Plataformas, social capital proxies are included in the estimation, thereby improving the confidence that any identified impact can be attributed to the Plataformas program.

The findings provide compelling evidence that the Plataformas program enhances yields through increased input use as well as through a general shift in technology. Increases in input use are likely to be a response to higher returns to potato production resulting from the link to higher-value markets and thus high potato prices. An analysis of gross margins and potato prices (not reported) show a significant increase for both of these indicators for Plataformas participants. On the other hand, the technological shift is likely to have been induced by the use of more effective farming techniques that are learned through FFS. Many of the Plataformas’ recommendations, which are likely to translate into yield increases, are difficult to measure. However, the positive and significant value of participation gives a clear indication that participant farmers are obtaining higher yields.

In evaluating agricultural projects, it is critical to recognize that these may induce changes in production technology and not simply increase input use. Failing to incorporate this into the analysis can potentially underestimate the impact of a project. Incorporating impact evaluation into a structural model is complicated by the need to have an identification strategy that ensures unbiased estimates of impact. In this chapter, a number of steps have been taken to ensure this is the case by taking great care in defining treatment and control groups, both, during the data collection as well as at the analysis phase. Ideally, however, an experimental approach—where treatment and control are randomly assigned—would have been used to ensure a proper counterfactual and simplify the analysis. Such experiments are rare in agricultural projects, which should hopefully change in the near future.

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Table 4.A1: Full results of Weighted Production Function within DA framework

Dependent Variable: Yields (log kg per ha)	**Weighted Prod Function in DA framework**		
Variable name	**Coef.**	**P>|t|**	
Plataforma participation (dummy 1=yes)	1.469	0.01	**
Conventional Inputs			
Land area (log/ ha)	0.214	0.16	
Land area *Plataformas	-0.476	0.01	***
Seed (log kg /ha)	0.609	0.00	***
Seed *Plataformas	0.055	0.69	
Family labour (log nr of days/ ha)	0.512	0.02	**
Family labour*Plataformas	-0.492	0.03	**
Paid labour (log nr of days/ ha)	0.062	0.37	
Paid labour*Plataformas	0.001	0.99	
Tractor (log nr of hours/ha)	0.042	0.57	
Tractor *Plataformas	0.130	0.16	
Animal labour (log nr of days/ ha)	-0.047	0.67	
Animal *Plataformas	-0.019	0.88	
Chemical fertilizer (1 if applied)	0.150	0.59	
Chemical fert *Plataformas	0.173	0.61	
Organic fertilizer (1 if applied)	-0.053	0.62	
Organic fertilizer *Plataformas	0.040	0.81	
Farm characteristics			
Irrigation (dummy 1=yes)	0.073	0.48	
Flat plot (dummy 1=yes)	0.020	0.81	
Black soil (dummy 1=yes)	0.066	0.52	
Altitude (log)	-1.238	0.26	
Household Characteristics			
Female (dummy 1=yes)	0.014	0.90	
Indigenous (dummy 1=yes)	0.049	0.61	
Age (log # years)	0.057	0.71	
Average education (log # years)	-0.113	0.04	**
Dependency ratio	0.159	0.44	
Microenterprise (dummy)	0.046	0.74	
Migrants (dummy)	-0.016	0.87	
Credit constraint (dummy)	0.021	0.82	
Livestock owned (factor)	0.010	0.81	
Access to electricity (dummy)	-0.224	0.13	
Cement house owner (dummy)	0.112	0.31	
Access to sewage system (dummy)	0.434	0.02	**
Log Dist. to paved road (km)	-0.030	0.56	
Durable assets (factor)	0.105	0.09	*
Agricultural assets (factor)	0.071	0.12	
Social Capital *(all dummy vars)*			
Ag. Association (>1 year)	-0.129	0.26	
Non Ag. Association	0.068	0.58	
External ag. Association	-0.848	0.00	***
External non ag. Associations	-0.023	0.81	

Table 4.A1 (cont:): Full results of Weighted Prod. Funct. within DA framework

Dependent Variable: Yields (log kg per ha)	**Weighted Prod Function in DA**	
Variable name	**Coef.**	**P>|t|**
μ1	-0.425	0.33
Curative fungicide (kg or l /ha)	1.393	0.33
Curative*Plataformas	-1.368	0.34
Preventive fungicide (kg or l /ha)	-0.037	0.29
Preventive*Plataformas	0.122	0.06 *
Insecticide (kg or l /ha)	0.059	0.51
Insecticide*Plataformas	-0.097	0.30
Shannon index of diversity	0.666	0.42
Shannon index*Plataformas	-0.734	0.41
Number of traps (nr of traps/ ha)	0.363	0.77
Number of traps*Plataformas	-0.364	0.77
Location specific effects (dummies)		
Tixan	-0.490	0.23
Palmira	-1.098	0.01 ***
San Andres	-0.360	0.22
Santa Fe de Galan	0.305	0.32
Cacha	-1.356	0.01 ***
Licto	-0.584	0.12
Punin	-1.840	0.02 **
Quimiag	0.088	0.77
San Juan	-0.901	0.00 ***
San Luis	-0.733	0.10 *
Juan Benigno	-0.020	0.96
Pilahuin	-0.167	0.51
Tisaleo	0.338	0.34
Time specific effects (dummies)		
Jul-06	0.040	0.80
Aug-06	0.034	0.83
Sep-06	-0.315	0.34
Oct-06	0.109	0.44
Nov-06	0.074	0.47
Dec-06	-0.039	0.73
Jan-07	-0.096	0.57
Feb-07	-0.744	0.08 *
Mar-07	0.247	0.34
Apr-07	0.211	0.60
May-07	1.122	0.00 ***
Jul-07	1.624	0.00 ***
constant	12.594	0.16
Observations	845	
Adj. R2	0.61	

Notes: * = significant at the 10% level, ** = 5% ; and *** = 1%
Achupallas is the base category for the location specific effects
June 2006 or earlier is the base category for the time specific effects

Chapter 5

Modern variety adoption and risk management in drought prone areas: Insights from the sorghum farmers of eastern Ethiopia[34]

Abstract: *Adoption rates of improved or modern varieties (MV) of sorghum are generally rather low in Eastern Ethiopia. While MV may represent an effective means of coping with droughts, given their early maturing traits, landraces may prove to be better adapted to marginal production conditions and be more drought tolerant. Whether MV adoption is a risk reducing technology is, thus, very much context-dependent. Based on a unique dataset from Eastern Ethiopia in a year of extreme weather conditions, this chapter finds that risk factors drive farmers' decisions to adopt MVs coupled with access to markets and social capital. On the one hand, findings show that farmers use MVs to mitigate moderate risks. On the other hand, farmers most affected by extreme weather events are less likely to use MVs suggesting that MV adoption does not necessarily represent an effective means of coping with drought. Moreover results show that MV growers are more likely to be affected by sorghum failure in the survey year of extreme drought once controlling for exogenous production factors.*

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[34] This chapter is based on the article: R. Cavatassi, L. Lipper and U. Narloch (2010), Modern variety adoption and risk management in drought prone areas: Insights from the sorghum farmers of eastern Ethiopia forthcoming in Agricultural Economics. The authors would like to acknowledge Jeffrey Hopkins for his contribution to an earlier draft of this paper and to thank two anonymous referees for their valuable comments. The usual disclaimer applies.

5.1 Introduction

Improving farm level resilience to agricultural production shocks is essential to reducing poverty and improving household food security throughout the developing world, particularly in areas at high risk of climatic shocks and with a high percentage of the population dependent on agriculture as in Ethiopia. One of the primary causes of household food insecurity in Ethiopia is the risk of agricultural production failure due to drought, resulting in reduced harvest and farm incomes (Dercon et al., 2005; Doss et al., 2008). Such shocks, although transient, tend to have a persistent impact on household consumption levels in Ethiopia (Dercon, 2004) worsening chronic problems of low yields and food insecurity rooted in poverty (Sperling and Cooper, 2004). Dercon et al. (2005) found that households in Ethiopian villages that are affected by at least one drought within five years face a 20% lower per-capita consumption level over the same time period.

The Ethiopian government is pursuing a strategy of improving agricultural productivity primarily through agricultural intensification, involving an increased use of inputs, including seeds of improved crop varieties (McGuire, 2005; Byerlee et al., 2007). Considerable resources have been devoted to the development and dissemination of modern varieties (MV)[35], however adoption rates have been low, and farmers maintain the use of landraces (LR) for many crops and in many areas of the country (Byerlee et al., 2007).

Landraces are the product of centuries of selection by farmers and the natural environment. They are typically adapted to specific agro-ecological conditions and usually grown with very little capital inputs such as fertilizers, pesticides or irrigation. Ethiopia is particularly rich in local crop genetic diversity as it is the centre of origin and diversity for several crop species, including sorghum, the focus of the present chapter (Vavilov, 1992; Tanto and Demissie, 2000; McGuire, 2005).

There are several reasons why farmers may prefer landraces over improved varieties. The country's tremendous variation in altitude, temperature, rainfall, soil type and ecological settings, as well as the diverse "environments" in which Ethiopian farmers cultivate their crops gives rise to the need for a wide range of adapted crop varieties, which the formal plant breeding system is incapable of meeting. In general, research efforts to breed improved varieties have primarily concentrated on more favored and high-potential environments in which the increase in productivity and yield response to complementary inputs is high (Bellon, 2006). In contrast, landraces are generally the product of farmer selection for adaptation to specific environments (FAO, 1998; Mekbib, 2006). High genotype-environment interactions can result in higher performance from landrace compared with improved

[35] In this chapter we use the term modern varieties interchangeably with improved varieties to refer to crop varieties that are the result of a process of scientific breeding programs as opposed to traditional varieties or landraces that are the result of farmer selection. Included in our definition of modern varieties are those developed through the process of pure line selection conducted by scientific breeding programs.

varieties (Ceccarelli et al., 2001; Bellon, 2006). These “crossover” effects (i.e. changes in the rank of genotypes between environments) tend to be more common in marginal environments and in farming systems with low capital inputs where landraces are often found to perform better than improved varieties (Matlon, 1990; McGuire, 2005; Bellon, 2006; Mekbib, 2006). The photoperiodicity of landraces, that is the sensitivity of their biological functions to the duration of light, is another potential factor affecting farmers’ choice of varieties, as it provides an important mechanism of environmental adaptation. Photoperiod sensitive varieties can better adjust to changes in rainfall patterns, and avoid problems of mold, insect and bird damage that affect many early maturing varieties (Traoré et al., 2007). Uncertainty over the length of growing period and the initiation of the rainy season generate high values for photo periodic varieties that allow the farmer to respond to a range of planting dates (Niangando, 2001; Traoré et al., 2007). Improved varieties are generally not photoperiod sensitive and often reducing or eliminating this factor to broaden the range of adaptation is an objective of breeding programs. These factors might, at least partially, explain the low adoption rates of improved varieties and high levels of sorghum crop genetic diversity persisting in Ethiopian farmers’ fields.

Sorghum is a crop essential for food security throughout semi-arid Sub-Saharan Africa. Drought stress impacts on sorghum can occur at seedling, pre-flowering and post-flowering (Rosenow et al., 1983). Yield impacts depend on the timing and length of drought, as well as the characteristics of the varieties in use and their response to the type of drought stress. Varieties may have characteristics that allow it to “escape” from drought or resist its negative impacts, by either maintaining a more favorable water balance or by protecting cellular functions from dehydration (Tuberosa and Salvi, 2006). Early maturing improved varieties fall into the first category, whereas landraces have traits (including photoperiodicity) related to the second category. Early maturing varieties (early flowering) can be effective in addressing late-season drought stress and have lower total seasonal evapotranspiration (Blum Website). Early maturing improved varieties have been shown to be effective in reducing downside production risk in some situations in sub-Saharan Africa (Matlon, 1990; Ahmed, et al., 2000; Mekbib, 2006). However, adoption rates of such varieties in the area have generally been very low (Ahmed et al., 2000; McGuire, 2005).

Understanding the motivations and constraints of farmers in adopting improved sorghum varieties designed to reduce a major source of production risk is thus essential in designing an effective strategy for intensifying agricultural production. The literature shows that risk is a major factor in the decision to adopt modern crop varieties (Feder, 1980; Just and Zilberman, 1983; Antle and Crissman, 1990; Smale et al., 1994). Empirically assessing the risks associated with MV versus LR adoption in the drought prone and highly variable production environment of Ethiopia and its impacts on variety choice is thus an important one to understand in moving ahead with agricultural development strategies for the country.

In this chapter we explore how agricultural households in the Hararghe region of eastern Ethiopia manage their diverse set of sorghum varieties to cope with risks of crop failure. We use a unique dataset from an area rich in local sorghum genetic diversity and with high rates of poverty. Sorghum is the most extensively grown crop in the area, cultivated primarily for subsistence needs and critical for food security. Data from a shock year provides us with an opportunity to explore the role of genetic resource utilization in risk management. Although early maturing improved varieties of sorghum, developed as a means of coping with drought have been disseminated in the area, only 11% of farmers in our sample were found to be MV adopters, consistent with findings from other studies (McGuire, 2005; Mekbib, 2006). The question we explore in this chapter is the role of sorghum MV adoption in coping with downside risk exposure (i.e. probability of crop failure) in the context of a low productivity agricultural system subject to frequent climate shocks where most of the population is poor, but local genetic diversity for the crop is abundant.

The remainder of this chapter is organized as follows: section 5.2 presents the case study background and draws special attention to the forces affecting supply and demand of variety selection in Eastern Ethiopia. Considering MV adoption as a technology choice, a conceptual framework is presented in section 5.3 that addresses the following two questions: (i) what is the role of downside production risk in the decision to adopt MVs? and (ii) to what extent are improved sorghum varieties effective in reducing downside production risk in the Ethiopian context? Section 5.4 includes the econometric model and empirical results. Finally, section 5.5 concludes by discussing the policy implications for the study region.

5.2 The case study background

Ethiopia is one of the poorest countries in the world with high rates of food insecurity, and where many people depend on small-scale, low-productivity agriculture (Shiferaw and Holden, 1999). Drought is a major problem hobbling agricultural productivity in the country. In the 2000-01 and 2002-03 production seasons major drought affected the food security of over ten million people (Bramel et al., 2004).

The dataset used in this chapter was collected during the 2002-03 drought period in the Hararghe region of eastern Ethiopia. The sampling at household and community level was designed around seed system interventions carried out by the Hararghe Catholic Secretariat (HCS), a non-governmental organization operating in the area. HCS' small scale seed intervention comprised seed selection, multiplication and distribution of both landraces and improved varieties of wheat and haricot beans and to a lesser extent sorghum[36]. The surveys were undertaken in two rounds, the first one at the end of the main crop planting season in August 2002 and the second one after harvest in January/February 2003. The data comprises 720 households from 30 peasant associations (PA henceforth) located in the

[36] The data is based on a random sample of households stratified with regard to participation in the HCS-programs.

highland and midland regions. The PAs belong to three woredas (i.e. districts) namely Chiro, Meta and Dire Dawa, representative of the main agro-ecological zones in the region.

Sorghum is the most important staple crop in the study region. It is mainly cultivated for subsistence purposes[37]. It provides over one third of the cereal diet and is almost entirely grown by subsistence farmers to meet needs not only for food and income but also for feeding animals, brewing and construction purposes (McGuire, 1999, 2005; Mekbib, 2006).

5.2.1 Modern variety adoption in Haraghe region

Given the importance of sorghum for food security in the drought prone areas, the development of early maturing, drought escaping varieties have been a main focus of breeding programs in Ethiopia as well as other areas of sub-Saharan Africa (Matlon, 1990; Ahmed et al., 2000; McGuire, 2005; Mekbib, 2006).

Table 5.1 provides an overview of the range of sorghum varieties identified in the study, with a description of the variety traits or characteristics and classified into MVs or LRs. Before moving into describing how varieties were classified as improved or LR, two important points need to be made. First, almost all of the MVs farmers reported using in this study were sourced from the "informal" seed sector. Hence, they are not certified seeds but rather recycled seeds. Second, since sorghum has a low rate of outcrossing for pollination, there is the possibility that LRs and MVs are cross-pollinated in the field, resulting in varieties that combine genetic material from both. However, information from the agro-morphological characterization as well as related studies on sorghum variety management in the area indicate that LRs are fairly stable and distinct (Mekbib, 2006).

Given these premises, our variety categorization is based on variety names, triangulating information from farmers' categorization[38] with information from breeders and secondary sources on variety identity. We categorized a variety as a MV either when the variety name given by the farmer was associated only with a MV (as confirmed by breeders and secondary sources), or in cases where farmers identified a variety as improved, and information from breeders and secondary sources confirmed that indeed an improved version with that variety name existed in the area. The reason this was necessary, is that given the large utilization of farmers' varieties for sorghum in the area (Mekbib, 2006), a number of breeding initiatives have been carried out in the region to improve the performance of the most common and adapted landraces[39]. These breeding efforts were mainly based on pure line selection of some selected farmers' varieties and focused on using mainly early maturing traits. Even though the outcomes of such breeding efforts were given a scientific name, they were often

[37] Only 1% of the sample households sell part of the sorghum production on the market.
[38] While we acknowledge the limitations of using farmer variety names, attempts to improve varietal identity were made via focus group discussion, key informant interviews as well as agro-morphological characterization.
[39] Mainly muyra, muyra red and muyra white and wegere.

disseminated using the name of the local variety they were derived from. While the intention was apparently to enhance adoption through use of a familiar name, it introduced confusion in terms of variety identity. The same variety may in fact be a MV or a LR depending on whether it is the result of breeding effort or not. Essentially our classification of MV versus LRs is based on verifying information from farmers on variety name and classification, with that from secondary sources and local breeders. Our intention is, to the extent possible, to classify varieties into MV and LR categories based on a principles of scientific plant breeding, rather than farmers' taxonomy. While we recognize the latter is very important in understanding varietal choice and utilization decisions, for the question we are concerned with in this chapter, the plant breeding classification is more relevant.

Table 5.1: Classification of sorghum varieties grown in Hararghe region, 2002-2003

NAME	DESCRIPTION	ADOPTION RATE	LAND AREA	NUMBER IN USE	
				LR	MV
Muyra red	It's a type of muyra characterized by red colour grains.	28.70%	1.52	126	17
Muyra	The most common variety characterised by goose neck and compact head.	12.40%	1.93	54	8
Abdelota 'alaa'	It means Juicy.	11.00%	4.55	55	
Masugi dima	It's a type of masugi variety characterized by red colour grains.	10.40%	3.29	52	
Geldi	Landrace but because it is mainly distributed by HCS or vendors some farmers believe it is an improved variety	6.40%	0.99	32	
Itibele	The name of this variety indicates a very very red variety, usually characterized by compact head.	6.20%	3.32	31	
Fendisha	"pops". It is characterised by straight and semi-compact head. It is a variety that makes good injera and it is very easy to store. Disadvantage is that it needs a longer growing season as it needs 10 months. High yielding under good rain conditions but easy to loose if not enough rain.	5.20%	1.31	26	
Chafarae	Dispersed/loose panicle	5.20%	3.01	26	
Wegere	Characterised by white seeds and semi-compact goose neck head. Two varieties of wegere have been released by Alemaya: AL 70 in 1970 and ETS 2752 in 1978. Both have white seeds and similar panicle.	5.20%	2.21		26
Chekore	Variety with straight head	3.60%	1.58	18	
Masugi adii	Masugy type of variety of white colour	2.60%	2.97	13	
Masugi dalech	Masugy type of variety of grey colour	2.20%	2.85	11	
Dima	It's a very distinct red type of sorghum.	1.80%	3.45	9	
Gebabe	Characterized by very short stalk which is usually a disadvantage but can be an advantage in steep slopes or in areas susceptible to wind where lodging is a problem and short stalk is preferred. Short stalk is also good for intercropping with chat or coffee.	1.60%	2.94	8	
Zengada	Usually utilized for making local alcohol (beer) and it is not good as food.	1.40%	2.45	7	
Amajigta	It means "doesn't lodge". Distributed by HCS or farmer vendors.	1.20%	1.58	6	
Jammal abdala	It is a landrace that indicates the name of the person that first distributed that variety in the area.	1.00%	1.38	5	
Hamdea	It means "thank to God" and indicates a good quality. It is a particular type of Muyra	1.00%	1.24	5	
Muyra aliso	Particular type of muyra	0.80%	1.32	4	
Bele	Early maturing variety	0.80%	3.63	4	
Ahmed isee	Landrace. Indicates the name of a person.	0.60%	1.39	3	
Daslee	Landrace. Not very common or easy to find but with very good performances.	0.60%	1.86	3	
Filatta	Very rare landrace variety.	0.60%	1.62	3	
Wahelu	No information available	0.60%	1.17	3	

Table 5.1 (continued): Classification of sorghum varieties grown in Hararghe region, 2002-2003

NAME	DESCRIPTION	ADOPTION RATE	LAND AREA	NUMBER IN USE	
Warabi	It is a term which relates to the variety performance. It means "we have something" and usually indicates resistance to drought.	0.60%	0.92	3	
Muyra white	Type of muyra characterized by white colour	0.60%	2.50	1	2
Aliso	Particular type of muyra	0.40%	0.75	2	
Mesengo	Rare to find.Landrace.	0.40%	2.80	2	
Muyra chekore	Black type of muyra with straight head.	0.40%	0.98	2	
Muyra dini	Red type of muyra	0.40%	0.88	2	
Katamara	Rare landrace.	0.40%	1.00	2	
Cherchero	Short and early maturing.	0.40%	0.63	2	
Feshe	Very rare. Landrace.	0.20%	3.00	1	
Qillee	Very rare. Landrace.	0.20%	0.50	1	
76 t1 #23 (mv)	Released in 1979 by Alemaya and Melkasa Research center.Also distributed by HCS	0.20%	1.00		1
Sharitae	Rare variety. No info available	0.20%	0.25	1	
Adem mussa	It's the name of the person that first distributed the variety in the area	0.20%	2.00	1	
Bamiliq	It is a term which means "meets the challenge", "escape the problem" and it indicates a good resistance. It is an early maturing variety	0.20%	4.00	1	
Bishinga dima	Red type of sorghum	0.20%	5.10	1	
Other		0.20%	4.00	1	
				527	54

Notes: [1] Mean value in timmad conditional on utilization of the respective variety.

Table 5.2 reports the extent of modern variety adoption and intra-crop (i.e. within crop) diversity amongst sorghum growers. The table also compares the differences in means for MV and LR growers for reported variables using t-test statistics, as reported in the last column. Within the sample of 446 sorghum-growers, MV adoption rates are rather low. Nearly 89% of the households (396 households) cultivate solely landraces, and only 11% of the households adopt MVs. Of these, about one third is represented by "partial adopters" in the sense that they grow MVs[40] in addition to LR. Accordingly, the overall land area planted with MVs is rather small, covering only about 8% of the total sorghum land area. No significant differences are reported in the total area planted to sorghum between the two groups, while LR growers seem to have a slightly larger land extension than MV adopters significant at 5% level. On average, MV adopters allocate slightly more than 80% of their land area under sorghum to MVs (1.82 timmad[41]).

As most farmers only use one variety, the extent of on-farm intra-crop diversity in the study area is rather limited. Only 13% of LR growers cultivate more than one sorghum variety, whereas 38% of the MV adopters do so. This implies that the latter manage significantly higher levels of on-farm sorghum diversity, as can be seen from results on various measures of diversity including the variety count, the Shannon and Simpson index for proportional abundance and the Berger-index for relative abundance[42]

[40] With 1/2 to 2/3 of their sorghum area dedicated to MV.
[41] One timmad corresponds to 1/8 of ha.
[42] For more information on diversity indexes see: Baumgärtner, 2002; Smale, 2005.

reported in Table 5.2. Only one of the MV growers that cultivate more than one variety uses more than one improved variety. All the others use a mix of traditional and improved varieties.

According to local experts, landraces are normally preferred to early maturing MVs since the latter generally yield fewer desired traits and lower amounts of straw residues for feed and construction purposes (Lipper et al., 2005; McGuire, 2005). In effect, it appears that improved varieties are likely to supplement, rather than substitute for landraces, similar to the findings of Benin et al. (2006) for wheat and maize in the highland areas of northern Ethiopia and by Ahmed et al. (2000) in other areas of sub-Saharan Africa. Environmental heterogeneity and experimentation with new varieties have often been found to result in partial adoption (Bellon and Taylor, 1993).

Whether modern varieties represent a threat to crop genetic diversity, a concern raised in many contexts (see e.g. Frankel, 1970; Harlan et al., 1973; Hawkes, 1983; Brush et al., 1992; Brush, 1995) is thus uncertain and depends on the long term implications of current adoption patterns, as well as on the measures of diversity considered. Smale (1997) argues that MVs displacing LRs does not necessarily imply a reduction of genetic material in the field. She observes that since MVs may be crosses between a number of LRs and other MVs, a new MV might preserves LR genetic material and yet bring new genetic material into the existing population (Smale, 1997).

Our data indicate that MV sorghum growers dedicated a smaller portion of land to landrace varieties at the time of the survey. To the degree this represents a trend, landrace area could significantly diminish. At the community level however, landrace growers are still the vast majority for sorghum and thus MV adoption might in effect be adding to diversity rather than diminishing it.

An understanding of both the demand for, and the supply of, crop genetic resources is needed to understand variety choice (Bellon, 2004). This includes consideration of the types of varieties needed to fit the specific production and consumption requirements of the farm household, as well as the availability of and accessibility to varieties that can meet them (Bellon, 2004). The following sections address these questions.

Table 5.2: Extent of MV adoption and intra-crop diversity among LR growers and MVadopters

	total	**only LR growers**	**MV adopters**	**p-value***
no of households	446	396	50	
total land area in timmad	4.25	4.36	3.45	0.048
sorghum land area in timmad	2.55	2.59	2.23	0.241
area allocated to LRs in timmad	2.35	2.59	0.42	0.000
area allocated to MVs in timmad	0.20	-	1.82	-
average number of varieties	1.17	1.13	1.42	0.000
intra-crop shannon index	0.11	0.09	0.26	0.000
intra-crop simpson index	0.07	0.06	0.18	0.000
intra-crop berger index	1.13	1.11	1.29	0.000

Notes: *P-value computed by a two-sided t-test.

Source: authors' calculation using FNPP (FAO Netherlands Partnership Programme): Seed System Impact on Household Welfare and Agricultural Biodiversity data set

5.2.2 The formal seed sector and seed supply

Limited seed industry development and barriers to seed marketing, together with poorly targeted crop breeding policies hinder widespread adoption of modern crop varieties in Ethiopia (Ahmed, et al., 2000; Mulatu, 2000; McGuire, 2005; Byerlee et al., 2007). Difficulties with seed quality and timely delivery have been identified as a problem for farmers using the seed supplied by the formal sector (Lipper et al., 2006; Byerlee et al., 2007). Access to credit is another potential constraint farmers face in obtaining improved sorghum varieties in Ethiopia, as they commonly obtain the seeds of such varieties, as well as other production inputs, via credit packages from the government extension service (Mulatu, 2005). These problems are mostly related to obtaining formal sector certified seed of improved varieties. Farm saved and sales in local markets of recycled open-pollinated improved varieties are other widely used means of accessing improved varieties.

Farm saved seed is the main seed source for most Ethiopian sorghum farmers (McGuire, 2005; Mulatu, 2005; Lipper et al., 2006). Off farm sources of seed range from gift giving and exchanges via social networks to market transactions. Our sample shows that only about 15.5% of the farmers interviewed had ever used external sources to replace or renew seeds of the varieties in use in 2002-03 production year. Moreover, although MVs are known by farmers to decline in productivity much faster than LRs, the rate of renewal is higher for the landraces in use (15.1%) than for the modern varieties (11.5%). In addition, while about 49% of the LR seeds are obtained through gifts and other exchange mechanisms, all MVs are purchased through cash payments at local markets.

Surprisingly, in the sampled population, only 18% of the sorghum MV adopters indicate any difficulty in getting seeds, compared to 31% of the sorghum LR producers. Of the farmers that indicated any preferences for alternative seed sources, rates are about the same for LR growers and MV users. Overall, about 37% of the sorghum growers would like to have planted additional or different varieties with rates being about the same for landrace growers and MV users. Interestingly, early maturity was the most frequent trait that farmers reported they would want from different or additional varieties (43%) – considerably higher than good yields in grain (29%).

These results suggest that generally, modern varieties are as accessible as landraces in the study region, albeit through informal seed sector sources, so that supply constraints are not likely to be the driver for the limited extent of MV adoption. Low adoption rates may thus be due to lack of demand. This is the issue explored in the next section.

5.2.3 Demand for sorghum varieties and its traits

There is not one single variety that is able to satisfy both consumption and production needs at the same time. Hence, farmers demand multiple varieties to meet a range of objectives (Bellon, 1996; Smale et al., 2001). Even if there are no supply side constraints, farmers are unlikely to adopt modern varieties if they do not provide the attributes farmers need. Several studies have indicated high private values of landraces in Ethiopia across a range of crops (Mulatu, 2000; Lipper et al., 2005; McGuire, 2005; Benin et al., 2006). The sorghum farmers surveyed in this study were asked to rank the most desirable attributes of their varieties. They were given a list of 19 variety characteristics identified through open ended questions during the pilot phase and ranging from production to risk management and to consumption-based attributes. The farmers had the options of providing up to three preferred traits ranking from most to second and third preferred attribute associated with the varieties in use. As table 5.3 shows, attributes such as yield and risk management potential appear to be more important than consumption characteristics, although the latter are relatively more important for landrace growers.

Table 5.3: Most desirable Sorghum attributes: MVs versus LRs

	all varieties	LR	MV	p-value*
high return				
good yield in grain	37.5%	36.1%	51.9%	0.027
good yield in residuals	3.4%	3.2%	5.6%	0.419
good grain quality	1.5%	1.7%	0.0%	1.000
good fodder quality	3.8%	3.4%	7.4%	0.138
risk management				
early maturity	11.9%	12.1%	9.3%	0.662
resists drought	11.0%	11.2%	9.3%	0.821
good adaptability	11.9%	12.1%	9.3%	0.662
other resistance attributes	4.5%	4.7%	1.9%	0.498
consumption				
taste of food/cooking quality	4.8%	5.1%	1.9%	0.502
other				
other attributes	2.1%	2.3%	0.0%	0.615
no advantage stated	7.4%	7.8%	3.7%	0.413
total number of varieties	581	527	54	

Notes: *P-value for a two-sided Fisher's exact test.

Source: authors' calculation using FNPP (FAO Netherlands Partnership Programme): Seed System Impact on Household Welfare and Agricultural Biodiversity data set

Unsurprisingly, the most important trait was good yield in grain. MVs are more likely to be associated with higher yields than landraces, as more than 50% of MV users ranked this attribute as the most important trait associated with their variety, while only 36% of landrace users do so, and was the only significant difference found between the two groups. Good residues (in straw or grain to use for purposes other than food), in addition to good grain quality and good fodder quality were ranked as less important attributes. Risk management characteristics, such as good adaptability, early maturity and drought resistance are considered the most desirable attributes for more than 30% of the varieties in use.

A key issue affecting the demand for improved and traditional varieties is their adaptability to marginal and variable production conditions without the use of complementary inputs, which is frequently the case for many Ethiopian farms. Early maturity is a variety trait that may provide farmers with an ex-ante means of coping with drought, by virtue of the short rainy season required for production and by giving the option of planting twice on the same plot over the two production seasons typical of Eastern Ethiopia's agriculture. Another trait farmers may demand is drought tolerance, which refers to the capacity of the plant to adjust water use efficiency over a production season, including photoperiodicity (Tuberosa and Salvi, 2006). Table 5.3 indicates no significant differences between MV and LR growers with regard to demand for these risk attributes, although a higher percentage of LRs are associated with these attributes (40% versus 30% for MVs). Given that modern varieties in the study region have been bred specifically with a focus on early maturity, it is surprising that no significant differences are found between LR and MV growers with regard to reported demand for the trait. Instead the trait was found to be one of the most desirable characteristics for all farmers. When asked about attributes of the varieties farmers would have liked to have planted, 43% of these unavailable varieties were associated with short maturity and 29% with good yields in grain.

5.2.4 Drought and sorghum failure

In addition to understanding the reasons for MV adoption, it is important to assess how these improved varieties perform under extreme weather conditions, which occour frequently in the study site. As with other crops, sorghum landraces are generally considerably lower in grain productivity as compared with improved varieties when grown under optimal moisture conditions with recommended practices (e.g. Byerlee et al., 2007). However, crossover effects, whereby sorghum landraces outperform improved varieties, have been found under the Eastern Ethiopia farms (Mulatu, 2000; McGuire, 2005; Mekbib 2006). Yet the role of improved sorghum varieties in reducing the risk of crop failure due to drought is potentially more important for the study area, given the high level of rainfall variability. Evidence from other parts of Sub-Saharan Africa have indicated that early maturing, improved varieties of sorghum have been effective in decreasing downside risk (Matlon, 1990; Ahmed et al., 2000).

Given the harsh drought conditions of the production year studied, almost every farmer faced harvest shortfalls and nearly a quarter of the planted crops did not produce any output[43]. In what follows we refer to sorghum (crop) failure when planted sorghum varieties yielded no harvest. Table 5.4 provides a comparison of performance between MVs and LRs for crop failures. MV adopters have a lower percentage of crop failures than LR growers. Similarly, MV adopters experience a lower

[43] Each farmer has been asked about the harvest time of the planted crops on the operated plots. If none of the sorghum planted was harvested or to be harvested they could indicate the 'crop failed'.

percentage of harvest loss and report higher sorghum output.[44] These results suggest that MV varieties perform better than landraces under the adverse conditions of the 2002-03 production season. Yet these results could be misleading, as the same factors that lead to MV adoption could also indicate a reduced vulnerability to drought, for example location in a favorable agro-ecological zone. To control for these confounding factors requires a multivariate analysis of the factors determining sorghum-failure.

Table 5.4: Sorghum output 2002/03: Landrace users versus MVadopters

	total	only LR growers	MV adopters	p-value*
households with sorghum failure %	35.20	36.87	22	0.038
total area under failing sorghum varieties (in timmad)	0.94	1.00	0.44	0.030
sorghum loss in % of expected harvest	77.2	78.4	68.2	0.007
sorghum yield in kg per timmad	86.2	82.1	118.2	0.125

Notes: *P-value computed by two-sided t-test for continious variables and by a Fisher's Exact test for sorghum failure.
Source: authors’ calculation using FNPP (FAO Netherlands Partnership Programme): Seed System Impact on Household Welfare and Agricultural Biodiversity data set

5.3 Conceptual approach linking risk and modern variety adoption

The adoption of MVs may be considered a technology choice (I). When land endowment is limited and adoption rate low as in the area studied, land allocation models might have limited explanatory power. Technology adoption decisions are particularly important in situations of high food insecurity, where the probability of complete crop failure is rather likely and where risk adverse farmers have limited capacity for ex-post consumption smoothing. In such contexts we can expect that small-scale farmers choose their production technology to minimize the probability of disaster outcomes, such as complete crop failures (e.g. Moscardi and de Janvry, 1977). Given the high incidence of crop failure in Hararghe under the 2002 drought conditions, understanding the impact of production technologies on the exposure to downside production risks is an important research question. This kind of disaster-avoidance behaviour is rooted in the standard household model where the farmer maximizes his expected utility from a bundle of consumption goods, given his production and income constraints.

Staple crop production levels are determined by land area (L_S), a vector of other production inputs, like labour and fertilizer, (X_S), the technology parameter, I, and stochastic weather conditions (ε) conditional to agro-ecological production conditions (Φ_{Agro}):

[44] The data on sorghum output is not fully in accordance with the information on sorghum failure. For instance, some farmers report no sorghum harvested, but they do not report any sorghum failure, which would have been expected. This may be due to recall biases, as farmers have been asked about sorghum output in the second survey only, i.e. in January 2003, while harvesting occurs over the entire production season. In contrast farmers were asked about sorghum failure in the first (August 2002) as well as in the second round of data collection.

$$Q_S = q(L_S, X_S, I, \varepsilon;\ \Phi_{Agro}) \tag{5.1}$$

Assuming that weather conditions, ranging from extreme drought to flood[45], follow a normal distribution with a mean of zero, production levels can take zero values, if weather conditions are extremely adverse. In these cases the crop fails given the chosen input levels and technologies. Accordingly, farm households allocate their production inputs and chose their production technologies in order to maximize expected outcome subject to keeping the probability of crop failure below an acceptable level of disaster, $\Pr(Q_S = 0) \leq \alpha$, which corresponds to a safety-first criterion by Telser (1955).

The probability of crop failure, *Pr*, can be described by a vector of weather related risk variables $\Phi_{Weather}$, capturing the sensitiveness of staple crop-production to climatic variability. The acceptable level of disaster, α, is determined by the household's level of risk aversion explained by structural household variables, Φ_{HH}, reflecting household risk preferences, and by household specific means Φ_{Assets} for ex-post consumption-smoothing like ownership of assets and access to insurance mechanisms and credit.

Accordingly, Φ_{HH}, Φ_{Assets}, and $\Phi_{Weather}$ enter the households technology adoption decision through the safety-first behaviour of the household. In subsistence farming contexts, where households are exposed to extreme poverty and/or food insecurity and highly variable production environments and where markets for certain goods are assumed to be missing or imperfect, we can expect that the farm decisions on their staple-crop production (Q_S), including the varieties to use, will be very much driven by such risk management aspects. Given the scarce resources, high dependence on agriculture for food security and high risk of food insecurity for farmers in this situation, the minimization of the probability of falling below a minimum threshold of agricultural production to meet subsistence food requirements is a key driver of farm production decisions, including variety choice.

However, variety choice is not only driven by risk management objectives, but also by farmers' demand for a range of variety traits (Bellon, 1996; Smale et al., 2001). Factors, such as consumption related traits like cooking quality and taste may also influence variety choice, so that taste-shifters enter the technology-adoption decision via the vector with structural household variables Φ_{HH}.

At the same time farmers face constraints when adopting new technologies. First of all, there is land constraint given by the total land endowments: $L_S \leq L$. Secondly, MVs may not be cultivable under the agro-ecological conditions found on the farmer's plots: Φ_{Agro}. Thirdly, certain varieties may not be accessible, so that constraints in form of access to markets for inputs Φ_{Market}, and to social

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[45] Likely to occur when rainfall finally come on steep and drought soils.

capital, e.g. intra-community and inter-community networks for seed exchange Φ_{soc} , enter the technology adoption equation.

The general reduced form solution for technology adoption (i.e. MV adoption) can thus be written as follows:

$$I_{MV} = l_{MV}\left(L,\ \Phi_{HH},\ \Phi_{Agro}, \Phi_{Market},\ \Phi_{Soc},\ \Phi_{Assets},\ \Phi_{Weather} \right), \tag{5.2}$$

where the adoption of modern varieties is explained by total land endowments, household demographics, agro-ecological conditions, market access, social capital, household assets and weather-related risk variables.

We expect that the farmers who are most sensitive to climatic risk and with the least capacity for ex-post consumption smoothing would be most likely to adopt a technology that reduces risk. However, whether MV adoption increases or reduces risk in subsistence production systems is context-dependent. As pointed out earlier, for sorghum in Ethiopia the relationship is ambiguous. On the one hand, most modern varieties are bred with early maturing traits in order to escape drought. On the other hand, most of the landraces appear to be better adapted to the marginal and harsh environment like the one under study and are thus more drought tolerant. Therefore, it is very much an empirical question if modern variety adoption is a risk reducing technology and can thereby contribute to food security in times of drought.

If modern varieties are less sensitive to rainfall conditions, they would contribute to lower variability in output and thus reduce exposure to downside risks, such as sorghum crop failure in drought periods. As can be derived from the output function in equation (5.1), failure of any variety depends on the land area cropped, input use and rainfall levels given a vector of agricultural production conditions. The disturbance term is determined by actual weather conditions in the given production period, i.e. $\varepsilon = R$. Therefore, the probability of experiencing any crop failure, *F*, can be expressed in the following reduced form:

$$F = \mathrm{f}\left(L_S, X_S, I\ , R;\ \Phi_{Agro} \right) \tag{5.3}$$

In this conceptual section two questions have been elaborated i) are more risk averse farmers with climatically sensitive production systems more/less likely to adopt modern varieties (equation 5.2); and ii) does modern variety adoption reduce/increase the probability of being affected by crop failure (equation 5.3). These are crucial questions to explore in the context of climatic risk and safety-first behaviour of farm-households. As both relationships are very much context dependent, these questions have to be addressed empirically to gain insights into the role of modern varieties in reducing the exposure to downside production risks in the study region.

5.4 Econometric analysis

In the context of extreme climatic risks, there is a need to go beyond mean-variance approaches. A standard econometric procedure would be to extend Just-Pope (1978) production functions to higher moments, as in Di Falco and Chavas (2009). Yet such methods are based on the assumption of a normal distribution of the stochastic disturbance term, reflecting climatic risks. As we only have cross-sectional data from one year of extreme drought, this disturbance term is highly negative, so that the yield distribution is found to be skewed to the right. In order to explore the connection between MV adoption and downside risk exposure more limited econometric models have to be applied, such as analyzing the likelihood of sorghum crop failure.

MVs are adopted if marginal benefits from their utilization exceed marginal adoption costs. As these are unobserved, the difference in marginal benefits and costs can be modelled by the unobserved latent variable, y_1^* and MV adoption is undertaken if this variable crosses a normalized threshold, i.e. $y_1^* > 0$. In accordance with equation (5.2), we model MV adoption as a function of a vector of explanatory variables, x_1'. In our framework and as expressed in (5.3) we also want to assess the probability of being affected by crop failure, and particularly how MV adoption influence the probability of experiencing crop failure. The probability of crop failure can be modelled as a cumulative distribution function of another unobserved latent variable, y_2^*. This is determined by a vector of explanatory variables (x_2') and by a binary variable for the utilization of MV (y_1).

Accordingly, the following equation system applies:

$y_1^* = x_1'\beta_1 + \mu_1$, $y_1 = 1$ if $y_1^* > 0$, else 0

$y_2^* = x_2'\beta_2 + y_1\alpha + \mu_2$, $y_2 = 1$ if $y_2{*} > 0$, else 0

α, β_i are the parameters to estimate while μ_i are the error terms.

This recursive simultaneous probit model can be estimated by fitting a maximum likelihood bivariate probit model (Greene, 1998). This approach allows for an endogeneity test by providing a likelihood-ratio test for the correlation coefficient of the error terms (rho) between the two equations (Knapp and Seaks, 1998). The endogeneity assumption is supported for several model specifications at 10% significance levels. For the final model, exogeneity is rejected at 8.6% (see table 5.5). The error terms are negatively correlated at 6.3% significance level. This implies that the random effect of MV adoption has a negative impact on sorghum failure.

Table 5.5: Endogeneity-test in the maximum-likelihood estimation of the bivariate probit model

	mean	std	P>z
rho: correlation coefficient of error terms	-0.721	0.235	
Fisher's z transformed rho	-0.910	0.490	0.063
Likelihood-ratio test of rho=0:	chi2(1) =2.950		Prob > chi2 = 0.086

5.4.1 Explanatory variables

As elaborated in the conceptual model, explanatory variables for MV adoption include i) land endowments, ii) household demographics, iii) access to social capital, iv) access to market, v) agro-ecological conditions, vi) household assets and vii) climatic risk; whereas for sorghum failure the same agro-ecological variables as in v) are used in addition to household demographics and input variables viii). The descriptive statistics for the landrace growers and MV adopters are summarized in Table 5.6.

Table 5.6: Descriptive statistics of explanatory variables for sorghum grower households in Hararghe region

variable name	description	total mean	only LR growers	MV adopters
i) land endowments				
operated area	total area of operated plots in production year 2002 in timmad	4.25	4.36	3.45
ii) household demographics				
household size	number of household members at the beginning of the year	6.96	7.01	6.58
dependency	number of children and old members in proportion to total household size	0.50	0.50	0.49
ethnicity	dummy =1 if household belongs to the ethnic group of Oromo	0.90	0.91	0.80
female head	dummy = 1 if household is female headed, else 0	0.07	0.07	0.08
age head	age in years of household head	40.30	40.27	40.50
education	total years of education of all household members	3.97	3.82	5.14
iii) social capital				
seed exchange	dummy = 1 if household exchanges seed with other farmers, else 0	0.65	0.66	0.54
farmers association	dummy =1 if any household member belongs to intra-community farmers/production group, else 0	0.14	0.14	0.18
seed organisation	dummy = 1 if contact with any inter-community organisation for seed provision, else 0	0.27	0.27	0.22
HCS	dummy = 1 if households participates in HCS, else 0	0.47	0.47	0.46
iv) market variables				
closest city	distance in minutes from PA to nearest town	208.66	212.73	176.42
distance to market	distance in km from PA to next market	9.05	9.24	7.52
distance to inputshop	distance in km from PA to next inputshop	20.32	20.45	19.26
v) agro-ecological conditions				
Meta	dummy = 1 if woreda is Meta, else 0	0.38	0.37	0.46
Chiro	dummy = 1 if woreda is Chiro, else 0	0.42	0.44	0.26
altitude	altitude of PA in metres	1922.84	1919.40	1950.12
black soil	dummy = 1 if plot with black soil is cultivated, else 0	0.53	0.52	0.60
gentle terrain	dummy = 1 if plot with non-steep terrain is operated, else 0	0.61	0.60	0.72
irrigated	dummy = 1 if irrigated plot is operated, else 0	0.30	0.29	0.36
vi) household assets and insurance				
agricultural assets	total value of agricultural assets (not including livestock) in birr	88.98	89.02	88.71
non-agricultural assets	total value of non-agricultural assets in birr	53.97	52.61	64.67
livestock	total value hold in livestock in birr	560.97	551.85	633.17
credit restricted	dummy = 1 if credit request was not approved or if household did not ask for credit, beacause of difficult conditions, else 0	0.43	0.42	0.52
seed aid	dummy = 1 if household receives seed in case of emergency from other farmers, else 0	0.31	0.30	0.36
vii) climatic risk				
sorghum stresses in the past	number of sorghum stresses in the last 10 years	3.73	3.72	3.82
harvest losses in the past	number of harvest losses due to drought in the last 10 years	2.99	3.03	2.64
viii) sorghum production inputs				
labor for planting	total labour force for planting sorghum plots in no. of days	6.55	6.58	6.30
labor for land preparation	total labour force for preparing sorghum plots in no. of days	8.05	7.95	8.80
labor for weeding	total labour force for weeding sorghum plots in number of days	13.67	13.52	14.88
animal time	total animal use in sorghum production in number of days	5.75	5.89	4.64
fertilizer	kg of fertilizer used on sorghum plots	72.35	74.15	58.16
very bad rain	dummy = 1 if household judges overall production conditions as very bad, else 0	0.78	0.80	0.66

Source: authors' calculation using FNPP data set

Land endowments are expressed by the operated land area and its squared value to control for differences between smaller and larger landholdings. Table 5.6 indicates the sample population comprises very small average size of landholdings (4.2 timmad corresponding to slightly more than 0.5 ha).

Household demographic variables include household size, dependency ratio (i.e. ratio between dependants and labour force within the households), ethnicity and gender. Agricultural knowledge and experience, expressed by years of formal education and age of the household head complement household demographic information. On average, households consist of seven family members, with a forty-year old household head and with a low level of education. 90% of the sample households belong to the Oromo ethnic group and only 7% are headed by females.

Access to seeds is facilitated by networks at different levels (see Nagarajan and Smale, 2006; Winters et al., 2006; Lipper et al., 2009) as expressed by a number of seed-distribution related social capital variables such as dummy-variables for inter-household seed exchange (65%), intra-community farm-associations (14%), inter-community organizations that provide seeds (27%) and HCS-participation (47%).

Market accessibility is controlled for by distance to the closest city for the remoteness of large hub-markets and by distance to the next smaller local market. Distance to input shop is a proxy for the accessibility of farm inputs that may be needed for certain technologies that MV adoption requires (Benin et al., 2006). With an average of almost four hours to the next city, 9 km to the next market and 20 km to the next input shops, sorghum household farms in the sample can be considered rather remote.

Information about soil colour, as a proxy for fertility, as well as data on slope, irrigation and altitude reflect the agro-ecological environment in which the farms operate. Data show that land quality is on average poor with steep slopes and poor soils, although some variation is reported given the values of standard deviation[46]. Dummies for the woredas of Meta and Chiro are included to control for regional fixed effects.

Variables that reflect households' ability to cope with risks include agricultural and non-agricultural assets as well as livestock. Most households are very poor, holding very little assets. The highest values, although still very low, are through livestock holdings[47]. Access to seed aid (31%) represents a kind of ex-post emergency assistance and thus a sort of insurance mechanism. Last but not least in this group of variables, 43% of the household report credit constraints, representing yet another difficulty for coping with downside risk production.

Climatic risk variables are proxied by the number of times sorghum stresses occurred in the previous ten years (on average nearly 4 per household between 1991-2001) and by the number of

[46] Not reported here.
[47] One ETB corresponds to 0.12USD at the end of 2002.

substantial harvest losses due to drought in the same period (on average 3 per household between 1991-2001). While the former variable reflects risks associated with sorghum production, the latter controls for risks at a larger scale, such as livelihood vulnerability.

Sorghum production inputs include the operated land area, labour time, both human and livestock labour used in cultivation (land preparation, planting and weeding) in addition to fertilizers. The use of human and animal labour as well as fertilizers is rather low, indicating that sorghum production in the study site is not labour-intensive with fairly low capital inputs.

Weather conditions are proxied by a dummy for households that reported overall production conditions in 2002 as having been very bad (78%). Finally, the Berger index for relative abundance is included as a measure for intra-crop diversity to check its potential role on influencing the chances of crop failure.

5.4.2 Econometric results

Regression results for the determinants of MV adoption are shown in table 5.7. Household preferences seem not to play a key role in adoption decisions, as only age of the household head is weakly significant. Contrary to what has been found in many other contexts (e.g. Bellon and Taylor, 1993; Benin et al., 2006) agro-ecological variables do not seem to influence adoption decisions either.

On the other hand, regional dummies are highly significant indicating that the likelihood of MV adoption is higher in Dire Dawa, where modern sorghum varieties have been distributed by external organizations (Mulatu, 2005) and where access to market is relatively easier than in the other woredas. In addition variables expressing access to markets and to social capital seem to be among the most crucial factors in adoption decision, similar to findings from Winters et al. (2006) and Benin et al. (2006) for variety choice and seed access. Adoption of improved varieties of sorghum is positively correlated with proximity to local markets. Even though farmers reported no difficulties in accessing seeds of MV as described in section 5.2.2, these regression results imply that seed supply networks are indeed more effective when built on local market transactions. Seed exchanges on a more ad-hoc one to one or as-needed basis reduces the likelihood of adopting improved seed by 8.2% supporting the observation that informal transactions facilitate the exchange of traditional varieties, as reported in section 5.2.2. Against expectations, participation in the HCS program, aiming at the distribution of varieties, was not found to promote modern sorghum variety adoption

Contrary to the findings of many other studies (see e.g. Bellon and Taylor, 1993; Benin et al., 2006), the probability of MV adoption was not significantly affected by size of landholding, asset holdings nor credit accessibility. Findings of this study suggest that in the Hararghe region MVs are neither planted by farmers with larger landholdings as a form of experimentation, nor by farmers with a higher ability to bear the risks of such a technology adoption. In this context, however, it is important to stress that landholding is relatively limited and scattered to allow for such experimentation.

Table 5.7: MV adoption: Maximum-likelihood estimate of the bivariate probit model

variable	dy/dx	P>|z| value
operated area	-0.018	0.258
opretaed area squared	0.008	0.534
household size	-0.009	0.210
dependency	0.004	0.693
ethnicity	-0.085	0.122
female head	0.002	0.972
age head	0.009*	0.084
age head squared	-0.906*	0.099
education	0.003	0.23
seed exchange	-0.082***	0.007
farmers association	0.068	0.124
seed organisation	-0.035	0.188
HCS	0.025	0.431
closest city	-0.003	0.814
distance to market	-0.006***	0.004
distance to inputshop	-0.002	0.282
Meta	-0.136**	0.038
Chiro	-0.150***	0.007
altitude	0.006	0.531
black soil	0.031	0.225
gentle terrain	0.044	0.103
irrigated	-0.001	0.975
agricultural assets	0.001	0.420
non-agricultural assets	0.001	0.343
livestock	0.000	0.849
credit restricted	0.010	0.689
seed aid	0.010	0.735
sorghum stresses in the past	0.011*	0.072
harvest losses in the past	-0.037***	0.004
constant	-0.742	0.589

Notes: **Asterisk** (*), double asterisk (**), and triple asterik(***) denote variables significant at 10%, 5%, and 1% respectively. **Marginal effects** of the explanatory variables on the dependent variables are calculated for a one unit change holding all other variables constant at their mean, but of **dummy variables** for a discrete change from 0 to 1, of dependency ratio for one more dependent, of **closest city** for one more hours of travel time, of **altitude** for an increase by 100m, and of **all assets** for an increase by 10ETB.

Source: authors' calculation using FNPP data set

Most interestingly, both climatic risk variables enter the regression significantly, but with contrary signs. The average farmer, i.e. holding all variables at their mean, is 1.1% more likely to adopt MVs for each additional time sorghum stress was experienced in the past ten years, and 3.7% less likely to do so, for each additional substantial loss of harvest due to drought they experienced. Thus, farmers who are subject to moderate production risks seem to adopt MVs to mitigate the risk of sorghum failure. Yet farmers that experienced catastrophic risks, such as complete harvest losses, are less likely to do so, relying on landraces to maintain food security. In other words, non-adoption appears to be the “safety-first” strategy of the most vulnerable households.

This finding is supported by the results in Table 5.8 showing the drivers of sorghum failure in a year of extreme drought. Controlling for exogenous factors such as agro-ecological conditions and input variables, and holding all these variables constant at their mean values, we find that MV adopters are 35% more likely to experience failure of at least one of their planted varieties at a 10% significance level. The MVs used in the Hararghe region are bred with early maturity traits and do not thus seem to be an efficient means of risk mitigation, as they seem to be more likely to fail under adverse rainfall conditions. Early maturing varieties provide drought escape rather than drought tolerance, which our results suggest are less appropriate for risk management in the context of the study site.

Table 5.8: Sorghum-failure: Maximum-likelihood estimates of the bivariate probit model

variable	**dy/dx**	**P>|z| value**
operated area	-0.033	0.256
opretaed area squared	0.027	0.243
age head	-0.007	0.438
age head squared	-0.322	0.425
education	-0.009*	0.059
labor for planting	-0.011**	0.044
labor for land preparation	0.005	0.183
labor for weeding	0.003	0.161
animal time	0.013**	0.036
fertilizer	0.000	0.965
very bad rain	0.220***	0.000
Meta	0.343***	0.000
Chiro	0.385***	0.000
altitude	-0.003	0.816
black soil	-0.098**	0.045
gentle terrain	-0.049	0.341
irrigated	-0.124**	0.025
MV	0.351*	0.073
berger index	0.267*	0.082
constant	-1.253	0.16

Notes: **Asterisk** (*), double asterisk (**), and triple asterik(***) denote variables significant at 10%, 5%, and 1% respectively. **Marginal effects** of the explanatory variables on the dependent variables are calculated for a one unit change holding all other variables constant at their mean, but of **dummy variables** for a discrete change from 0 to 1, of **altitude** for an increase by 100m, and of berger-index for a change in the index from 1 to 2.
Source: authors’ calculation using FNPP data set

Land quality variables, such as access to black soil or irrigation were all found to decrease the likelihood of sorghum failure, as would be expected. The question arises whether crop failure associated with MV adoption is linked to land quality. Are the adopters on poor quality lands the most vulnerable to failure, and do sorghum improved varieties need to be produced under relatively good conditions in order to reduce downside risk? To explore this issue further we created variables measuring the interaction between land quality variables and MV adoption. The addition of these variables do not greatly change any of the coefficients in the estimations however, and the interaction terms are not significant, indicating that the MV crop failures cannot be linked solely to land quality; but rather a more complex set of factors is at work. Furthermore, the risk of crop failure increases by 26.7% when moving from a fully specialized system to a system where land is more equally distributed across a wider range of varieties, as indicated by the berger index. This result is not unexpected, as the more varieties planted, the more likely it is that one of these varieties will fail in response to rainfall conditions. [48]

The highly variable pattern of rainfall and weather conditions in the area unsurprisingly has a significant impact on increasing the likelihood of crop failure. Households affected by very bad rainfall conditions are indeed 22% more likely to experience crop failure. In addition, location specific effects, expressed by location dummies, are another important determinant of sorghum failure. In particular, households in Meta and Chiro woredas are significantly more likely to have a crop failure in sorghum than households residing in the area of Dire Dawa.

Last but not least, increasing the level of education appears to be one important way to reduce the likelihood of experiencing crop failure. More educated farmers are indeed more likely to be able to avoid crop failures.

5.5 Conclusions

The analysis conducted provides interesting insights on the role of downside risk production on MV adoption as well as on the potential of MV adoption to reduce the probability of crop failure. The analysis indicates that exposure to weather variability plays a key role in the decision to adopt sorghum MVs in Eastern Ethiopia, along with access to markets and social networks. Farmers who experienced moderate production stresses and climatic risk tend to adopt MVs, while those who have been most vulnerable to extreme weather events, mainly consisting of droughts that have led in the past to crop failure, prefer to stick to landraces. This finding suggests that the sorghum MVs currently available in the area are not an effective means of coping with the catastrophic risk that drought represents in the study site. However, MVs of sorghum in the area were bred with the purpose of drought escape rather than for drought tolerance. In other words, the MV available in the area require moisture over a shorter period than most landraces, thus providing an higher likelihood of harvest or offering the alternative to plant another crop or variety in the second season of the year. Whilst these MV offer such traits they are more susceptible to failure if rainfall shortages occur over the period they are grown. This conclusion is supported by results showing that MV adopters are more likely to suffer from crop failure in a year of extreme drought, like the one analyzed, when controlling for exogenous

[48] The inclusion of other diversity measures in the crop-failure model does not provide any information on the extent to which sorghum diversity does influence sorghum performance.

factors such as other input variables and agro-ecological conditions. While it is possible that the rainfall in the 2002-2003 year was so scant as to be insufficient for even short season varieties to provide some harvest, different results could be experienced in milder drought years.

Effective risk production coping strategies have assumed even greater importance in the context of climate change and the predicted increase in extreme weather events. Improving germplasm to produce varieties more adaptable to climatic changes and extreme weather events is a crucial means of achieving food security that will become even more important as climate change progresses. While the findings of the present analysis suggest the adoption of improved sorghum varieties does not represent an effective risk management strategy, the finding is confined to the specifics of the type of drought risk present, as well as the MVs available and the production and marketing context of this study. However, broader implications can be derived.

First is the importance of considering the nature of the risk to be confronted when looking for effective coping strategies. The type of germplasm needed to cope with catastrophic versus chronic risks is different, and this affects the farm level demand and use of varieties (Anderson et al., 2006). In this case, it appears that landraces are more suitable for coping with catastrophic risks, whereas the types of MVs currently available are more suitable for managing chronic risk.

Secondly preserving the richness of infra-crop diversity and promoting the accessibility to a diverse range of crop varieties may be an important part of facilitating farmer capacity to manage their risk. A number of studies, including McGuire (2005) and more recently Di Falco et al. (2007) and Di Falco and Chavas (2009) found that diversity within crops managed on Ethiopian farms is an important way of reducing downside production risk. Likewise, in the Haraghe region sorghum farmers use infra-specific diversity as a strategy to manage moderate production risks even though such intra-crop diversity is undermined by regularly occurring droughts.

Thirdly, crossover effects seem to play an important role under the production conditions of eastern Ethiopia, where landraces perform better than improved varieties due to marginal production conditions and limited use of complementary inputs. In this situation, the potential for improved varieties to outperform landraces seems to be limited, since the crop is used primarily for subsistence purposes, with low rates of complementary input use and low farm level returns (Ahmed et al., 2000). These are factors that can also explain the low levels of MV adoption in the area in combination with breeding efforts that are mainly tailored to more favourable production areas (Bellon, 2006).

Fourth, the results presented indicate that given the production and marketing conditions found in the area, the adoption of improved sorghum varieties increases rather than reduces on farm diversity measured by different types of diversity indexes including the number of varieties, evenness and relative abundance. Yet the data indicate that farmers who do adopt MVs plant the majority of their sorghum production area to these improved varieties. Whilst MV adopters might be trading the potential of achieving higher yields with MVs for the greater security that LRs can provide, our results suggest this as a risky strategy given the potential harsh weather conditions in the area and given the limited capacity of the farmers to access other forms of coping strategies.

Finally, given that sorghum is the most important staple crop in the area and a crucial crop to achieve food security under the area's difficult weather conditions, the results suggest that focusing further breeding research on drought tolerance traits would be beneficial. Although not generalisable to any level and type of drought or weather conditions, given also the restricted types of MV in our sample, our results suggest that while adoption of modern varieties bred for drought escape may be risk reducing under certain conditions, they are likely to increase the risk of crop failure in situations of high climate risk.

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Chapter 6

Sowing the seeds of social relations: the role of social capital in crop diversity[49]

Abstract: *This paper explores the relationship between social capital and crop diversity. The study is conducted in an area of Ethiopia where inter-specific diversity is significant and where diversity includes crops that are important in terms of their genetic value given the country is a centre of origin or diversity for these crops. The results indicate that linking social capital (links with outside groups) does not lead to a decline in crop diversity but actually increases it, suggesting that interventions by formal organizations do not necessarily lead to reduction in inter-specific diversity. However, the results also suggest that households with strong social links within a community (bonding social capital) are less likely to be diversified. Policies that seek to promote sustainable utilization should be wary the major role played by grassroots organization.*

[49] This chapter is based on the working paper *Sowing the seeds of social relations: the role of social capital in crop diversity*, by P. Winters, R. Cavatassi and L. Lipper, FAO-ESA working paper series, ESA 06/16. R. Cavatassi contributed on data analysis and writing, particularly, sections 6.3 and 6.5.

6.1 Introduction

Crop diversification is a key strategy in agricultural and rural development programs targeting low income agricultural producers, due to the opportunities it offers for managing risk and heterogeneous production conditions, as well as increased income generation through entry into new markets. The promotion of crop diversification has important implications for agricultural biodiversity. Modern agriculture is increasingly reliant on a small number of crop species with three cereal crops; wheat, maize and rice, providing over 50% of the world's plant derived calorie intake (FAO, 1998). Farming systems with high levels of inter-specific crop genetic diversity are more likely to include production of minor or indigenous crop species which are high in diversity (FAO, 1998). Entire pools of genetic resources are lost when a crop species is no longer cultivated and becomes extinct. In addition, inter-specific diversity (i.e. diversity across crops) is likely to have impacts on intra-specific diversity (i.e. diversity within crop), as the two may be either substitutes or complements. With implications for agricultural productivity and human welfare as well as agricultural biodiversity, understanding the determinants of the diversity of crop species grown by farmers is an important area of inquiry. The research also has important policy implications as increasing attention is being focused on strategies and policies to promote the sustainable utilization of plant genetic resources which incorporates both environmental and development objectives. Both the International Treaty on Plant Genetic Resources (IPTGR) and the Convention on Biological Diversity (CBD) require signatories to adopt policies to promote the sustainable utilization of plant genetic resources. While these may be desirable objectives, the policy instruments that should be used to attain sustainable utilization are not clearly identifiable. In fact, it has been argued that some agricultural policies, such as the promotion of modern crop varieties, while achieving the objective of increased on-farm productivity may actually lead to a narrowing of the genetic resource base[50] which runs counter to the principles of sustainable utilization. Questions clearly remain regarding the best methods of achieving the objectives of the ITPGR and CBD.

The literature on farmer motives for crop diversification indicates that both supply and demand factors determine diversity levels both at the farm and more aggregate levels. Three key factors emerge as important motives driving farmers' "demand" for crop diversity: i) managing risk, ii) adapting to heterogeneous agro-ecological production conditions; and iii) diversification to meet market demands. There is a particularly rich literature on risk management and diversification in

[50] Brush (1995) acknowledged that the adoption of MVs caused genetic erosion, while some other studies have found that the introduction of HYVs had broadened the genetic portfolio of varieties held by farmers (Brush 1992; Bellon 1996; Smale 1997).

agriculture.[51] In this literature, crop diversification is viewed as providing an ex ante means of insuring against failure in any one crop, which is particularly important in situations where formal insurance mechanisms are non-existent and ex post coping strategies are limited. In addition, crop diversification is associated with a diminished risk of pest and disease invasion contributing to stability of yields (Sullivan, 2003; Guy et al., 2005). Pingali and Rosegrant (1995) also argue that agricultural diversification is an important strategy to manage price risk as well, but only at a macro level, with little impact at the household level. Maintaining crop diversity has also been found to be a strategy adopted by farmers to exploit the highly heterogeneous agro-ecological conditions, as well as to efficiently utilize other factors of production such as labour and animal power and avoid bottlenecks particularly when off-farm opportunities are available (Worede et al., 2000). Finally, crop diversification is considered an important step in the transition from subsistence to commercial agriculture. With economic growth, households start to produce for markets and adopt new crops to meet demand. In the transition from subsistence to commercial production farms become semi-commercial with mixed cropping systems which are associated with higher levels of crop diversity than subsistence systems (Pingali and Rosegrant, 1995). As commercialization proceeds, however, farms become more specialized although the agricultural economy may be more diversified.

Recognizing these motivations for crop diversity, one key factor in determining actual crop diversity outcomes relates to access to crops and specifically to the seeds for planting. In most developing countries, the access to seeds and information about crops and seeds is often obtained through non-market channels including formal organizations, such as the government, international donors and NGOs, and informal networks that include some form of association with other households. In the social capital literature, these are referred to respectively as linking social capital and bonding social capital (World Bank, 2000). Social capital is defined as a variety of different entities with two common elements: they all consist of some aspect of social structure and they facilitate actions of actors within that structure (Coleman, 1988). The entities have mutually beneficial goals and are usually characterized by trust, cooperation, involvement in the community, and sharing (Putnam, 1995). Linking social capital consists of vertical ties between distinct social and economic classes such as between poorer households and those with influence in formal organizations including government agencies. This form of social capital involves intercommunity links. In contrast, bonding social capital refers to the strong horizontal ties connecting family members, neighbours and business associates usually at an intra-community level. These groups tend to be more homogeneous in that they share a similar economic and social background. This can be beneficial in that it allows for easier flow of information but it can be limiting in that the similarities between participants limit the range of information. According to some theorists, the process of economic development involves individuals

[51] See for example Newberry and Stiglitz (1981) Chavas and Holt (1990), Rosenzweig and Binswanger (1993) and Fafchamps (1999).

moving from forms of bonding to linking social capital as they proceed from “getting by” to “getting ahead” (Foster et al., 2003).

In this chapter, we focus on how seed supply limitations influence crop diversity and the role that social networks play in overcoming this barrier. We focus on social capital as it is considered an important feature of informal seed systems which involves seed exchanges in the context of social interaction. The expectation is that different forms of social capital influence access in a unique manner and thus have a differential impact on the farm level choice of crop and variety to plant, and therefore on-farm crop diversity. Much of the literature on seed systems cites the importance of exchanges within networks built on family, community or other social ties, a form of bonding social capital (Almekinders et al., 1994; Badstue, 2004; McGuire, 2005). With this type of social capital, ties are likely to be stronger than in linking social capital and thus are expected to provide better access. However, given the close geographic proximity of such ties, there may be lower crop diversity available through such ties. On the other hand, linking social capital, whose vertical structure requires connections to individuals and organizations outside the community, might provide greater choices among crops and varieties to plant. Although these ties may be weaker, the greater availability may lead to higher levels of on-farm crop diversity, as farmers can select and plant the materials needed to meet heterogeneous production and consumption conditions.

To meet the objectives of this chapter the remaining sections are organized as follows. In section 6.2, we develop a model that examines how agricultural household decision-making determines on-farm diversity and the role of social capital in this process. Section 6.3 then presents the necessary background information on the study site as well as basic information on the method of data collection and a description of the data. Section 6.4 presents the empirical approach used to analyze the data while section 6.5 provides results of the analysis. Finally, section 6.6 provides conclusions.

6.2 Crop diversity, social capital and the agricultural household model

To understand on-farm crop diversity and the influence of social capital on diversity, it is important to begin by considering the behaviour of agricultural households with respect to crop choice. A common approach toward investigating household decision-making in these contexts is to employ an agricultural household model where households are both consumers and producers of agricultural goods and face market constraints (Singh et al., 1986). In the case of on-farm crop diversity, this approach has been formally used by Van Dusen (2000) and Van Dusen and Taylor (2005) and conceptually by a number of other authors (see Smale et al., 2005). In this chapter we follow a similar approach developing a model that helps understand the factors that influence household decision-making and lead to a certain crop diversity outcome.

While following the Van Dusen and Taylor (2005) approach, the model presented below differs from their model in one key way. In their model, agricultural households choose, among other things, output directly and the household maximization problem yields a set of optimal production levels. Assuming that the household does not value diversity itself, it is this optimal set of production levels that determines the diversity outcome. Since these optimal production levels depend on prices, production constraints and other factors, diversity also depends on these factors. The approach taken in this chapter is similar except that instead of choosing output directly, output is considered a function of the resources allocated to crop production, particularly land and labour resources. As will be seen, specifying the model this way allows for examining the trade-offs between using household resources, particularly labour, for crop production or for other activities including non-agricultural activities and investment in social capital. Including the relationship between diversity and these activities in the analysis is important in the context of this study, which is why this approach is taken.

Before proceeding to the model a note on the relationship between crops and seeds is necessary. On-farm crop diversity is related to the crops a household chooses to produce, and therefore the seeds planted to produce those crops. In the context of developing countries such as Ethiopia, the grain produced for consumption and sale is often no different than the grain used for seed (Sperling and Cooper, 2003). Farmers often use seed saved from their own output for planting or obtain grain from other sources to use as seed that could also be consumed. If a market for a particular crop does not exist, it is unlikely that the seed market would exist independently. For simplicity, the model below focuses on crop production and the allocation of resources when markets for particular crops do or do not function. For our purposes, this can be considered equivalent to the seed market not functioning. Either situation will have a similar effect on on-farm crop diversity.

Proceeding to the model, consider an agricultural household that maximizes utility of consumption of crops, X_i for $i=1,\ldots,\overline{X}$ and a non-agricultural consumption good, C. Household utility depends on the preferences and other factors, z^h, that are determined by cultural factors, socioeconomic conditions and other household characteristics. The household is endowed with family labour, $\overline{L}$, and land, $\overline{A}$. Households are assumed to be unable to rent land in or out and, hence, land is a fixed factor of production. Similarly, households are assumed to be unable to hire in workers and are therefore constrained by their labour endowment. The household produces crops, Q_i, for $i=1,\ldots,\overline{X}$, using a combination of labour, L_i, and land, A_i, subject to production constraints particularly agro-ecological characteristics, z^p. The ability to obtain crops for consumption and produce crops depends on characteristics of the market, z^m, which includes such factors as the transaction costs in purchasing and selling crops. Under certain circumstances, transaction costs may be sufficiently high to make a particular crop inaccessible. The household can also allocate labour, L_y, to a non-agricultural productive activity to earn outside income, Y, the returns to which depend on conditions in the non-agricultural market, z^y.

To incorporate social capital into the model, note that in this context the benefits of such ties are in the provision of crops (or seeds) under certain circumstances. Presumably, the right to such crops requires some sort of investment on the part of the household both in time and other costs. For our purposes, we assume the only cost is in the time devoted to developing and maintaining such ties, $L_{s.}$ This time input provides the household with additional crop for consumption, *S*, and depends on local conditions that influence access to social capital, z^s.

The household can therefore obtain agricultural output, or equivalently seed, through production, through market channels if the market functions adequately and through the use of non-market channels by using social capital. For simplicity, we assume two extreme cases of market functioning for agricultural goods: one in which the market functions perfectly and the other in which there is no market for the good such that $X_i = M, N$ where *M* is the marketable crop and *N* is the non-market crop. This assumption simplifies matters by allowing us to consider only two commodities and to consider the extreme of zero transaction costs in the market and transaction costs that are so high as to make the market not function at all. The household therefore produces the consumption commodity *M* in the amount Q_m using a combination of labour, L_m, and land, A_m, and commodity *N* in the amount Q_n using a combination of labour, L_n, and land, A_n both subject to production constraints, z^p. The household can buy or sell Q_m if production levels do not match the desired consumption *M*. For commodity *N*, the household can obtain more than Q_n through the use of its social capital *S*.

The agricultural household model can be therefore expressed as follows:

$$\underset{M,N,C,L_i,A_j}{Max} U\left(M, N, C; z^h\right) \tag{6.1}$$

subject to: $$Y + p_M\left(Q_M - M\right) = p_C C \tag{6.2}$$

$$N = Q_N + S \tag{6.3}$$

$$Q_M = Q_M\left(L_M, A_M; z^p\right) \tag{6.4}$$

$$Q_N = Q_N\left(L_N, A_N; z^p\right) \tag{6.5}$$

$$S = S\left(L_S; z^s\right) \tag{6.6}$$

$$Y = Y\left(L_Y; z^y\right) \tag{6.7}$$

$$\overline{L} = L_M + L_N + L_S + L_Y \tag{6.8}$$

$$\overline{A} = A_M + A_N \tag{6.9}$$

where p_C is the price of the consumption good and p_M is the price of the market crop.

Given the objective function to maximize and our constraints, first-order conditions would determine the optimal labour, land and consumption levels of the three goods. Since our interest is in understanding crop diversity, we are particularly interested in the optimal level of land and labour allocated to production, which are defined as follows:

$$L_j = L_j^*\left(\overline{L}, \overline{A}, p_M, p_C, z^h, z^p, z^y, z^s\right) \text{ for } j=M, N, Y, S \tag{6.10}$$

$$A_j = A_j^*\left(\overline{L}, \overline{A}, p_M, p_C, z^h, z^p, z^y, z^s\right) \text{ for } j=M, N \tag{6.11}$$

The optimal level of land and labour are then a function of initial land and labour endowments, prices, household characteristics, production (agro-ecological) characteristics, characteristics of the nonagricultural economy and conditions that influence social capital formation.

Returning to the more general formulation of the model, the optimal levels of labour and land determine the optimal quantities produced of each crop as follows:

$$Q_i = Q_i^*\left(L_i^*\left(\overline{L}, \overline{A}, p_1, ..., p_{\overline{X}}, p_C, z^h, z^p, z^m, z^y, z^s\right), A_i^*\left(\overline{L}, \overline{A}, p_1, ..., p_{\overline{X}}, p_C, z^h, z^p, z^m, z^y, z^s\right)\right)$$

Or

$$Q_i = Q_i^*\left(\overline{L}, \overline{A}, p_1, ..., p_{\overline{X}}, p_C, z^h, z^p, z^m, z^y, z^s\right) \text{ for } i=1\ldots \overline{X} \tag{6.12}$$

Following Van Dusen and Taylor (2005), we assume that households do not value diversity in itself and that the diversity outcome is the result of household behaviour with respect to the choices of resources allocated to different crops. Diversity, *D*, can be expressed as a derived demand as follows:

$$D = D\left(Q_1^*\left(\overline{L}, \overline{A}, p_1, ..., p_{\overline{X}}, p_C, z^h, z^p, z^m, z^y, z^s\right), ..., Q_{\overline{X}}^*\left(\overline{L}, \overline{A}, p_1, ..., p_{\overline{X}}, p_C, z^h, z^p, z^m, z^y, z^s\right)\right)$$

Or

$$D = D^*\left(\overline{L}, \overline{A}, p_1, ..., p_{\overline{X}}, p_C, z^h, z^p, z^m, z^y, z^s\right) \tag{6.13}$$

The results indicate that diversity is a function of initial endowments of labour and land, prices, household characteristics, production constraints, characteristics of the non-agricultural economy and conditions that influence social capital formation. This relationship is similar to the model presented by Van Dusen and Taylor except that it adds the characteristics of the non-agricultural economy and the importance of social capital and explicitly includes initial endowments.

Generally, crop diversity is measured through different indices based on data, on the number of crops planted and the area planted of each crop (Magurran, 1988; Meng et al., 1998; Baumgärtner, 2004). The analysis above assumes that the household decision can then be viewed as one where within a given community or region there are $\overline{X}$ crops available but access to those crops, which is determined by the factors noted in equation (6.13), may make it so that household does not allocate land to all crops and allocates different amounts of land to individual crops. This allocation decision partially determines the on-farm crop diversity outcome.

Along similar lines, the household can decide whether to allocate labour to non-agricultural productive activities or for the development of social capital. With regard to the latter, the model can easily be extended to distinguish between linking (vertical ties) or bonding (horizontal ties) social capital with households choosing to allocate labour to neither, one or the other or both, based on the marginal value of allocating labour to developing each type of social capital. Such an allocation would depend on the value to the household of obtaining access to additional output for consumption from creating these ties.

The model predicts that diversity will be a function of the factors identified in equation (6.13) and formalizes what is generally included in empirical analysis of diversity outcomes. The addition of this model is to explicitly show the role social capital may play in influencing diversity outcomes. Below we test the impact of linking and bonding forms of social capital on-farm level inter specific diversity.

6.3 The Ethiopian context and data

The data used in this paper was collected as part of a study to examine the relationship between seed systems and crop utilization patterns in the eastern part of Ethiopia. Ethiopia is a centre of origin and diversity for several agricultural crops and the population is highly dependent on low productivity agriculture and food insecurity rates are high.

The specific study site is located in the Hararghe zone, an area in the eastern part of Ethiopia that has been a repeated recipient of both food and seed emergency relief supplies because of chronic food deficits and problems of seed insecurity. Hararghe is also of interest because it is considered a primary centre of origin for sorghum and most varieties planted in the region are landraces, although formal sector breeding has been undertaken for almost 25 years (McGuire, 1999). In addition to sorghum, farmers in Hararghe also produce maize, wheat, haricot bean (often intercropped with sorghum and maize), khat – a stimulant and mild narcotic as well as a profitable cash crop – and a host of other crops depending on local conditions. Because of the food security situation there have been numerous interventions in the seed system by the government and NGOs. Among the NGOs of particular interest is the Hararghe Catholic Secretariat (HCS), which has been active in the Hararghe region since the early 1990’s with a range of seed system interventions, including seed selection, multiplication and distribution for both landrace and improved varieties of wheat, sorghum and haricot bean.

Studies of seed systems in the Hararghe area indicate that the informal seed sector is the primary source of seed supply (Storck et. al, 1991; Mulatu, 2003; McGuire, 2005). For most crops, saved seed from the farmer’s own harvest is the primary seed source. Other important sources are exchanges with family members and friends, markets, extension program and emergency seed relief. The relative importance of the source varies among crops and production season. Social relations are an important part of the seed system and thus seed sourcing decision. McGuire (2005) finds that access to off-farm sources of supply is critical for a high percentage of farmers and that social networks both within and among communities are an important source of such supply. He also notes that social interactions can be an important aspect even in market exchanges which require some level of trust between buyer and seller and in some cases involve patron-client relationships. Mulatu (2004) finds the informal seed sector very active in the provision of wheat seed, primarily consisting of “recycled” modern varieties that are exchanged under a wide range of arrangements, ranging from gifts to cash sales. Wheat and sorghum are representative of very different types of crops; wheat is an introduced crop to the area and most seeds are improved varieties, as compared with sorghum which is native to the zone and has a high level of local diversity. Wheat is used primarily as a cash crop and sorghum for subsistence. Yet in both cases the informal seed sector is the primary source of seeds.

The data used in this paper was designed to evaluate the effects of the HCS intervention and to minimize sources of variation not related to seed systems. The sample was limited to woredas (counties) where HCS had been active and included peasant associations (PAs) only within the mid and highland areas, which have similar agro-ecological zones and fairly uniform cropping patterns. PAs that participated with the HCS program and those that did not were included in the sample. In the three woredas, a total of 30 PAs were selected: 15 PAs in which HCS project had been implemented and 15 similar PAs in which HCS did not distribute seeds. The principle governing the selection of non-participant PAs (i.e. the control group) was to identify those as similar as possible to the HCS project areas and households. The program targeted farmers who were known to be good farmers and with good farming conditions (in terms of land owned, type of soils etc), but who had fallen into debt due to crop failures beyond their control. Within the communities that HCS selected for their project, the PA committee nominated candidates for project participation based on HCS criteria.

To select the sample, households were divided into three groups: 1) households that participated in the HCS seed program (HCS); 2) households that did not participate, but lived within communities where the program was implemented (non-HCS I), and 3) households that did not participate and lived in communities where no program was implemented (non-HCS II). Approximately 24 households from each of the 15 HCS PAs were randomly selected from a list of names of HCS participants for inclusion in the sample. The remainder of the total sample was equally divided between the two types of non-participant groups. Non-participants in project area were selected for the sample with the assistance of the PA committees. PA committees were asked to identify farmers within the community that fit the criteria but who had not (yet) participated in the HCS project. Since the demand for project participation was greater than HCS could meet, there were ample numbers of households on the waiting list for HCS participation. This list was used as the non-HCS I sample frame. Similarly, for households in non-HCS communities (non-HCS II), households within these areas were selected for inclusion in the PA sample frame through a process of consultation with PA committees.

A number of different survey instruments were used to collect data on household and community characteristics, crop production and the cropping systems, but this paper is based primarily on the household and community data. Of the 720 households in the sample, data for 699 was complete enough for this analysis.[52] The scope of the survey is the cropping season of 2002. The household survey instrument was implemented in two rounds in order to ensure sufficient detail on agricultural production. The first round was conducted towards the end of the Meher (main crop) planting season

[52] There appears to be no systematic differences between the 21 households with some missing data and the remaining households. Dropping these observations does not appear to pose a problem for the analysis.

in August 2002. The second round was done after the harvest of the Meher crop in early 2003. In each of the 30 PAs surveyed, data on community characteristics was gathered through the use of a community level survey instrument administered to key informants, usually PA leaders.

Table 6.1 presents summary statistics of the households included in the analysis. Households have on average 3.4 units of household labour defined as adults of over 14 years old and below 60. Less than 2% of households have one adult and just over 75% have two to four adults in the household. The remaining 20% of households have five or more adults. On average, households have access to 4 timmad of land. A timmad is equivalent to approximately one-eighth of a hectare so on average households have access to one-half of a hectare for farming. Ninety-two percent of households have less than eight timmads (one hectare) with the largest household holding less than three hectares. Given the widespread poverty in the area, the small size of holdings is not surprising. In terms of household characteristics, the average age of the household head is just below 40 and the average education of adults is only 1.1 years. Forty-two percent have no adult members with any education and only one percent has an education level of six years or more. The dependency ratio, measured as the number of children divided by the number of adults, is 1.24 on average suggesting for each adult there is over one child to feed. Given the high level of poverty, ownership of animal traction in the form of oxen is a key measure of wealth. On average household own 0.4 oxen but nearly two-thirds of households own no oxen.

Variability of production characteristics is likely to lead to a wider range of crops planted. To measure variability, we use the number of plots with different slopes, soil colours and soil texture. The data indicate that an average of 0.42 of the households' plots is of different slope, 0.48 of the plots have different soil types and 0.42 of the plots have different texture. In other words, two out of every five households have differing slopes, differing colours and differing textures, suggesting some household face some agro-ecological variability. Another measure of agro-ecological characteristics is the altitude of the plot. Data at the plot level however was not available so community level altitude was used. The average reported altitude is 2056 meters ranging from 1100 meters to 2650 meters.

In terms of market characteristics, 26.2% of households in the sample are found to be constrained in the credit market which is likely to influence their production decisions. Car access and distance to market are used as indicators of market performance with those with limited car access and further from cities facing greater market imperfections and transaction costs. Approximately one-third of households live in communities that are not accessible by car suggesting they are very remote. This is confirmed with the data on distance to the nearest city which shows an average distance of 103 kms. There is a wide range of distance to the nearest city however with the closer communities being within 7 km and the farthest at 346 km. In terms of alternative income generating activities of households, around one-half of households have at least one member who participates in off-farm activities.

The key variables of interest are the measures of social capital. First, note that by the design of the survey around half of the households participate in HCS. Furthermore, just fewer than 50% of households participate in some other organization, including other NGO’s, national and internationally based groups and the private sector. Of these other organizations approximately 90% focus on agriculture and 75% have a principal focus on seed provision. Thus these other organizations are likely to also be linked to diversity. These two types of affiliations – HCS and other organizations – are proxies for the household’s vertical ties or linking social capital. Second, households on average belong to two associations with nearly 30% belonging to three or more associations. This is used as a measure of horizontal or bonding social capital. The associations that households belong to are peasant associations (77% of households), self-help (idir) groups (77%), women’s groups (17%), farmers’ groups (14%) and other types of groups (18%) mostly focusing on production. Peasant associations (PAs) are responsible for the implementation of government decrees in the rural areas and all recognized household heads are supposed to be members of the PA. PAs are empowered by the government to form service cooperatives that are combinations of two or more peasant associations for the provision of basic economic services, such as production inputs, credit, consumer goods, and marketing services. Once a service cooperative is formed, members are required to pay fees to provide funding for the cooperative (Hogg, 1990). Self-help groups, referred to as Idir, are associations established among neighbours to raise funds that will be used during emergencies and can be characterized as traditional financial associations. Idirs are long-term associations that are informal, bottom-up, and widely practiced among Ethiopian (Bekerie, 2004).

Table 6.1: Household characteristics

Number of household = 699

Category	*Variable*	*All households*
Labor endowment	Household labor	3.4
Land endowment	Land access (timmad)	4.04
Household characteristics	Age of head (years)	39.7
	Average adult education (years)	1.15
	Dependency ratio	1.24
	Oxen owned	0.41
Production constraints	No. plots with different slope	0.42
	No. plots with different colored soil	0.48
	No. plots with different texture	0.46
	Altitude of PA (meters)	2056
	Credit constrained	26.2%
Market characteristics	Community accessible by car	67.1%
	Distance to closest city (km)	102.5
Nonfarm market	Participation in non-farm activity	50.8%
Social capital	Participation in HCS	51.6%
	No. organizational affiliations	0.48
	No. memberships in associations	2.03
Woreda	Dire Dawa	13.7%
	Meta	52.4%

Source: authors' calculation using FNPP-Ethiopia data set

To measure inter-crop diversity at the household level, three indices that are adapted from the ecological literature are used. The *richness index* is a count of the total number of crops that the household reports planting over the season of interest. The *Shannon index* expresses proportional abundance or evenness, accounting for the land shares allocated to each crop as well as the number of crops. The index gives less weight to rare species than common ones, but is more sensitive to differences to small degrees of relative abundances than the Simpson index, another widely used evenness index measure of diversity (Magurran, 1988; Baumgärtner, 2004). The *Berger-Parker index* of inverse dominance reflects the relative abundance of the most common species (Magurran, 1988; Baumgärtner, 2004), or in the case of this study, the most widely grown on each plot by each household.

In Table 6.2, the mean values of the three indices have been summarized. The count data indicate that households planted on average 2.73 crops during the period of study with a range from one crop to seven. Seventeen percent of households only produced one crop and the majority (74%) produced 2-4 crops. The Shannon and Berger-Parker diversity are based on area planted and are therefore left-censored when the household only produces one crop. In the case of the Shannon index by definition it is censored at 0 and in the case of the Berger-Parker index it is censored at 1.

Table 6.2: Diversity measures
Number of household = 699

Diversity measure	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Count	2.73	1.25	1	7
Shannon index	0.79	0.47	0.00	1.79
Berger-Parker index	1.92	0.74	1.00	4.53

Source: authors' calculation using FNPP-Ethiopia data set

6.4 Empirical approach to analyzing diversity

To evaluate the factors influencing diversity and in particular the role of social capital, we want to estimate equation (6.13). As noted in the previous section, diversity is defined using three measures, a count of the number of crops planted, the Shannon index and the Berger-Parker index. Since the count variable is the number of crops planted and takes a nonnegative integer value, a Poisson regression model is appropriate. Both the Shannon and Berger-Parker indices are censored at zero and one respectively and therefore a censored regression model is appropriate and a tobit model is used. Following the literature on agricultural diversity, diversity is specified as a linear function of the factors identified in equation (6.13).

Although efforts were made to create a sample with a proper control and treatment group that allows for the analysis of HCS participation and its effects on diversity, attempting to collect data that replicates an experimental design after the fact is always problematic. Even though the same criteria were used to select control groups as was used by HCS to identify participants, there is still the possibility that in a regression the coefficient on HCS will suffer from program placement bias. A number of steps are taken to avoid this bias. First, equation (6.13) includes a number of observable factors that, other than influencing diversity, may influence participation. Assuming common support, including these factors potentially limits bias in the HCS coefficient. Second, an instrumental variable approach is used to instrument HCS. The instruments used are those that are uncorrelated with diversity but influence participation thus overcome the bias that is caused by the correlation between participation and the error term. In the case of the count variable, using an instrumental variable approach with the Poisson model proved to be complicated. We therefore run a least squares regression to show that results for the least squares and Poisson are remarkably similar and proceed to use a standard instrumental variable approach for the count data. For the Shannon and Berger-Parker indices instrumental variable tobits are used. Finally, a third approach followed is taken from the evaluation literature. To evaluate the impact of HCS on diversity, a propensity score matching (PSM) procedure is used.[53] In PSM, the treatment group (HCS participants) is matched to a control group based on observable characteristics using a propensity score which is calculated using a probit on the probability of participation in HCS. In our case, we use non-participants in both the HCS and non-HCS communities as potential matches and a kernel-based matching procedure is used. After matching HCS participants with controls using this procedure, the difference between diversity in the treatment and control is determined to see how HCS influenced diversity. The benefit of this procedure over the other methods is that the PSM procedure confines attention to a matched sub-sample where there is common support and unmatched observations are dropped if appropriate (Ravallion, 2005). The range of methods employed to evaluate the impact of HCS on crop diversity is used to ensure an accurate assessment of impact. If the results are consistent across these different techniques, this provides greater support that the measure of impact is accurate.

6.5 Social capital and on-farm crop diversity

Table 6.3 presents the results for the analysis of on-farm crop diversity. Note that in all cases the regression is run using both actual HCS participation and predicted HCS participation following an instrumental variable approach. For the count variable, the least squares results are also shown and as can be seen are very similar to the Poisson. Recall that the count of the total number of crops is considered a measure of richness, the Shannon index expresses proportional abundance or evenness and the Berger-Parker index reflects the inverse of the relative abundance of the most widely grown crop by each household or the inverse of the degree of specialization into any one crop. The covariates included in the regressions represent the variables that are found to be determinants of diversity in equation (6.13) with the exception of the price variables. There are two reasons for excluding prices.

[53] See chapter 3 and 4 this thesis and Smith and Todd (2005) for discussion of this technique.

First, many of the farmers in this study do not sell or buy in the market and therefore there is no data available. Second, even if there was data available the reported price would not necessarily reflect the market price since the farm gate price would include transaction costs. Given the limited geographic area under which this study is conducted, within the country and given the similarities the woredas selected[54] we assume that market prices of the relevant commodities do not vary and thus do not include prices in the analysis. We proceed by examining each of the variables included in the regressions and discussing how they influence diversity as measured by each of these indicators. Note in all cases, the marginal effect of the variables calculated at the sample mean is reported rather than the coefficient. This allows for better comparison of the different regressions. Given that results for the variables other than HCS participation tend not to vary substantially across the basic regression and instrumental variable model the results of each specification are not specifically discussed except in the case of HCS.

According to equation (6.13), the household endowment of labour, $\overline{L}$, and land, $\overline{A}$, will influence the diversity outcome. The labour endowment is expected to be negatively related to diversity. A household with less labour resources and thus more binding labour constraint will be less able to spread labour over competing crop activities. The results do indicates a negative relationship between a household's labour endowment and diversity but in no cases is this relationship statistically significant. The land endowment is expected to be positively related to diversity at least for these very small size land holdings. Recall that households on average have one-half a hectare of land (4 timmad) and greater land holdings are likely to be employed with additional crops. The results indicate a significant positive relationship for both the count variable and the Shannon index. For the Berger-Parker index, the results are positive but insignificant. This indicates that farmers are using additional land to plant more crops and put more area into those crops but that the principal crop they produce still tends to dominate the production area.

The next set of variables control for household characteristics (z^h). The age of the household head indicates both the experience of the household in agriculture as well as the life cycle stage of the household. While positive in all cases, the age of the household head does not appear to significantly influence the number of crops produced but does affect the area of production as indicated by the significant results for both the Shannon and Berger-Parker indices. Older household heads appear to plant a more equal share of land to each crop. The results for adult education suggest that education leads to greater diversity as measured by the count variable and Shannon index. More educated households, possibly because they have better information, tend to plant more crops and have them more evenly planted. Finally, the dependency ratio measures the ratio of dependents to the number of adult labourers. Given that many households produce for home consumption this characteristics of the

[54] The woredas and villages were selected to ensure the less possible exogenous variability in terms of agro-ecology and socio-economic conditions.

household may influence crop choice. The results suggest that the ratio of dependents is negatively associated with evenness. This may be because households with more dependents feel compelled to produce more of certain food crops although based on the results from the Berger-Parker index this is not the primary crop. As noted, oxen ownership is a key indicator of household wealth given the high level of poverty in the study region. The results indicate that wealthier farmers tend to plant a greater number of crops which may be because they have a greater capacity to access seeds for these crops as well as draft power to cultivate different crops.

Measures of the production characteristics (z^p) of the farm are indicated by agroecological variables. The expectation is that greater variability in agroecology leads to greater diversity. The results provide strong support for this hypothesis and indicate that having plots with different slopes and different soil textures positively influence diversity. Having plots with different colours, however, does not appear to influence diversity. Although PAs are at a range of altitudes this does not appear to influence diversity in any way.

Characteristics of the market (z^m) and conditions in the nonagricultural market, (z^y) are the next set of variables to consider. When markets for credit are limited the expectation is that this limits the ability of household to access seed of certain crops. Thus a negative relationship between credit constraints and diversity is expected. The results provide strong support for this hypothesis with negative and statistically significant results for all regressions. Accessibility by car and distance to the near city are both attempts to measure transaction costs with inaccessible and more distant communities facing higher transaction costs than accessible and less remote communities. Higher transaction costs can impact diversity both through output markets and seed markets. High transaction markets limit the opportunity to buy and sell output and thus the household will produce based on their own requirements rather market considerations. The expectation is that this would lead to greater diversity if the market limits the range of crops households produce. On the input side, higher transaction costs may limit the ability of households to access seed and thus certain crops thereby limiting diversity. The results of the analysis indicate a negative relationship between accessibility and distance to market and diversity. These relationships are significant for both the Shannon and Berger-Parker indices indicating that areas accessible by car have lower diversity and those that are further away from the city have lower diversity. The negative sign on distance to market indicating that high transaction costs limit crop choice and thus, Hararghe being largely a subsistence farming area, our sample farmers' decisions are mainly driven by input conditions. Finally, the anticipated impact of participation in non-farm activity by a household member on diversity depends largely on the motivation for participation in such activities. If participation is primarily done with the intent of relaxing liquidity constraints, it may enhance diversity by allowing households to purchase inputs and seed. If it is done as an alternative to agricultural production and thus takes away labour from crop production it may lead to lower diversity. The results indicate that it is positively and significantly related to diversity suggesting it helps overcome liquidity constraints.

Overall the results indicate that responding to agro-ecological heterogeneity and market opportunities may be more important drivers of crop diversification than risk management. We would expect to find a negative relationship between crop diversification and other means of risk coping if indeed they are substitutes. The primary means of coping with risk in the Ethiopian countryside is sales of livestock and thus oxen holdings represent insurance as well as draft power. Other risk coping mechanisms are diversification into non-farm income-generating activities, which is also found to have a consistently positive relationship with all three measures of crop diversity.

As can be seen in the table, the social capital variables (z^s) that measure both linking and bonding social capital are significant in all regressions across all specifications. As expected, the HCS variable is positive for all the measures of diversity indicating that the program increases both the number of crops and leads to a more even share of area to each crop. For the instrumental variable approach four variables are used that are considered exogenous to diversity but matter to placement: frequency of PA meetings, whether the community received emergency relief in the last 10 years, the PA level share of wheat produced and a poverty index. The first two variables are taken from the community survey and reflect communities that are well-organized and have previous experience in receiving outside assistance. The third community variable reflects HCS selection of communities in which wheat was important. Finally, the poverty index is used to control for any selection bias towards wealthier or poorer farmers in the program. Although testing the exclusion restriction is not possible, all of the instruments are significant in the participation equation and none significant when included in any of the diversity regressions. Looking at the results for the instrumental variable specification, we see that in all cases the marginal effect of HCS is slightly higher than in the base specification. This suggests that these estimates were a downward biased estimate of the effect of HCS on diversity and that HCS has even a greater impact than initially observed. Along with HCS, affiliation with other organizations also has a significant and positive effect on all measures of diversity. The results strongly suggest that linking social capital enhances crop diversity in the context of very poor agricultural producers. In contrast, the number of associations the household is affiliated with – a measure of bonding social capital is negative and strongly significant for all measures. The results suggest that bonding social capital limits diversity in these contexts.

Table 6.3: Factors influencing crop diversity

Number of household = 699

	Count						*Shannon index*				*Berger-Parker index*			
	Poisson		*OLS*		*IV*		*Tobit*		*IV Tobit*		*Tobit*		*IV Tobit*	
Variable	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*	*Marginal effect*	*P>|z|*
Household labor	-0.019	0.54	-0.016	0.64	-0.017	0.62	-0.015	0.29	-0.016	0.28	-0.022	0.35	-0.024	0.44
Land access	**0.041**	**0.01**	**0.049**	**0.01**	**0.041**	**0.04**	**0.018**	**0.01**	**0.013**	**0.07**	0.018	0.12	0.018	0.24
Age of head	0.006	0.11	0.005	0.17	0.005	0.16	**0.004**	**0.02**	**0.004**	**0.02**	**0.006**	**0.01**	**0.008**	**0.02**
Adult education	**0.058**	**0.02**	**0.070**	**0.02**	**0.065**	**0.03**	0.010	0.39	0.008	0.53	0.020	0.30	-0.007	0.80
Dependency ratio	**-0.091**	**0.09**	-0.067	0.18	-0.069	0.17	**-0.053**	**0.03**	**-0.055**	**0.02**	-0.022	0.61	-0.073	0.19
Oxen owned	**0.110**	**0.07**	**0.151**	**0.03**	**0.162**	**0.03**	0.045	0.12	**0.051**	**0.08**	0.060	0.23	0.082	0.21
Plots-slope	**0.198**	**0.02**	**0.199**	**0.05**	**0.198**	**0.06**	**0.083**	**0.02**	**0.082**	**0.02**	0.104	0.11	**0.145**	**0.07**
Plots-colored soil	0.025	0.77	0.020	0.85	-0.015	0.89	0.031	0.43	0.011	0.78	0.063	0.37	0.072	0.42
Plots-texture	**0.385**	**0.00**	**0.463**	**0.00**	**0.479**	**0.00**	**0.123**	**0.00**	**0.132**	**0.00**	**0.133**	**0.03**	**0.181**	**0.02**
Altitude	0.000	0.45	0.000	0.45	0.000	0.89	0.000	0.43	0.000	0.78	0.000	0.75	0.000	0.70
Credit constrained	**-0.206**	**0.02**	**-0.193**	**0.03**	-0.141	0.16	**-0.117**	**0.01**	**-0.089**	**0.05**	**-0.190**	**0.00**	**-0.222**	**0.03**
Accessible by car	-0.128	0.14	-0.155	0.11	**-0.166**	**0.09**	**-0.078**	**0.05**	**-0.084**	**0.04**	**-0.129**	**0.06**	**-0.152**	**0.09**
Distance to city	**-0.002**	**0.10**	-0.002	0.11	-0.002	0.21	**-0.002**	**0.01**	**-0.001**	**0.04**	**-0.003**	**0.00**	**-0.004**	**0.01**
Non-farm activity	**0.173**	**0.02**	**0.183**	**0.02**	**0.190**	**0.02**	**0.082**	**0.02**	**0.086**	**0.01**	**0.129**	**0.03**	**0.170**	**0.03**
Participation in HCS	**0.204**	**0.01**	**0.207**	**0.02**	**0.501**	**0.05**	**0.114**	**0.00**	**0.276**	**0.01**	**0.159**	**0.01**	**0.554**	**0.03**
Organizations	**0.170**	**0.02**	**0.148**	**0.05**	**0.159**	**0.04**	**0.118**	**0.00**	**0.124**	**0.00**	**0.128**	**0.02**	**0.239**	**0.00**
Associations	**-0.158**	**0.00**	**-0.156**	**0.00**	**-0.148**	**0.00**	**-0.073**	**0.00**	**-0.069**	**0.00**	**-0.115**	**0.00**	**-0.135**	**0.00**
Dire Dawa	**-1.249**	**0.00**	**-1.240**	**0.00**	**-1.229**	**0.00**	**-0.863**	**0.00**	**-0.856**	**0.00**	**-1.495**	**0.00**	**-2.052**	**0.00**
Meta	-0.309	0.19	-0.257	0.31	-0.142	0.60	-0.219	0.05	-0.156	0.20	-0.419	0.02	-0.470	0.07

Notes: In all cases, constants were included in regressions but are not reported. In all cases, robust standard errors were calcuated. Marginal effects are calculated at the mean and for censored regressions are for the latent variable. Instruments used for IV regressions are a poverty index, frequency of PA meetings, whether the community received emergency relief in the past, PA share of production of wheat, and whether sorghum seed was avaiable at the fair. Bold indicates signficance with at least 90% confidence. Source: authors' calculation using FNPP-Ethiopia data set

As noted in the previous section, to confirm our results for the HCS participation variables a matching procedure is used using a kernel based matching procedure[55]. Table 6.4 presents these results. Before discussing the results it is worth noting that as the first step of the matching procedure a propensity score is determined for participants and non-participants in order to match the two sets of households. This process also allows a comparison of whether the households are similar in their observable characteristics; that is, whether there is common support. Note that no households are trimmed from the sample and that the propensity scores for participants and non-participants clearly overlap. This suggests that there is common support implying that participants and non-participants are similar and that the design of the survey was relatively successful at replicating an experimental design. Looking to the results in table 6.4, they indicate a clear positive relationship between HCS participation and the diversity measures although the magnitude of the results for the Shannon index and Berger-Parker index are lower and not significant in the case of the Berger-Parker index. The actual impact is closer to the marginal effects found in the basic regression raising some uncertainty of the results for the instrumental variable regression. Given this result, it is difficult to draw a clear conclusion about the magnitude of the impact of HCS on diversity but it does suggest there is clearly a positive and substantial impact of HCS on the number of crops planted.

Table 6.4: Verifying the effects of HCS using propensity score matching
Number of household = 699

	Count		***Shannon index***		***Berger-Parker index***	
	Mean diff	*P>|z|*	*Mean diff*	*P>|z|*	*Mean diff*	*P>|z|*
HCS impact on diversity	**0.231**	**0.02**	**0.084**	**0.01**	0.068	0.27

Notes: Standard errors are determined through bootstrapping and are used to calculate p-values.
Source: authors' calculation using FNPP-Ethiopia data set

Returning to table 6.3, note that the levels of diversity in woreda of Dire Dawa are significantly lower than for the base category Chiro. Wheat production is much lower in Dire Dawa than in the other regions and there is some concern that this may be somehow influencing the results. Rerunning the model with only the other two woredas (Chiro and Meta) leads to the same results as presented above. There is also a concern that some variables may be capturing differences across PAs that are not controlled for in the regressions. As an additional test of the results the regressions were run using PA-level fixed effects (excluding the PA level data.) Again, the results remained fundamentally the same suggesting this as not a problem.

[55] Note that matching is done using a Gaussian kernel. Tests using alternative kernel estimates as well as using nearest neighbour matching gave results similar to those presented in Table 6.4.

6.6 Conclusions

A number of international treaties related to crop genetic diversity require signatories to adopt policies that will promote the sustainable utilization of plant genetic resources. While a range of policies is possible, one set of likely policies in poorer areas such as the study area of Ethiopia is to provide farmers with access to seeds of new crops and varieties using both the formal and informal seed sectors. There is some concern that such a policy while improving farmer welfare might lead farmers to specialize in their agricultural production and thus lead to a reduction in crop diversity. In this study, we explore the possibility that farmers participating in organizations with links external to the community, e.g. linking social capital, are more likely to have reduced levels of crop diversification. The study is conducted in an area of Ethiopia where inter-specific diversity is significant and that diversity includes crops that are of importance in terms of their genetic value since it is a centre of origin or diversity for these crops. The results indicate that linking social capital does not lead to a decline in crop diversification but actually increases it in these particular contexts. The results suggests that interventions by formal organizations need not lead to reduction in inter-specific diversity and may in fact enhance it and bring about sustainable utilization. However changes in inter-specific diversity are likely to also have impacts on infra-specific diversity and these are not well understood. Future research is needed to assess this relationship.

Our results indicate that the access to seeds and information is a strong determinant of household's capacity to diversify their crop production, and that social capital has a critical role in the household's access. The impact of social capital on the household's utilization of crop genetic resources can occur through changes in the household demand for crop diversity by improving information about market opportunities and/or the supply of seeds needed to diversify. It is not surprising that households with links to organizations that span community and national boundaries have better access to information and seeds. It is surprising that households with strong social links within a community are less likely to be diversified, and that the effect is quite strong and significant. One possible explanation is the possible tradeoffs between infra and inter-specific diversity; if links within local communities are more likely to lead to diversification within crops then the demand for diversification between crops may be lessened. The result may also be tied to the characteristics of the households which are associated with each type of social capital. The degree of access farmers have to linking social capital is likely to be restricted, and factors such as wealth and education important in acquiring this type of capital. The opposite appears to be true for bonding social capital which is widely accessible and built on principles of mutual aid and generosity. Our results indicate that liquidity constraints are a barrier to crop diversification and thus to poorer producers and this may be an effect that is expressed in the negative relationship between bonding social capital and diversification.

Policy-makers interested in promoting the sustainable utilization of crop genetic resources need to consider not only seed supply and inclusion of the informal sector into seed programs, but also the role of social capital in the effectiveness of measures to improve the flow of seeds and information to farmers. Efforts aimed at improving farmers’ ability to accumulate linking social capital are clearly an important part of a strategy to improve access to crop genetic resources. It is also important to consider the policy implications of the negative relationship between bonding social capital and crop diversity. The results suggests that policies that seek to promote sustainable utilization should be wary of only working to promote greater grassroots organization since it may not support crop diversity.

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Chapter 7

Discussion and conclusions

7.1 Introduction

Enormous are the challenges smallholder farmers face to achieve food security or improve their wellbeing. Production choices, given farmers' endowments, constraints and agro-ecological conditions, play a crucial role in achieving these goals. In marginal environments, characterized by difficult agro-ecological and production conditions, difficulties are related to managing production shocks and the risk of crop failure, exacerbated by frequent droughts and obstacles in accessing input and output markets. In more commercialized contexts the difficulties are more the ability to reach the market by meeting required standards and to sell at a sufficient price to guarantee positive returns.

Crop variety choice is an essential element in the farming system of smallholder farmers to be able to harvest any produce in harsh conditions and to be able to integrate with a dynamic market in more commercialized contexts. Nonetheless, crop or variety choices, while offering potential positive benefits to farmers, might also lead to genetic erosion or to increasing the spread of pests or diseases if uniform mono-cropping patters are the result. Moreover, the potential health and environmental impacts that the race to achieving market standards might imply, for example through an increased use of pesticides, is also at stake. These are the main themes analyzed in this thesis by using a variety of data, instruments, methods and approaches, among which impact evaluation plays a chief role.

The second chapter gives an overview of all these elements focusing in particular on the role of Plant Genetic Resources for Food and Agriculture (PGRFA) within the framework of the various challenges agricultural production and natural resources are currently facing. The chapter draws on the second State of the World of PGRFA (FAO, 2010) and on the numerous country reports that provide the basis for its documentation. However, in presenting a rather broad and deep analysis, it also uses a number of different data sources and documentations despite the serious data limitations encountered in that only few, if any, datasets available differentiate yields, impacts or outcomes between modern varieties (MV) versus landraces (LR) or between different seed sources. The chapter takes an innovative approach in considering PGRFA not as "victims" of agricultural modernization, but rather by emphasizing the ways in which PGRFA have been and continue to be important tools for achieving broader social goals.

Chapters 3 addresses the impacts and outcomes of market participation on yields and gross margins as well as on the use of pesticides and agro-biodiversity for potato in the country of Ecuador, where agricultural development and market integration are essential elements to improve smallholders' wellbeing. The modalities and the extent to which farmers' technology has modified in the same context, as embodied in the production function, are analyzed in chapter 4.

Chapter 5 analyses variety adoption choices made to manage difficult production conditions and frequent production shocks that characterise the area of Eastern Hararghe in Ethiopia. The role of social networks and seed system functioning within this framework is taken into account in chapter 6.

The remainder of this chapter is organized as follows. Section 7.2 gives an overview of approaches used and data sources. Section 7.3 provides answers to research questions addressed in chapter 1. Section 7.4 draws general conclusions and policy implications, indicating also scope for further research.

7.2 Approach and data

After analyzing in detail the role and contribution of PGRFA to food security and sustainable agricultural development in chapter two, this thesis focuses on applying rigorous impact evaluation methodologies as well as in adapting the standard household model to specific research questions and requirements. For the latter, it integrates the safety first criterion and the role of social capital and networks in seed access and production choices.

The second chapter draws mainly on reports from countries world-wide on the state, gaps and needs of PGRFA as well as on a number of other ad hoc or more general datasets and documentation. For all the other chapters, primary as well as secondary data sources have been used. More in particular, for the country of Ecuador primary data were collected through specifically designed household level and community level survey instruments which were based on results and information gathered through key informant interviews, stakeholder consultation, value chain analysis and farmers' focus group discussions. The data were collected in August 2007 and contained specific questions on socio-demographic and economic indicators, as well as on agricultural production, with particular emphasis on potato production, and on variety adoption and use of pesticides. Specific attention has been devoted to select the sample, using also secondary data, in order to make sure that a sound impact evaluation could be conducted, in other words that treatment and control households would be reasonably comparable.

With regard to Ethiopia, primary data sources were collected in two rounds after planting of the Meher cropping season in August 2002 and after harvest of the same season in January 2003. The survey instruments were designed on the basis of literature review and key informants interview whereas farmers' focus groups and agro-morphological analysis have been conducted ex-post to validate findings and, above all, to validate sorghum and wheat variety names based on traits and other agro-morphological characteristics.

7.3 Answers to the research questions

This section presents in brief the answers to the research questions addressed in Chapter 1.

1. *What is the role of CGR and particularly of Plant Genetic Resources for Food and Agriculture (PGRFA) in achieving food security and alleviate poverty within the context of some of the emerging and difficult challenges now facing agriculture? And what is the role of markets and seed system within this context?*

Chapter 2 looks at the role of PGRFA in the context of some of the emerging and difficult challenges now facing agriculture, providing a review of the current status of PGRFA in relation to sustainable agricultural development and food security. Drawing on literature review, on the second report on the State of the World's of PGRFA (FAO, 2010) as well as on a number of data sets and other external sources of documentation, the chapter identifies some key challenges and gaps needed to be addressed in order to achieve the objective of food security within a sustainable development framework.

The analysis reveals that despite the enormous advances in agriculture over the last few decades, a substantial increase, ranging in the order of 70%-100%, in agricultural production is required to meet food demand and eradicate poverty. Whereas most of the needed increase will have to come from enhancing crop yields and sustainable intensification, a significant share of the increase, will also have to come from more marginal environments, home to many of the world's poorest people. Consequently, while high-yielding varieties and associated practices will remain an important strategy for meeting future food needs, a pipeline of new varieties for marginal areas or for adaptation to changing conditions will also be needed. Agricultural research and plant breeding for "less favoured" agro-ecosystems is increasingly recognizing the unsuitability of intensive mono-cropping for such areas and the importance of conserving natural resources by diminishing the use of external inputs (Hazell, 2008). Not only new varieties will play a major role in these systems, were poverty is as high if not higher than in high potential areas, but the types of technologies used must be different than those applied in high potential and high input systems (Hazell, 2008).

A key aspect to achieving food security and poverty eradication, which need to be strengthened, is represented by market functioning and ensuring net returns to agricultural producers. The need to stimulate programs and polices that address the whole value chain from input to output markets removing barriers and obstacles small farmers face is evident from the analysis conducted as well as from a number of empirical findings reported. Furthermore, it emerges clearly, from the review conducted, the need for greater harmonization between the formal and informal seed sectors, as well as between public and private institutions concerned with conservation, crop improvement and seed systems.

Within this framework, it is, however, important to avoid or mitigate the negative environmental impacts often accompanying development processes, including genetic vulnerability and an increasing use of pesticides. These concerns are exacerbated by the projected and actual impacts of climate change on production and productivity, which in turn calls for the need of breeding for adaptation purposes. Given the varied production conditions characterizing most of the more marginal production environments, and the increase in climatic shocks and variability due to climate change, it is critically important that farmers and plant breeders have ready access to a wide range of genetic diversity.

Agricultural diversification strategies at variety, crop or activity level, as well as niche markets or specific movements to support diversity can help maintain a good genetic pool of PGRFA. Nevertheless, efforts need to be strengthened to ensure the availability of a wider diversity of varieties for a larger range of crops, across more environments and at a readily affordable price. Last but not least, the analysis conducted shows that there is a need for more accurate and reliable measures, standards, indicators and baseline data for sustainability and food security that will enable a better monitoring and assessment of the progress made in these areas, a rather evident limit encountered in conducting the analysis and review presented in the chapter.

2. *a) Does market integration, through participating in the Plataformas in Ecuador, increase farmers' welfare as measured by potato yields and gross margins? b) What are the primary mechanisms through which the program has improved welfare? c) Has participation led to health or environmental degradation with respect to agrochemicals utilization and changes in varietal use?*

Rigorous impact evaluation is conducted and presented in chapter 3 to empirically asses whether market integration, achieved by participating in the multi-stakeholder Plataformas program in the Ecuadorian Sierra, has been successful in increasing yields and profits of potato producing smallholders while protecting farmers' health and the environment. In addition, the mechanisms in place to reach these objectives have also been analysed.

As the assessment study was set up ex post (after project implementation), non-experimental methods had to be used in order to identify impact. In addition, a series of measures had to be taken to collect the data in such a way that it was possible to create a reasonable counterfactual: a control group similar to the intervention (treatment) group in all ways except that it did not receive the intervention.

To this purpose, first participating communities (treatment communities) were identified and listed. Second, treatment and a set of potential control communities were identified on the basis of geographic, agro-ecological and socio-demographic characteristics. Further, by applying propensity score matching (PSM) as described in the chapter, control communities that were most comparable to treatment communities were identified, so allowing for a compilation of a final community list after detailed consideration and fine tuning with key local organizations and informants. The final community list comprises 35 communities in which a total of 1007 households were randomly selected. Participants as well as non-participants households within treated communities, in addition to non beneficiaries in control communities were selected in order to explore alternative counterfactual groupings to determine the role of spillover effects.

With the data available, four different econometric methods namely: ordinary least squares (OLS), propensity score matching (PSM), propensity score weighted least squares (WLS) and instrumental variable (IV) regression, were employed to ensure results were not driven by a specific methodology and to guarantee a sound level of confidence in the impact estimates.

Findings show that results are consistent when using approaches based on selection on observables (PSM and WLS) as well as when using an approach that deals with unobservables (IV). Moreover, spillover effects show to be minimal, whereas the main source of potential bias is related to program selection of beneficiaries which is mainly based on social capital criteria which can be controlled.

Results demonstrate that the Plataformas program successfully improved the welfare of beneficiary farmers and that the benefits were limited to farmers that directly participated. There appear to be little, if any, spillover effects on non-participants. More in particular, yields and gross margins result to be positive and significant for beneficiaries with estimated differences very similar across specifications. The mechanisms by which the Plataformas obtain these positive effects are through selling higher percentages and amounts of potato harvest than non-beneficiaries, in addition to selling at a 30% higher price. Even though participant farmers incur higher input costs, particularly for seeds but also for hired labour and fertilizers, benefits are sufficient to outweigh the added costs.

Environmental and health effects show somewhat mixed results. Participants seem to use slightly more insecticides and chemical fertilizers, but most of the other indicators related to agrochemical utilization are not significantly different across groups. Moreover, products utilized are likely to be less toxic given the Total Environmental Impact (TEI) is not significantly different from non-beneficiaries and in general has a negative sign. The impacts of the Farmer Field School (FFS) teaching within the Plataforma program have clearly had an impact on the utilization of traps for Andean weevil and in knowledge diffusion since a significantly higher percentage of participant farmers apply traps and is able to recognize the toxicity of agrochemicals therefore tending to use more protective gears. On the other hand, concerns about negative impacts on agricultural biodiversity of the Platforms have proven to be unfounded since results suggest that participants and non-beneficiaries maintain the same level of diversity. While most of the cultivated varieties are modern, results and literature (Wismantel, 1988) suggest that genetic erosion, if any, happened in the past due to a combination of natural causes (El Niño), agro-industrialization and farmers' preferences in response to changing market opportunities.

The analysis conducted has been extended to regional as well as farm size analysis. The regional analysis shows that farmers in Chimborazo, which are on average poorer than farmers in Tungurahua, have achieved higher and better results through participating in the Plataformas. Farm-size analysis shows that benefits are mainly achieved by medium farmers while large farmers are able to obtain benefits mainly thanks to economies of scale. Finally, smallholders need to intensify technology and reduce direct as well as transaction costs to be able to achieve higher returns.

3. *a) To what extent participating in the Plataformas program has had an impact on yield through modifying the production technology? b) To what extent participation in the Plataforma has influenced the use of yield enhancing inputs versus damage abating inputs?*

Programs designed to improve returns to agriculture comprise a series of different interventions which are likely to influence crop production not only through changes in input types and quantities utilized but also through the production technology. Chapter 4 assesses these kinds of effects by incorporating technology changes in evaluating the Plataforma program intervention in the Ecuadorian Sierra.

The *Plataformas de Concertación*, which are alliances between small-scale farmers and a range of agricultural support service providers[56], supply participants with new technologies and high quality seeds in addition to promoting farmer organizations that help facilitate access to high-value potato markets. It operates through the entire potato supply chain directly linking smallholder farmers to restaurants, supermarkets and processors and providing them with training through Farmer Field Schools (FFS) focused on meeting the demands of high-value markets and generally assisting with potato production. The FFS include an Integrated Pest Management (IPM) component designed to use a variety of complementary pest control strategies to reduce the use of pesticides while managing pest populations at an acceptable level.

Given the different facets of the Plataforma intervention, the production technology may be altered in different respects. In particular, there are three channels in which the Plataformas could have influenced agricultural productivity. First, participation in the Plataformas could have a direct effect on overall yields by providing training to farmers regarding soil management, crop rotation, etc. Second, participation in the Plataformas could have influenced production practices and yield enhancing input utilization, for example through teaching practices such as seedling or fertilizer application. Finally, the Plataformas could have an effect on reducing yield losses through changes in damaging input use. Indeed, certain production inputs, such as pesticides, have the main purpose of controlling the potential nature-induced damage. Pesticides, as well as other damage control agents, are not directly productivity enhancing and, in fact, if overused they might even reduce productivity (Mauceri et al., 2005). Their productivity should rather be defined in terms of their contribution to

[56] These include the National Institute of Agricultural Research (INIAP), the International Potato Center (CIP), various NGOs, researchers, universities and local governments. The alliances are also supported by international donors, such as the Swiss Agency for Development and Cooperation (SDC).

decrease or abate the potential damage or potential yield losses due to pests or diseases. In this respect, realized output should be considered as a combination of potential output and loss from damage (Lichtenberg and Zilberman, 1986).

To assess in which way and to what extent the production technology has been altered through participation in the Plataforma program, a structural model which moves beyond the standard impact evaluation has been used. More in particular, a damage abatement framework where the overall production function is defined by a combination of standard production function and damage abatement function has been applied. In addition, a series of interaction terms to determine the impact of participation on the production technology have been included. Further, to avoid biased estimation, weights, created by using the inverse predicted probability of membership, are included within the regression thus controlling for differences in observable characteristics of the treatment and control, in addition to social capital proxies to control for possible unobservable characteristics related to participation. To ensure identification of program impact, the data set was carefully constructed in order to have a reasonable counterfactual for comparing treated and control farmers.

The findings provide unambiguous evidence that the Plataformas program enhances yields through increased input use as well as through a general shift in technology. Increases in input use are likely to be a response to higher returns to potato production resulting from the link to higher-value markets and high potato prices. Likewise, the technological shift is likely to have been induced by the use of more effective farming techniques that are learned through FFS, while pesticides used do not seem to have a significant effect on production with the moderate exception of preventive fungicides for Plataforma participants.

4. *a) Are more risk adverse farmers with climatically sensitive production systems more/less likely to adopt modern varieties? b) Does modern variety adoption reduce/increase the probability of being affected by crop failure?*

Adoption rates of modern varieties (MV) of sorghum are rather low in Eastern Ethiopia, the area where the case study presented in chapter 5 has been conducted. While MV may represent an effective means of coping with droughts, given their early maturing traits, landraces may prove to be better adapted to marginal production conditions and be more drought-tolerant. Whether MV adoption is a risk reducing technology is, thus, very much context-dependent and needs to be empirically determined.

Data from a shock year, in a context of low productivity agricultural system, subject to frequent climatic shocks, where most of the population is poor, but local genetic diversity for the crop is abundant, provides a good opportunity to explore the role of genetic resource utilization in managing downside risk exposure, the probability of crop failure.

In this framework, MV adoption is considered a technology choice made within the standard household model, where farmers who are both producers and consumers of agricultural goods, maximize their expected utility from a bundle of consumption goods given their production and income constraints (Singh et al., 1986). In a context of high food insecurity and frequent production shocks, households make their technology choices minimizing the probability of complete crop failures (e.g. Moscardi and de Janvry, 1977). MVs are thus adopted if marginal benefits from their utilization exceed marginal adoption costs. To assess both the probability of MV adoption as well as the probability of being affected by crop failure, and in turn how MV adoption influence the probability of crop failure, a maximum likelihood bivariate probit model has been estimated and presented in chapter 5.

The analysis conducted shows that exposure to weather shocks plays a major role in the choice of variety adoption in the context studied, together with access to markets and social networks. Farmers who face moderate production stresses and climatic risk have a higher tendency of adopting MVs, while those who have been most vulnerable to extreme weather events, leading to past crop failures, prefer to stick to landraces.

This result is likely to be mainly due to the type of sorghum MVs currently available in the area which are not effective means of coping with the catastrophic risk that drought represents in the area studied. Nevertheless, since MVs of sorghum in the area were bred with the purpose of drought escape rather than drought tolerance, if there is not enough moisture over the short period they are grown they are more susceptible to failure. While this is more likely to occur in a year of extreme drought like the one analyzed, different results could be experienced in milder drought years.

With regard to potential risk of genetic erosion likely to occur when adopting MV, findings indicate that given the production and marketing conditions which characterize the area, the adoption of improved sorghum varieties increases rather than reduces on farm diversity, although MV adopters plant the majority of their sorghum production area to MVs.

Finally, results show that adoption of modern varieties is likely to increase the risk of crop failure. Therefore, while MV adopters might be trading the potential of achieving higher yields for the greater security that LRs can provide, this seem to be a risky strategy given the potential harsh weather conditions in the area and given the limited capacity of the farmers to access other coping strategies. Considering the major role of sorghum as a key staple crop in the area to achieve food security, it would thus be advisable to focus further breeding efforts on drought tolerance traits rather than on drought escape traits such as short maturing.

5. *a) How does agricultural household decision-making shape on-farm diversity? b) What is the role of social capital in determining on-farm level diversity of crops?*

The way in which seed supply limitations influence crop diversity and the role that social networks play in overcoming these limitations is examined in chapter 6 by using a standard household model adapted to directly account for the role of social capital. More in particular, within the standard household model where the household is both a producer and a consumer of agricultural goods, output is considered a function of the resources allocated to crop production, particularly land and labour. This approach allows to examine the trade-offs between using household resources, particularly labour, for crop production or for other activities that include non-agricultural activities and investment in social capital. To incorporate social capital into the model, the benefits of the social capital ties are represented by their provision of crops (or seeds). Moreover, the influence of social capital is examined in its form of linking as well as bonding social capital[57].

A poisson and two tobit regressions where run where diversity, the dependent variable, is measured by indicators adapted from the ecological literature and which include the count as well as the left censored Shannon and Berger-Parker indexes. Because the sample was selected around a seed intervention project run by the Hararghe Catholic Secretariat (HCS) a number of steps were taken to avoid potential program placement bias. First, each regression run includes a number of observable factors that, other than influencing diversity, may influence participation. Second, an instrumental variable approach was used to instrument HCS. Third, a propensity score matching (PSM) procedure was also applied. The range of methods employed ensures an accurate assessment of impacts and give robustness to results obtained.

Findings show that access to seeds and information are strong determinants of household's capacity to diversify crop production, whereas social capital has a critical role in facilitating access. However, whether social capital is of bonding or linking type the role it plays can be radically different. Whilst households with links to external organizations have better access to information and seeds, households with strong inter-community social links are less likely to be diversified across crops. Nevertheless, the tradeoffs existing between infra and inter specific diversity in constructing the production portfolio might also play a role in determining diversity. Whereas links within local communities are more likely to lead to diversification within crops, the demand for diversification between crops may be lessened. Furthermore, these differences might also be linked to the different characteristics of the households associated with each type of social capital. The degree of farmers' access to linking social capital is indeed likely to be limited and hindered by factors such as wealth and education, while the opposite holds true for bonding social capital which is widely accessible and built on principles of mutual aid and generosity.

7.4 General conclusions, policy implications and scope for future research

This thesis can be generally subdivided into three parts. After examining the importance of agriculture and of PGRFA to feed a growing world population within a sustainable development

[57] Linking social capital involves intercommunity links, consisting of vertical ties between distinct social and economic classes such as between poorer households and those with influence in formal organizations. Bonding social capital consists of strong horizontal ties connecting family members, neighbours or business associates at an intra-community level usually characterized by very similar economic and social background (World Bank, 2000).

framework, it uses impact analysis to assess the potential positive benefits of market participation and of seed system functioning on smallholder farmers, in addition to understanding the motivation of their farming, production and crop variety choices.

Sound impact evaluation, grounded on scientific approaches, is a powerful instrument to determine effects of programs or projects on a number of outcomes and for showing the way forward on achieving sustainable economic development. While impact evaluations have become widespread in the last decade and the methods of impact evaluation widely known, they are not yet very common in agricultural and rural development projects, particularly when environmental effects are also at stake. Carefully evaluating agricultural and rural development projects, particularly in developing countries, using rigorous scientific methods would help foster research and, more importantly, would help to assess their actual effects and impacts on food security as well as on other relevant socio-economic and natural resources indicators crucial for developing and applying project strategies and programs to support sustainable agriculture development.

Nevertheless, one interesting and important question that often arises from results of impact evaluation of the type conducted and reported in this thesis for the country of Ecuador, is whether the programs that bring positive impacts are self-sustainable when the interventions end and whether they are cost-effective. In the specific example reported here, whether there is sufficient value added in the new market opportunities to cover the costs of the Plataformas and still provide farmers with a sufficient income increment to justify program participation is one interesting question, also raised by Thiele et al. (2009). Although the *Plataformas* program received substantial subsidies through project funding which is considered to be a reasonable investment given the sizeable level of benefits obtained, in the long run and for scaling up the program, other funding mechanisms would need to be explored to achieve the financial sustainability for the Plataformas. Unfortunately the lack of data did not allow, for the moment, to assess the costs and determine the sustainability of the Plataformas. Therefore, a new round of data collection to evaluate the current results the program is providing, given a certain withdraw of external support, would be advisable and of great interest.

In impact evaluation the challenge is to determine what would have happened in the absence of a program. While program participants are observed receiving the “treatment”, they are not observed in the absence of the program (Ravallion, 2005). Given this is the case, it is necessary to identify a group that did not receive the program, but that could act as a reasonable counterfactual in the sense that they have a similar range of characteristics as program participants, but that did not participate. Ideally, through randomly assigning eligible individuals to a treatment group, who receive the program, and a control group, that does not, a reasonable counterfactual can be established. Unfortunately in the real world this is a procedure very much rejected and rarely used, even though, if used by applying rigorous ethical approaches in randomizing the sample, it would dramatically add value to research conducted in this field and to information for policy makers working on development programs.

One interesting added value of the analysis conducted and presented in this thesis has been the recognition that the agricultural program evaluated might have induced changes in production technology which have been taken into account within a structural model. Failing to incorporate this into the analysis could instead potentially underestimate the impact of a project.

The thesis presented has also brought some interesting insights into understanding the motivations and constraints of farmers in adopting improved sorghum varieties designed to reduce a major source of production risk. Motivations which are essential in helping the design of effective strategies for intensifying agricultural production and in moving ahead with agricultural development strategies and with breeding for more specific needs identified. Nevertheless, a number of limitations have to be pinpointed in the analysis presented. Firstly, the data available is only cross-section and related to a year of extreme drought. While the particular adverse weather situation allows drawing some interesting conclusions, another round of data collection would significantly add value to the implications of our findings. Moreover, serious limitations encountered in tracing crop variety names with their genetic and agro-morphological traits should also be overcome through more ad hoc agro-morphological analysis and characterization.

The findings strengthen, if possible, the importance of effective risk production coping strategies which have assumed even greater importance in the context of climate change and the predicted increase in extreme weather events. In this context, improving germplasm to produce varieties more adaptable to climatic changes and extreme weather events is a crucial means of achieving food security.

Throughout the thesis and by the different tools, approaches and analysis used it always emerges clearly the core role played by social capital in influencing market or program participation as well as in information and seed flows. While, social capital might be a difficult element to measure and take into account in developing programs and projects, policy-makers interested in promoting rural development, market integration or the sustainable utilization of crop genetic resources need to consider its role in the effectiveness of measures and initiatives taken. Efforts aimed at improving farmers' ability to accumulate social capital as well as at collecting necessary data to more precisely understand and pinpoint its role, represent an important strategy to achieve sustainable development and food security.

Needless to highlight again the importance of facilitating access to output and input markets for small-farmers, as well as the importance of reconciling formal and informal seed system and of strengthening the links between public and private institutions concerned with conservation, crop improvement and seed systems. However, it is important to stress once more the need for more accurate and reliable measures, standards, indicators and baseline data for sustainability and food security that will enable a better monitoring and assessment of the progress made in these areas.

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Summary

Food insecurity and environmental degradation are the most urgent challenges at the forefront of international concerns. Threats posed by a growing population, more frequent and adverse climatic shocks and increasingly pressing energy needs, call for an improved management of natural resources.

Agriculture contributes to food security and human well-being directly through food production and indirectly by providing income to agricultural producers. Depending on how it is managed it can be a source of environmental degradation or an important provider of environmental services.

This thesis examines how small scale farmers achieve the objectives of food security and of improving their welfare through crop production choices, farming technology and market access. The impacts of farming techniques on the use of pesticides and on agro-biodiversity are also assessed. The analysis is conducted in a marginal but market oriented versus a marginal and harsh production context, after addressing how Plant Genetic Resources for Food and Agriculture (PGRFA) could be used as key tools for achieving food security and sustainable agricultural development.

Chapter 2 discusses the role and contribution of PGRFA to food security and sustainable agricultural development. The chapter does not see PGRFA as victims of agricultural modernization but rather it looks at the role of PGRFA in the context of some of the emerging and difficult challenges now facing agriculture and emphasizes the ways in which PGRFA have been and continue to be important tools for achieving broader social goals. The chapter provides a review of the current status of PGRFA which is instrumental to identify some of the key gaps and needs for further research, which conclude the chapter.

The analysis reveal that despite the enormous advances in agriculture over the last few decades, a substantial increase, ranging in the order of 70%-100%, in agricultural production is required to meet food demands and to eradicate poverty. Whereas most of the needed increase will have to come from enhancing crop yields and sustainable intensification, a significant share of the increase, will also have to come from more marginal environments, home to many of the world's poorest people. Consequently, while high-yielding varieties and associated practices will remain an important strategy for meeting future food needs, a pipeline of new varieties for marginal areas or for adaptation to changing conditions will also be needed. To be able to breed this pipeline of varieties it is critically important that farmers and plant breeders have access to a wide range of genetic diversity which need to be maintained and strengthened. The chapter stresses also the importance of greater harmonization

between formal and informal seed sector as well as the importance of strengthening both input and output market functioning in order to ensure sufficient net returns to agricultural producers, key for poverty alleviation.

Chapter 3 examines the challenges and the benefits of linking smallholders to high-value food markets through multifaceted intervention such as the Plataformas program in the Ecuadorian Sierra. The chapter presents a rigorous impact evaluation conducted to assess whether the Plataformas program has been successful in increasing yields and profits of potato producing smallholders while protecting farmers' health and the environment. The mechanisms by which these objectives are achieved have also been analysed.

In addition to careful sample selection, multiple evaluation methods are employed to ensure identification of program impacts. These include ordinary least squares (OLS), propensity score matching (PSM), propensity score weighted least squares (WLS) and instrumental variable (IV) regression. Findings show that results are consistent when using approaches based on selection of observables (PSM and WLS) as well as when using an approach that deals with unobservables (IV) and suggest that the program successfully improved the welfare of beneficiary farmers, as measured by yields and gross margins. These benefits are achieved through improving the efficiency of agricultural production and through selling at higher prices. No significant health or environmental effects were found. Overall, the program provides clear evidence that combining improved agricultural service provision with facilitating market access can be successful.

Chapter 4 moves a step further from the analysis presented in the previous chapter by evaluating the Plataformas program's impacts within a production framework. The chapter starts from recognizing that programs composed by a series of different interventions are likely to influence crop production not only through changes in input and output indicators but through the production technology. With this in mind, the chapter examines the impact of the Plataforma program on the production technology by distinguishing the different types of inputs and of factors that might influence productivity. In particular common yield enhancing inputs are distinct from damage abating inputs such as pesticides and level of agro-biodiversity used. The analysis is conducted by applying a damage abatement framework in which pesticides and agro-biodiversity are seen in their damage abating rather than output enhancing role. A weighted regression, where weights are constructed through Propensity Score Matching, is employed in estimating the production function to ensure proper program identification. The function incorporates a series of interaction terms to assess the impact of the program on the production technology.

The findings provide unambiguous evidence that the Plataformas program enhances yields through increased input use as well as through a general shift in technology. Increases in input use are likely to be a response to higher returns to potato production resulting from the link to higher-value markets and high potato prices. Likewise, the technological shift is likely to have been induced by the use of more effective farming techniques that are learned through Farmers Field Schools (FFS). Although, evidence indicates that participant farmers tend to use more preventative fungicides and pesticides, the toxicity of products used is evidently lower given that the Total Environmental Impact Quotient is about the same for the two groups. Pesticides used do not seem to have a significant effect on production with the only exception of preventative fungicides for Plataforma participants which suggest room from improvement.

By using primary data collected in the eastern Hararghe of Ethiopia in a year of extreme drought, chapter 5 analyses whether more risk adverse farmers with climatically sensitive production systems are more or less likely to adopt modern varieties (MV) and the effect of MV adoption on the probability of crop failure. MV adoption is considered a technology adoption decision, which is particularly important in situations of high food insecurity, where the probability of complete crop failure is rather likely and where risk adverse farmers have limited capacity for ex-post consumption smoothing. In this context, small-scale farmers are expected to choose their production technology to minimize the probability of complete crop failure.

A maximum likelihood bivariate probit model is utilized to analyse the probability of adoption of MV and the probability of experiencing crop failure for MV adopters.

Findings suggest that what drives farmers’ decisions to adopt MVs are mainly risk related factors coupled with access to markets and social capital. However, while farmers tend to use MVs to mitigate moderate risks, those most affected by extreme weather events are less likely to use MVs suggesting that MV adoption does not necessarily represent an effective means of coping with drought. Moreover results show that MV growers are more likely to be affected by sorghum failure once controlling for exogenous production factors. Although, these findings are based on a year of extreme drought, they suggest that focusing further breeding research on drought tolerance traits would be beneficial for a crop like sorghum crucial for food security.

Chapter 6 explores the effects of seed supply limitation and the role of social capital in determining crop diversity in the area of eastern Hararghe in Ethiopia. The analysis is set up around an impact evaluation study and steps to avoid program placement bias are undertaken.

In a difficult production context in which informal seed exchanges play a crucial role interchangeably with formal seed flows, social capital represents an important feature of the overall seed flows. Different forms of social capital are hypothesized to influence access to seeds and have differential impacts on the farm level choice of crop and variety to plant, and thus on-farm crop diversity. Calculating on-farm crop diversity through measures adapted from the ecological literature, factors determining the level of diversity cultivated are assessed by poisson and tobit regressions applied within the agricultural households model.

The results indicate that linking social capital does not lead to a decline in crop diversity but actually increases it, suggesting that interventions by formal organizations do not necessarily lead to reduction in inter-specific diversity. However, the results also suggest that households with strong social links within a community (bonding social capital) are less likely to be diversified. Furthermore, these differences might also be linked to the different characteristics of the households associated with each type of social capital. The degree of farmers' access to linking social capital is indeed likely to be limited and hindered by factors such as wealth and education, while the opposite holds true for bonding social capital which is widely accessible and built on principles of mutual aid and generosity.

Overall, the thesis shows, using a variety of methods, sources and approaches, the importance of crop variety grown in achieving food security and increasing well-being through market access and through being able to adapt to frequent production shocks and difficult harsh conditions. Markets and seed sources are crucial elements in determining small scale farmers' agricultural production and returns. Throughout the thesis emerges the need of a large pool of crop varieties that could serve both to adapt to changing production and climatic conditions as well as to changing nutritional and human needs. The analysis presented demonstrates also that programs and policies aimed at linking smallholders to the markets are likely to be successful if implemented throughout the whole production-distribution-retail chain. To guarantee successfulness of such programs and policies but also to facilitate access to seeds, information and varieties it is clear the crucial role played by social capital and networks in influencing program participation as well as in determining access to seeds and varieties. While, social capital might be difficult to measure and take into account in developing programs and projects, policy-makers interested in promoting rural development, market integration or the sustainable utilization of crop genetic resources need to consider its role in the effectiveness of measures and initiatives taken. Last but not least it is important to highlight that, among the various methods employed, a chief role is played by impact evaluation whose rigorous application can greatly influence the way forward on achieving sustainable economic development by suggesting effective and ineffective aspects of programs, policies and interventions.

Samenvatting

Onzekerheid in voedselvoorziening en kwaliteitsvermindering van de leefomgeving zijn de meest dringende internationale problemen. De bedreigingen van een groeiende bevolking, meer frequente en nadelige weersomstandigheden door klimaatverandering en de steeds groeiende behoefte aan energie, vragen om een beter beheer van onze natuurlijke hulpbronnen.

De landbouw draagt bij aan de voedselvoorziening en het welzijn van de mensheid op een directe manier door voedselproductie en op een indirecte manier door inkomen te genereren voor agrarische producenten. Afhankelijk van het beheer kan de landbouw de kwaliteit van de leefomgeving verminderen of kan het een belangrijke bron zijn van ecosysteemdiensten.

Dit proefschrift onderzoekt hoe kleinschalige boeren in hun eigen voedsel kunnen voorzien en hun welvaart kunnen verbeteren door middel van gewaskeuzes, landbouwtechnieken en toegang tot de markt. Verder wordt de invloed van landbouwtechnieken op het gebruik van pesticiden en agrobiodiversiteit onderzocht. De analyse wordt uitgevoerd waarin een context waar men georiënteerd is op de markt vergeleken wordt met een context waarin de agrarische productie moeilijk en de opbrengst marginaal is. Verder wordt gekeken hoe genetische diversiteit in planten voor voedsel en landbouw (“Plant Genetic Resources for Food and Agriculture” (PGRFA)) gebruikt kan worden als belangrijkste middel om de voedselvoorziening veilig te stellen en de landbouw duurzaam te ontwikkelen.

Hoofdstuk 2 behandelt de rol en bijdrage van PGRFA aan de voedselvoorziening en duurzame ontwikkeling in de landbouw. Dit hoofdstuk beziet de PGRFA niet als slachtoffer van de modernisering in de landbouw maar bekijkt de mogelijke rol van PGRFA in een aantal opkomende lastige problemen in de landbouw en het benadrukt dat PGRFA altijd een belangrijk instrument was en blijft om bredere maatschappelijke doelen te realiseren. Het hoofdstuk geeft een overzicht van de huidige status van PGRFA, teneinde de belangrijkste leemtes in onze kennis te vinden. Het hoofdstuk eindigt dan ook met een aantal aanbevelingen voor verder onderzoek.

De analyse toont aan dat, ondanks de enorme vooruitgang in de landbouw van de afgelopen decennia, een substantiële verhoging van de landbouwproductie in de orde van 70%-100%, noodzakelijk is om aan de groeiende vraag naar voedsel te voldoen en om armoede uit te roeien. Hoewel het grootste deel van de verhoging zal moeten komen uit het verbeteren van gewasoogsten en duurzame intensivering, zal ook een belangrijk deel van de verbetering moeten komen van de meer marginale gronden, waar de allerarmsten wonen. Hoewel variëteiten met een hoge opbrengst en bijbehorende technieken dus een belangrijke strategie voor de toekomstige voedselbehoefte zullen blijven, is daarnaast een lijn van nieuwe variëteiten nodig die gebruikt kunnen worden op marginale gronden en die aangepast zijn aan wisselende omstandigheden. Om zo'n lijn te kunnen kweken is het van cruciaal belang dat boeren en plantenveredelaars de beschikking hebben over een grote genetische diversiteit aan plantmateriaal. De genetische diversiteit dient daarom behouden en versterkt te worden. Het hoofdstuk benadrukt ook het belang van het afstemmen van de formele en de informele zaadsector en verder het belang van het versterken van de marktwerking op de markt voor grondstoffen en afzet zodat agrarische producenten voldoende netto opbrengsten hebben. Deze opbrengsten zijn namelijk uiterst belangrijk voor het opheffen van armoede.

Hoofdstuk 3 onderzoekt de voordelen en uitdagingen bij het koppelen van kleine producenten en markten voor hoogwaardige producten door op meerdere fronten maatregelen te nemen, zoals het *Plataformas* programma doet in de hoogvlakte van Ecuador. Het hoofdstuk geeft een nauwkeurige effect analyse, om te kijken of het *Plataformas* programma succes gehad heeft bij het verhogen van de oogst en winst van kleinschalige aardappelproducenten aan de ene kant, en het beschermen van de gezondheid van de boeren en het milieu aan de andere kant. Daarnaast worden de mechanismen waarmee deze doelstellingen bereikt worden geanalyseerd.

Naast een zorgvuldige bemonsteringsprocedure, worden meerdere evaluatiemethoden gebruikt om er zeker van te zijn dat alle effecten van het programma als zodanig geïdentificeerd worden. Deze methoden zijn onder andere de *Ordinary Least Squares* (OLS), *propensity score matching* (PSM), *propensity score weighted least squares* (WLS) en *Instrumental variable regression* (IV). De effecten zijn hetzelfde zowel voor methodes die alleen gebruik maken van metingen (PSM en WLS) als voor de methode die ook rekening houdt met niet gemeten variabelen (IV), en ze suggereren dat het programma met succes de welvaart van de deelnemende boeren heeft verbeterd, gemeten in termen van oogst en bruto marges. Deze 'positieve uitkomsten worden bereikt door het verbeteren van de efficiëntie van de agrarische productie en door de verkoop tegen hogere prijzen. Er werden geen significante gezondheids- of milieu-effecten gevonden. Het programma toont dus aan dat, over het algemeen genomen, de combinatie van het verbeteren van de agrarische dienstverlening met het faciliteren van toegang tot de markt zeer succesvol kan zijn.

Hoofdstuk 4 gaat nog een stap verder met de analyse van het vorige hoofdstuk door de effecten van het *Plataformas* programma te analyseren in een productiekader. Het hoofdstuk begint met de onderkenning dat bij een programma dat uit verschillende maatregelen bestaat, de productie van gewassen niet alleen beïnvloedt wordt door veranderingen in de grondstof- en afzetindicatoren, maar ook door het veranderen van productietechnieken. Met dat in gedachten, onderzoekt het hoofdstuk de effecten van het *Plataformas* programma op de productietechnieken, door onderscheid aan te brengen in de verschillende typen grondstoffen en factoren die de productiviteit zouden kunnen beïnvloeden. Om precies te zijn: grondstoffen voor het verbeteren van de oogstopbrengstverschillen van de middelen om schade te beperken, zoals pesticiden en het niveau van agrobiodiversiteit dat gebruikt wordt. De analyse wordt uitgevoerd in een schadebeperkend kader, waarin pesticiden en agrobiodiversiteit worden beschouwd in hun schadebeperkende rol, in plaats van de opbrengstverhogende rol. Een gewogen schatting, waar de gewichten worden geconstrueerd met behulp van de *Propensity Score Matching* procedure, wordt gebruikt om de productiefunctie te schatten, om er zeker van te zijn dat de effecten van het programma precies geïdentificeerd worden. De functie bevat een aantal interactie termen om de invloed van het programma op productietechnieken te onderzoeken.

De bevindingen tonen onweerlegbaar aan dat het *Plataformas* programma de oogst verbetert zowel door het verhogen van de inzet van grondstoffen als door het veranderen van productietechnieken. Het gebruik van extra grondstoffen is waarschijnlijk een reactie op de hogere opbrengsten in de aardappelproductie als resultaat van de koppeling tussen de markt voor hoogwaardige producten en de hogere prijzen voor aardappelen. Op dezelfde manier is de verandering in technieken waarschijnlijk veroorzaakt door het gebruik van effectievere landbouwtechnieken die geleerd worden bij de veldscholen voor boeren. Hoewel de metingen aangeven dat deelnemende boeren meer geneigd zijn om preventieve fungiciden en pesticiden te gebruiken, is de giftigheid van de gebruikte producten duidelijk lager, gezien het feit dat de totale milieu-invloed quotiënt (Total Environmental Impact Quotient) hetzelfde is voor de twee groepen. De gebruikte bestrijdingsmiddelen lijken geen significante invloed te hebben op de productie van de *Plataformas* deelnemers, behalve de preventieve fungiciden. Er is dus ruimte voor verbetering.

Met primaire gegevens die verzameld zijn in oostelijk Hararghe in Ethiopië in een extreem droog jaar, analyseert hoofdstuk 5 of risicomijdende boeren met productiesystemen die gevoelig zijn voor het klimaat, juist meer of minder geneigd zijn om moderne variëteiten (MV) te gaan gebruiken en het effect van deze variëteiten op de kans op een mislukte oogst. Het gaan gebruiken van MV wordt beschouwd als een beslissing om een techniek over te nemen, die extra belangrijk is in situaties waarin onzekerheid bestaat over de voedselvoorziening, waar de kans op misoogsten nogal waarschijnlijk is en risicomijdende boeren slechts een beperkte capaciteit hebben om hun consumptie ex-post te spreiden. Men verwacht dat in zo’n context kleine boeren de productietechnieken kiezen die de kans op volledige misoogst minimaliseren.

Er wordt een *maximum likelihood bivariate probit* model gebruikt om te kijken wat de kans is dat MV gebruikt gaan worden en wat de kans op misoogst is als boeren MV gebruiken.

De resultaten suggereren dat de beslissing van boeren om MV te gaan gebruiken vooral gebaseerd is op risico-gerelateerde factoren, samen met de toegang tot de markt en sociaal kapitaal. Hoewel boeren geneigd zijn om MVs te gebruiken om matige risico’s weg te nemen, zijn zij die het meest gevoelig zijn voor extreme weersomstandigheden minder geneigd om MVs te gebruiken. Dit suggereert dat het gaan gebruiken van MV niet noodzakelijkerwijs een goede manier is om om te gaan met droogte. Bovendien laten de resultaten zien dat zij die MVs verbouwen een grotere kans hebben op een sorghum misoogst, als gecorrigeerd wordt voor exogene productiefactoren. Hoewel deze bevindingen gebaseerd zijn op een jaar van extreme droogte, tonen ze toch aan dat een verdere verdieping in het veredelingsonderzoek naar eigenstolerantie goed zou zijn voor een gewas als sorghum, dat zo cruciaal is voor de voedselvoorziening.

Hoofdstuk 6 onderzoekt de effecten van de beperkingen van zaadvoorziening op, en de rol van sociaal kapitaal in de diversiteit van gebruikte gewassen in oostelijk Hararghe in Ethiopië. De analyse is opgezet rond een impact evaluatie en er worden stappen ondernomen om te voorkomen dat er *program placement bias* plaatsvindt. .

In een context van moeilijke productieomstandigheden, waar informele uitwisselingen van zaad een cruciale rol spelen naast de formele zadensector, is sociaal kapitaal een belangrijk element in de algehele zaadstromen. Van verschillende vormen van sociaal kapitaal wordt verondersteld dat ze invloed hebben op de beschikking over zaad, en dat ze een onderscheidbare invloed hebben op gewaskeuze en te planten variëteiten op boerderijniveau, en dus op de diversiteit aldaar. Deze diversiteit wordt gemeten aan de hand van verschillende maten uit de ecologische literatuur. De factoren die de mate van de diversiteit in gewassen op de boerderij bepalen worden onderzocht door middel van poisson en tobit regressies, binnen een model van een landbouw huishouden.

De resultaten geven aan dat het koppelen van sociaal kapitaal de diversiteit in gewassen niet vermindert, maar juist verhoogt, wat op zich weer suggereert dat maatregelen van officiële organisaties niet noodzakelijkerwijs leiden tot een vermindering van diversiteit tussen soorten. Aan de andere kant laten de resultaten ook zien dat huishoudens met sterke banden binnen een gemeenschap juist minder geneigd zijn om te diversificeren. Verder zouden deze resultaten ook gekoppeld kunnen worden aan de verschillende eigenschappen van de huishoudens die geassocieerd worden met de verschillende vormen van sociaal kapitaal. De mate van toegang tot koppelend sociaal kapitaal wordt waarschijnlijk beperkt en gehinderd door factoren zoals rijkdom en opleiding, terwijl voor bindend sociaal kapitaal juist het tegenovergestelde het geval is, omdat het makkelijk toegankelijk is, en gebaseerd is op principes van wederzijdse hulp en liefdadigheid.

Dit proefschrift laat, met behulp van een verschillend aantal methoden, bronnen en benaderingen, zien hoe belangrijk variëteit in geplante gewassen is voor het bereiken van zekerheid in de voedselvoorziening, voor het verhogen van de welvaart door toegang tot de markt, en door de mogelijkheden te bieden voor aanpassing aan veelvoorkomende schokken in productie en zware omstandigheden. Markten en bronnen van zaad zijn cruciale elementen die het productieniveau en de opbrengsten van kleinschalige boeren bepalen. Door het hele proefschrift heen komt de behoefte aan een grote verzameling van gewas variëteiten naar voren, die kunnen dienen als aanpassingsmogelijkheden zowel voor veranderende klimatologische omstandigheden als voor veranderende voeding en andere menselijke behoeften. De gepresenteerde analyse laat ook zien dat programma's en beleid gericht op het koppelen van kleine boeren aan markten waarschijnlijk succes hebben als ze over de gehele productie-distributie-verkoop keten worden doorgevoerd. Om succes bij zulke programma's en beleid te garanderen, maar ook om de toegang tot zaad, informatie en variëteiten mogelijk te maken zijn sociaal kapitaal en netwerken van cruciaal belang, omdat ze deelname en de toegang tot zaad en variëteiten beïnvloeden. Hoewel sociaal kapitaal moeilijk te meten is en lastig om mee te nemen in ontwikkelingsprogramma's en projecten, moeten beleidsmakers die geïnteresseerd zijn in rurale ontwikkeling, marktintegratie en duurzaam gebruik van genetische gewas diversiteit, rekening houden met de rol van sociaal kapitaal in de effectiviteit van de genomen maatregelen en initiatieven.

Tenslotte is het belangrijk om aan te geven dat, onder de gebruikte methoden, een belangrijke rol was weggelegd voor de impact evaluatie. De grote precisie bij toepassing van deze methode kan goed helpen op ons verdere pad naar duurzame economische ontwikkeling, doordat deze methode zowel de effectieve als de ineffectieve aspecten van programma's, beleid en maatregelen aan het licht brengt.

About the author

Romina Cavatassi was born in 1972 in San Benedetto del Tronto (AP), Italy. In 1997 she graduated in Economics¸ *cum laude*, at the University of Bologna, Italy with a thesis on Contingent Valuation Method applied to groundwater exploitation in the area of Bologna. In 1999 she obtained a scholarship for post-graduate training. In 2000 she obtained a MSc in Environmental Assessment and Evaluation from the London School of Economics and Political Sciences in London. Her MSc thesis focused on studying the Not In My Backyard (NIMBY) syndrome for the location of a landfill waste disposal in Val Vibrata (TE), Italy. After her MSc she did an internship in the Investment Center of the Food and Agriculture Organization of the United Nations in Rome (FAO) focusing on analysing and reviewing valuation methods for environmental benefits in forestry and watershed investment projects. From 2001 she was employed by the Agricultural Development Economics (ESA) division of FAO to conduct analysis of the impact of seed system intervention on farmers' wellbeing and agricultural biodiversity. A case study in the country of Ethiopia was run as part of the project. In 2006 she started her PhD research at the Environmental Economics and Natural Resources Group at Wageningen University which she combined with field work and analysis of a case stuydy for linking smallfarmers to the market in the country of Ecuador. She has done field work in the countries of Ethiopia, Bolivia and Ecuador. Her work and research activities involved survey design and primary data collection for which she has earned a rather good experience. Results of her research activities have been presented at international conferences and published in peer reviewed journals. She is currently working for FAO on evaluating constraints and potentials to increase rice productivity for small-scale farmers in the river valley of Senegal. She is a mother since 2007.

Training and supervision plan

Annex to statement
Name Romina Cavatassi
PhD student, Mansholt Graduate School of Social Sciences (MG3S)
Completed Training and Supervision Plan

Description	**Institute / Department**	**Year**	**ECTS***
Courses:			
Writing clearly and concisely	FAO	2004	0.7
Report writing	FAO	2005	0.3
Presentation skills	FAO	2006	1
Spanish	FAO Language Skills	2006	1.5
Mansholt Introduction course	Mansholt Graduate School of Social Sciences	2002	1.5
Research Proposal	Development and writing up	2006	6
Environmental Evaluation of Economic Development	London School of Economics and Political Sciences	2000	3
Environmental Regulation	London School of Economics and Political Sciences	2000	3
Econometrics for PhD students and researchers	Centro Interuniversitario di Econometria	2003	3
Advanced econometrics	Wageningen University	2006	6
Economic Models	Wageningen University	2006	6
New institutional economics: Governance of transactions, incomplete contracts, & bargaining	Mansholt Graduate School	2007	4
Presentations at conferences and workshops:			
Presentation at International Association of Agricultural Economists, Durban, South Africa		2003	1
Presentation at International Conference, IPGRI, Rome		2004	1
Seminar at FAO: Linking Smallholder Potato Farmers to the Market while Caring for the Environment (LISFAME)		2008	1
Seminar at FAO: Assessing the impact of agricultural programs on potato production and pesticide utilization: Evidence from the Ecuadorian Sierra		2009	1
Presentation at International Conference Inter_American Development, Bank, Washington DC		2009	1
Total (minimum 30 ECTS)			**41**

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