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ASSESSING STRATEGIES TO REDUCE POVERTY IN RURAL MOZAMBIQUE

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Doctoral Thesis

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“The structural adjustment program has arrived but poverty has worsened and its reduction remains chimerical.”

Tazi, a popular singer
in the early 1990s in central Mozambique

Dedicated to my late dad
Armando Cunguara (1954 – 2006)

Acknowledgments

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Abstract

An overwhelming majority of the population in Africa relies on subsistence agriculture for their livelihoods. Agriculture also contributes to a large percentage of the national income. Yet in Africa, agricultural productivity is extremely low, which is correlated with several intertwined factors, such as the low use of improved technologies, market failure, obsolete or lack of basic infrastructure and poor health during the beginning of the cropping season. Smallholder farmers are caught in poverty traps and are unable to participate either in the input market, partly because they cannot afford to purchase the inputs, or in the output market because they do not produce enough and/or market infrastructure is missing. Therefore, poverty reduction is the main goal of many African countries, and this study looks at the specific case of Mozambique.

The poverty reduction literature can be roughly grouped into the following three lines of economic research: the role of economic growth, the role of nonfarm employment activities, and the role of agricultural productivity growth. These three strands of the literature will guide the analysis presented throughout this study. Thus, the first objective is to assess the trends in household incomes, poverty, and food security, in the midst of a neoliberal development model adopted by Mozambique, which focuses heavily on economic growth. The second objective is to assess the role of nonfarm activities in reducing household vulnerability to drought, while exploring the recent advances in econometric modeling of censored regressions. The third objective is to evaluate the economic impact of interventions that can enhance agricultural productivity, such as the use of improved technologies and the receipt of extension services, while exploring the recent advances in impact assessment analysis. The analysis is based on several nationally representative agricultural surveys in Mozambique, covering the period 1996 to 2008.

The results suggest that in rural areas the number of poor households has increased in the last decade. This may be linked to a combination of the development policy adopted by the Government of Mozambique, and to recurrent droughts and floods. The receipt of extension services had a significantly positive impact on farm income, but they are unlikely to reduce poverty at present, due to their lower (and decreasing) coverage, and the inability of visited smallholder farmers to follow up with the technical recommendations. In general, the use of improved agricultural technologies did not have a significant impact on household incomes, which might be linked to the fact that market infrastructure development is not keeping pace with their promotion. Results also show that poorer households are more likely to engage in nonfarm activities. However, they also tend to earn the lowest incomes because they are unable to overcome the barriers to participation in nonfarm activities offering higher returns.

These results indicate that a more proactive and interventionist role by the government could help in the fight against poverty. The policy options include increased investments in market infrastructure and agricultural services. This is particularly the case in central and northern Mozambique, where the agricultural potential is relatively higher and the average cropped area is larger. The southern provinces might benefit from a slightly different set of development policies, due to their lower potential for crop production and the smaller landholdings. There, the emphasis could be on promoting participation in nonfarm activities to compensate for poorer crop production, while ensuring that such access does not increase income inequality. Generally, households in all regions would benefit from better access to nonfarm activities, both as a means to cope with the vagaries of the weather, and as a more permanent strategy to reduce poverty.

Keywords: poverty reduction; technology adoption; nonfarm income; Southern Africa.

Thesis structure

This dissertation comprises two constituent parts: an introductory part (Part A) and a collection of five papers (Part B).

Part A starts with a review of the relevant literature on poverty in Africa and analyses the specific situation in Mozambique. It then covers relevant theoretical concepts of poverty alleviation and presents the conceptual framework of the thesis. The data used in the thesis is characterized and the econometric approaches used are briefly discussed. Part A shows how the papers in Part B are related to each other and how their results allow a comprehensive assessment of several strategies to alleviate rural poverty in Mozambique. It also provides some perspectives for future research as well as the methodological, theoretical, and policy implications derived from the study.

Part B comprises the following five papers:

1. Cunguara, B., Langyuntuo, A., Darnhofer, I. (2011). The role of nonfarm income in coping with the effects of drought in southern Mozambique. *Agricultural Economics,* in press. (JCR SCI Impact Factor: 0.673)
2. Cunguara, B., Darnhofer, I. (2011). The impact of improved agricultural technologies on household incomes in rural Mozambique. *Food Policy*, 36(3): 378-390. (JCR SCI Impact Factor: 1.606)
3. Cunguara, B., Moder, K. (2011). Is agricultural extension helping the poor? Evidence from rural Mozambique. *Journal of African Economies*, in press – Published on-line: doi: 10.1093/jae/ejr015 (JCR, SSCI Impact Factor: 0.698)
4. Cunguara, B., Hanlon, J., Whose wealth is it anyway? Mozambique's outstanding economic growth with worsening rural poverty. Resubmitted to *Development and Change* in June 2011.
5. Cunguara, B., Mabiso, A., Hanlon, J., Trends in food security in Mozambique, 1996/2008. Submitted to *Food Policy* in October 2010.

These five papers are referred to in curly brackets throughout the thesis.

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Part A:

Whose wealth is it anyway?

Worsening poverty in rural Mozambique despite rapid economic growth

1 Introduction

This chapter provides background information on poverty in Mozambique. It also reviews and discusses the main strands of the poverty reduction literature, while identifying the research gaps, which in turn justify the present study. This leads to the overall outline of the study, presented at the end of the chapter.

1.1 Background: Rural poverty in Mozambique

Mozambique has undergone significant structural changes in the last 50 years. First, it suffered from three decades of almost continuous war: the 1964-74 liberation war, the 1976-80 Rhodesia war, and the 1981-92 destabilization war (Hanlon, 2010). Second, the implementation of the structural adjustment program (SAP) in the mid-1980s started the transition from a socialist to a capitalist regime, with marked macroeconomic effects on employment, economic growth, inflation and exchange rates. Third, the peace agreement signed in 1992 allowed once again the movement of people between rural and urban areas, which would later encourage migration to cities and towns. Since 2001, the implementation of the poverty reduction strategy papers (known under their acronym: PARPA) contributed to the structural changes. But there is one thing that barely changed over the course of this period: poverty reduction has always been the government's overarching goal.

Mozambique has been consistently ranked among the poorest countries in the world for at least the last two decades (UNDP, 2009). Its population is predominantly rural and 80 percent is engaged in agriculture, contributing about 20 percent of the Gross Domestic Products (GDP) (INE, 2010). This suggests that labor productivity in the agricultural sector is significantly lower than in the non-agricultural sector, given that the former employs the majority of the population but the latter has the largest share of the GDP.

In 1996-97 the mean consumption per capita was below the absolute national poverty line (Arndt et al., 2006). This implies that even if the total consumption had been equally distributed among Mozambicans, all citizens would have lived in absolute poverty. In the so-called 'Washington Consensus,' economic growth was therefore identified as the prime mover in poverty reduction. At the core of the 'Washington Consensus' – as reflected in the SAP and subsequently in the PARPA – are macroeconomic policies presumed to lead to economic growth, which in turn would trickle down to the poor (Dollar and Kraay, 2000; Shorrocks and Van der Hoeven, 2004).

In Mozambique, the official poverty statistics are derived from the consumption expenditure surveys. So far, there have been three surveys. The first survey showed that in 1996-97 an overwhelming 69 percent of the population was poor. Nevertheless, significant improvement has been made, resulting in a sharp decline in poverty headcount to 54 percent in 2002-03. This was made possible through the on-going political stability following the end of the war in 1992, and may reflect the expansion of cultivated area (Arndt et al., 2006; Virtanen and Ehrenpreis, 2007). However, agricultural productivity remained low, and there is also no evidence of improvement between 1996 and 2002. Indeed, between 1996 and 2002 the production of most crops fell, measured both per hectare and per adult household member (Boughton et al., 2006). Furthermore, caloric production per capita shows a decline in the subsequent period up to 2008 (MPD/DNEAP, 2010). The main constraints to productivity growth include the cyclical occurrence of natural hazards, limited access to public services (e.g., agricultural extension), low use of improved agricultural technologies, poor market infrastructure, and poor farmers' health in late dry season (Joubert and Tyson, 1996; Usman and Reason, 2004; Walker et al., 2004; Skarstein, 2005; Mather, 2009; Cunguara and Darnhofer, 2011; Cunguara and Moder, 2011).

The third consumption expenditure survey showed that 55 percent of Mozambicans were poor in 2008-09 (MPD/DNEAP, 2010). This is not only above the government's target of 45 percent by 2009, but also suggests that at the national level poverty has barely been reduced compared to 2002. While empirical evidence exists on the relationship between economic growth and poverty reduction (Roemer and Gugerty, 1997; Dollar and Kraay, 2000; Fischer, 2003), this relationship tends to be demonstrated in cross-country studies, using aggregate data. This can conceal that within a country, compared over time, such a correlation may be weak. Also, at one point in time, statistics aggregated at the national level may mask successful cases of poverty reduction. In Mozambique, although poverty incidence remained virtually unchanged between 2002 and 2009, poverty incidence changed by 26 percentage points in both Cabo Delgado and Zambézia provinces, however with a decline in the former and an increase in the latter. It would therefore be of little consolation to the population in Zambézia to be told that on average poverty incidence remained unchanged.

Three potential factors can explain the weak correlation between economic growth and poverty reduction. First, the accuracy of official statistics can be questioned. Arndt et al. (2010) point to the examples of Tanzania and Mozambique, two countries with rapid economic growth but little change in poverty levels. They argue that differences in the methods, as well as the accuracy of national growth and poverty accounting may explain the paradox. Indeed, the official statistics show that on average the agricultural output is increasing by about six percent a year in the last decade (INE, 2010), even in a year of widespread drought such as 2005. However, the third national poverty assessment blames the underperformance of the agricultural sector as one of the main reasons for the lack of progress in poverty reduction (MPD/DNEAP, 2010), raising doubts on the accuracy of the official statistics and the national accounts.

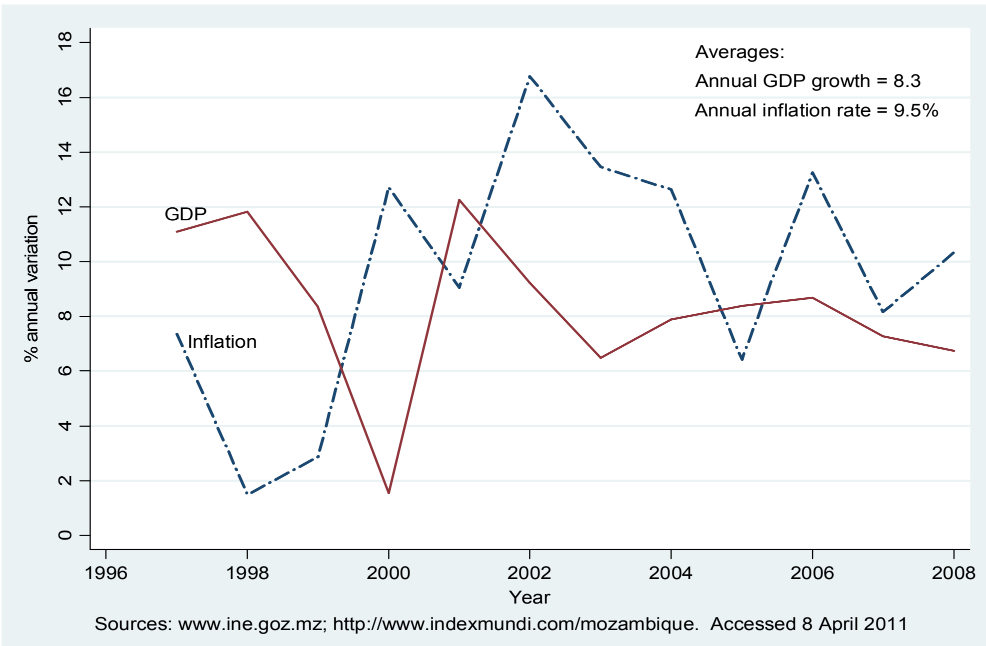
Second, the extent of the effect of economic growth on poverty reduction depends on the structural characteristics of the country, a feature often not accounted for in cross-country studies. Historically, Mozambique possesses two distinct poles of development, the relatively urban south and the predominantly rural areas in central and northern Mozambique (Silva, 2007). Most Portuguese settlers lived in the south where some urbanization took place. Agricultural production from the central and northern provinces was exported from the northern ports, thus there were few incentives to connect the south and the north. Market segmentation contributes to the fact that the southern provinces remain dependent on food imports, and thus vulnerable to price fluctuations in the international markets. Additionally, not least as a result of internal migration, the urban population is growing rapidly, especially in the food-deficit southern provinces (INE, 2010).

Economic growth and (urban) population growth, combined a stagnating agricultural sector may result in inflation of prices for staple foods, exacerbating poverty (Kalechi, 1976; Bhaduri, 2006; Rakshit, 2009). An increase in prices for staple foods may have a negative impact on farmers' wellbeing because the demand for food is usually inelastic (Engel's law), and the majority of the population (including farmers) is net consumer of food (Boughton et al., 2007). Handa and Mlay (2006) found high (nearly unitary) income elasticity for basic staple foods (e.g., cassava) among poor households in rural Mozambique.

Furthermore, price instability discourages investment in staple food production by surplus households in northern Mozambique, which have the assets and the favorable conditions to produce more (Poulton et al., 2006a). It also encourages deficit households in the southern provinces to devote scarce resources to staple food production to ensure their livelihoods, limiting diversification and the increased incomes that typically come with it (Tostão and Tschirley, 2010). Furthermore, the uncertain returns due limit investments in services such as input supply, provision of credit, storage and processing, thus reinforcing behaviors that lead to continued price instability (Tostão and Tschirley, 2010).

Cirera and Nhate (2007) argue that changes in the exchange rate in neighboring countries tend to be fully transmitted to consumer prices in the domestic market. Although available statistics show that the GDP has been increasing rapidly, inflation rates tend to be higher (Figure 1). This suggests an increased cost of living, which disproportionately affects the poor, who spend most of their income on food. A robust GDP growth and the lack of progress in poverty reduction in the last decade suggest that most of the benefits of economic growth accrue to wealthier households. As a result, inequality levels are likely to increase over time. Nevertheless, the Gini coefficient remained almost the same between 2002-03 and 2008-09, raising questions about who is really benefiting from the economic growth.

Figure 1 Annual GDP growth and inflation rates in Mozambique



The third potential explanation for the weak correlation between rapid economic growth without significant changes in either poverty headcount or inequality is that the benefits of economic growth may accrue to foreign investors. Mozambique was quite successful in attracting foreign investment, such as the aluminum smelter (Mozal), the pipeline for exporting natural gas to South Africa, the mining of titanium in Chibuto and Moma, and the coal mines in Tete (Arndt and Tarp, 2009). However, these 'mega projects' create few local jobs, have few local linkages, and have a small impact on poverty reduction (Thirtle et al., 2003a). They benefit from large tax exemptions, rely heavily on imported goods, and only a very small fraction of their production is consumed locally (Virtanen and Ehrenpreis, 2007). For instance, in 2006 Mozal contributed about 56 percent of total exports and 6.5 percent of the GDP (Sonne-Schmidt et al., 2009). However, the standard income tax of 32 percent that Mozal foundry would be entitled to bear has been replaced by a fixed turnover tax of $4 million, which is less than one percent of Mozal's total export value in 2006 (Andersson, 2001; Sonne-Schmidt et al., 2009).

In the last few years, the rising cost of living has sparked a series of riots throughout the country, especially in urban areas (Hanlon, 2010). This led the government to readjust some development policies. First, in 2008 subsidies were introduced, e.g. for diesel, wheat, water and electricity. These measures proved to be financially unsustainable, and in 2011 some of the subsidies are either due to expire (e.g., diesel subsidies) or will be replaced by cheaper measures (e.g., food vouchers to be given to households below a certain salary threshold).

But these measures are usually biased towards the urban population, and do not address the underlying problems of population growth and stagnating agricultural productivity.

Access to economic opportunities outside agriculture would help increasing consumption, but low educational attainment, poor access to financial markets, and weak infrastructure prevent many smallholders from participating in nonfarm activities, especially those of high return {Cunguara et al., 2011a}. The education system is particularly fragile. Indeed, the war that erupted a year after the independence had a significantly negative effect on education levels. In 1990 only seven percent of the population had completed the primary education, about 68 percent had no formal education, and primary school dropout rates were as high as 60 percent (Caucutt, 2007). In 2002, household heads in rural Mozambique had completed about two or three years of formal education (Walker et al., 2004).

It is also unfortunate that an already challenging task of reducing poverty has been made even harder by the high prevalence of HIV/AIDS (Dorward et al., 2004). It is estimated that in Mozambique, about 12 percent of the population is infected by HIV (CNCS, 2009), and AIDS was the main cause of death among teachers in 2002 (Collins, 2006). The loss of skills of the person with AIDS and loss of time for skill transfer to children can potentially contribute to severe labor shortages and knowledge loss, which would result in cropping shifts and declines in agricultural production (Topouzis and Guerny, 1999), with significant poverty implications.

This study evaluates poverty reduction options in rural Mozambique, with the goal of identifying synergies between economic growth, participation in nonfarm activities, and agricultural productivity growth. The study adds to the existent literature showing that a well-developed agricultural sector can support both economic growth and smallholder participation in nonfarm activities (Matsuyama, 1992; Benfica, 2006; Thurlow, 2008).

1.2 Literature review and identification of research gap

In Africa, a large part of the economic literature concerned with poverty has tended to focus on one of the following three research areas: the role of economic growth, the role of nonfarm activities, and the role of growth in agricultural productivity. The selection of the right combination of strategies depends on an accurate understanding of the main factors associated with poverty. It is therefore essential to review each strand of the economic literature on poverty, and identify the complementarities between the underlying theories, in order to address the multidimensional features of poverty (Ravallion, 1996; Bourguignon and Chakravarty, 2003).

The role that economic growth can play in reducing poverty is summarized in the neoliberal development theory. The theory behind neoliberalism is that macroeconomic stability and greater efficiency in resource allocation will favor economic growth, which should reduce poverty and inequality (Portes, 1997). This leads to an almost exclusive focus on the role that market forces can play in poverty reduction, while the government is assumed to be more effective at reducing poverty by stressing investment in human capital and infrastructure (Hulme and Shepherd, 2003). Typical examples of such policies include the structural adjustment program (SAP) and the poverty reduction strategy papers (PARPA). Due to high poverty levels and low density of infrastructure (including education), economic growth is still one of the development priorities in Mozambique, as expressed in various strategic documents to reduce poverty.

Using a sample of 92 countries, Dollar and Kraay (2002: p219) argue that “growth on average does benefit the poor as much as anyone else in society, and so standard growth-enhancing policies should be at the center of any effective poverty reduction strategy.” A similar view is shared by Fischer (2003: p2) who argues that “as far as economics is concerned, the big challenge is poverty, and the surest route to sustained poverty reduction is economic growth.” Government and donors have therefore converged on the policy mantra that, at the economic level, growth provides the panacea for poverty reduction. As argued by Dollar and Kraay (2002: p218), macroeconomic policies associated with liberalization, such as reducing inflation, moderating the size of the government, trade liberalization, and establishing a sound financial system are good for both generating economic growth and reducing poverty.

Nevertheless, such a focus on ‘getting the prices right’ may not meet the needs of the different types of poor farmers (Sen, 1981; Hulme and Shephard, 2003). The neoliberal theory may encourage a focus on those poor whom the market can ‘liberate’ from poverty, but may neglect the needs of those who need different types of support or policy changes (Hulme and Shepherd, 2003; Boughton et al., 2007; Barrett, 2008). Indeed, Donaldson (2008) surveys cases where the income of the poor increased significantly less than was expected given economic growth. Cassie and Jensen (2009) take a similar approach and look at the time period in Burkina Faso where the correlation between economic growth and poverty reduction was strong. Likewise, Skarstein (2005) argues that the structural adjustment program has contributed in part to the stagnation of agriculture in Tanzania in the period from 1985 to 1998. McMillan et al. (2002) show that in Mozambique liberalization and privatization policies curtailed the development of the cashew sector, greatly raising unemployment due to the collapse of cashew processing factories.

Two other issues emerge when development policies have an excessive focus on ‘getting the prices right.’ First, as argued by Stiglitz (1998), such a focus does not recognize that the government had played an active role in successful development efforts in the United States and many other developed countries. Second, little is said about the distribution of the benefits of economic growth. It appears as if per capita GDP growth directly translates into improved standards of living, particularly of the poor (Blackmon, 2008). Yet, notwithstanding consistent rapid economic growth in Mozambique (and in Tanzania), poverty levels remained unchanged in the last decade (Arndt et al., 2010; MPD/DNEAP, 2010). This leads to focus on the plight of the rural poor. It also leads to considering other pathways out of poverty besides economic growth, and on how such alternatives might strengthen economic growth.

The second strand of the economic literature on poverty reduction relates to income diversification and the role of nonfarm employment. Income diversification is embedded in the portfolio theory, and consists of three dimensions. The first pertains to the reduction of the risk inherent to a rain fed agricultural production system, which leads to fluctuation in farm income (Reardon et al., 1998). This entails combining nonfarm portfolios of different risk profiles. It has also been summarized as an *ex ante* risk management behavior, and *ex post* coping with adverse shocks such as a drought (Barrett et al., 2001).

The second dimension of the portfolio theory concerns market failures in rural areas, particularly for credit and land (Reardon, 1997; Bryceson, 1999; Barrett et al., 2001; Thirtle et al., 2003a). Missing markets can encourage nonfarm diversification, such as when farmers own smaller landholdings and they are unable to rent in more land (Barrett et al., 2001). Nevertheless, missing markets can also hamper income diversification, such as when participation in nonfarm activities requires a substantial financial investment and farmers lack access to any credit (Barrett et al., 2001). Under these conditions, such investments can be facilitated by smallholders’ ownership of liquid assets, i.e., assets that can be easily turned into cash, such as livestock (Thirtle et al., 2003b; Walker et al., 2004).

The third dimension of the portfolio theory comprises the links between farm and nonfarm investments (Reardon, 1994; Mathenge and Tschirley, 2007; Oseni and Winters, 2009). On the one hand, income gains from the use of improved technologies can be invested in nonfarm activities. On the other hand, nonfarm incomes can be used to purchase modern inputs, and therefore increase farm incomes through agricultural productivity growth. In addition, the diminishing or time-varying returns to labor or land can motivate household diversification into the nonfarm employment sector. These differences in the motivations to diversify manifest in differences in nonfarm incomes at the regional, household, and individual levels. At the regional level, such differences stem from differences in agro-ecology and infrastructure such as roads (Walker et al., 2004).

At the household level, once the decision to diversify is made, the nonfarm opportunities available usually differ across income groups (Reardon, 1997; Reardon et al., 2006; Cunguara et al., 2011a}. Poorer households are usually driven by ‘push factors,’ which are related to risk reduction, response to diminishing factor returns in any given use or smaller landholdings, and reaction to crisis or liquidity constraints (Barrett et al., 2001; Reardon et al., 2006). On the contrary, wealthier farmers are usually driven by ‘pull factors,’ mainly for accumulation purposes and strategic complementarities between activities, such as crop-livestock integration (Barrett et al, 2001; Reardon et al., 2006).

Within the household, due to child care-giving responsibilities and relatively limited access to education, women face higher entry barriers to employment in the formal sector (Haggblade et al., 2001). Thus, women tend to engage in informal activities that can be operated from the home (e.g., beer brewing), require low capital investments (e.g., collect firewood) and build on skills they already have (e.g., domestic worker) {Cunguara et al., 2011a}. Within female-headed households, a further distinction can be made between widow and non-widow headed households, given that widows are usually among the most economically disadvantaged households (Walker et al., 2004), and therefore relatively less capable of investing in nonfarm income generating activities.

Worth noting is that although participation in nonfarm activities has the potential to reduce poverty, one contentious issue remains: it can also increase income inequality. It has been shown that poorer households usually do not own enough cash to invest in nonfarm activities, lack access to credit, and have fewer liquid assets. This financial barrier will deter them from participating in nonfarm activities in general. Meanwhile, wealthier households systematically engage in the most lucrative nonfarm activities (Reardon, 1997; Reardon et al., 2006). As a result, wealthier households earn returns many times greater than do poorer households. Wealthier households are also more capable of investing in the use of improved agricultural technologies, and thus attain higher agricultural productivity levels.

The role of growth in agricultural productivity comprises the third strand of the poverty literature. It is frequently argued that growth in agricultural productivity is a fundamental pre-requisite for widespread poverty reduction (Lipton, 1977; Timmer, 1997; Arndt et al., 2000; Irz et al., 2001; Mellor, 2001; Thirtle et al., 2003a; Dorward et al., 2004; Doss, 2006; Ravallion, 2009). Using data from Mozambique and Vietnam, Arndt et al. (2010: p8) show that “agricultural growth will have disproportionately large impacts on rural incomes”. “This confirms”, the study continues, “the strategic role that the agricultural sector can play in economic development and poverty reduction in Mozambique and indicates that the better performance of agriculture likely contributed to the more rapid reductions in poverty experienced in Vietnam.” Furthermore, multipliers are usually greater in rural areas. This implies that agricultural productivity growth will also favor urban households, and forms part of the explanation why economic growth does not generate as much poverty reduction, particularly in a low-income economy with a large rural sector like Mozambique (Rahman and Westley, 2001; Arndt et al., 2010).

The importance of agriculture in Africa as a major source of employment, its contribution to the national income, and its multiplier effect on the rural economy has motivated several studies on the impact of agricultural productivity growth. In some cases, as in de Janvry and Sadoulet (2002), the focus has been on estimating the impact of growth in agricultural productivity in reducing poverty. In others, as in Ravallion (2009), the focus has been in the identification of pre-conditions in which productivity growth in smallholder agriculture can reduce poverty in Africa. In both cases, it is implicitly assumed that improved technologies have a significant impact on household livelihoods. There are some profitability studies estimating the impact of adopting improved technologies (Oehmke and Crawford, 1996; Howard et al., 2003), but in most of these studies it is also implicitly assumed that users and non-users of improved technologies had similar productivity levels before the adoption took place.

The assumption that adoption of improved technologies or the receipt of agricultural services has a positive and significant effect on household incomes (or farm incomes) might not always hold when selection bias is accounted for. Different regions suffer from different weather shocks. Additionally, households are affected differently by labor shortage, and the adoption of improved technologies is correlated with other factors affecting productivity (Doss, 2006; Imbens and Wooldridge, 2009). Moreover, farmers or villages may be systematically selected by development agencies, based on some criteria or rule, leading to an endogenous program placement effect. Therefore, although improved technologies theoretically have the potential to reduce poverty, empirical evidence on the impact of their use, based on the analysis of households with similar characteristics, is still small (e.g., Mendola, 2007; Kassie et al., 2008).

Nevertheless, the agricultural productivity in Sub-Saharan Africa remains among the lowest in the world (Frisvold and Ingram, 1995; Savadogo et al., 1998). This is because in most of these countries smallholder farmers are provided with only limited technical and economic opportunities to which they can respond (Schultz, 1964). Most farmers lack the access to credit or cash, and lack information about improved technologies. In the specific case of Mozambique, at least 85 percent of farmers lack access to extension services, especially the poorest farmers (Mather, 2009). The receipt of extension services provides farmers with information about cropping practices and managerial skills, optimal input use, and high yield varieties (Birkhaeuser et al., 1991). Moreover, about 97 percent of farmers in Mozambique lack access to credit, making it harder to adopt improved technologies even if they have access to information about them through agricultural extension services.

African governments can minimize the constraints to agricultural productivity growth by increasing investments in key public goods such as roads, communication infrastructure, agricultural research, and improving the management of water resources (Rutan, 2002; Poulton et al., 2006b). There is also evidence that a guaranteed output market stimulates the adoption of improved technologies, which in turn contributes to agricultural productivity growth (Boughton et al., 2007; Barrett, 2008; Cunguara and Darnhofer, 2011}.

In any case, as much as nonfarm incomes can be invested in improved agricultural technologies, or growth in agricultural productivity generates income that can be invested in nonfarm activities, there are some complementarities between the neoliberal theory, the portfolio theory, and the theory of technological change. For instance, Stern (1996) found a statistically significant relationship between economic growth and agricultural productivity growth. In addition, Stern (1996) applied the endogenous growth theory to the role of agriculture in economic development and found that agriculture will continue to be of central importance in many African countries. As a result, analyzing each strand of the literature separately is only a starting point, which should be complemented by an analysis of the relationship between each research area and the underlying development theory.

1.3 Research objectives

The three strands of the economic literature (economic growth, diversification into the nonfarm sector, and agricultural productivity growth) will guide the analysis presented throughout this study. Thus, the first objective is to assess the trends in household incomes, poverty, and food security, in the midst of a neoliberal development model adopted by Mozambique, which focuses heavily on economic growth. The second objective is to assess the role of nonfarm employment in reducing household vulnerability to drought, while exploring the recent advances in econometric modeling of censored regressions. The third objective is to evaluate the economic impact of interventions that can potentially enhance agricultural productivity, such as the use of improved technologies and the receipt of extension services, while exploring the recent advances in impact assessment analysis.

2 Theoretical concepts

This chapter reviews the theoretical concepts of the poverty literature. First, it presents the theoretical framework. This is followed by a brief review of the approaches used to understand the causes of rural poverty, and the justification of the approach used in this study. Finally, a conceptual framework is presented, while describing how its components are related to each other.

2.1 Theoretical framework

The notion of linking poverty reduction to a combination of development strategies emanates from the fact that poverty is a multidimensional concept (Ravallion, 1996; Bourguignon and Chakravarty, 2003). As such, broad-based poverty reduction strategies require exploring the complementarities of various mechanisms that can potentially reduce poverty. Three such mechanisms are prominent in the economic literature, namely: economic growth, household diversification into nonfarm activities, and agricultural productivity growth.

The neoliberal development theory posits that the benefits of economic growth would trickle down to the poor (Romer, 1990). Poverty reduction strategies adopted by the Government of Mozambique fit into this theoretical framework. It is implicitly assumed in PARPA that the development strategies are applicable to all types of smallholder farmers, and therefore not much emphasis is placed on tailor-made approaches. In a country as poor as Mozambique, economic growth has certainly multiple benefits. There are many possible links between economic growth and other sectors of the economy. For illustrative purposes, however, only a few are provided below, bearing in mind that this list of possible links is not exhaustive.

First, with economic growth, the government would be able to invest in road infrastructure, which would create more employment opportunities and thus reduce poverty. Second, government revenues could also be used to improve the infrastructure connecting the surplus agricultural areas in the north and center to food deficit regions in the south, and thus stimulating trade. These interventions would also have the potential to foster agricultural productivity growth because improved inputs would be more readily available, while at the same time marketing infrastructure would be improved. Third, the government could also create employment opportunities through credit and saving schemes. Fourth, investments in irrigation schemes would also trigger agricultural productivity growth, which in turn would generate sufficient cash to allow smallholder farmers to participate in the nonfarm employment sector.

Nevertheless, the adoption of a neoliberal development policy implied that the government would practically not intervene in the agricultural sector. Therefore, despite the potential complementarities between the numerous development policies, the government may have missed the opportunity to develop the agricultural sector. If that is the case, then the results should be reflected in household welfare given the importance of agriculture. That is, the benefit of economic growth might have by-passed the rural poor in several ways. This study explores the trends in selected welfare indicators, creation of nonfarm employment opportunities, the use of improved technologies, and many other indicators set forth in PARPA.

2.2 Review of approaches used to understand the causes of rural poverty

An important element in poverty studies is knowing who is poor or having an approach for determining who is poor. The literature provides three main approaches: a quantitative, qualitative, and a multidimensional approach. The latter approach is a combination of the first two. The main difference between the three approaches lies on the welfare measure, how the poverty line is defined, and the analytical methods used to study poverty.

The quantitative approach uses a monetary measure as the welfare measure, such as household incomes or consumption levels. Households are deemed to be poor if their incomes or consumption levels are below a specified threshold, i.e., the poverty line. Three methods are used to set the poverty line: the food energy intake method, the cost of basic needs method, or the $1/day criterion often used for international comparisons (Tarp et al., 2002). Methodological differences within the quantitative approach are known to yield different poverty measures. For instance, the second consumption expenditure survey conducted in Mozambique provides two alternative poverty estimates, depending on the method used to define the poverty line.

There are theoretical reasons why consumption is seen to be more accurate than income as the welfare measure. First, consumption tends to be less volatile than household incomes, and its use reduces the probability of misclassifying households as poor (or non-poor) (Gradin et al., 2004). Second, when using income as the welfare measure, the assumption is that a market exists for all goods, which is not the case in many developing countries. Third, there is no guarantee that households with income at or even above the poverty line would actually allocate their incomes so as to purchase the minimum basic needs bundle (Thorbecke, 2005). Fourth, income figures obtained through household surveys are more likely to be underreported than consumption expenditure (Alderman, 1992).

The qualitative approach uses a different welfare measure and poverty line. Here, the welfare measure can be asset endowment or the perceptions on whether consumptions of food, housing, and clothing were adequate for household needs (Pradhan and Ravallion, 2000). It can also be household's own perceptions about the current economic condition relative to a previous period (Walker et al., 2004). The welfare measure is relatively easier to obtain from simple surveys. However, setting the poverty line is quite challenging. The main desirable features of a poverty line are its consistency and specificity. Consistency is related to making equal classifications for households with the same living standard, but a household whose perception that the current economic condition has worsened can actually be better-off than someone with the opposite perception. Meanwhile, specificity is associated with its applicability to the communities under consideration, and household heterogeneity can make it harder to make comparisons within a given community.

Finally, the multidimensional approach to poverty measurement emerges as a recognition that household welfare depends on both monetary and non-monetary variables (Bourguignon and Chakravarty, 2003). Although higher incomes or consumption levels will likely generate higher welfare in the quantitative approach, it may be the case that markets for some qualitative attributes do not exist, such as with some public goods, or that these markets are highly imperfect (Bourguignon and Chakravarty, 2003). Therefore, the monetary approach as the sole welfare measure is often inappropriate. One popular example of a multidimensional welfare measure is the Human Development Index (HDI). The appealing feature of the HDI is its ability to summarize the standard of living, health indicators, and adult literacy in a single index.

An equally important element in poverty studies is how to analyze the determinants of poverty. In cases where the research focus is on a monetary measure, the determinants of poverty are usually modeled through an OLS regression, where the dependent variable is the total household income/consumption, after a logarithmic transformation, in order to ensure normality and to allow the coefficients to be interpreted as elasticities (see for example Walker et al., 2004; Datt and Jolliffe, 2005). Independent variables usually include a set of demographic variables (e.g., age, gender, and education of household head), access to public services (e.g., the receipt of agricultural extension and membership to a farmers' association), access to financial services (e.g., credit), asset endowment (e.g., cropped area and livestock herd size), location dummies (e.g., agro-ecology or district dummies) and other variables. Some variables are included both in linear and quadratic forms to capture life cycle effects (e.g., age of household head) or diminishing returns (e.g., cropped area or livestock).

Nevertheless, monetary measures tend to be more subject to measurement error than stock variables such as durable assets, because they can only rarely be directly observed and verified (Barrett et al., 2006). Moreover, the stock of productive financial, physical, natural, social and human assets largely determines household income or consumption levels. Therefore, understanding the dynamics of assets is fundamental to understanding persistent poverty and longer-term socio-economic dynamics (Barrett et al., 2006). Unlike the monetary approach where the interest is often in finding who was poor at the time of the survey and which factors are associated with poverty, the asset-based approach often uses the stock of assets to predict who will be structurally poor (Carter and Barrett, 2006). Some studies have focused on understanding who among the poor is structurally positioned to take advantage of new economic opportunities when they become available (Adato et al., 2006). Other studies have focused on the identification of those who are more resilient to negative shocks such as the occurrence of natural calamities (Hoddinott, 2006).

The asset-based approach can also be used to determine asset thresholds separating the transitorily poor from those caught in a poverty trap (Adato et al., 2006). Similarly, the literature often distinguishes between policies to help the structurally poor to move out of poverty from those that directly reduce the risks that may drive non-poor into poverty or the transitorily poor into an escape from poverty (Barrett et al., 2006). This analysis usually requires panel data due to the need to track households over time. The stock of assets can also be used to calculate a welfare index. Some studies have used the principal components analysis to generate such indices (see for example, Filmer and Pritchett, 2001; Langyintuo and Mungoma, 2008). Then an arbitrary poverty line is used to generate a binary variable indicating the poverty status. This binary variable can be used as the dependent variable in a Probit or Logit model to estimate the factors associated with the poverty status.

2.3 Justification for the approach used

This study is mainly based on the quantitative approach, and household incomes were the main welfare measure, mainly due to data availability and the research questions addressed. Although consumption is believed to be a better welfare measure than household incomes, consumption data were not readily available. Moreover, when the research objective is to analyze the determinants of rural poverty and their implications for agricultural development, the analysis of data on consumption expenditure may not lead to specific, actionable conclusions. This is because data on the relevant agricultural variables may be missing from consumption surveys, or variation in data on consumption expenditure may be relatively small and more difficult to explain. Likewise, although the multidimensional approach to poverty is more appealing than the quantitative and qualitative approaches, the dearth of appropriate data conditioned the empirical approach. Nevertheless, the study used various other welfare measures, although not with the same analytical depth as it was in the case with household incomes.

2.4 Conceptual framework

Three mechanisms with the potential to reduce poverty were examined. These are the economic growth, participation in nonfarm activities, and agricultural productivity growth. The choice of these three mechanisms was guided by the fact that poverty is a multidimensional concept, and as such, its reduction requires a combination of different strategies. As discussed in the previous chapter, an exclusive focus on one poverty reducing mechanism is unlikely to result in a broad-based poverty reduction.

The analysis begins by exploring each of the three alternatives to reduce poverty. The role of economic growth in reducing poverty is covered in Cunguara and Hanlon {2011} and in Cunguara et al. {2011a}. In Cunguara and Hanlon {2011}, the analysis pertains to changes in incomes and poverty. The economic condition of smallholder farmers is then correlated with changes (or lack of it) in farming. The analysis also looks at poverty traps, and provides a discussion of the implications of the neoliberal development policy imposed by the donors, while considering alternative policies that might raise agricultural productivity, reduce poverty, and improve food security.

Cunguara et al. {2011a} proceeds by looking at trends in selected assets, food insecurity, and farmers' perception of their economic condition. This provides a basis for comparison of trends in different welfare indicators. The key assumption is that if economic growth reduces poverty, then a GDP growth should be positively correlated with changes in household incomes and food security. The study considers two main sources of changes in incomes and food security: agricultural productivity growth and participation in nonfarm activities.

Cunguara et al. {2011b} examines the role of nonfarm income generating activities in reducing poverty. Earlier, the literature review section linked the participation in nonfarm activities to the reduction of smallholders' vulnerability to drought. This hypothesis is empirically tested among smallholder farmers in southern Mozambique, a region that is frequently affected by drought. The analysis also focuses on the factors associated with the decision to participate in different types of nonfarm activities as well as the incomes earned from each activity.

The third source of change, agricultural productivity growth, is covered in Cunguara and Darnhofer {2011} and Cunguara and Moder {2011}. Two potential sources of agricultural productivity growth are examined: the use of improved agricultural technologies {Cunguara and Darnhofer, 2011} and the receipt of extension services {Cunguara and Moder, 2011}. The technologies evaluated (improved maize seeds, animal traction, tractor mechanization, and improved granaries) were selected based on the expected impact on household income and on data availability. Besides the four technologies included in this analysis, the available data (TIA05) also included the use of chemical fertilizers and pesticides. However, since the survey did not collect data on the type and amount of agro-chemical used or on the crops on which they were applied, the available data was not meaningful enough to be included.

One equally important methodological issue concerned drawing causal relations. Although it is often assumed that the use of improved technologies can increase farm income and thus enhance household incomes, establishing a causal relationship requires dealing with a range of confounding factors, such as the selection bias and endogenous program placement. Sample selection bias may arise in practice for two reasons (Heckman, 1979). First, there may be self selection by smallholders to participate in nonfarm activities {Cunguara et al., 2011b}, to use improved technologies {Cunguara and Darnhofer, 2011} or to receive extension messages {Cunguara and Moder, 2011}. Second, the data may be non-randomly selected because of deliberate placement of development projects. For instance, the coverage of extension services might be higher in the central and northern provinces due to the higher agricultural potential in those two regions.

A causal interpretation of the results is dependent on several assumptions, such as the overlap and unconfoundedness assumptions. The former postulates that the conditional distributions of the covariates of users and non-users (or participants and non-participants) overlap completely. On the other hand, the unconfoundedness assumption asserts that all variables that need to be adjusted for are observed and included in the model. In other words, beyond the observed covariates (modeled through the propensity score), there are no unobserved characteristics of the individual that are associated with both the potential outcome and the treatment. This is also referred to as selection on observables, exogeneity, or ignorability (Imbens and Wooldridge, 2009). Several diagnostic tests were used to assess the plausibility of these two assumptions {Cunguara and Darnhofer, 2011; Cunguara and Moder, 2011}.

Moreover, a causal interpretation of the results could also be affected by spillover effects such as the diffusion of knowledge. A key assumption is that the receipt of extension services or the use of improved technologies by one farmer does not affect outcomes for another farmer (Rubin, 1980). This assumption can be violated when there is interaction between farmers. For instance, farmers who received extension services can share the information on agricultural innovation with their peer neighbors. Details on how the analysis ‘controlled’ for spillover effects are provided in Cunguara and Moder {2011}.

3 Methods

This chapter describes the main data sources used to analyze households' livelihoods and incomes in rural Mozambique. It then discusses how different data sources were made comparable, followed by the econometric approaches used to analyze the data.

3.1 Data sources

The analysis is drawn from all available (seven) national agricultural surveys from Mozambique, commonly known as TIA (Portuguese acronym for *Trabalho de Inquérito Agrícola*). The surveys cover the period from 1996 to 2008, and were implemented by the Department of Statistics within the Directorate of Economics of the Ministry of Agriculture. With the exception of TIA96, the sampling frame for the remaining TIA surveys draws from the Census of Agriculture and Livestock of 1999-2000. The TIA samples were stratified at the provincial level and agro-ecological zone, making them nationally representative at both levels. The sample size varies between 3,891 households covered in TIA96, and 6,248 households in TIA06.

The surveys were designed to be comparable in order to allow the analysis of trends in several indicators, such as agricultural production, household incomes, the receipt of agricultural services, asset endowments, and the use of improved technologies. Nevertheless, they differ quite significantly. In particular, the survey instrument for the estimation of production of root crops (cassava and sweet potatoes) changed considerably from 1996 to 2002, and then again from 2003 onward (Boughton et al., 2006). For instance, in TIA96 the estimate of the total production of cassava was obtained using a single recall question, although the crop is harvested at several intervals throughout the agricultural season. These methodological changes dramatically affect the production estimates. Consequently, they also affect the estimates of total household incomes because farm income represents more than 60 percent of total incomes (Mather et al., 2008), and cassava is the second most important crop (after maize).

In addition to differences in the survey instrument, enumerators were most likely less trained in 1996. By then, the peace accord was only four years old, illiteracy rates were significantly higher, TIA96 was the first nationally representative survey in many years, and training of enumerators may have not been as thorough and rigorous as the remaining surveys (Boughton et al., 2006). In other words, it is possible that, for example, better-trained enumerators in 2002 prompted respondents with more questions about the various crops. As a result, TIA surveys show a significant increase on the average number of crops grown by each household from 1996 to 2002. Nevertheless, some of the increase may be attributed to an increase in cropped area.

Under the conditions described above, the most comparable TIA surveys are those conducted from 2002 to 2008, which include TIA02, TIA03, TIA05, TIA06, TIA07, and TIA08. Most of the analysis presented is therefore based on TIA surveys conducted in that period, while TIA96 data are used sparingly. TIA96 was only used in two papers {Cunguara and Hanlon, 2011; Cunguara et al., 2011b}, mostly with categorical variables, such as asset ownership and whether or not the household used improved technologies. These categorical variables are less problematic than continuous variables such as yield data.

While the analysis excluded TIA96 from most of the papers due to its unreliability, other TIA surveys were not included in some of the analysis, simply because the surveys did not collect the required data. For example, the analysis of trends in total household incomes {Cunguara and Hanlon, 2011}, food security {Cunguara et al., 2011b}, and determinants of nonfarm income {Cunguara et al., 2011a} was restricted to TIA02, TIA05, and TIA08, because data on incomes are not available from the other surveys.

The choice of the survey data for the analysis of the impact of the receipt of extension services {Cunguara and Moder, 2011} or the use of improved agricultural technologies {Cunguara and Darnhofer, 2011} was motivated in the same way. However, the analysis was restricted to TIA05 for two reasons. First, relative to all other TIA surveys, the receipt of extension services was highest in 2005, which is a desirable feature in impact assessment analysis to have a relatively larger sub-sample of beneficiaries. Secondly, because droughts are occurring more frequently (Joubert and Tyson, 1996; Usman and Reason, 2004), and 2005 was a drought year, the analysis of TIA05 is more illustrative of the risks associated with a rain fed agricultural system common to about 98 percent of smallholder farmers in Mozambique (Mather, 2009).

In addition to the availability and reliability of the data, the analysis also considered regional differences in terms of agricultural potential and infrastructure. The analysis of the role of nonfarm income generating activities in reducing poverty {Cunguara et al., 2011a} was therefore restricted to the southern provinces, which are characterized by erratic rainfall, but have better road infrastructure, more livestock and remittances, thus favoring diversification into nonfarm activities. Similarly, the analysis of the impact of animal traction {Cunguara and Darnhofer, 2011} is restricted to the southern provinces because its use is relatively low in central provinces and practically nonexistent in northern provinces. Furthermore, the analysis of the impact of tractor mechanization is also restricted to southern provinces, where 56 percent of all tractors are located, while the analysis on improved maize seeds and improved granaries is restricted to the central provinces, due to relatively higher potential for crop production and more households using these technologies {Cunguara and Darnhofer, 2011}.

Since nonfarm activities differ in terms of entry barriers (Reardon, 1997), nonfarm activities are further disaggregated into seven types: (i) unskilled agricultural wage on small or large farms; (ii) unskilled non-agricultural wage; (iii) skilled or specialized non-agricultural wage; (iv) extraction of flora and fauna products of low returns; (v) extraction of flora and fauna products of high returns; (vi) other self-employment activities of low returns; and (vii) other self-employment activities of high returns. The definition of these seven types of nonfarm activities builds on previous poverty research on Mozambique (Walker et al. 2004; Mather et al., 2008), and is based on the amount of financial investment needed to access them.

Finally, for consistency and comparability purposes, the inflators used to update the 2005 income levels to 2008 are similar to those described in detail in Mather et al. (2008). The 2002 income levels were inflated to reflect the prices in 2005, using data from the consumption expenditure survey of 2002/03 (IAF). IAF 2002/03 consumption quantities (flexible adjusted) from the food consumption basket of each IAF poverty region were used to update the incomes to 2005. These quantities were valued using 2002 retail prices from the Agricultural Market Information System (SIMA), then the basket was revalued with 2005 and 2008 SIMA prices to update the cost of an identical (fixed) consumption basket. The consumption quantities are therefore the weights for the commodity prices. The inflators are fixed because the weights are not allowed to change over time.

3.2 Econometric methods used

The main welfare indicators used in this study are total household income (and in some cases its components: cash incomes, farm and nonfarm incomes), asset endowments, and the perception of the economic condition. The analysis focused on changes for the whole population as well as quantiles of selected welfare indicators. In addition, Kernel density curves were used to evaluate changes in income distribution over time {Cunguara and Hanlon, 2010}. The study also examined the changes in the official poverty and inequality levels, which are based on consumption expenditure surveys.

A significant methodological challenge concerned choosing the food security measure. For this purpose, a measure of caloric acquisition was used. Food security was defined as the ability to obtain the required calories based on farmers' production and purchase of food. A food composition table was used to convert the physical quantities of food that were retained by the household for home consumption. Likewise, cash incomes were converted into caloric values using SIMA maize prices, while taking into account the share of food expenditure. Then, the estimated calories that could be purchased as food were added to calories from farmers' own production that was retained for home consumption. Median provincial prices were used to account for regional differences in prices.

Next, the factors associated with the food security status were modeled using a Probit model. The main goal of estimating a Probit model was to explore the correlations between food security, agricultural production, use of improved technologies, and participation in nonfarm income generating activities {Cunguara et al., 2011a; Cunguara and Darnhofer, 2011; Cunguara and Moder, 2011; Cunguara et al., 2011b}.

Another important methodological issue that the study had to deal with concerned the selection bias. This was relevant for the impact assessment papers {Cunguara and Darnhofer, 2011; Cunguara and Moder, 2011}, and for the paper on participation in nonfarm income generating activities {Cunguara et al., 2011a}. Two distinct methods were used to account for selection bias, and the choice of the method was guided by the nature of problem. In the impact assessment papers, the main objective was to estimate the average treatment effect of either the receipt of extension services {Cunguara and Moder, 2011} or the use of improved technologies {Cunguara and Darnhofer, 2011}. Meanwhile, the objective of modeling nonfarm activities was to analyze the factors associated with both the decision to participate, and the levels of incomes earned from each activity, while considering the correlation between the different types of nonfarm activities {Cunguara et al., 2011a}.

In the case of the impact assessment analysis, a two-stage estimation procedure was used to deal with sample selection bias. The first stage concerned estimating a propensity score model, where the dependent variable was a dummy variable indicating either the receipt of extension services {Cunguara and Moder, 2011} or the use of selected improved technologies {Cunguara and Darhofer, 2011}. The propensity score is defined as the conditional probability of receiving treatment (Rosenbaum and Rubin, 1983). For ease of estimation, most applications have used a Logit model to estimate the propensity score (Dehejia and Wahba, 2002), and this study takes a similar approach. The propensity score was used to identify farmers with similar observable covariates, so that the difference in incomes could be attributed either to the use of improved technologies {Cunguara and Darnhofer, 2011} or the receipt of extension services {Cunguara and Moder, 2011}.

Accordingly, a series of diagnostic measures were used to ensure that users/non-users of improved technologies or beneficiaries/non-beneficiaries of the receipt of extension services had indeed similar covariates, i.e., the overlap assumption was satisfied. The diagnostic tests included the analysis of normalized differences and graphical illustration of the propensity score. In addition, placebo regressions and sensitivity tests to the propensity score model were used to assess the plausibility of the unconfoundedness assumption {Cunguara and Darnhofer, 2011; Cunguara and Moder, 2011}.

The sensitivity test consisted of comparing the results from the propensity score model, based on the original and a series of simulated data. The simulated data were drawn from the original TIA05 data. The concept behind this sensitivity test is that by drawing a large number of samples, the estimated parameters will be close to the "true" parameters. Also, if the parameters from the original and from the simulated data are comparable, then it is likely that the specification of the propensity score is correct and stable. Determining how many random samples should be drawn to be considered a 'large sample' is somewhat arbitrary.

For this study, 25,000 data sets were drawn for each of the four technologies {Cunguara and Darnhofer, 2011} or for the receipt of extension services {Cunguara and Moder, 2011}, each new data set being of the same size as the original TIA05 data. Once the diagnostic tests supported the unconfoundedness and overlap assumptions, a sub-sample of matches was used in the second stage of the estimation procedure.

The second stage concerned the estimation of an Ordinary Least Square (OLS) model on the whole sub-sample of matches (matching and regression) or on quintiles of the propensity score (sub-classification and regression). In addition to matching and regression, and sub-classification and regression, a third approach was used: the doubly robust estimator. The latter approach combines weighting and regression, which can lead to additional robustness by reducing the correlation between the omitted and the included covariates (Imbens and Wooldridge, 2009). The dependent variable in each of the three approaches is the income (farm income or total household income, depending on the research question) after logarithmic transformation. This ensures normality and allows the estimated coefficients to be interpreted as elasticities. Having estimated the average treatment effect, the results from matching and regression were used to simulate whether the receipt of extension services can help reduce poverty {Cunguara and Moder, 2011}.

Unlike the impact assessment methods discussed above, the analysis of the role of nonfarm income activities in reducing poverty {Cunguara et al., 2011a} used a different approach to deal with selection bias. Here, a multivariate sample selection model was used, following the model of Yen (2005), which is an extension of the Heckman approach, and a generalization of the Tobit model. The multivariate sample selection model accommodates censoring in the dependent variable and correlations among error terms across equations. The model avoids biased and inconsistent estimates of the standard errors for each type of nonfarm income generating activity that are caused by estimating the equations independently (a two-stage estimation procedure) and thus ignoring the correlation between types of nonfarm income activities (Greene, 2003).

Seven types of nonfarm activities were modeled. Therefore, a system of seven pairs of equations was estimated. Each pair consisted of a selection and level equations. The former concerned the estimation of the factors associated with the decision to participate (dummy variable) in each type of nonfarm activity. The level equations concerned the estimation of the factors associated with the returns earned (continuous variable) from each nonfarm activity. Therefore, a Probit model was used in the selection equations, whereas an OLS was used in the level equations. The system was estimated simultaneously, while imposing the error correlation between each pair of the selection and its corresponding level equation. Moreover, the error correlation matrix was used as a diagnostic test of sample selection bias. The test consisted of ascertaining whether the correlation of each pair of equations was significantly different from zero.

4 Results: summary of the papers

Earlier, three lines of poverty research were identified: the role of economic growth and neo-liberal development policies in reducing poverty, agricultural productivity growth, and participation into the nonfarm employment sector. The discussion below is guided by these three strands of the economic literature on poverty.

4.1 Economic growth as a pathway out of poverty in rural Mozambique

The first objective of this study was to assess the trends in household incomes, poverty, and food security {Cunguara and Hanlon, 2011; Cunguara et al., 2011b}, in the midst of the neoliberal development model adopted by Mozambique. The results suggest that in Mozambique poverty levels remained statistically unchanged in the last decade. Using data from the consumption expenditure surveys, official statistics indicate that in 2009 about 55 percent of the population lived below the national poverty line, compared to the previous poverty incidence figure of 54 percent in 2002 (Table 1).

Table 1 Poverty statistics in Mozambique by survey year and location

Description/ Survey year	Poverty headcount			Poverty gap			Squared Poverty gap		
	1996-97	2002-03	2008-09	1996-97	2002-03	2008-09	1996-97	2002-03	2008-09
National	69.4	54.1	54.7	29.3	20.5	21.2	15.6	10.3	11.0
Urban	62.0	51.5	49.6	26.7	19.7	19.1	14.6	9.6	9.6
Rural	71.3	55.3	56.9	29.9	20.9	22.2	15.9	10.7	11.6
Northern provinces	66.3	55.3	46.5	26.6	19.5	16.6	13.9	8.9	8.0
Central provinces	73.8	45.5	59.7	32.7	16.0	24.3	18.0	7.9	13.0
Southern provinces	65.8	66.5	56.9	26.8	29.1	22.1	13.9	16.0	11.4
Niassa	70.6	52.1	31.9	30.1	15.8	12.3	16.1	6.7	6.5
Cabo Delgado	57.4	63.2	37.4	19.8	21.6	11.5	9.1	9.5	4.8
Nampula	68.9	52.6	54.7	28.6	19.5	20.0	15.3	9.3	9.8
Zambézia	68.1	44.6	70.5	26.0	14.0	27.9	12.3	6.1	13.9
Tete	82.3	59.8	42.0	39.0	26.3	16.5	22.5	15.3	8.9
Manica	62.6	43.6	55.1	24.2	16.8	21.1	11.7	9.2	11.1
Sofala	87.9	36.1	58.0	49.2	10.7	27.0	32.1	4.3	17.1
Inhambane	82.6	80.7	57.9	38.6	42.2	20.9	21.4	26.0	10.1
Gaza	64.6	60.1	62.5	23.0	20.6	28.3	10.9	9.3	16.7
Maputo Province	65.6	69.3	67.5	27.8	31.1	25.6	14.7	17.2	12.5
Maputo City	47.8	53.6	36.2	16.5	20.9	11.8	7.7	10.3	5.2

Source: Third National Poverty Assessment (2010) – MPD/DNEAP.

Nampula and Zambézia provinces account for about half of the national population. These two provinces are predominantly agricultural-based. Poverty levels increased significantly there. Market segmentation and poor road infrastructure puts a major hurdle in the agricultural value chain (Tostão and Brorsen, 2005). Farmers in the central and the northern provinces are usually unable to sell their surplus to the deficit southern provinces, and if they do sell, it is usually soon after the harvesting season when prices are substantially lower.

Other welfare indicators were also examined. Households in 2008 perceived their economic conditions as significantly better than in 2005, but not as good as in 2002. This suggests that between 2002 and 2008 their economic condition worsened, which is consistent with trends both in household incomes from TIA and consumption expenditure surveys for the same period. This might seem paradoxical since ownership of some assets shows improvements. One explanation is that assets are unequally distributed in rural Mozambique. For instance, although on average the percentage of households with thatched roofs has declined, the change was greater among the top quintile of per capita cash income. Interestingly, thatched roofs, often associated with low incomes, are common even among the wealthiest in rural Mozambique.

A similar pattern recurs with other assets. All quintiles experienced an increase in cropped area between 2002 and 2005, which is consistent with changes observed in household income between these two periods. However, in the period leading up to 2008 all quintiles experienced a decline in the cropped area, and the decline was relatively greater among the lowest quintiles of per capita cash income.

Regarding food security, the results show that food insecurity was lowest in 2002, but has been increasing ever since. About 43 percent of rural households were food insecure in 2002, which implies that they had to rely on food aid. Of note is that the definition of food security used in this study accounts for both produced and purchased food. Lowering food prices would therefore have a positive effect on food security. This can be accomplished by increased investment in agro-processing and storage in rural areas, especially in the regions with a high potential for crop production (Arndt et al., 2001).

In 2008 the percentage of food insecure households increased to about 48. The results also show that an overwhelming majority of households in the bottom three quintiles of cash income per capita are food insecure. Moreover, food insecurity decreases when moving from the bottom to the upper quintiles, but the change is noticeably greater from the fourth to the top quintile. This is because the median cash income per capita in the top quintile is about twice as high as the median among households in the fourth quintile, and maize production is about three times higher among those in the top quintile.

Food security can be enhanced either through market participation, agricultural productivity growth (through the use of improved technologies) or both. However, the use of improved technologies remains extremely low and access to agricultural services decreased in recent years, hence the yields also remain low. Agriculture continues to be one of the most important economic activities in Mozambique. Rapid economic growth wins high praise from the international community, and has been driven by growth in industrial production, mainly in 'mega projects.' However, the results of this study suggest that the benefits of economic growth have so far bypassed the poor.

Economic growth is concentrated in the industry, mostly located in peri-urban areas, with few linkages with the rest of the economy. The urban population is growing, so is the demand for food and the reliance on food imports, especially in the southern provinces. Yet investments in agriculture and rural areas tend to be disproportionately lower. Government's expenditures in the agricultural sector is less than the 10 percent of the total budget agreed by many African countries as part of the Comprehensive African Agriculture Development Program (CAADP) initiative. Similarly, the percentage of total international aid allocated to agriculture is low, relative to the other sectors. Furthermore, provinces of greater agricultural potential and population size tend to receive comparatively less government budget for agriculture.

4.2 Non-agricultural pathway out of poverty in rural Mozambique

The second objective of this study concerned the role of household diversification outside the agricultural sector in reducing drought vulnerability and poverty {Cunguara et al., 2011a}. This study applied recent developments in econometric modeling of censored regressions to untangle the relationship between drought, participation in nonfarm activities, and poverty. In general, participation in nonfarm activities increased for almost all activities between 2002 and the drought year 2005, but decreased in the period from 2005 to 2008.

Regarding household demographics, the low levels of educational attainment explain in part the low participation in ‘skilled non-agricultural’ activities, and the relatively higher participation in ‘unskilled agricultural’ and ‘unskilled non-agricultural’ activities. The relatively high share of female-headed households engaged in nonfarm activities in the southern provinces may reflect male outmigration, who may seek employment in urban centers or in the mining sector in neighboring South Africa. Therefore, remittances are higher in the south, which enables some smallholder farmers to participate in nonfarm activities that require some initial investment, such as ‘skilled’ and ‘unskilled’ non-agricultural activities of high return.

Overall, the effect of drought on the participation in nonfarm activities does not present a uniform pattern, neither in the proportion of households participating in a single type of nonfarm activity, nor in the per capita earning from each nonfarm income activity. However, when assessing the proportion of households who participated in more than a single type of nonfarm activity, there is a significant difference between the drought year 2005 and the two other years (2002 and 2008). This indicates that households tend to participate in more than one type of nonfarm activity in a year of drought, but the activities in which they engage in vary, depending on availability, accessibility or expected return {Cunguara et al., 2011a}.

The results of the multivariate sample selection models show that relatively poorer households are more likely to participate in nonfarm activities but often earn less than wealthier households. This can be related to the inability of poorer households to raise the money necessary to cover the initial investments. Such barriers to enter into high return activities can be eased through livestock ownership. Livestock promotion programs are thus likely to have a significant impact on poverty reduction. Alternatively, the government or any development agency could offer direct support, e.g., in the form of micro-credit or group savings schemes within farmers’ associations.

Worth noting is that households in the bottom quintile of net income per capita participate in nonfarm activities mostly as a drought coping mechanism, whereas households in the top quintile engage in nonfarm activities as a permanent livelihood strategy {Cunguara et al., 2011a}. Income diversification through on-going participation in nonfarm activities can thus be a pathway out of poverty. This calls for policy interventions supporting participation in nonfarm activities, such as ensuring primary education for the rural population and improving road infrastructure to allow access to markets.

When designing these policies, however, equity issues should be taken into account, especially to ensure that the poorer and female-headed households will benefit directly from the interventions. Despite the challenges involved, policy makers should avoid designing interventions that relegate poor households to low-return activities such as ‘unskilled agricultural and non-agricultural’ wage labor. These serve primarily as short-term coping strategies, rather than being a pathway out of poverty.

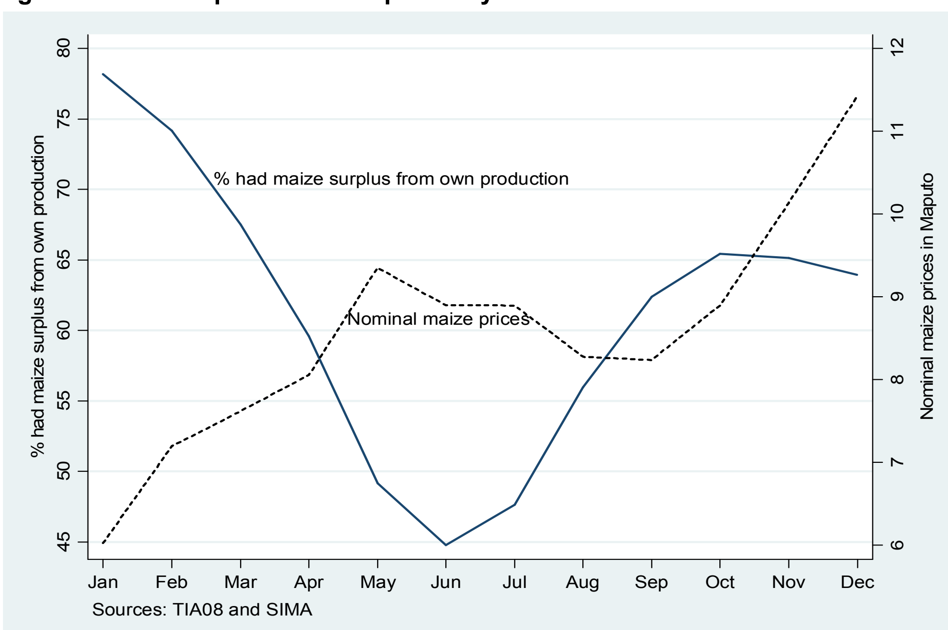
Breaking some of the barriers to participation in nonfarm activities of high return requires rather long term investments, such as in education. In the short run, however, it would be necessary to increase the profitability of activities that are predominant among the poor. These include milling and agro-processing activities, highlighting the synergy between agricultural and nonfarm activities. It will also be necessary to raise agricultural productivity and production. This would then stimulate the demand for non-agricultural goods, thus increasing nonfarm incomes.

4.3 Agricultural productivity growth as the route out of poverty

The third and last objective of this study was to assess the economic impact of interventions that can potentially enhance agricultural productivity growth, and hence reduce poverty {Cunguara and Moder, 2011; Cunguara and Darnhofer, 2011}. The results suggest that agricultural productivity did not improve. Maize is Mozambique's main staple crop, and its production levels have not changed in the past decade. Moreover, the poorest 20 percent of smallholder farmers produce only one percent of the country's maize, while the top 20 percent produces more than half. On average, farmers only produce enough food to feed their families adequately for less than eight months of the year, and this did not improve in recent years {Cunguara and Hanlon, 2011}.

As discussed in section 4.1, this implies that smallholders rely on food purchases. However, they participate in the market in relatively unfavorable conditions, usually selling the majority has maize surplus soon after the harvesting season. This is when prices are substantially lower, between January and May (see Figure 2). Then most farmers run out of maize by June, and they have to purchase maize. However, in June prices are usually very high, which has a negative welfare effect. Thus, policies to reduce the markup price, especially during the late dry season, would have a marked impact on food security and poverty.

Figure 2 Maize surplus vs maize prices by month in 2008



One reason for lack of improvement in agricultural productivity is that the use of improved technologies is extremely low in regions of higher agricultural potential. For instance, the use of chemical fertilizers is lowest in northern Mozambique: only 0.2 percent of farmers use chemical fertilizer on maize. In addition, the use of animal traction in the northern provinces is practically nonexistent due to the occurrence of the trypanosomiasis disease in cattle. Furthermore, the access to public services such as agricultural extension and commodity price information has declined in recent years, despite the evidence from some studies suggesting that the receipt of such services has a significant impact on farm income {Cunguara and Moder, 2011}.

In terms of the impact of the use of improved technologies, the results from matching and regression and the doubly robust estimator show that, in general, the adoption of improved agricultural technologies was surprisingly not statistically significant in enhancing household incomes in rural Mozambique {Cunguara and Darnhofer, 2011}. However, the results from sub-classification and regression show that adoption of improved technologies has a positive and significant impact in increasing incomes for households with access to the markets, despite drought. The study also evaluated the impact of the receipt of extension services. The results consistently show that the impact of agricultural extension on farm income is positive and statistically significant. On average, the receipt of extension advice increases farm incomes by 12 percent.

Although the receipt of extension services increases farm incomes, extension visits alone may not have a significant impact on poverty reduction. Agricultural extension fails to develop technologies that require few off-farm resources. Moreover, the coverage of extension services is rather small to have a significant impact on poverty reduction. At the national level, extension services reached 15 percent of the rural population in 2005, but visited households are usually not the poorest ones. Additionally, extension services show a downward trend since 2005.

5 Discussion and conclusion

This chapter discusses the key results in light of the poverty reduction literature. These results are drawn from the papers included in Part B, which are referred to in curly brackets. Some methodological and theoretical implications are then drawn from those five papers. This is followed by policy implications and perspectives for future poverty reduction research.

5.1 Discussion of the key results in light of the literature

There is a growing recognition that past approaches, especially those predicated on simply getting the macro economy and prices 'right', which was the preoccupation of donor agencies in the 1980s and 1990s, did not generate the broadly based economic growth needed for sustainable poverty reduction (Stiglitz, 1998; Williamson, 2003; Killick et al. 2005; Barrett et al., 2006). The results presented in this study also suggest that poverty levels remained unchanged, and food security increased {Cunguara and Hanlon, 2011; Cunguara et al., 2011b}, which does not support previous poverty research on Mozambique. Nevertheless, the third national poverty assessment recognizes that not much progress has been made in reducing poverty in the last decade. The recognition that economic growth alone might not reduce poverty has in turn motivated a search for a better understanding of the micro-level constraints to poverty reduction (Barrett et al., 2006), and new developing strategies are emerging.

In 2009 the Government of Mozambique launched the National Program to Stimulate Food Production (hereafter PAPA). The program consists of stimulating the use of improved seeds and chemical fertilizers. In Africa, some studies have analyzed the impact of improved technologies in reducing poverty. These studies typically use the net present value or other profitability approaches, and in general, show a positive and significant impact of the adoption of improved technologies (Oehmke and Crawford, 1996; Simalenga and Longisa, 2000; Howard et al., 2003). This study, however, shows that in general, the use of improved technologies surprisingly do not have a significant impact in reducing poverty because of the poor market infrastructure in Mozambique and the cyclical occurrence of droughts {Cunguara and Darnhofer, 2011}. This finding does not support the usual perception that adoption of improved technologies will significantly increase household incomes (Panin, 1989; Oehmke and Crawford, 1996; Simalenga and Longisa, 2000).

The receipt of agricultural extension has a positive and significant impact on farm income {Cunguara and Moder, 2011}. Targeting the poorest households, however, results in lower farm incomes. This explains the insignificant impact of the receipt of extension services found in Walker et al. (2004), and more recently in Mather (2009). Neither study estimated the impact of agricultural extension based on household typology. Nevertheless, agricultural extension alone is unlikely to reduce poverty. This resonates with recent research suggesting that extension services fail to develop resource-poor technologies (Snapp et al., 2003; van den Berg and Jiggins, 2007). Farmers often do not have the resources to adopt and adapt the recommendations provided by the extension workers.

Participation in nonfarm income generating activities has the potential to reduce poverty in rural Mozambique {Cunguara et al., 2011a}. This result has long been acknowledged by other studies on Mozambique (see, for example, Walker et al., 2004; Benfica, 2006). The results also show that participation in nonfarm activities increases during a drought year, and the poorest households are more likely to engage in the nonfarm employment sector {Cunguara et al., 2011a}. Nevertheless, the access to nonfarm activities is significantly skewed, with the poorest households engaging in 'low return activities', while their wealthier counterparts have better access to 'high return' nonfarm income generating activities. This result is consistent with similar studies conducted in Africa (see for example, Reardon, 1997; Benfica, 2006; Debela et al., 2011).

5.2 Methodological implications

This study contributes to the understanding of poverty in several ways. First, the analysis of household income diversification {Cunguara et al., 2011a} was based on recent developments in econometric modeling of censored regressions. This allowed accounting for the correlations between the decisions to participate in various types of nonfarm activities and the incomes earned from such activities, while controlling for sample selection bias.

Second, the use of recent developments in the econometric analysis of impact assessment studies showed a rather surprising result. When properly accounting for sample selection bias and endogenous program placement, the use of improved technologies had no statistically significant impact on household incomes, unless the household had access to markets {Cunguara and Darnhofer, 2011}. This implies that impact assessment research should deal with sample selection whenever possible. This usually requires baseline data on probable adopters before the adoption takes place. Panel data, however, are rare in Mozambique, and this study used a cross-sectional approach which can be extended to other development projects where panel data are nonexistent.

Third, this study contributes to the debate of food security measurement by proposing a food security measure that captures food availability through farmers' own production, and access to food through purchases. The proposed food security measure showed a similar trend with that of household incomes, consumption, or poverty, thus lending support to its validity as a proxy of food security {Cunguara et al., 2011b}.

Fourth, the sensitivity analysis of the propensity score is challenging, as the literature provides little guidance on how it could be performed (Gibson-Davis and Foster, 2005; Gilligan and Hoddinott, 2007). This study contributes to the impact assessment literature by proposing a method to assess the plausibility of the unconfoundedness assumption, which consists on generating a 'large sample' of simulated data and comparing the estimated coefficients to those from the original data {Cunguara and Darnhofer, 2011; Cunguara and Moder, 2011}. The results showed no reason for concern, and hence the unconfoundedness assumption was reasonable.

Finally, the results from the papers included in this study suggest that poverty reduction strategies in rural Mozambique should be analyzed at the regional level. This result has been reported elsewhere (see Silva, 2007). For instance, some interventions are more suitable for the southern provinces (e.g., animal traction and participation in nonfarm activities) while others may be suitable for the central and northern provinces, provided that certain conditions are met.

5.3 Theoretical implications

This study analyzed three streams of the poverty literature: economic growth, participation in nonfarm activities, and agricultural productivity growth. In relation to these three strands of the literature, different perspectives and development theories have been discussed. Reducing poverty is very challenging, and development programs must account for the diversity of household characteristics, the agro-ecology, livelihood resources, access to the markets, among other variables. The results imply that none of the development theories is as effective in reducing poverty as a judicious combination of them. Therefore, development strategies should have an appropriate balance between the various theories. This balance, however, may be missing in the PARPA.

The results from the impact assessment papers {Cunguara and Darnhofer, 2011; Cunguara and Moder, 2011} suggest that technological change requires an enabling environment for an effective and profitable adoption to occur. Most importantly, access to output markets proved to have a crucial role. Successful promotion of the use of improved technologies should be accomplished by investments in market infrastructure. Put differently, emphasis should not be placed on increasing production alone, but the whole agricultural system.

Finally, rapid economic growth may not be effective in reducing poverty if it is concurrent with population growth, especially in urban areas, with the stagnation of agriculture and with inflation. This result has long been highlighted in the literature (Kalechi, 1976; Bhaduri, 2006; Rakshit, 2009).

5.4 Policy implications

The theory behind liberalization common in most African countries was that state-owned boards were expensive and inefficient, and in a free market smallholder farmers would capture more of the surplus and prosper. Neoliberal development policies in Mozambique resulted in significant economic growth in the 15 years up to 2010. In addition, it is hard to dispute the importance of economic growth in a poor country like Mozambique. Yet the dawning recognition that poverty is not being reduced, at least not as quickly as previously thought, calls for some rethinking in poverty reduction strategies.

First, economic growth is a necessary but not sufficient instrument to generate a broad-based poverty reduction in Mozambique. Donors and the Government may need to stress not only the social areas (Millennium Development Goals 2-6), but also pay more attention to agriculture and creation of nonfarm employment opportunities (Millennium Development Goal 1). This is related to agricultural growth and income diversification, which in turn requires recognition that the government should play a proactive role in improving the market infrastructure.

Second, to reduce poverty, it may be more effective to devise regional strategies instead of a national PARPA. The current PARPA recognizes that there are significant regional differences in terms of poverty, food security, and agricultural potential. But this recognition is not translated into clear regional strategies to reduce poverty. Accordingly, Mozambique suffers from natural calamities almost every year – droughts or dry spells in the south, and floods in the center and north. Instead of simply acknowledging this problem, the strategies to reduce poverty should take the occurrence of droughts and floods into account. For instance, the promotion of nonfarm employment opportunities could be intensified in the southern provinces. In the meantime, significantly more investments in market infrastructure are required in the central and northern provinces, which would make the use of improved technologies profitable.

Third, the issue of poverty not being reduced is not only related to policies and vagaries of the weather, but also the government's role. The IMF and other donors allow protection for the sugar sector, where the plantations are owned by trans-national corporations who said their investment was dependent on protection, but not for other crops grown by smallholder farmers. Large tax breaks and other de facto subsidies are permitted for foreign investors, particularly in the mineral and energy sectors, but agricultural subsidies are practically not allowed for smallholder farmers. One of the world's largest tobacco companies has been given exclusive rights to control tobacco production in much of the country and set up what is, in effect, a marketing board, but the state is not allowed to create a similar system for other crops.

5.5 Perspectives for future research

The results from Cunguara et al. {2011a} are based on the assumption that the effect of a drought on the participation in nonfarm activities will take place within the same agricultural year. Although this is likely for many activities that are used as short-term coping strategies, long-term and strategic diversification behavior may not be adequately captured. Also, it is likely that engaging in any nonfarm activity will have a long-term effect, e.g., through learning and building social networks (Eriksen and Silva, 2009), which will affect subsequent participation in nonfarm activities. Furthermore, the behavior of households in a given year is likely to be affected by the quality of the previous agricultural year(s). Future studies on the determinants of participation in nonfarm activities based on panel data spanning longer period of time would provide valuable insights allowing for better understanding of these correlations.

Participation in nonfarm income proved to be one of the mechanisms to cope with the vagaries of the weather. However, other mechanisms should also be considered in future studies, both in drought and flood prone areas. Some of the alternatives include studying the potential impact of using water harvesting and conservation technologies. These studies should include a cost-benefit analysis. Additionally, whenever possible such technologies should be adapted and tailored to meet the socio-economic conditions of smallholder farmers.

So far the food security measure only captures two components of food security, namely food availability and access. Food utilization and farmers' resilience are not accounted for. In the future, it would be interesting to improve the food security measure to better reflect farmers' constraints to food security.

Regarding the survey instrument, improvements are likely to yield more accurate data and thus allow more nuanced analysis. For example, the timing of the use of improved technologies should be recorded. Sowing improved seeds in November will have a different impact than sowing in December. Likewise, plowing in November will likely have a different impact than plowing in late December. Furthermore, there are numerous extension methods that could be used by the extension workers, which in turn differ in terms of the effectiveness. These differences can affect the estimates of the impact of the receipt of extension services or the use of improved technologies. The survey instrument should therefore collect information on the type of extension method. Other important suggestions to improve the survey instrument are described in Doss (2006).

References

Adato, M., Carter, M. May, J., 2006. Exploring poverty traps and social exclusion in South Africa using qualitative and quantitative data. Journal of Development Studies, 42(2), 226-247.

Alderman, H., 1992. Incomes and Food Security in Ghana. CFNPP Working Paper Nº 26. Ithaca, NY.

Arndt, C., Jensen, H., Robinson, S., Tarp, F., 2000. Marketing Margins and Agricultural Technology in Mozambique. Journal of Development Studies 37(1), 121-137.

Arndt, C., Tarp, F., 2001. Who gets the goods? A general equilibrium perspective on food aid in Mozambique, Food Policy 26, 107-19.

Arndt, C., James, R, Simler, K., 2006. Has Economic Growth in Mozambique been Pro-Poor? Journal of African Economies 15(4), 571-602.

Arndt, C., Tarp, F., 2009. Taxation in a low-income economy: the case of Mozambique. Routledge.

Arndt, C., Garcia, A., Tarp, F., Thurlow, J., 2010. Poverty Reduction and Economic Structure Comparative Path Analysis for Mozambique and Vietnam. UNU WIDER Working Paper No. 2010/122.

Barrett, C., 2008. Smallholder market participation: concepts and evidence from eastern and southern Africa, Food Policy, 33(4), 299-317.

Barrett, C., Reardon, T., Webb, P., 2001. Nonfarm income diversification and household livelihood strategies in rural Africa: concept, dynamics, and policy implications. Food Policy 26(4), 315-331.

Barrett, C., Carter, M., Little, P., 2006. Understanding and reducing persistent poverty in Africa: Introduction to a special issue. Journal of Development Studies 42(2), 67–177.

Bhaduri, A. (2006) 'Structural Change and Economic Development: On the Relative roles of Effective Demand and the Price Mechanism in a 'Dual Economy', pp. 110-123 in Bhaduri (2006) Employment and Development. *Essays from an Unorthodox Perspective*. New Dehli: Oxford University Press.

Birkhaeuser, D., Evenson, R., Feder, G., 1991. The Economic Impact of Agricultural Extension: A Review. Economic Development and Cultural Change 39(3), 607-650.

Blackmon, P., 2008. Rethinking poverty through the eyes of the International Monetary Fund and the World Bank, International Studies Review, 10:179-202.

Boughton, D., Mather, D., Tschirley, D, Walker, T., Cunguara, B., Payongayong, E., 2006. Changes in Rural Household Income Patterns in Mozambique, 1996-2002, and Implications for Agriculture's Contribution to Poverty Reduction. Ministry of Agriculture Working Paper No. 61E. Maputo.

Boughton, D., Mather, D., Barrett, C., Benfica, R., Abdula, D., Tschirley, D., Cunguara, B., 2007. Market Participation by Rural Households in a Low-Income Country: An Asset-Based Approach Applied to Mozambique. Faith and Economics 50, 64-101.

Bourguignon, F., Chakravarty, S., 2003. The measurement of multidimensional poverty. Journal of Economic Inequality 1: 25–49.

Brück, T., FitzGerald, V., Grigsby, A., 2000. Enhancing the private sector contribution to post-war recovery in poor countries. QEH Working Paper Series QEHWPS45(3), International Development Centre, University of Oxford, UK.

Brück, T., van den Broeck, K., 2006. Growth, Employment and Poverty in Mozambique. Discussion Paper 21.

Bryceson, D., 1999. African rural labour, income diversification and livelihood approaches: A long term development perspective. Review of African Political Economy 26(80), 171-189.

Carter, M., Barrett, C., 2006. The economics of poverty traps and persistent poverty: an asset based approach. Journal of Development Studies 42(2), 178-199.

Casse, T., Jensen, S., 2009. Do we understand the linkages between economic growth, poverty targets and poverty reduction? Review of African Political Economy 36(122), 539–553.

Caucutt, E., Kumar, K., 2007. Education for all. A welfare-improving course for Africa? Review of Economic Dynamics, 10, 294-326.

Cirera, X., and Nhate, V., 2007. An empirical estimation of the degree of price transmission from border to consumer prices in Mozambique. Research Report No. 39E, Chapter 11. National Directorate of Studies and Policy Analysis. Ministry of Planning and Development, Mozambique.

CNCS (Conselho Nacional de Combate ao SIDA), 2009. Plano Estratégia Nacional de Resposta ao HIV e SIDA 2010 – 2014. Maputo: Conselho Nacional de Combate ao SIDA.

Collins, C., 2006. Mozambique's HIV/AIDS Pandemic: Grappling with Apartheid's Legacy. Social Policy and Development Programme Paper No. 24, United Nations Research Institute for Social Development, Geneva, Switzerland.

Crook, R., 2003. Decentralisation and poverty reduction in Africa: The politics of local-central relations. Public Administration and Development 23, 77–88.

Cunguara, B., Darnhofer, I., 2011. Assessing the impact of improved agricultural technologies on household incomes in rural Mozambique. *Food Policy*, 36(3):378-390.

Cunguara, B., Hanlon, J., 2011. Poverty is not being reduced in Mozambique. Paper resubmitted to Development and Change on 2 June, 2011.

Cunguara, B., Moder, K., 2011. Is agricultural extension helping the poor? Evidence from rural Mozambique. *Journal of African Economies*, (in press).

Cunguara, B., Langyintuo, A., Darnhofer, I., 2011a. The role of nonfarm income in coping with the effects of drought in southern Mozambique. *Agricultural Economics*. (in press).

Cunguara, B., Mabiso, A., Hanlon, J., 2011b. Trends in food security in Mozambique, 1996/2008. Submitted to Food Policy in October 2010.

Datt, G., Jolliffe, D., 2005. Poverty in Egypt: modeling and policy simulation. Economic Development and Cultural Change, 53(2), 327-346.

Dehejia, R., Wahba, S., 2002. Propensity score-matching methods for nonexperimental causal studies. The Review of Economics and Statistics 84 (1), 151-161.

de Janvry, A., Sadoulet, E., 2002. World poverty and the role of agricultural technology: direct and indirect effects. Journal of Development Studies 38(4), 1-26.

Dollar, D., Kraay, A., 2002. Growth is good for the poor. Journal of Economic Growth 7, 195-225.

Donaldson, J., 2008. Growth is good for whom, when, how? Economic growth and poverty reduction in exceptional cases. World Development 36(11), 2127-2143.

Dorward, A., Kydd, J., Morrison, J., Urey, I., 2004. A policy agenda for pro-poor agricultural growth. World Development 32(1), 73–89.

Doss, C., 2006. Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. Agricultural Economics 34, 207-219.

Fauvet, P., 2000. Mozambique: growth with poverty – A difficult transition from prolonged war to peace and development. Africa Recovery 14(1), 12-19.

Filmer, D., Pritchett, L., Estimating wealth effects without expenditure data – or tears: an application to educational enrollments in states of India. Demography 38(1), 115–132.

Fischer, S., 2003. Globalization and its challenges, The American Economic Review 93(2), 1-30.

Fórum Nacional do MARP, 2008. Mecanismo Africano de Revisão de Pares, Relatório de Auto-Avaliação do País, Tomo I, Maputo. (www.marp.org.mz, last accessed 18 March 2010)

Fox, L., Bardasi, E., van den Broeck, K., 2005. Poverty in Mozambique: Unraveling Changes and Determinants. Africa Region Working Paper Series No. 87, World Bank, Washington DC.

Frisvold, G., Ingram, K., 1995. Sources of agricultural productivity growth and stagnation in sub-Saharan Africa. Agricultural Economics 13: 51-61.

Gibson-Davis, C., Foster, M., 2005. Using propensity scores to estimate the effect of food stamps on food security. Discussion Paper no. 1293-05, Institute for Research on Poverty, University of Wisconsin, Madison.

Gilligan, D., Hoddinott, J., 2007. Is there persistence in the impact of emergency food aid? Evidence on consumption, food security, and assets in rural Ethiopia. American Journal of Agricultural Economics 89(2), 225-242.

Gore, C., 2000. The rise and fall of the Washington Consensus as a paradigm for developing countries. World Development 28(5), 789-804.

Government of Mozambique, 2006. Plano de Acção de Redução de Pobreza Absoluta 2006-2009.

Gradin, C., Cantó, O., del Rio, C., 2004. Inequality, poverty and mobility: choosing income or consumption as welfare indicators. Paper Prepared for the 28th General Conference of The International Association for Research in Income and Wealth, Cork, Ireland, August 22–28, 2004.

Haggblade, S, Hazell, P., Brown, J., 2001. Farm-nonfarm linkages in rural Sub-Saharan Africa. World Development 17(8), 1173-1201.

Handa, S., and Mlay, G., 2006. Food consumption patterns, seasonality and market access in Mozambique. Development Southern Africa, 23(4): 541-560.

Hanlon, J., 2009. Mozambique: the panic rage of the poor. Review of African Political Economy 36(119), 125-130.

Hanlon, J., 2010. Mozambique: the war ended 17 years ago, but we are still poor. Conflict, Security & Development 10(1), 77-102.

Hanlon, J., Smart, T., 2008. Do Bicycles Equal Development in Mozambique. Woodbridge: James Currey.

Heckman, J., 1979. Sample selection bias as a specification error. Econometrica 47(1): 153-161.

Hoddinott J., 2006. Shocks and their consequences across and within households in Rural Zimbabwe. Journal of Development Studies 42(2), 301-321.

Howard, J., Crawford, E., Kelly, V., Demeke, M., Jaime, J.J., 2003. Promoting high-input maize technologies in Africa: the Sasakawa-Global 2000 experience in Ethiopia and Mozambique. Food Policy 28, 335-348.

Hulme, D., Shepherd, A., 2003. Conceptualizing chronic poverty. World Development 31(3), 403-423.

Imbens, G., Wooldridge J., 2009. Recent developments in the econometrics of program evaluation. Journal of Economic Literature 47 (1), 5-86.

INE (Instituto Nacional de Estatística), 2004. Anuário estatístico. Maputo, Mozambique.

INE (Instituto Nacional de Estatística), 2010. Área de Estatística: Produto Interno Bruto. http://www.mozdata.gov.mz/pxweb2007/Database/INE/00/54/54.asp. (accessed on June 5th, 2010).

Irz, X., Lin, L., Thirtle, C., Wiggins, S., 2001. Agricultural Productivity Growth and Poverty Alleviation. Development Policy Review 19 (4), 449-466.

Joubert, A.M., Mason, S.J., Galpin, J.S., 1996. Droughts over southern Africa in a doubled-CO2 climate. International Journal of Climatology 16(10), 1149-1156.

Kalecki, M. (1976) 'Problems of Financing Economic Development in a Mixed Economy, pp. 98-115 in M. Kalecki, *Essays in Developing Economies*. Brighton: Harvester Press.

Kassie, M., Pender, J., Yesuf, M., Kohlin, g., bluffstone, R., Mulugeta, E., 2008. Estimating returns to soil conservation adoption in northern Ethiopian highlands. Agricultural Economics 38, 212-232.

Killick, T., 1995. IMF programmes in developing countries: design and impact, London: Routledge.

Langyintuo, A., Mungoma, C., 2008. The effect of household wealth on the adoption of improved maize varieties in Zambia. Food Policy 33, 550-559.

Lipton, Michael, 1977. Why poor people stay poor? Urban bias in world development. London: Temple Smith.

MacMillan, M., Horn, K., Rodrik, D., Elbadawi, I., and O'Connell, S.,2003. When economic reform goes wrong: Cashews in Mozambique. *Brookings Trade Forum*, pp.97-165.

Mathenge, M., Tschirley, D., 2008. Off-farm work and farm production decisions: Evidence from maize-producing households in rural Kenya. Working Paper No. 33, Tegemeo Institute of Agricultural Policy and Development, Kenya.

Mather, D., 2009. Measuring the impact of public and private assets on household crop income in rural Mozambique, 2002-2005. MINAG Working Paper n. 67E, Maputo, Mozambique.

Mather, D., Cunguara, B., Boughton, D., 2008. Household income and assets in rural Mozambique, 2002-2005: Can pro-poor growth be sustained. MINAG Working Paper no. 66E, Maputo, Mozambique, 2008.

Matsuyama, K., 1992. Agricultural productivity, comparative advantage, and economic growth. Journal of Economic Theory 58, 17-34.

Mellor, J., 2001. Faster more equitable growth: agriculture, employment multipliers and poverty reduction, paper prepared for USADD/G/EGAD.

Mendola, M., 2007. Agricultural technology adoption and poverty reduction: a propensity-score matching analysis for rural Bangladesh. Food Policy 32 (3), 372–393.

MPF/UEM/IFPRI (Mozambique Ministry of Planning and Finance/ Eduardo Mondlane University/International Food Policy Research Institute). 1998. Has Economic Growth in Mozambique been Pro-Poor? Understanding poverty and well-being in Mozambique: the first national assessment (1996–7). Maputo.

MPF/IFPRI/PU (Mozambique Ministry of Planning and Finance/International Food Policy Research Institute/Purdue University). 2004. Poverty and well-being in Mozambique: the second national assessment (2002–3). Maputo.

Njoh, Ambe J., 2008. Implications of Africa's Transportation Systems for Development in the Era of Globalization. Review of Black Political Economy 35:147–162.

Oehmke, J., Crawford, E., 1996. The impact of agricultural technology in sub-Saharan Africa. Journal of African Economies 5 (2), 271-292.

Oseni, G., Winters, P., 2009. Rural nonfarm activities and agricultural crop production in Nigeria. Agricultural Economics 40(2), 189-201.

Panin, A., 1989. Profitability assessment of animal traction investment: The case of Northern Ghana. Agricultural Systems 30 (2), 173-186.

Pradhan, M., Ravallion, M., 2000. Measuring poverty using qualitative perceptions of consumption adequacy. The Review of Economics and Statistics 82(3), 462-471.

Portes, A., 1997. Neoliberalism and the sociology of development: emerging trends and unanticipated facts. Population and Development Review 23(2), 229-259.

Poulton, C., Kydd, J., Dorward, A., 2006a. Overcoming Market Constraints on Pro-Poor Agricultural Growth in Sub-Saharan Africa. Development Policy Review 24 (3), 243-277.

Poulton, C., Kydd, J., Wiggins, S., and Dorward, A., 2006b. State intervention for food price stabilization in Africa: can it work? Food Policy, 31(4):342–356.

Prowse, E., 2005. Trypanosomosis, the disease and its control – An analysis of a new tsetse-repellent technology. Swedish University of Agricultural Sciences, Uppsala.

Rahman, A., Westley, J., 2001. The challenge of ending rural poverty. Development Policy Review 19(4), 553-562.

Rakshit, M. (2009) 'Understanding the Indian Macroeconomy, pp. 15-56 in Rakshit (2009) *Macroeconomics of Post-Reform India*. New Delhi: Oxford University Press.

Ravallion, M., 1996. Issues in Measuring and Modelling Poverty. The Economic Journal, 106(438), 1328-1343.

Ravallion, M., 2004. Pro-Poor Growth: A Primer. World Bank Policy Research Working Paper No. 3242.

Ravallion, M., 2009. Evaluating three stylized interventions, Journal of Development Effectiveness 1(3), 227–236.

Reardon, T., 1997. Using evidence of household income diversification to inform study of rural nonfarm labor market in Africa. World Development 25(5), 735-747.

Readon, T., Crawford, E., Kelly, V., 1994. Links between nonfarm and farm investment in African households: adding the capital market perspective. American Journal of Agricultural Economics, 76(5), 1172-1176.

Reardon, T., Stamoulis, K., Balisacan, A., Cruz, M.E., Berdegue, J., Banks, B., 1998. Rural Nonfarm Income in Developing Countries, in FAO (Eds.), The State of Food and Agriculture, FAO, Rome.

Reardon, T., Berdegué, J., Barrett, C., Stamoulis, K., 2006. Household income diversification into rural nonfarm activities, In: Haggblade, S., Hazell, P., Reardon, T, (Eds.), Transforming the Rural Nonfarm Economy. Johns Hopkins University Press, Baltimore.

Romer, P., 1990. Endogenous Technological Change. Journal of Political Economy 98(5), 71–102.

Roemer, M., Gugerty, M., 1997. Does economic growth reduce poverty?, CAER I1 Discussion Paper No. 4, Harvard Institute for International Development.

Rosário, C., Tvedten, I., Margarida, P., 2008. Mucupuki: Social Relations of Rural-Urban Poverty in Central Mozambique. CMI Brief 8.2, Bergen: Chr Michelsen Institute.

Rosenbaum, P., Rubin, D., 1983. The central role of the propensity score in observational studies for causal effects. Biometrika 70 (1), 41-55.

Rubin, D., 1980. Randomization analysis of experimental data: the fisher randomization test: comment. Journal of the American Statistical Association, 75 (371), 591–593.

Ruttan, V., 2002. Productivity Growth in World Agriculture: Sources and Constraints. The Journal of Economic Perspectives, 16(4), 161-184.

Savadogo, K., Reardon, T., Pietola, K., 1998. Adoption of improved land-use technologies to increase food security in Burkina Faso: Relating animal traction, productivity, and nonfarm income, Agricultural Systems 58 (3), 441-464.

Schultz, T., 1964. Transforming Traditional Agriculture. New Haven, London: Yale University Press.

Sen, A., 1981. Poverty and Famines: An Essay on Entitlement and Deprivation. Oxford: Clarendon Press.

Silva, J., 2007. Trade and income inequality in a less developed country: The case of Mozambique. Economic Geography 83(2): 111-136.

Simalenga, T., Jongisa, E., 2000. Assessing the profitability of using animal traction under smallholder farming conditions. South African Journal of Agricultural Extension 29, 1-9.

Simler, K., Mukherjee, S., Dava, G., Datt, G., 2004. Rebuilding after war: micro-level determinants of poverty reduction in Mozambique. IFPRI Research Report no. 132.

Shorrocks, A. and Van der Hoeven, R., 2004, 'Introduction', in Shorrocks and Van der Hoeven (eds), Growth, Inequality and Poverty. Prospects for Pro-Poor Economic Development, UNU-Wider Studies in Development Economics, Oxford: Oxford University Press, pp.1–12.

Skarstein, R., 2005. Economic liberalization and smallholder productivity in Tanzania: from promised success to real failure, 1985–1998. Journal of Agrarian Change 5(3), 334-362.

Snapp, S., Blackie, M., Donovan, C., 2003. Realigning research and extension to focus on farmers' constraints and opportunities. Food Policy, 28:349-363.

Stephens, E., Barrett, C., 2008. Incomplete credit markets and commodity marketing behavior. Working Paper, Cornell University, Ithaka, New York.

Stern, N., 1996. Growth theories, old and new and the role of agriculture in economic development. FAO, Economic and Development Paper 136

Stiglitz, J., 1998. Towards a New Paradigm for Development: Strategies, Policies, and Processes. 1998 Prebisch Lecture at UNCTAD, Geneva, October 19, 1998.

Tarp, F., Arndt, C., Jensen, H.T., Robinson, S., Heltberg, R., 2002. Facing the development challenge in Mozambique. IFPRI Research Report 129.

Thirtle, C., Lin, L., Piesse, J., 2003a. The Impact of Research-Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia and Latin America. World Development 31(12), 1959–1975.

Thirtle, C., Beyers, L., Ismael, Y., Piesse, J., 2003b. Can GM-technologies help the poor? The impact of Bt cotton in Makhathini Flats, KwaZulu-Natal. World Development 31(4), 717–732.

Thorbecke, E., 2005. Multi-dimensional poverty: conceptual and measurement issues. Paper prepared for The Many Dimensions of Poverty International Conference, UNDP International Poverty Centre, Brasilia, August 29-31, 2005.

Timmer, C., 1997. How well do the poor connect to the growth process? Harvard Institute for International Development, CAER II Discussion Paper No. 17, HIID, Cambridge, MA.

Topouzis, D., Guerny, J., 1999. Sustainable agricultural/rural development and vulnerability to the AIDS epidemic. FAO and UNAIDS joint publication. UNAIDS Best Practice Collection. Rome: FAO. December.

Tostão, E., Tschirley, D., 2010. On the role of government in food staples markets: Perspectives from recent research and implications for Mozambique. Flash n. 54, Ministry of Agriculture, Maputo, Mozambique.

Tostão, E., and Brorsen, B.W., 2005. Spatial price efficiency in Mozambique's post-reform maize markets. Agricultural Economics, 33(2): 205-214.

Tschirley, D., Donovan, C., Weber, M.T., 1996. Food aid and food markets: lessons from Mozambique. Food Policy 21(2), 189–209.

UNDP (United Nations Development Program), 2009. Human Development Report 2009, New York.

Usman, M., Reason, C., 2004. Dry spell frequencies and their variability over southern Africa. Climate Research 26, 199-211.

van den Berg, H., Jiggins, J., 2007. Investing in farmers – the impact of farmer field schools in relation to integrated pest management. World Development, 35(4), 663-686.

Virtanen, P., Ehrenpreis, D., 2007. Growth, Poverty and Inequality in Mozambique. Country Study 10, International Policy Centre for Inclusive Growth. Brazil.

Walker, T., Tschirley, D., Low, J., Tanque, M., Boughton, D., Payongayong, E., Weber M., 2004. Determinants of Rural Income, Poverty and Perceived Well-Being in Mozambique in 2001-2002. MINAG Research Report No. 57E. Maputo: Ministry of Agriculture.

Williamson, J., 2003. From reform agenda: a short history of the Washington Consensus and suggestions for what to do next, Finance and Development, 10–13.

World Bank, 2008. Beating the odds: Sustaining inclusion in a growing economy – A Mozambique poverty, gender, and social assessment. Report No. 40048-MZ. The World Bank, Washington DC.

Yen, S.T., 2005. A multivariate sample-selection model: Estimating cigarettes and alcohol demands with zero observations. American Journal of Agricultural Economics 87(2), 453-466.

Part B: Papers

Cunguara, B., Langyuntuo, A., Darnhofer, I. (2011). The role of nonfarm income in coping with the effects of drought in southern Mozambique. *Agricultural Economics,* in press. (JCR SCI Impact Factor: 0.673)

Cunguara, B., Darnhofer, I. (2011). The impact of improved agricultural technologies on household incomes in rural Mozambique. *Food Policy*, 36(3): 378-390. (JCR SCI Impact Factor: 1.606)

Cunguara, B., Moder, K. (2011). Is agricultural extension helping the poor? Evidence from rural Mozambique. *Journal of African Economies*, in press (JCR, SSCI Impact Factor: 0.698)

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Cunguara, B., Mabiso, A., Hanlon, J., Trends in food security in Mozambique, 1996/2008. Submitted to *Food Policy* in October 2010.

The role of nonfarm income in coping with the effects of drought in southern Mozambique

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Agricultural Economics (in press)

Abstract

To reduce their dependence on subsistence agriculture, farm households in rural Africa may diversify their income sources by participating in the nonfarm sector. In years of drought, nonfarm income can also be part of the coping strategies. A multivariate sample selection model was used to analyze three years of data from a nationally representative household survey in Mozambique. The analysis was guided by the following three questions. During a drought year: (i) Do households increase their participation in nonfarm activities? (ii) Are poorer households as likely as others to participate in and benefit from nonfarm activities? And (iii) Which factors are associated with higher nonfarm incomes? The results suggest that households are more likely to engage in at least one nonfarm income generating activity during a drought year. Although poorer households are more likely to engage in nonfarm activities, they are less likely to participate in nonfarm activities of high return. The results suggest that policies reducing entry barriers (e.g. improved road infrastructure, micro-credit schemes, and livestock promotion programs) and increasing education levels can facilitate income diversification, thus allowing rural households to better cope with the effects of drought. When designing polices, care must be taken to avoid exacerbating income inequality by targeting measures towards poorer and female-headed households.

Keywords: multivariate sample selection; poverty; coping strategies; rural Mozambique.

JEL Classification: I31, O16, Q01, R11.

1 Introduction

Rural households in Africa, especially the poor, often lack access to key agricultural inputs and to the markets necessary to achieve an agricultural-led pathway out of poverty (Lanjouw and Lanjouw, 2001; Jayne et al., 2003). This is the case in southern Mozambique, where agriculture is almost entirely dominated by smallholder farmers. The average cultivated area per household is about 1.4 hectares (World Bank, 2006). Due to a high pressure on land, farm sizes cannot be expanded. In addition, smallholder farmers rarely have the means to invest in improved technologies due to a lack of resources. The agricultural options are further restricted by the fact that frequent dry spells negatively affect yields (Joubert et al., 1996; Usman and Reason, 2004). Thus, two-thirds of the production is for home consumption (World Bank, 2006), and smallholders are unlikely to move out of poverty through crop production. Therefore, one option for farmers to complement subsistence farming is to engage in nonfarm income generating activities (Walker et al., 2004; Reardon et al., 1998). Indeed, in Mozambique, the share of nonfarm income was about 22% in 2002 (a non-drought year) and 31% in 2005 (a drought year) (Mather et al., 2008).

The promotion of nonfarm income generating activities among farming communities has the potential of reducing poverty through several mechanisms. First, by combining nonfarm portfolios of different risk profiles, the risk inherent in rainfed agriculture, which leads to fluctuation in farm income, can be mitigated (Reardon et al., 1998). Second, nonfarm income generating activities can create positive spillover effects on agricultural activities, as they help overcome market failures in agriculture, particularly for credit (Reardon, 1997; Bryceson, 1999; Thirtle et al., 2003). Third, if the income from nonfarm activities is reinvested in the farm (Mathenge and Tschirley, 2007; Oseni and Winters, 2009) and the increased output from agriculture is used to expand non-agricultural activities, it might even allow for a positive feedback loop.

Participation in nonfarm income activities can thus be a long-term strategy to adapt to stresses such as shortage of agricultural land (Reardon and Taylor, 1996; Haggblade et al., 2005), or a short-term strategy to cope with or mitigate shocks such as drought (Reardon and Taylor, 1996; Barrett et al., 2001; Haggblade et al., 2006; Kinsey et al., 1998). Households are also likely to flexibly adapt their strategies over time, e.g. by shifting the type of activities engaged in, or by intensifying their participation in years of drought, when their income and subsistence from crop and animal production are threatened.

It is widely acknowledged that nonfarm income has the potential to reduce rural poverty in Mozambique (Walker et al., 2004; Boughton et al., 2006; Walker et al., 2006). Yet so far, its role in mitigating the effects of drought has not been modeled. This paper thus assesses the role of nonfarm income in coping with the effect of drought, and analyses which factors influence the ability of households to benefit from this diversification strategy. The following three questions guide the analysis: (i) Do households increase their participation in nonfarm activities during a drought year? (ii) Are poorer households as likely as others to participate in and benefit from nonfarm activities during a drought year? And (iii) Which factors are associated with the income generated from nonfarm activities during a drought year?

The remainder of the paper is organized as follows: The next section describes the empirical approach used, characterizing the study area, offering details on the data used, presenting the multivariate sample selection model used and discussing the covariates included in the model. Section 3 presents the results, i.e. the influence of a drought year on the participation in nonfarm activities, the differences between households of different wealth categories and the impact of the covariates included in the model. This is followed by a brief discussion of the limitations of the approach used, some concluding remarks, and derived policy implications.

2. Empirical approach

2.1. Choice of study site and data sources

Based on agro-ecological characteristics, Mozambique can be broadly divided into three regions: the sub-humid north, the sub-humid center which also includes humid highlands, and the semi-arid south. These natural conditions are confounded by socio-political influences, such as unreliable transportation due to a sparse all-weather road infrastructure (especially in central and northern provinces), and low education levels (also relatively lower in central and northern provinces). Additionally, events in neighboring countries are likely to have an effect, e.g. economic turmoil in Zimbabwe is likely to impact activities in central Mozambique; or the quality of the agricultural season in Malawi and Zambia, which can affect nonfarm activities in the northern provinces (Haggblade et al., 2010).

The analysis in this paper is restricted to the three southern provinces of Inhambane, Gaza and Maputo. This allows for assessing the influence of drought on participation in nonfarm activities in a more homogeneous region. Moreover, these provinces are suitable for livestock production and support some crop production, despite limited and erratic rainfall (Joubert et al., 1996; FAO, 2004). Livestock production has been shown to play an important role in breaking some of the barriers to participation in the nonfarm employment sector, since they can be used to generate the cash needed for investments (Thirtle et al., 2003). Also, the education levels are higher in the southern provinces. Compared to the illiteracy rates among women in the Northern provinces (80%), in 2003 the city of Maputo had illiteracy rates of 22% and Maputo province of 38% (INE, 2005). Finally, in the southern provinces, which include the capital city, transportation and market access are better. Thus, overall the context in southern Mozambique seems relatively more favorable to nonfarm income generating activities than the northern provinces.

In years of drought, water availability is reduced below the optimal level required by a crop during each growth stage, resulting in impaired growth and reduced yields (FAO, 2004:4). The water content in the soil is also influenced by other variables such as the water-holding capacity and degree of evapotraspiration, but it is largely dependent upon rainfall amount and distribution. The southern provinces received an average of 760mm of rainfall in the 2002 agricultural year, 350mm in the 2005 agricultural year, and 420mm in the 2008 agricultural year[1]. The year 2005 had both the poorest distribution and the lowest amount of rainfall in comparison to 2002 and 2008 (Mather et al., 2008; Uaiene and Arndt, 2009). This is also reflected in the fact that 2005 had the lowest grain yields recorded for the period 1996-2008 (Cunguara and Hanlon, 2010). The agricultural year 2005 is thus referred to as the drought year while that of 2002 is referred to as non-drought year. The agricultural season of 2008 was not necessarily a non-drought year, but it was included to capture policy changes and to assess whether farmers maintain their participation in nonfarm activities once a severe drought is over.

In southern Mozambique the agricultural year starts in November and can be divided into four periods (Garrett and Ruel, 1999): early rains, from November to January; rains from February to April, which can be used for a second planting; harvest of first planting from May to July; and harvest of second planting from August to October. The data for the National Agricultural Survey (Trabalho de Inquérito Agrícola or ‘TIA’) was collected at the end of the agricultural year. For example, the data for the 2005 agricultural year (Nov. 2004 – Oct. 2005) were collected starting in October 2005. Thus, the TIA data allow a retrospective assessment of the whole agricultural year and it can be assumed that low rainfall in the early or main rainy season will lead households to implement coping measures before the end of the agricultural year.

[1] The rainfall estimates are based on data kindly provided by FEWS NET office in Maputo.

This study uses data collected for the agricultural years 2002, 2005, and 2008 (i.e. TIA02, TIA05, and TIA08). The TIA02 and the TIA05 both include 1,154 panel households, and the TIA08 includes 1,196 households from the districts sampled in the panel survey in the southern provinces. The surveyed households were asked whether or not their family members participated in each of the following seven types of nonfarm income generating activities: (i) unskilled agricultural wage on small or large farms; (ii) unskilled non-agricultural wage (e.g. domestic worker); (iii) skilled or specialized non-agricultural wage (teaching, management positions, government clerk, trained agricultural workers with at least 10 years of schooling, and mining); (iv) extraction of flora and fauna products of low returns, which includes cutting firewood, sticks, grass and palm tree leaves, collecting honey and bush fruits, and hunting; (v) extraction of flora and fauna products of high returns, which comprises charcoal production and fishing; (vi) other self-employment activities of low returns, which includes handcrafting, carpentry, cloth making, bicycle and radio repairing, blacksmith, and brick production; and (vii) other self-employment activities of high returns, such as production and sale of home-made beverages, trading with food and non-food products, trading with livestock, agro-processing and milling activities.

The seven types of nonfarm activities have been defined around a key characteristic, e.g. whether they are a form of self-employment or whether they require investments. For example, fishing requires a higher initial investment (e.g. the purchase of fishing nets and canoes) than hunting, explaining why these two activities are not in the same group. This grouping logic means that the activities grouped in one of the above seven types do not necessarily generate similar incomes. For example, bicycle and radio repairing, as well as blacksmithing are grouped together, but the latter is likely to generate higher incomes.

Two types of activities were included, although they might not seem relevant to the analysis of the effect of drought. First, although it might sound paradoxical, poorer farmers can increase participation in ‘unskilled agricultural wage activities’ during a drought year (see Walker et al., 2004), e.g. by working for wealthier farmers producing horticultural crops using irrigation or in dried river beds (Eriksen and Silva, 2009). Secondly, participation in ‘skilled or specialized non-agricultural employment’ is indeed not expected to be affected by drought. This activity could thus have been excluded from the econometric model. However, the adoption of different nonfarm activities is likely to be recursively determined, e.g., households with members engaged in ‘skilled non-agricultural activities’ are more likely to be financially capable of undertaking ‘self-employment activities of high return’. Thus excluding ‘skilled or specialized non-agricultural employment’ could mean discarding valuable information.

In addition to the binary variables indicating participation, the TIA surveys also collected information about the income obtained from each nonfarm activity. To better compare the income generated by households of different sizes, this paper uses net income per adult equivalent (compiled as consumption adult equivalent, CAE) as an indicator of the efficiency of participation in nonfarm activities. To compare net income per adult equivalent from nonfarm activities between the three years, incomes were inflated to 2008 levels. The inflators used to update the 2005 income levels to 2008 are similar to those described in detail in Mather et al. (2008), where 2002 income levels were inflated to reflect the prices in 2005. Based on the consumption expenditure survey of 2002-2003, the consumption quantities from the food consumption basket of each poverty region were used to update the incomes to 2005. These quantities were valued using 2002 retail prices obtained from the Agricultural Market Information Systems (SIMA). Then the basket was revalued with 2005 and 2008 SIMA prices to update the cost of an identical consumption basket. The consumption quantities are therefore the weights for the commodity prices.

The seven types of activities comprise the set of seven binary indicator variables. These are used to model the differences between the three agricultural years, and the factors associated with the decision to participate in nonfarm activities.

2.2 The multivariate sample selection model

Previous studies have typically used a Tobit model (e.g., van de Walle and Cratty, 2003) or a Heckman's probit model (e.g., Benfica, 2006; Mathenge and Tschirley, 2007) to analyze the factors associated with the decision to participate or not to participate in nonfarm activities. Although a Tobit model can be used to evaluate both the probability and the level of participation in nonfarm activities, it can result in biased estimates in the presence of sample selectivity bias. Indeed, the Tobit model assumes that the decision to engage in nonfarm activities and the level of participation in such activities are affected by the same set of factors (Greene, 2003). Furthermore, the Tobit model defines non-participation in nonfarm activities as based purely on economic factors, ignoring the fact that households may have a range of reasons to refrain from participating in nonfarm income generating activities.

Since the income generated through nonfarm activities is only observed among households who were able to participate in such activities, Heckman's probit model with sample selection would be a reasonable choice of econometric framework. This approach was used in a similar study in Mozambique (see for example, Benfica, 2006). However, in the present setting Heckman's sample selection model may not be as efficient, because it does not take into account the full information about the error correlation (Yen, 2005).

Following the model of Yen (2005), which is an extension of the Heckman approach and a generalization of the Tobit approach, a multivariate sample selection method is used. This accommodates censoring in the dependent variable and correlations among error terms across equations. It also allows to avoid biased and inconsistent estimates of the standard errors for each type of nonfarm income generating activity, that are caused by estimating the equations independently and thus ignoring the correlation between types of nonfarm income activities (Greene, 2003).

A system of m equations is considered, where each outcome variable Y_{it} (net income per consumption adult equivalent, or net income/CAE for short) is governed by a binary sample selection rule:

$$\begin{aligned} &\log(Y_{it}) = X_t\beta_{it} + \nu_{it} && \text{if } Z_t\alpha_{it} + u_{it} > 0 \\ &Y_{it} = 0 && \text{if } Z_t\alpha_{it} + u_{it} \le 0 \\ &Y_{it} && i = 1,\ldots,m \end{aligned} \tag{1}$$

Where Z and X are vectors of exogenous variables, α_i and β_i are conformable parameter vectors, v_i and u_i are random errors, the subscript t denotes the agricultural season, and m is the number of nonfarm activities being modeled (Yen, 2005). When estimating equation (1), the error correlation corr[v_i, u_i] is imposed between each pair of selection equation and its corresponding level equation. Three models are estimated, i.e., one model for each agricultural year.

2.3. Description of the vectors X and Z, and their expected relationships

To assess the potential influence of a range of variables on the participation in nonfarm activities, vectors *X* and *Z* include the following exogenous variables: household size, gender of the household head, highest level of education in the household, cropped area, tropical livestock units, bicycle ownership, membership to a farmers' association, and district dummies.

Household size is expressed in labor adult equivalents (Deaton, 1997), which allows to control for household composition. Household size is used as a proxy for labor availability, as it is expected larger households to be more likely to participate in nonfarm income generating activities (Benfica, 2006). Indeed, Reardon (1997) shows that a larger family allows a household to supply more labor for non-agricultural activities, since sufficient family members remain at home to meet labor demands for subsistence agriculture.

Gender of the household head is included, as poverty in rural Mozambique disproportionately affects female-headed households (Boughton et al., 2006; Walker et al., 2006; World Bank, 2006). Due to household chores, child caregiving, and limited access to education, women face higher entry barriers to employment in the formal sector (Haggblade et al., 2001). Women thus tend to engage in informal activities that can be operated from home, require low capital investments and build on skills they already have (Eriksen and Silva, 2009). Female-headed households are expected to participate less in nonfarm activities of high return, and if they participate, to earn less than male-headed households. It would have been useful to distinguish between widow and non-widow headed households, as widow-headed households represented 9.1% of the rural population in 2002, and 10.6% in 2008 (Cunguara and Kelly, 2009). Unfortunately this was not possible, as the TIA data set included too few cases of widows participating in nonfarm activities.

Regarding education, the highest level of educational attainment in the household is expected to positively influence the participation in nonfarm activities, the type of nonfarm activities engaged in, as well as the efficiency of participation (Jayne et al., 2003; Matsumoto et al., 2006; Winters et al., 2007).

Cropped area can influence participation in nonfarm activities in several ways, thus its coefficient can be either positive or negative (see a review in Winters et al., 2007). Households with smaller cropped area may decide to engage in nonfarm activities to make up for their limited resource base (crops and livestock), and hence the coefficient on landholdings would be negative. At the same time, households with larger cropped area are likely to have better access to resources (including education) and may thus have more incentives and capacity to participate in (high income) nonfarm activities, so that the coefficient on cropped area would be positive.

Tropical livestock units were included as a proxy for a household's ownership of liquid assets. Participation in some activities may require initial investments and households who have livestock (e.g. small ruminants and chickens) can sell them to overcome the liquidity constraint (Osbahr et al., 2008). The coefficient of tropical livestock units is thus expected to be positive in both the level of participation and efficiency of participation equations.

Bicycle ownership was included as a proxy variable for a different type of asset. Bicycle ownership is strongly correlated with both crop income and small business income (Walker et al., 2004). This is consistent with the commonly observed practice of farmers using earnings from crop sales to purchase bicycles that are subsequently used for small business activities. Indeed, bicycles allow better access to markets, especially in areas with few all-weather roads.

Finally, membership to a farmers' association was included, as members are more likely to have access to group lending. This is particularly true for the agricultural season of 2008, since the new central government which took office in 2005, initiated a program to support local investment initiatives in 2007 (locally known as '7 milhões') as part of an effort to decentralize and provide more flexible resources at the district level (Donovan and Tostão, 2010). Membership to a farmers' association may thus allow access to funds, e.g. for the initial investments needed to start a nonfarm activity.

3 Results and discussion

3.1 Effect of drought on participation

In a first step, summary statistics were compiled for each of the three years (Table 1). The most common nonfarm activity is 'other self-employment of high return', undertaken by 18% of households in 2002, 19% in 2005, and 26% in 2008. In general, participation in nonfarm income generating activities increased for almost all activities between 2002 and the drought year 2005. Then participation in some activities decreased between 2005 and 2008, especially for 'other self-employment activities of low return.'

Table 1 Descriptive statistics for 2002, 2005 and 2008

	Mean		Std. Err	Mean	Std. Err	Mean		Std. Err
	Year 2002			Year 2005		Year 2008		
Participation in nonfarm activities (%)								
Unskilled agricultural wage income	4.27	***	0.68	13.13	1.26	11.17		1.22
Unskilled non-agricultural wage income	7.86		1.01	8.13	1.05	9.52		1.05
Skilled non-agricultural wage income	11.67	**	1.21	15.35	1.34	9.58	***	1.03
Extraction of flora and fauna products of low returns	10.37		1.12	12.29	1.31	10.52		1.29
Extraction of flora and fauna products of high returns	7.51		0.94	7.67	0.97	8.01		0.94
Other self-employment activities of low return	15.91		1.42	18.54	1.49	6.74	***	0.97
Other self-employment activities of high return	17.97		1.50	19.09	1.52	25.83	***	1.66
At least one nonfarm activity	54.43	***	1.91	66.99	1.82	57.93	***	1.88
Nonfarm income/CAE by source (Meticais)								
Unskilled agricultural wage income	148		34	210	38	154		30
Unskilled non-agricultural wage income	275		45	238	38	442	**	77
Skilled non-agricultural wage income	1,048		149	1,433	312	947		244
Extraction of flora and fauna products-low returns	114		23	300	116	181		42
Extraction of flora and fauna products-high returns	285		82	351	109	241		59
Other self-employment activities of low return	283		65	187	30	679		432
Other self-employment activities of high return	1,147		299	736	155	1,217	*	201
Exogenous variables								
Highest level of education in the HH	4.06	***	0.10	4.90	0.11	5.70	***	0.12
Male-headed households (%)	70.52	***	1.72	62.64	1.86	63.27		1.85
Household size (labor adult equivalent)	4.46	***	0.09	5.37	0.11	4.29	***	0.09
Household is member of a farmers' association (%)	4.00	***	0.63	8.52	0.92	9.85		1.07
Cropped area (ha)	1.41	***	0.04	1.76	0.12	1.58		0.05
Households owning a bicycle (%)	7.06		0.90	6.36	0.89	24.59	***	1.56
Tropical livestock units	1.64		0.09	1.84	0.10	1.68		0.09
Number of observations	1,154			1,154		1,196		

Sources: Authors' calculations based on TIA02, TIA05, and TIA08

Notes: Meticais is the Mozambican currency ($1.00 USD = 26.00 Meticais in 2008); Mean income from each nonfarm;

***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively. The null hypothesis is that the means from drought year (2005) are equal to those from a non-drought year (either 2002 or 2008).

The incomes earned (net income/CAE) from 'agricultural wage' activities increased between 2002 and 2005, before decreasing in 2008, however the difference was not statistically significant (Table 1). Relative to 2002, net income/CAE from 'extraction of forestry products of low return' almost tripled in the drought year. The net income/CAE from 'other self-employment' and 'non-agricultural wage' activities increased significantly between 2005 and 2008. This is in line with a rapid increase observed in prices since October 2007, which is associated with the high fuel prices in 2007 and 2008 (Arndt et al., 2008). However, between 2005 and 2008 the net income/CAE from agricultural-related activities, that is, 'extraction of forestry products' and 'unskilled agricultural wage' decreased, although not significantly. This may be related to the subsistence nature of agricultural activities in Mozambique. The low use of purchased inputs, for example, in the 'extraction of forestry products,' means a relatively smaller impact of fluctuations in fuel prices.

Regarding household demographics, educational attainment is generally low: on average the highest level of educational attainment in the household was about four years in 2002, five in 2005, and six years in 2008 (Table 1). Although the improvement in education has been statistically significant at the 0.01 level, low educational levels explain in part the low participation in 'skilled non-agricultural activities,' and the relatively higher participation in 'unskilled agricultural' and 'unskilled non-agricultural' activities. The relatively high proportion of female-headed households (29.5%) may reflect male out-migration, who may seek employment in urban centers or in the mining sector in neighboring South Africa. This indicates that these households may receive remittances, which may enable them to participate in nonfarm activities that require some initial investment, such as 'skilled and unskilled non-agricultural activities of high return.'

With regard to assets, households cultivated an average of 1.4 hectares in 2002 and 1.8 hectares in 2005, but cropped area decreased in 2008 to 1.6 hectares. Similarly, households owned significantly fewer animals in 2008 than in 2005 (Table 1). One possible explanation is that households were compelled to sell their livestock to buffer the negative effects of drought in 2005, but they have not been able to recover their initial stock of animals.

Overall the effect of drought on the participation in nonfarm activities does not present a uniform pattern, neither in the proportion of households participating in one of the seven types of nonfarm activities, nor in earnings from each nonfarm income activity. This might be related to the fact that the individual activities grouped in each activity type are quite heterogeneous. However, when assessing the proportion of households who participated in at least one nonfarm activity, there is a significant difference between the drought year 2005 and the two other years (Table 1). This indicates that households tend to participate more in nonfarm activities in a year of drought, but the activities they engage in vary, possibly depending on availability, accessibility or expected return. This is supported by a study showing that household strategies will change and adapt as a drought progresses (Eriksen and Silva, 2009).

3.2 Effect of household wealth on participation

The decision to engage in nonfarm activities seems to be related to total household income (Figure 1). Two patterns can be distinguished: first, participation in nonfarm activities is consistently lower among households in the lowest quintile of net income/CAE, and is positively correlated with household income/CAE. Second, for all quintiles, participation is higher in the drought year 2005, and the difference in participation in nonfarm activities (when comparing the three years) is significantly smaller for the highest income group, relative to the lowest income group (Figure 1). This may indicate that wealthier farmers participate in nonfarm income generating activities as a long-term strategy that is less influenced by the quality of the agricultural season, whereas households of relatively low income tend to engage in nonfarm income generating activities mostly as a strategy to cope with the effects of drought.

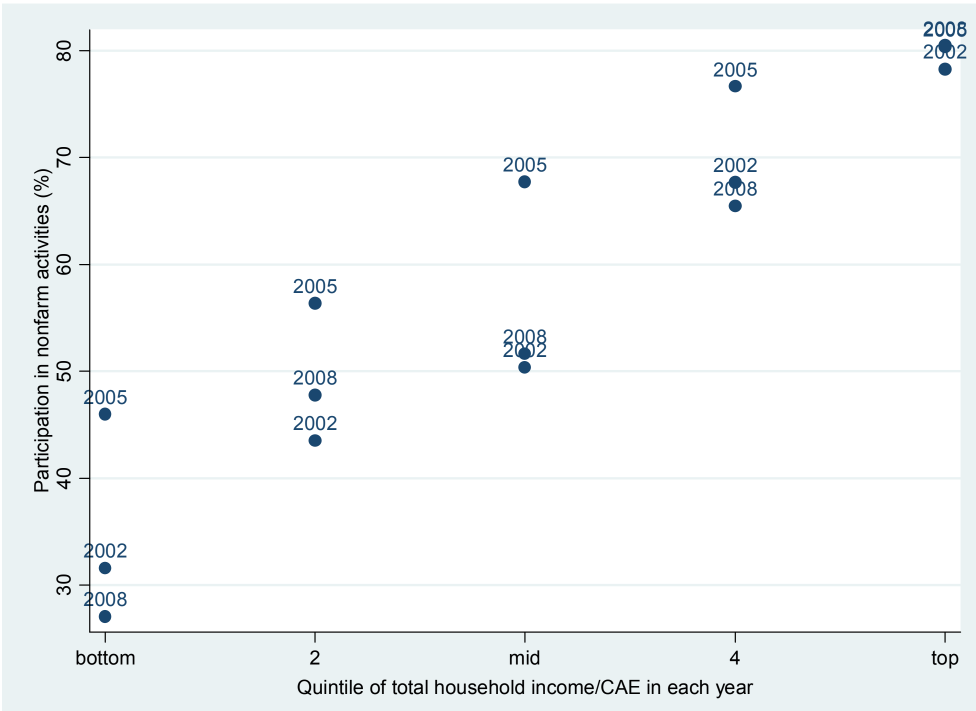

Figure 1 Percentage of households engaged in at least one nonfarm activity

The participation in nonfarm activities during a drought year does not necessarily lead to higher income among the first four quintiles of net income/CAE (Figure 2). However, the mean net income/CAE earned through nonfarm activities seems to increase exponentially when moving from the lowest to the highest quintile of net income/CAE. This result is consistent with other studies, which show a positive and significant correlation between wealth and income generation through nonfarm income generating activities (Reardon, 1997; Barrett et al., 2001; Block and Webb, 2001; Walker et al., 2004; Benfica, 2006; Mather et al., 2008).

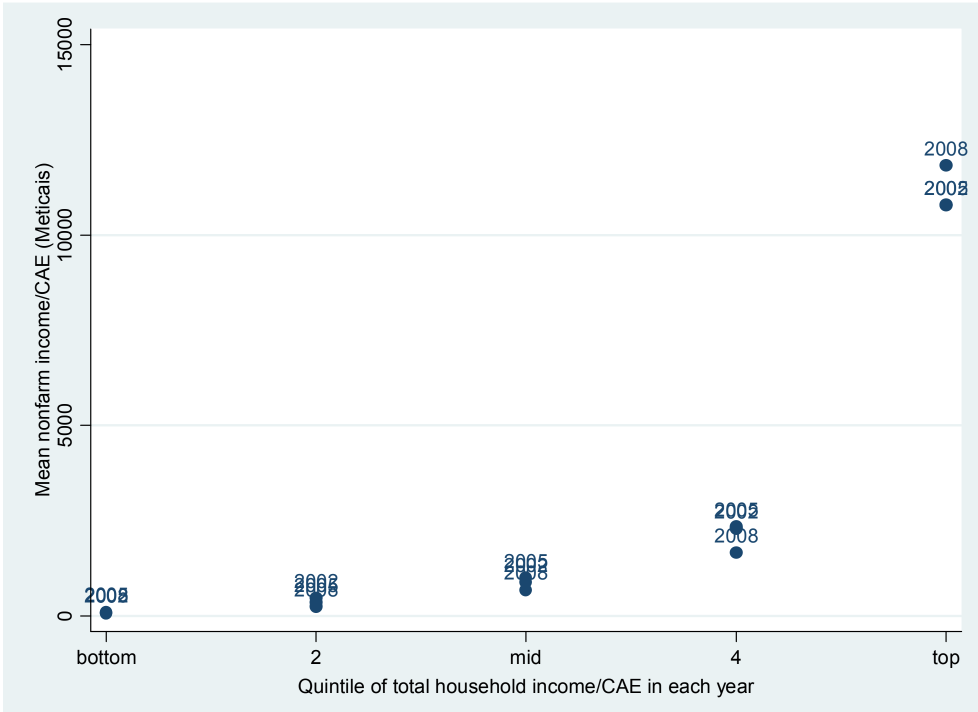

Figure 2 Mean nonfarm income/CAE, by year and quintile of total income/CAE

The mean net income/CAE from nonfarm activities remains at the same very low level in all three years for the lower quintile of net income/CAE, whereas it shows some fluctuation when moving to the upper income quintiles (Figure 2). This may be related to the type of activities engaged in. This would be the case if households in the lower quintiles engage in nonfarm activities which they cannot intensify in a year of drought. For example petty trade through a kiosk can dwindle in a year of drought as the households in the surrounding village have no cash to purchase goods (Eriksen and Silva, 2009). Households in the lower quintile might then be able to switch to another nonfarm activity, but not increase their incomes. On the other hand, wealthier households may engage in activities which can be intensified in years of drought, such as trading in towns which are farther away; or they may have the resources to engage in additional activities. This is consistent with studies showing that wealthier households own assets that can be turned into cash and thus can allow participation in nonfarm activities that generate higher returns. In other words, they own the assets that allow them to overcome the problems linked to lack of credit markets (Thirtle et al., 2003; Osbahr et al., 2008). Overall, it indicates the presence of entry barriers into nonfarm activities of high return, which cannot be engaged in by the poor, even in years of drought when they would need it the most.

3.3 Exogenous factors influencing participation

The results of the multivariate sample selection models indicate that sample selectivity is present for all nonfarm activities, as the error correlation between each selection equation and its corresponding level equation is statistically significant (See appendix, Table A1 for TIA02 results). The significance of the error correlation validates the use of a multi-equation multivariate sample selection model, rather than using a pairwise sample selection model. The model fits the data reasonably well in the second stage (levels' equations), with the highest Pseudo-R^2 being equal to 0.47, even if the Pseudo-R^2 from the first stage are relatively small.

The results of the multivariate sample selection model are presented for the agricultural years of 2002, 2005 and 2008 (Tables 2, 3, and 4 respectively). The results show that households whose members are relatively more educated are significantly more likely to diversify their sources of income outside the agricultural sector. Higher education levels are also negatively and significantly correlated with the decision to engage in 'unskilled agricultural wage' activities and the 'extraction of forestry and fauna products.' Moreover, the results also show that education not only affects the ability to access certain types of nonfarm income generating activities, but also the level of income generated through them. As expected, for all three years, education is positively and significantly correlated with the levels of net income/CAE generated from 'skilled non-agricultural activities,' irrespective of the occurrence of drought. During a non-drought year, higher education level is also significantly correlated with net income/CAE obtained from 'other self-employment activities of high return' (Table 2). This result is in line with the well documented relationship between lack of education and poverty (see for example, Schultz 1999; Jayne et al., 2003; Matsumoto et al., 2006).

Table 2 Multivariate sample selection model results for the year 2002

Selection equations	Y_1		Y_2		Y_3		Y_4		Y_5		Y_6		Y_7	
	Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.	
Intercept	-0.84	***	-1.94	***	-2.36	***	-1.21	***	-1.54	***	-0.94	***	-1.38	***
Highest level of education	-0.04	***	0.04	***	0.12	***	0.01	***	-0.04	***	-0.02	***	0.06	***
Head's gender (1=male)	-0.04	***	0.13	***	0.80	***	0.39	***	0.42	***	0.07	***	0.14	***
HH size (labor adult equiv.)	0.00	***	0.04	***	0.03	***	-0.01	***	0.01	***	0.02	***	0.03	***
Farmer association (1=yes)	-0.13	***	0.06	***	0.12	***	0.11	***	-0.08	***	0.29	***	-0.01	
Cropped area (ha)	-0.04	***	-0.01	***	-0.04	***	-0.07	***	-0.07	***	0.01	***	-0.03	***
Bicycle ownership (1=yes)	-0.46	***	-0.34	***	0.05	***	0.13	***	0.60	***	0.08	***	0.00	
Tropical livestock units	-0.03	***	-0.04	***	-0.03	***	-0.03	***	0.00	***	-0.01	***	0.02	***
Pseudo-R^2	0.04		0.03		0.10		0.03		0.04		0.02		0.03	
Level equations														
Intercept	5.99	***	7.27	***	8.33	***	6.81	***	7.06	***	5.84	***	6.36	***
Highest level of education	0.01		0.23	***	0.10	***	-0.11		0.00		0.01		0.15	***
Head's gender (1=male)	0.01		-0.27		0.42	**	0.29		0.05		0.80	***	-0.09	
HH size (labor adult equiv.)	-0.15	**	-0.13	**	-0.14	***	-0.13	**	-0.08	*	-0.13	***	-0.13	***
Farmer association (1=yes)	-1.07		-0.76	*	-0.22		0.88		-0.41		-0.19		0.92	**
Cropped area (ha)	0.15		-0.06		-0.03		0.03		0.05		0.05		0.00	
Bicycle ownership (1=yes)	1.00		1.36	**	0.19		0.65		0.53		0.55		0.50	
Tropical livestock units	-0.01		0.05		0.03	*	-0.02		-0.03		0.01		0.07	***
Pseudo-R^2	0.21		0.40		0.28		0.21		0.29		0.16		0.17	

Sources: Authors' calculations based on TIA02 data

Notes: Y_1 – Unskilled agric. wage; Y_2 – Unskilled non-agric. wage; Y_3 – Skilled non-agric. wage; Y_4 – Self-employment (fauna and forestry products of low return); Y_5 – Self-employment (fauna and forestry products of high return); Y_6 – Other self-employment act. of low return; Y_7 – Other self-employment activities of high return; All statistics are population-weighted; District dummies included but not reported.

***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3 Multivariate sample selection model results for the year 2005

Selection equations	Y_1		Y_2		Y_3		Y_4		Y_5		Y_6		Y_7	
	Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.	
Intercept	-2.03	***	-2.20	***	-2.30	***	-1.24	***	-1.73	***	-1.34	***	-1.44	***
Highest level of education	-0.08	***	0.03	***	0.16	***	-0.07	***	-0.02	***	-0.02	***	0.07	***
Head's gender (1=male)	0.02	***	0.12	***	0.24	***	0.36	***	0.48	***	0.36	***	0.29	***
HH size (labor adult equiv.)	0.09	***	0.12	***	0.03	***	0.02	***	-0.01	***	0.03	***	0.03	***
Farmer association (1=yes)	0.07	***	-0.07	***	0.27	***	-0.12	***	0.04	***	0.03	***	0.08	***
Cropped area (ha)	-0.09	***	0.01	***	-0.04	***	0.01	***	-0.02	***	0.01	***	-0.08	***
Bicycle ownership (1=yes)	-0.20	***	-0.37	***	0.26	***	0.19	***	0.19	***	-0.54	***	-0.24	***
Tropical livestock units	0.02	***	-0.05	***	-0.01	***	-0.04	***	0.00	***	0.00		0.02	***
Pseudo-R^2	0.05		0.05		0.14		0.03		0.04		0.03		0.05	
Level equations														
Intercept	6.74	***	8.58	***	8.26	***	5.86	***	6.82	***	6.77	***	7.06	***
Highest level of education	-0.05		0.02		0.16	***	0.05		-0.02		0.04		0.07	
Head's gender (1=male)	1.32	***	-0.07		0.16		0.87	***	-0.45		-0.11		0.20	
HH size (labor adult equiv.)	-0.04		-0.16	***	-0.17	***	-0.21	***	0.04		-0.17	***	-0.21	***
Farmer association (1=yes)	0.43		0.02		-0.13		-0.40		-0.20		0.57		0.20	
Cropped area (ha)	-0.08		-0.06		0.00		-0.05		-0.04		0.08		0.14	
Bicycle ownership (1=yes)	0.12		-0.80		0.22		-0.29		0.49		-1.20	*	1.20	**
Tropical livestock units	0.01		0.07	*	0.04	*	0.08		0.11	**	0.02		0.00	
Pseudo-R^2	0.35		0.28		0.28		0.29		0.19		0.14		0.17	

Sources: Authors' calculations based on TIA05 data

Notes: Y_1 – Unskilled agric. wage; Y_2 – Unskilled non-agric. wage; Y_3 – Skilled non-agric. wage; Y_4 – Self-employment (fauna and forestry products of low return); Y_5 – Self-employment (fauna and forestry products of high return); Y_6 – Other self-employment act. of low return; Y_7 – Other self-employment activities of high return; All statistics are population-weighted; District dummies included but not reported.

***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table 4 Multivariate sample selection model results for the year 2008

Selection equations	Y_1		Y_2		Y_3		Y_4		Y_5		Y_6		Y_7	
	Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.	
Intercept	-1.22	***	-1.91	***	-2.41	***	-1.14	***	-1.44	***	-2.20	***	-1.14	***
Highest level of education	-0.04	***	0.07	***	0.14	***	-0.05	***	-0.03	***	0.04	***	0.10	***
Head's gender (1=male)	-0.04	***	0.26	***	0.31	***	0.36	***	0.45	***	0.43	***	-0.03	***
HH size (labor adult equiv.)	0.06	***	0.04	***	0.04	***	0.00		0.01	***	0.04	***	-0.04	***
Farmer association (1=yes)	-0.09	***	-0.03	***	-0.23	***	0.45	***	0.00		0.26	***	-0.10	***
Cropped area (ha)	-0.01	***	-0.01	***	-0.03	***	-0.01	***	-0.02	***	-0.01	***	0.02	***
Bicycle ownership (1=yes)	-0.07	***	-0.11	***	0.27	***	-0.06	***	-0.07	***	0.06	***	0.13	***
Tropical livestock units	-0.01	***	-0.07	***	-0.04	***	-0.05	***	0.00	***	-0.05	***	0.00	***
Pseudo-R^2	0.02		0.05		0.10		0.06		0.04		0.03		0.05	
Level equations														
Intercept	6.20	***	7.26	***	5.95	***	6.85	***	7.17	***	8.65	***	6.31	***
Highest level of education	0.00		0.04		0.27	***	-0.09		0.03		0.09		0.12	
Head's gender (1=male)	0.64	**	1.05	*	0.29		0.30		0.43		-1.13	*	0.33	
HH size (labor adult equiv.)	-0.28	***	-0.20		-0.13		-0.23	**	-0.10		-0.18		-0.21	***
Farmer association (1=yes)	-0.74		0.17		1.55		-0.73		-0.61		-2.06	**	-1.25	***
Cropped area (ha)	0.10	**	-0.03		-0.08		0.11	*	-0.04		0.02		0.04	
Bicycle ownership (1=yes)	0.33		-0.39		0.50		0.89	*	-0.02		0.58		0.79	***
Tropical livestock units	-0.01		-0.01		-0.01		0.07		-0.05		-0.05		0.05	
Pseudo-R^2	0.42		0.17		0.16		0.23		0.13		0.47		0.13	

Sources: Authors' calculations based on TIA08 data

Notes: Y_1 – Unskilled agric. wage; Y_2 – Unskilled non-agric. wage; Y_3 – Skilled non-agric. wage; Y_4 – Self-employment (fauna and forestry products of low return); Y_5 – Self-employment (fauna and forestry products of high return); Y_6 – Other self-employment act. of low return; Y_7 – Other self-employment activities of high return; All statistics are population-weighted; District dummies included but not reported.

***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Regarding the influence of the gender of household head, the results suggest that male-headed households participate more often in 'nonfarm activities of high return.' Moreover, during a drought year, male-headed households tend to engage in 'unskilled non-agricultural' activities more often (Table 3), whereas in a non-drought year (Tables 2 and 4) these activities are predominantly undertaken by female-headed households. Female-headed households also participate significantly more in the 'extraction of forestry and fauna products' (Table 4). It appears that female-headed households tend to engage in nonfarm activities that do not require distant travel and that allow for flexible time management, such as cutting firewood, sticks, grass and palm tree leaves, milling and agro-processing activities, or collecting honey and bush fruits. This may be associated with women's responsibility for household chores and child caregiving, as well as other potential barriers to access wage employment (e.g., relatively lower educational levels). Worth noting is that milling and agro-processing activities were the only 'other self-employment' activity where participation was greater among female-headed households.

In terms of income generated through nonfarm activities, male-headed households usually earn significantly higher net incomes/CAE (Table 2, 'skilled non-agricultural wage' and 'other self-employment of low return; Table 3, 'unskilled agricultural wage' and 'self-employment of low return'; Table 4, 'unskilled wage'). However, in 2008 female-headed households earned significantly higher incomes/CAE from 'other self-employment of low return.'

In general, a larger household size is associated with a greater likelihood of participation in nonfarm income sources in all three years, which agrees with Reardon (1997). However, larger households earn lower net income/CAE from nonfarm activities. This suggests that the additional family member will most likely not engage in nonfarm activities, or if he/she undertakes such activities, the marginal gain in net income/CAE is smaller than the average net income/CAE.

In a non-drought year, cropped area is mostly negatively correlated with participation in nonfarm income activities, suggesting that households cultivating smaller fields are more likely to engage in nonfarm activities (Tables 2 and 4). Meanwhile, in a drought year the likelihood of participation in 'extraction of forestry products of high return' and 'other self-employment of high return' is greater among households cultivating larger fields (Table 3). However, these households earn significantly lower incomes/CAE (Table 4).

Regarding livestock, an additional livestock unit increases the net income/CAE from 'self-employment activities of high return', both in a drought year (Table 3, activities 3 and 7) and in a non-drought year (Table 2, also activities 3 and 7). This result can indicate the presence of entry barriers into the nonfarm sector, especially to 'self-employment activities of high return' that may require some initial investment. Nevertheless, households with fewer livestock (usually the poor) are more likely to participate in nonfarm activities (Tables 2 and 4).

The estimation results also underscore the role of bicycle ownership for participating in 'self-employment activities of high return.' During both the drought year of 2005 and non-drought years of 2002 and 2008, bicycle ownership was significantly correlated with higher incomes/CAE from 'self-employment activities of high return' (Tables 2, 3, and 4, activity 7). This type of activity includes production and sale of home-made beverages and trading with food and non-food products, which can be facilitated by owning a bicycle. Indeed, Mozambique has one of the lowest road densities in Sub-Saharan Africa (Njoh, 2008), and the TIA05 data shows that, on average, a rural household in southern Mozambique is located 72 km from a tarred road. In this context, bicycle ownership might enhance the ability of farmers to carry their products to the market and profitably engage in 'self-employment activities of high return.'

4 Concluding remarks and policy implications

Rural households may diversify out of agriculture into a variety of income generating activities to cope with risk and uncertainty. By applying multivariate sample selection models to data from three years, this study analyzes whether households are likely to engage in nonfarm income generating activities to cope with the effects of drought. This analysis is based on the assumption that a drought will affect participation in nonfarm activities within the same agricultural year. This is likely for many activities that are used as short-term coping strategies. However, it might not adequately capture the effects of long-term and strategic diversification behavior. For example, it is likely that engaging in any nonfarm activity will have a long-term effect, e.g. through learning and building social networks (Eriksen and Silva, 2009) which will enable subsequent participation in nonfarm activities. Another aspect that may not be fully captured in this study is that the behavior of households in a given year is likely to be affected by the quality of the previous agricultural year(s). For example, if the previous year had adequate rainfall, households are more likely to have reserves and buffers allowing them to face a drought year and thus affect their decision to participate in a nonfarm activity.

Within these limitations, the model used shows that the number of households that participate in nonfarm income generating activities increases during a drought year. Despite the increased participation, households are unlikely to be able to generate a higher mean net income/CAE during the drought year necessary to compensate for the shortfall in income from crop production.

The results from the multivariate analysis show that relatively poorer households often earn less from nonfarm activities than wealthier ones. This can be related to the inability of the poorer households to engage in activities of high return, which tend to require initial investments. Such barriers to entry to high-return activities can be eased through livestock ownership, which is often a source of liquid asset (Osbahr et al., 2008). Thus, programs promoting livestock ownership are likely to enable poorer households to engage in activities of high return and thus reduce poverty levels (Walker et al., 2004). In designing such programs, equity issues must be taken into account to ensure that the poorer, the less educated and the female-headed households benefit, as they are often those that find it most difficult to access high-return activities.

The analysis also suggests that households in different wealth categories emphasize different strategies. These strategies seem to be linked to the type of activities engaged in. Unskilled agricultural and non-agricultural wage labor may be a short-term coping strategy, whereas skilled non-agricultural wage labor or self-employment activities of high return are more likely to be a long-term diversification strategy. Households in the bottom quintile of net income/CAE tend to participate in nonfarm activities mostly as a short-term drought coping mechanism, whereas those in the top quintile seem to engage in nonfarm activities mostly as a long-term livelihood strategy. Income diversification through on-going participation in nonfarm activities may thus be a pathway out of poverty. To enable a continuous participation in nonfarm activities, policy interventions are needed, such as improving road infrastructure and transport services to allow access to markets, as well as increasing educational levels.

However, investments in physical infrastructure and education will only have an effect in the long term. One way of increasing nonfarm incomes among the poor in the short term, is to increase the profitability of their current activities, e.g., adding value to agricultural production. Indeed, participation in milling and agro-processing activities was greater among female-headed households, which are often poor. Investments in the agro-processing sector can thus increase the profitability of such activities, contributing to poverty reduction in the short term. The importance of agro-processing activities (or the agro-industry in general) in reducing poverty in rural Mozambique had been highlighted earlier by Benfica et al. (2002).

Policies targeting poverty reduction through increasing nonfarm income should thus aim at promoting opportunities for households to engage in short-term coping strategies and in long-term strategic diversification strategies; as well as at balancing measures which are expected to have an impact in the long-term with those that can have an impact in the short-term. This would allow farm households to flexibly adapt their livelihood strategies depending on household resource availability, rainfall variability and market opportunities.

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References

Arndt, C., Benfica, R., Maximiano, N., Nucifora, A., Thurlow, J., 2008. Higher fuel and food prices: impacts and responses for Mozambique. Agricultural Economics 39(1), 497-511.

Barrett, C., Reardon, T., Webb, P., 2001. Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. Food Policy 26(4), 315-331.

Barrett, C., Reardon, T., 2000. Asset, Activity, and Income Diversification among African Agriculturalists: Some Practical Issues. Report for USAID/BASIS/CRSP, Cornell and Michigan State University.

Benfica, R., 2006. An analysis of income poverty effects in cash cropping economies in rural Mozambique: Blending econometric and economy-wide models. PhD Dissertation, Michigan State University, East Lansing, MI.

Benfica, R., Tschirley, D., Sambo, L., 2002. The impact of alternative agro-industrial investments on poverty reduction in rural Mozambique. Working Paper 51E, Ministry of Agriculture, Maputo, Mozambique.

Block, S., Webb, P., 2001. The dynamics of livelihood diversification in post-famine Ethiopia. Food Policy 26(4), 333-350.

Boughton, D., Mather, D., Tschirley, D., Walker, T., Cunguara, B., Payongayong, E., 2006. Changes in Rural Household Income Patterns in Mozambique 1996-2002 and Implications for Agriculture's Contribution to Poverty Reduction. Working Paper 61E, Ministry of Agriculture, Maputo, Mozambique.

Bryceson, D., 1999. African rural labour, income diversification and livelihood approaches: A long term development perspective. Review of African Political Economy 26(80), 171-189.

Cunguara, B., Hanlon, J., 2010. Poverty is not being reduced in Mozambique. Working Paper n. 74. London School of Economics and Political Science.

Cunguara, B., Kelly, B., 2009. The impact of PARPA II in promoting the agricultural sector in rural Mozambique. An impact assessment study commissioned by the FAO. Maputo, Mozambique. http://www.open.ac.uk/technology/mozambique/pics/d119369.pdf

Davis, B., Winters, P., Reardon, T., Stamoulis, K., 2009. Rural nonfarm employment and farming: household-level linkages. Agricultural Economics 40(2), 119-123.

Davis, B., Winters, P., Carletto, G., Covarrubias, K., Quiñones, E.J., Zezza, A., Stamoulis, K., Azzarri, C., Digiuseppe, S., 2010. A cross-country comparison of rural income generating activities. World Development 38(1), 48-63.

Deaton, A. 1997. The Analysis of Household Surveys. Washington, D.C.: World Bank.

Dercon, S., 1998. Wealth, risk and activity choice: cattle in western Tanzania. Journal of Development Economics 55(1), 1-42.

Donovan, C., and Tostão, E. 2010. Staple food prices in Mozambique. Prepared for the Comesa policy seminar on “Variation in staple food prices: Causes, consequence, and policy options”, held in Maputo, Mozambique, 25-26 January 2010.

Ellis, F., 2004. Occupational Diversification in Developing Countries and Implications for Agricultural Policy. Hot Topic Working Paper. Overseas Development Group, University of East Anglia, Norwich, UK.

Eriksen, S., Silva, J., 2009. The vulnerability context of a savanna area in Mozambique: household drought coping strategies and responses to economic change. Environmental Science and Policy 12(1), 33-52.

FAO, 2004. Drought impact mitigation and prevention in the Limpopo river basin. Land and Water Discussion Paper 4. Food and Agriculture Organisation, Rome.

FAO, 2005. Aquastat: FAO’s information system on water and agriculture. http://www.fao.org/nr/water/aquastat/countries/mozambique/index.stm

Garrett, J., Ruel, M., 1999. Are Determinants of Rural and Urban Food Security and Nutritional Status Different? Some Insights from Mozambique. World Development 27(11), 1955-1975.

Government of Mozambique, 2006. Poverty Reduction Strategy Paper II. Maputo: Council of Ministers.

Greene, W.H., 2003. Econometric Analysis. Prentice Hall, New Jersey.

Haggblade, S, Hazell, P., Brown, J., 2001. Farm-nonfarm linkages in rural Sub-Saharan Africa. World Development 17(8), 1173-1201.

Haggblade, S., Longabaugh, S., Tschirley, D., 2010, Spatial and regional dimensions of food security in Zambia, Policy Synthesis No. 38, Ministry of Agriculture and Cooperatives, Agricultural Consultative Forum and Michigan State University, Lusaka, Zambia.

Haggblade, S., Hazell, P., Reardon, T., 2005. The rural non-agricultural economy: Pathway out of poverty or pathway in? International Food Policy Research Institute and Michigan State University. Proceedings of the research workshop ‘The Future of Small-Farms’, June 26–29, 2005, UK.

INE (National Institute of Statistics), 2005. Report on Millennium Development Goals. Maputo, Mozambique.

Jayne, T.S, Yamano, T., Weber, M., Tschirley, D., Benfica, R., Chapoto, A., Zulu, B., 2003. Smallholder income and land distribution in Africa: Implications for poverty reduction Strategies. Food Policy 28(3), 253-275.

Joubert, A.M., Mason, S.J., Galpin, J.S., 1996. Droughts over southern Africa in a doubled-CO_2 climate. International Journal of Climatology 16(10), 1149-1156.

Kinsey, B., Burger, K., Gunning, J.W., 1998. Coping with drought in Zimbabwe: Survey evidence on responses of rural households to risk. World Development 26(1), 89-110.

Lay, J., M'Mukaria, G.M., Mahmoud, T.O., 2007. Boda Bodas Rule: Non-agricultural activities and their inequality implications in Western Kenya. Kiel Working Paper No. 1314, Kiel, Germany.

Lanjouw, J, Lanjouw, P., 2001. The rural nonfarm sector: Issues and evidence from developing countries. Agricultural Economics 26(1), 1-23.

Maertens, M., 2009. Horticulture exports, agro-industrialization, and farm-nonfarm linkages with the smallholder farm sector: evidence from Senegal. Agricultural Economics 40(2), 219-229.

Mathenge, M., Tschirley, D., 2007. Off-farm work and farm production decisions: Evidence from maize-producing households in rural Kenya. Paper submitted for the CSAE Conference 2007 on ‘Economic Development in Africa’, held 18-20 March 2007 at St. Catherine’s College, University of Oxford, UK.

Mather, D., Cunguara, B., Boughton, D., 2008. Household income and assets in rural Mozambique, 2002-2005: Can pro-poor growth be sustained? Working Paper 66E. Ministry of Agriculture, Maputo.

Matsumoto, T., Kijima, Y., Yamano, T., 2006. The role of local nonfarm activities and migration in reducing poverty: Evidence from Ethiopia, Kenya, and Uganda. Agricultural Economics 35(3), 449-458.

MPF (Ministry of Planning and Finance), IFPRI (International Food Policy Research Institute), and University of Purdue, 2004. Poverty and Well-Being in Mozambique: The Second National Assessment. Maputo: National Directorate of Planning and Budget.

Njoh, A.J., 2008. Implications of Africa's Transportation Systems for Development in the Era of Globalization. Review of Black Political Economy 35, 147-162.

Osbahr, H., Twyman, C., Adger W.N., Thomas, D.S.G., 2008. Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. Geoforum 39(6), 1951-1964.

Oseni, G., Winters, P., 2009. Rural nonfarm activities and agricultural crop production in Nigeria. Agricultural Economics 40(2), 189-201.

Reardon, T., 1997. Using evidence of household income diversification to inform study of rural nonfarm labor market in Africa. World Development 25(5), 735-747.

Reardon, T., Taylor, J.E., 1996. Agro-climatic shock, income inequality, and poverty: evidence from Burkina Faso. World Development 24(5), 901-914.

Reardon, T., Stamoulis, K., Balisacan, A., Cruz, M.E., Berdegue, J., Banks, B., 1998. Rural Nonfarm Income in Developing Countries, in FAO (Eds.), The State of Food and Agriculture, FAO, Rome.

Reardon, T., Taylor, J.E., Stamoulis, K., Lanjouw, P. Balisacan, A., 2000. Effects of nonfarm employment on rural income inequality in developing countries: an investment perspective. Journal of Agricultural Economics 51(2), 266-288.

Reardon, T., Berdegué, J., Barrett, C.B., Stamoulis, K., 2006. Household income diversification into rural nonfarm activities, In: Haggblade, S., Hazell, P., Reardon, T, (Eds.), Transforming the Rural Nonfarm Economy. Johns Hopkins University Press, Baltimore.

Schultz, T., 1999. Health and school investments in Africa. The Journal of Economic Perspectives 13(3), 67-88.

Thirtle, C., Beyers, L., Ismael, Y., Piesse, J., 2003. Can GM-technologies help the poor? The impact of Bt cotton in Makhathini Flats, KwaZulu-Natal. World Development 31(4), 717–732.

Uaiene, R., Arndt, C., 2009. Farm household efficiency in Mozambique: A stochastic frontier approach, Discussion paper No. 66E, National Directorate of Studies and Policy Analysis, Ministry of Planning and Development, Maputo.

Usman, M., Reason, C., 2004. Dry spell frequencies and their variability over southern Africa. Climate Research 26(3), 199-211.

van de Walle, D., Cratty, D., 2003. Is the Emerging Non-Farm Market Economy the Route Out of Poverty in Vietnam? World Bank Working Paper 2950, Washington DC.

Walker, T., Boughton, D., Tschirley, D., Pitoro, R., Tomo, A., 2006. Using Rural Household Income Survey Data to Inform Poverty Analysis: An Example from Mozambique. Paper presented at the 26th Conference of the IAAE, held 12-18 August 2006 in Brisbane, Australia.

Walker, T., Tschirley, D., Low, J., Tanque, M., Boughton, D., Payongayong, E., Weber M., 2004. Determinants of Rural Income, Poverty and Perceived Well-Being in Mozambique in 2001-2002. MINAG Research Report No. 57E. Maputo: Ministry of Agriculture.

Winters, P., Davis, B., Carletto, G., Covarrubias, K., Stamoulis, K., Quiñones, J. Zessa, A., 2007. Assets, activities and rural poverty alleviation: Evidence from a multicountry analysis. Rural Income Generating Activities (RIGA) Publication, Agricultural and Development Economics Division, FAO, Rome.

Winters, P., Essam, T., Davis, B., Zezza, A., Carletto, C., Stamoulis, K., 2008. Patterns of rural development: A cross-country comparison using microeconomic data. ESA Working Paper No. 08-06, Agricultural Development Economics Division, FAO, Rome.

World Bank, 2006. Mozambique Agricultural Development Strategy – Stimulating smallholder agricultural growth. Report No. 32416-MZ, Agriculture, Environment and Social Development Unit, Africa Region. World Bank, Washington DC.

Yen, S.T., 2005. A multivariate sample-selection model: Estimating cigarettes and alcohol demands with zero observations. American Journal of Agricultural Economics 87(2), 453-466.

Table A1 Estimates of error correlation coefficients for the year 2002

	u_1		u_2		u_3		u_4		u_5		u_6		u_7	
	Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.	
u_1 Selection equation 1	1.00	***	-0.05	***	-0.09	***	0.03	***	-0.03	***	-0.02	***	-0.10	***
u_2 Selection equation 2	-0.05	***	1.00	***	-0.07	***	-0.03	***	0.04	***	0.01	***	-0.04	***
u_3 Selection equation 3	-0.09	***	-0.07	***	1.00	***	-0.05	***	-0.06	***	-0.02	***	-0.04	***
u_4 Selection equation 4	0.03	***	-0.03	***	-0.05	***	1.00	***	0.10	***	-0.02	***	-0.01	***
u_5 Selection equation 5	-0.03	***	0.04	***	-0.06	***	0.10	***	1.00	***	-0.01	***	0.00	
u_6 Selection equation 6	-0.02	***	0.01	***	-0.02	***	-0.02	***	-0.01	***	1.00	***	-0.02	***
u_7 Selection equation 7	-0.10	***	-0.04	***	-0.04	***	-0.01	***	0.00		-0.02	***	1.00	***
v_1 Levels equation 1	-0.12	***	-0.07	***	0.08	***	0.01	***	0.03	***	0.03	***	-0.05	***
v_2 Levels equation 2	-0.01	***	0.03	***	-0.02	***	0.01	***	0.00	***	0.00		-0.06	***
v_3 Levels equation 3	0.06	***	0.03	***	0.03	***	-0.01	***	-0.01	***	-0.03	***	0.03	***
v_4 Levels equation 4	0.00		0.01	***	-0.01	***	-0.01	***	0.00		0.00		0.01	***
v_5 Levels equation 5	-0.09	***	0.00		-0.08	***	0.02	***	-0.05	***	0.01	***	-0.02	***
v_6 Levels equation 6	-0.07	***	0.03	***	-0.01	***	0.00	**	-0.03	***	-0.01	***	0.03	***
v_7 Levels equation 7	0.01	***	-0.09	***	0.03	***	0.01	***	-0.06	***	0.00	**	0.00	***

Sources: Authors' calculations based on TIA02 data
***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.
District dummies included but not reported.

Table A2 Estimates of error correlation coefficients for the 2005

	u_1		u_2		u_3		u_4		u_5		u_6		u_7	
	Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.	
u_1 Selection equation 1	1.00	***	0.08	***	0.00	***	-0.03	***	-0.01	***	-0.03	***	0.02	***
u_2 Selection equation 2	0.08	***	1.00	***	0.01	***	0.02	***	0.05	***	0.01	***	-0.04	***
u_3 Selection equation 3	0.00	***	0.01	***	1.00	***	-0.06	***	-0.04	***	-0.03	***	-0.04	***
u_4 Selection equation 4	-0.03	***	0.02	***	-0.06	***	1.00	***	0.24	***	0.06	***	0.03	***
u_5 Selection equation 5	-0.01	***	0.05	***	-0.04	***	0.24	***	1.00	***	0.05	***	0.05	***
u_6 Selection equation 6	-0.03	***	0.01	***	-0.03	***	0.06	***	0.05	***	1.00	***	-0.04	***
u_7 Selection equation 7	0.02	***	-0.04	***	-0.04	***	0.03	***	0.05	***	-0.04	***	1.00	***
v_1 Levels equation 1	0.06	***	-0.03	***	-0.01	***	-0.04	***	-0.08	***	-0.01	***	-0.05	***
v_2 Levels equation 2	0.01	***	0.03	***	0.02	***	0.01	***	0.00	**	-0.04	***	0.06	***
v_3 Levels equation 3	-0.06	***	-0.02	***	0.00		-0.03	***	-0.04	***	-0.08	***	0.05	***
v_4 Levels equation 4	-0.07	***	-0.04	***	0.00	**	-0.04	***	-0.02	***	-0.01	***	-0.02	***
v_5 Levels equation 5	-0.03	***	-0.02	***	0.04	***	-0.01	***	-0.03	***	-0.03	***	0.00	
v_6 Levels equation 6	0.02	***	-0.08	***	0.00	***	-0.03	***	-0.06	***	-0.03	***	-0.04	***
v_7 Levels equation 7	-0.07	***	-0.02	***	0.00	*	-0.03	***	-0.03	***	-0.03	***	0.03	***

Sources: Authors' calculations based on TIA05 data
***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.
District dummies included but not reported.

Table A3 Estimates of error correlation coefficients for the year 2008

	u_1		u_2		u_3		u_4		u_5		u_6		u_7	
	Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.		Coeff.	
u_1 Selection equation 1	1.00	***	0.02	***	-0.03	***	0.09	***	0.05	***	-0.02	***	0.02	***
u_2 Selection equation 2	0.02	***	1.00	***	-0.08	***	0.05	***	-0.05	***	0.04	***	-0.05	***
u_3 Selection equation 3	-0.03	***	-0.08	***	1.00	***	-0.06	***	-0.01	***	-0.01	***	-0.07	***
u_4 Selection equation 4	0.09	***	0.05	***	-0.06	***	1.00	***	0.19	***	0.05	***	0.05	***
u_5 Selection equation 5	0.05	***	-0.05	***	-0.01	***	0.19	***	1.00	***	-0.02	***	0.00	
u_6 Selection equation 6	-0.02	***	0.04	***	-0.01	***	0.05	***	-0.02	***	1.00	***	0.05	***
u_7 Selection equation 7	0.02	***	-0.05	***	-0.07	***	0.05	***	0.00	*	0.05	***	1.00	***
v_1 Levels equation 1	0.00	**	-0.03	***	0.03	***	0.10	***	0.11	***	-0.02	***	-0.04	***
v_2 Levels equation 2	-0.05	***	-0.01	***	-0.07	***	-0.07	***	-0.01	***	0.00		0.01	***
v_3 Levels equation 3	-0.06	***	-0.05	***	0.07	***	0.02	***	0.00		-0.02	***	-0.06	***
v_4 Levels equation 4	0.01	***	-0.02	***	-0.01	***	0.03	***	-0.03	***	-0.04	***	-0.02	***
v_5 Levels equation 5	-0.06	***	-0.06	***	-0.04	***	-0.06	***	-0.05	***	0.01	***	-0.04	***
v_6 Levels equation 6	-0.03	***	-0.06	***	-0.03	***	0.01	***	0.00		0.05	***	0.02	***
v_7 Levels equation 7	-0.04	***	-0.05	***	0.00	**	-0.06	***	-0.01	***	0.01	***	0.04	***

Sources: Authors' calculations based on TIA08 data
***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.
District dummies included but not reported.

Assessing the impact of improved agricultural technologies on household income in rural Mozambique

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Abstract

In many areas of Africa, rural livelihoods depend heavily on subsistence farming. Using improved agricultural technologies can increase productivity in smallholder agriculture and thus raise household income and reduce poverty. Data from a nationally representative rural household survey from 2005 is used to assess the impact of four technologies – improved maize seeds, improved granaries, tractor mechanization, and animal traction – on household income in Mozambique. To ensure the robustness of the results, three econometric approaches were used: the doubly-robust estimator, sub-classification and regression, and matching and regression. The results show that, overall, using an improved technology did not have a statistically significant impact on household income. This may be associated with a widespread drought that occurred in 2005. Despite drought, distinguishing between households based on propensity score quintiles revealed that using improved technologies, especially improved maize seeds and tractors, significantly increased the income of those households who had better market access. Thus, to allow households to benefit from the use of improved technologies, policy makers need to reduce structural impediments to market participation by ensuring adequate road infrastructure and enabling access to markets.

1 Introduction

Agricultural productivity in Sub-Saharan Africa is among the lowest in the world (Savadogo et al., 1998; Fulginiti et al., 2004). For example, in Mozambique the yield of the most important staple crop, maize, is estimated at 1.4 tons ha^{-1}, which is far below the potential yield of 5-6.5 tons ha^{-1} (Howard et al., 2003). The low productivity can be linked to poor farmer health during the late dry season and the beginning of the cropping season (Abellana et al., 2008); the failure of agricultural commodity and credit markets (Mather, 2009); and the very limited use of improved agricultural technologies (Mather et al., 2008). To increase agricultural productivity, both the Government of Mozambique and Non-Governmental Organizations (NGO) are promoting the use of improved agricultural technologies in crop production (e.g. drought tolerant seeds, animal traction) as well as promoting the use of adequate storage facility for the harvested grain e.g., through improved granaries (Government of Mozambique, 2006).

The goal of promoting these improved technologies is to increase productivity so as to reduce food insecurity as well as produce a marketable surplus which contributes to household income. This approach has been summarized as the agricultural productivity pathway out of poverty and subsistence agriculture (Barrett, 2008). The first hurdle to be overcome is the adoption of the improved technology, which has been the subject of numerous studies (for a review see Feder et al., 1985; Sunding and Zilberman, 2001; Doss, 2006). Much less attention has been given to assess whether once a technology has been adopted, it has indeed fulfilled its promise of increasing household incomes.

Indeed, many studies focus on assessing the profitability of a technology. Some studies have used the net present value (see for example, Oehmke and Crawford, 1996; Howard et al., 2003). This approach implicitly assumes that users and non-users had the same productivity levels before the adoption took place, which may not be the case and may affect the validity of the results. Also, to assess the profitability for a wider population, baseline data on probable adopters would be needed before the adoption takes place. This may be possible in research trials or on a small scale, but is not feasible at the regional or national scale. Other studies estimate an Ordinary Least Squares (OLS) model and obtain the impact of the adoption by including a dummy variable indicating whether the farmer cultivated a certain crop (Walker et al., 2004) or used an improved technology. Here too it is implicitly assumed that the decision to adopt the improved technology is uncorrelated with other factors affecting productivity (Doss, 2006; Imbens and Wooldridge, 2009).

Many of these approaches to assess the economic impact of an improved technology do not allow taking the selection bias into account. Indeed, farmers are not randomly assigned to the two groups (users and non-users of a technology) but make the adoption choices themselves. Alternatively, farmers or villages may be systematically selected by development agencies, based on some criteria or rule, leading to an endogenous program placement effect. Therefore, users and non-users may be systematically different, and these differences may manifest in differences in household incomes that could be mistakenly attributed to the use of a technology. This means that an ex-post assessment of the impact of using an improved technology on household incomes is difficult, given a possible selection bias due to observed or unobserved household characteristics. Failure to account for this potential bias could lead to unreliable estimates of the impact of the technology.

There have been a few empirical studies in Sub-Saharan Africa that assessed the impact of improved technologies, while addressing the issues of selection bias and endogenous program placement (e.g., Mendola, 2007; Kassie et al., 2008). However, there is still very little empirical evidence about the impact of improved technologies on the income of households with similar observed characteristics.

In this study, to estimate the average effect of using an improved technology, the outcome variable (total household income) is compared between farmers using a given improved agricultural technology (called "users") and their counterparts with similar observable covariates who do not use the technology (called "non-users"). To ensure the robustness of the estimated average effect, Imbens and Wooldridge (2009) recommend using mixed methods that combine regression analysis with either the propensity score or matching methods. Specifically, they suggest using the following three approaches: the doubly robust estimator; sub-classification and regression; and matching and regression. Using these three methods has several advantages. First, they do not require baseline data on potential users before adoption takes place (Imbens and Wooldridge, 2009). Second, they ensure that the comparison of the outcome variable is undertaken between households with similar (i.e. overlapping) characteristics (Dehejia and Wahba, 2002). Third, when comparing sub-populations of households with similar characteristics, covariates are independent of the use of improved technologies, and thus a causal interpretation of the results is reasonable (Imbens and Wooldridge, 2009).

The remainder of the paper is structured as follows. First the conceptual model is presented, describing how the four selected agricultural technologies (i.e. improved maize seeds, animal traction, tractor mechanization, and improved granaries) can contribute to increasing household income. The methods section details how the three econometric approaches were implemented, and how the overlap and the unconfoundedness assumptions were tested. This section also defines the independent variables included in the models. The result section describes the effect of each of the four technologies on the household income, showing how the results of the three approaches complement each other and strengthen the analysis. The conclusion discusses the results and provides some implications for agricultural policy.

2 Data source and conceptual framework

This paper uses data from the National Agricultural Survey of 2005 (Trabalho de Inquérito Agrícola or TIA05). This nationally representative survey included 6,149 households and was implemented by the Ministry of Agriculture. The data was collected between September and November 2005 and cover the agricultural season from September 2004 to August 2005. This agricultural season was characterized by a widespread drought. Data from the national agricultural surveys show that 2005 had the lowest staple food production for the period 1996-2008 (Cunguara and Hanlon, 2010). Analysis of data from the year 2005 can thus be seen as indicative of the potential of improved agricultural technologies to increase household incomes in a drought year. As the occurrence of droughts and/or dry spells is becoming increasingly frequent, especially in the southern provinces (Joubert and Tyson, 1996; Usman and Reason, 2004), the ability of improved technologies to contribute to household income even in years of droughts can affect their adoption rate.

The outcome variable is the total household income in the 2004/05 agricultural season. Total household income was chosen, as the use of improved technologies may affect household resource allocation, and hence affect total household income and not just crop income. Moreover, crop income is the most important source of income, making up 63% of total household income in 2005 (Mather et al., 2008).

Total household income was calculated as the value of own production and off-farm earnings, less any paid-out costs. This approach was also used in other studies on Mozambique (Walker et al., 2004; Boughton et al., 2006; Mather et al., 2008; Mather, 2009), thus allowing for a comparison of results. TIA05 collected the following income sources: net crop income, livestock sales, off-farm self-employment such as income from natural resource-extraction or from a small-business, off-farm wage income, and remittances. The total household income was included in the models after logarithmic transformation to ensure that the dependent variable is normally distributed. The estimated coefficients can thus be interpreted as elasticities.

The technologies evaluated were selected based on the expected impact on household income and on data availability. Besides the four technologies included in this analysis, the TIA05 also included e.g. the use of chemical fertilizers and pesticides. However, since the survey did not collect data on the type or amount of agro-chemical used, nor on the crops on which they were applied, the data were not meaningful enough to be included.

The first agricultural technology modeled is the use improved maize seeds. The Sasakawa-Global program has been promoting the use of improved maize seeds in Mozambique since 1995 (Howard et al., 2003). Improved maize refers to the use of certified seeds of maize, which may or may not be hybrid. Most farmers using improved maize seeds obtain it through purchase (approx. 78% among those who used improved maize seeds, according to the TIA05 data). Others obtain it through government or NGO distribution, mainly during emergencies such as following a drought or flood (Remington et al., 2002). A study has estimated that the use of improved seeds can increase total factor productivity by 10%, and increase farmer’s incomes by almost 8% (de Janvry and Sadoulet, 2002). Other studies are less optimistic. For example, Howard et al. (2003) found that the income of farmers using improved maize seeds (after paying the input loans obtained through the Sasakawa-Global program in Mozambique) is not statistically different from the income of farmers using traditional seeds. Insufficient or erratic rainfall is likely to limit the ability of improved maize seeds to increase household income as it may not achieve higher yields than traditional seeds.

The second technology assessed in this paper is animal traction. This refers to the use of draught power in agriculture, mainly for plowing. Animal traction is practically not found in the northern provinces of Mozambique, mostly due to the occurrence of animal trypanosomiasis. Although some NGOs have encouraged the use of animal traction, especially in the central provinces (e.g. VETAID), it has not been vigorously promoted in Mozambique. It is revealing that animal traction is not mentioned in the Poverty Reduction Strategy Paper (PARPA II) by the Government of Mozambique. However, using animal traction allows incorporating soil fertility-enhancing inputs such as manure, resulting in higher crop yields. As the use of animal traction increases both land and labor productivity, it may affect household resource allocation even in years of drought, and hence affect total household income (Savadogo et al., 1998). In northern Gambia, animal traction was estimated to increase average annual incomes by 10-17% (Panin, 1989). Simalenga and Longisa (2000) also found positive returns to use of animal traction in South Africa.

The third technology considered is tractor mechanization. The benefits of using tractors include a more thorough, deeper and timely tillage, which can increase yields, as well as allowing the expansion of cropped area (Binswanger, 1978). In Mozambique, tractors were heavily promoted by the government soon after independence in 1975 (Filho, 1997; Bowen, 2000). Unfortunately tractor mechanization faced severe planning, management, and training problems (Pingali et al., 1987; Filho, 1997; Bowen, 2000). The use of tractors also affects household labor allocation, which is likely to be the case both in drought and non-drought years. Since tractors constitute capital investments, depreciation should be included in income calculations to avoid overestimating the impact on income. However, TIA05 data show that 98.7% of those who used tractors do not own them, but rented them. Thus, the exclusion of depreciation from the income calculations is not a major concern, and the estimated impact of using tractors can be interpreted as the opportunity cost of renting a tractor.

The fourth technology included in this study is the use of an improved granary. This refers to storage facilities built either using conventional or locally available material and are equipped with rat guards. Improved granaries prevent moisture damage and limit pest infestation, thus reducing post-harvest losses. This can reduce household expenditure on food and increase the household's access to food during the dry season, thus contributing to improving the nutritional status of the farm family members both in drought and non-drought years. Also, when faced with prospects of high food storage losses, farmers are more likely to sell their produce right after the harvesting season, at prices lower than they will have to pay to purchase maize during the dry season (Stephens and Barrett, 2008). In a year with high yields, an improved granary might thus allow a farmer to benefit from inter-temporal price arbitrage. Indeed, if they were able to delay their maize sales until November, farmers using improved maize seeds earned 24% more than non-users (Howard et al., 2003). In calculating the impact of improved granaries on household income, the cost of construction and depreciation were not accounted for due to lack of data. Thus, the impact of improved granaries on income may be overestimated.

The analysis of the effect of using these four technologies on household income was carried out at regional level to restrict the analysis to those regions where the technology is most widespread. This allows to improve the model fit and to increase the likelihood that the assumption on selection on observables is not violated. Based on agro-ecological characteristics, three broad regions can be distinguished in Mozambique: the northern provinces (Niassa, Cabo Delgado, Nampula, and Zambézia[2]), which have a good crop production potential, but cattle rearing is restricted due to trypanosomiasis incidence. The central provinces (Tete, Manica, and Sofala) have a high agricultural potential, but poor infrastructure, restricting access to markets. In the southern provinces (Inhambane, Gaza and Maputo) the potential for crop production is lower than in the central provinces due to limited rainfall, but they benefit from a better infrastructure and from the proximity of the capital city.

The analysis of the impact of animal traction is thus restricted to the southern provinces because its use is low in the central provinces and it is practically nonexistent in the northern provinces. Tractor mechanization is restricted to the southern provinces, where 56% of all tractors in Mozambique are located. Finally, the analysis on improved maize seeds and improved granaries are restricted to the central provinces, since these have the highest crop production potential. The northern provinces are excluded from the analysis.

3 The empirical model

3.1. Overview of the potential models

The literature on causal inference contains numerous approaches that can be used to evaluate the effect of a farmer's exposure to a 'treatment' (e.g., the use of an agricultural technology) on some outcome variable (e.g., household income). However, a number of methods that are frequently used in the literature cannot be applied in this study, either because some assumptions do not hold or because the necessary data was not available.

One econometric approach often encountered is the instrumental variable approach (Abadie, 2003; Angrist, 2004; Heckman and Navarro-Lozano, 2004; Lewbel, 2007; Yen et al., 2008). It relies on the presence of additional treatments (usually called instruments), and allows the researcher to construct estimators that can be interpreted as the parameters of a well-

[2] Zambézia province is administratively located in the central region. However, due to its economic integration with the northern provinces, most agricultural studies have included it in the northern region.

defined approximation to a treatment, even under the functional form miss-specification (Abadie, 2003). However, finding a credible instrument is a difficult task in practice (Imbens and Wooldridge, 2009). Furthermore, the instrumental variable approach does not rely on exogeneity assumptions, and thus violates the overlap assumption (Imbens, 2004).

Another approach is the regression discontinuity design (Cook, 2008; Imbens and Lemieux, 2008; Lee and Card, 2008; Lemieux and Milligan, 2008; McCrary, 2008). In a regression discontinuity design, the selection depends on a measured cutoff score on a continuous assignment variable that fully determines treatment. The regression of outcome on assignment estimates how the entire treatment variable and outcome are functionally related (Cook, 2008). This approach thus also violates the overlap assumption. An example of a hypothetical scenario where regression discontinuity design would be appropriate, is if only households above a certain income threshold were eligible for an improved technology. Yet, although wealthier households tend to use improved technologies more often than poorer farmers, it is hard to define an income threshold that reliably distinguishes users from non-users. Thus, the regression discontinuity design is not suitable for the present analysis.

A slightly different approach is known as the bounds approach and is described in detail in Horowitz and Manski (2006) (see also Manski, 2002; or Scharfstein et al., 2004). The main idea behind the bounds approach is that, even if one cannot infer the exact value of the parameter, one may be able to rule out some values that could not be ruled out a priori (Imbens and Wooldridge, 2009). Although this approach uses limited assumptions, in practice these bounds also need to be estimated, which leads to uncertainty regarding the estimands (Imbens and Wooldridge, 2009).

Finally, panel methods such as difference-in-differences (e.g., Heckman et al., 1997; Abadie, 2005), household fixed effects, and first differences would also be econometric approaches that control for unobservables. However, these methods require panel data that includes information on the use of each technology in two periods, which is not available in this case.

As the above discussion indicates, there is no single method that is appropriate for all applications. Imbens and Wooldridge (2009) thus recommend the use of several approaches to estimate treatment effects, e.g., the doubly robust estimator, matching and regression, and sub-classification and regression. To ensure the robustness of the results, all three approaches are used in this analysis.

3.2 The propensity score

3.2.1 Defining the propensity score and its independent variables

The propensity score is defined as the conditional probability of receiving treatment (Rosenbaum and Rubin, 1983). It can be expressed as:

$$e(x) = \Pr(W_i^k = 1 \mid X_i = x) = E[W_i^k \mid X_i = x] \qquad (1)$$

where W_i is a binary indicator: $W_i = 1$ for users, and $W_i = 0$ for non-users; k is the improved agricultural technology; and X_i is the vector of pre-treatment covariates. The vector X_i includes asset endowment, demographic characteristics, labor availability, access to information, access to credit or cash, road infrastructure, and district dummies (these were chosen over the agro-ecological zone dummies, as they are more accurate).

These independent variables were selected as they have been shown by previous studies to potentially influence the use of improved technologies. Asset endowment was included through two proxies: total cropped area and off-farm employment. Total cropped area may be relevant especially for the use of tractor mechanization and animal traction, which have been shown to be more profitable with larger cropped area (Pingali et al., 1987). The cropped area might also be related to using improved storage, assuming that an increase in cropped area results in higher harvested quantities, and hence a greater need for improved storage. Finally, a larger cropped area is also positively correlated with wealth, and consequently with the ability to purchase improved seeds, and to invest in the three other technologies considered. Participation in off-farm employment was also included as a proxy of asset endowment, as it is likely to indicate higher income (Walker et al., 2004), which can be invested in agriculture (Reardon, 1997; Langyintuo and Mungoma, 2008).

Two demographic characteristics of the household head were included: education and whether the head is a widow. Education was included, mostly because more educated households tend to be relatively wealthier (Walker et al., 2004), and hence have the means to purchase improved seeds or invest in other improved technologies. The gender of the household head was included in the model using two dummy variables: one indicating whether the head is a widow, and the other whether the head is a non-widow female. This distinction is based on previous studies in Mozambique, which tend to show that female-headed households, especially widows, are on average worse-off (Walker et al., 2004; Boughton et al., 2006; Boughton et al., 2007; Mather et al., 2008).

Labor availability was included by considering both available family labor and hired labor. Family labor was estimated by converting household size in adult equivalent (Deaton, 1997). Lack of labor can impair the use of technologies that would require more labor than the family can provide, especially where labor markets do not function effectively (Doss, 2006). However, where there is a labor market, households may hire labor to compensate for their limited family labor. Thus, a dummy variable indicating whether or not the household hired labor (either seasonal or full-time workers) is also included in the analysis. The coefficient on these three variables (household size, hired seasonal labor, and hired full-time workers) is expected to be positive, and the magnitude of the coefficient is likely to be larger for labor intensive technologies.

Access to information on improved technologies was included through two binary proxy variables: whether a household member belongs to a farmers' association, and whether the farmer had contact with extension services. The inclusion of these variables is based on the premise that farmers must have information about improved technologies before they can consider using them (Doss, 2006).

Access to credit or cash is included as a dummy variable, as their unavailability may constrain farmers from using technologies that require an initial investment (Doss, 2006). Assets that can be easily turned into cash (e.g., livestock) were also included, since they have been shown to help overcome credit constraints in rural areas (Reardon, 1997; Bryceson, 1999; Thirtle et al., 2003). The access to credit or cash is likely to affect the use of all four technologies in a similar way. The estimated coefficient is thus expected to be positive, although the magnitude of the coefficient is likely to be different, as some technologies require significantly more financial investment than others.

Finally, a variable for road infrastructure was used to assess farmers' access to inputs and markets (Feder et al., 1985). Farmers close to a tarred road are more likely to use improved technologies, especially tractor mechanization, since they need access to fuel and repair services. Using improved seeds might also be facilitated by a good road infrastructure: if the improved seeds are not available locally, farmers may need to travel to the nearest township, which is more likely if there are adequate roads and transport services (Eriksen and Silva, 2009). Road infrastructure is not only likely to affect the use of an improved technology, it is also likely to affect its attractiveness, since access to markets to sell surpluses – directly or through traders – is more likely where all-weather roads exist (Barrett, 2008). TIA05 includes a variable on the distance to the nearest tarred road at the village level, which may influence the balance of the covariates used in the propensity score.

The independent variables described above were used to find a suitable comparison group. Thus, given the household income of a farmer who uses an improved technology, the model allows a comparison with the income of a farmer who does not use the technology, but has very similar characteristics. This is usually estimated using flexible binary response models such as Logit or Probit. The main difference between using Probit or a Logit model is that the conditional probability approaches the extreme values of zero or one at a slightly slower rate in a Logit than in a Probit model, because the logistic distribution has slightly fatter tails. For ease of estimation, most applications have used the Logit model to estimate the propensity score (Dehejia and Wahba, 2002). This paper also uses a logistic regression to identify farmers with similar observable covariates so that the difference in the outcome variable can be attributed to the use of the technology.

3.2.2 Assessing the overlap assumption

The overlap assumption postulates that the conditional distributions of the covariates of users and non-users overlap completely. There are two formal methods of testing the overlap assumption. The first is to plot the distribution of the propensity scores of users and non-users and visually assess whether the overlap assumption holds. The second method is to calculate normalized differences between users and non-users (Imbens and Wooldridge, 2009). Formally, the normalized difference is given by:

$$\Delta x = \frac{\bar{x}_1 - \bar{x}_0}{\sqrt{\sigma_1^2 + \sigma_0^2}} \qquad (2)$$

where $\bar{x}_i$ is the mean and σ_i^2 is the sample variance. Imbens and Wooldridge (2009) consider a normalized difference greater than 0.25 (in absolute value) to be substantial. If the normalized difference is large (as it was the case with TIA05 data), some of the observations can be trimmed. The theoretical rationale for trimming is both to derive the asymptotic properties of the estimator, and to avoid an undue influence of households with very large (or very small) propensity score values. Hence, trimming allows achieving a more balanced sub-sample of users and non-users. In this analysis, the top 5% of the propensity scores of each of the four technologies assessed were trimmed.

3.2.3 Assessing the unconfoundedness assumption

The unconfoundedness assumption asserts that all variables that need to be adjusted for are observed and included in the model. In other words, beyond the observed covariates (modeled through the propensity score), there are no unobserved characteristics of the individual that are associated both with the potential outcome and the treatment. This is also referred to as selection on observables, exogeneity, or ignorability (Imbens and Wooldridge, 2009). Although the unconfoundedness assumption is not directly testable, there are two formal ways of assessing its plausibility.

One option is to estimate a pseudo causal effect that is known a priori to be zero (Heckman et al., 1997). The implementation of this procedure requires the identification of two or more control groups, for example eligible non-participants and ineligibles (Heckman et al., 1997). In practice, however, the identification of such control groups is difficult, as many criteria (e.g. widows are eligible non-participants because they are too poor) are likely to be controversial.

Another option is to use a placebo regression approach. In this analysis, an OLS regression was estimated with the same covariates used in the estimation of the propensity score, but with a different dependent variable (the age of the spouse of the household head). This dependent variable is known a priori not to be caused by the use of improved technologies. If the coefficient on the use of each improved technology is significantly different from zero, then there are omitted variables that are correlated with the use of improved technologies. Otherwise, the unconfoundedness assumption can be maintained and a causal interpretation of the results is reasonable. The results of the placebo regression (Table A1) show that there is no indication of omitted variables that are potentially correlated with the use of improved technologies.

3.2.4 Sensitivity analysis

A sensitivity analysis was conducted to assess whether the propensity score is well-specified. If this is the case, it means that the set of independent variables is sufficiently rich, so that adjusting for differences in these covariates leads to valid estimates of causal effects (Imbens and Wooldridge, 2009). In other words, a well-specified propensity score increases the likelihood that the assumption on selection on observables is not violated. The sensitivity analysis of the propensity scores also ensures that the estimates from the doubly robust approach are at least consistent, provided that the results reject a misspecification of the propensity scores.

The sensitivity analysis of the propensity score is challenging, as the literature provides little guidance on how it could be performed (Gibson-Davis and Foster, 2005; Gilligan and Hoddinott, 2007). In this analysis, the propensity score model was estimated using both the original and simulated data. The simulated data was drawn from the original TIA05 data. The concept behind this sensitivity test is that by drawing a large number of random samples, the estimated parameters will be close to the 'true' parameters. Also, if the parameters from the original and from the simulated data are comparable, then it is likely that the specification of the propensity score is correct and stable. Determining how many random samples should be drawn to be considered a 'large' sample is somewhat arbitrary. For this analysis, 25,000 data sets were drawn for each of the four technologies, each new data set of the same size of the original TIA05 data.

3.3 Doubly robust estimator

Although one method to estimate average treatment effects is sufficient to obtain consistent or even efficient estimates, incorporating regression may eliminate a remaining bias and improve precision (Imbens and Wooldridge, 2009). The interesting feature of the doubly robust estimator is that, as long as the parametric model for the propensity score or for the regression function is correctly specified, the resulting estimator for the average treatment effect is consistent (Wooldridge, 2007; Imbens and Wooldridge, 2009). The doubly robust estimator can be represented as:

$$\hat{\Delta}_{DR} = n^{-1}\sum_{i=1}^{n}\left[\frac{W_iY_i}{e(X_i,\beta)} - \frac{\{W_i - e(X_i,\beta)\}}{e(X_i,\beta)}m_1(X_i,\hat{\alpha}_1)\right] - n^{-1}\sum_{i=1}^{n}\left[\frac{(1-W_i)Y_i}{1-e(X_i,\beta)} + \frac{\{W_i - e(X_i,\beta)\}}{1-e(X_i,\beta)}m_0(X_i,\hat{\alpha}_0)\right] \quad (3)$$

where $e(X_i,\beta)$ is the postulated model for the propensity score, n is the number of users and non-users, and $m_i(X_i,\hat{\alpha}_i)$ is the postulated regression model. The parametric model for the propensity score was specified in section 3.2. The regression function is a linear model where the dependent variable is the outcome variable Y_i, i.e. the total household income.

Independent variables in the regression model were the same as discussed above, i.e., asset endowment, demographic characteristics, labor availability, access to information, access to credit or cash, road infrastructure, and district dummies.

3.4 Sub-classification and regression

The motivation for using sub-classification and regression is to contrast the average treatment effect in different blocks. This allows to identify whether there are variations across households using a technology (see Abedaw et al., 2010). The observations were thus grouped into blocks, i.e. quintiles of propensity scores. For each quintile q the following model was estimated:

$$Y_i = \alpha_q + \tau_q W_i + \beta_q X_i + \varepsilon_i \tag{4}$$

The average treatment effect is then calculated for each quintile. The vector X_i of independent variables is the same as the one used in the regression part of the doubly robust estimator.

3.5 Matching and regression

Using matching and regression allows to improve the model results by correcting for possible remaining bias (Imbens and Wooldridge, 2009), and to compare the robustness of the estimation results given the econometric approach used. The model is similar to the sub-classification and regression model, except that the estimation is carried out for the whole sub-sample of matches, as opposed to estimating one model for each of the five blocks.

4 Results

4.1 Descriptive analysis of unmatched samples

Two patterns in the demographic characteristics can be discerned. First, farms that used any of the four improved technologies had a household head with a higher education level than their counterparts (Table 1). Second, widow-headed households were less likely to use improved technologies, although the difference between users and non-users was statistically significant only for animal traction and improved granaries. This result is in line with previous research on poverty in Mozambique (Walker et al., 2004; Boughton et al., 2006; Boughton et al., 2007; Mather et al., 2008).

Both the household size and the use of hired labor were significantly higher among households who used improved technologies (Table 1). In particular, the difference in the use of hired labor was greater for animal traction and tractor mechanization. This may or may not indicate that the four technologies assessed are labor intensive. Indeed, increased use of labor might be related to indirect effects, e.g. if a new enterprise is started or if the agricultural system is modified.

The results also highlight the importance of access to credit or cash. In particular, access to credit was statistically significant for the use tractors and improved granaries. Tropical livestock units played a statistically significant role for all technologies, except improved maize seeds (Table 1). In addition, farmers using tractors and improved maize seeds were more likely to belong to a household whose head was engaged in off-farm employment.

Furthermore, households whose members belonged to a farmers' association were significantly more likely to use improved technologies. Use of technologies was also higher among those who were visited by extension agents. This indicates that information received through discussion with farmers or with extension agents can reduce the information asymmetry often associated with new technologies (Langyintuo and Mungoma, 2008).

Farmers using any of the four technologies also tended to cultivate more land (Table 1). This is especially evident for animal traction, as users cultivated twice as much land, compared to non-users. Surprisingly, cropped area was not statistically different between farmers using tractor mechanization and their counterparts, indicating that another factor played an important role.

Finally, road infrastructure is an important factor associated with the use of improved technologies. Two patterns can be distinguished: First, the distance to the nearest tarred road was significantly greater in the central provinces than in the southern provinces. This difference in road infrastructure validates the choice of modeling tractor mechanization for southern provinces only, as tractor use is linked to the proximity to a tarred road. Second, except for the use of improved maize seeds, the use of improved technologies was significantly higher in villages closer to a tarred road. This underscores the role of adequate road infrastructure in facilitating the use of improved technologies.

Few of the surveyed households use more than one of the four improved technologies included in this analysis. For example, at the national level, among those who used animal traction, only 2% used tractor mechanization. Similarly, among those who own an improved granary, only 6% used improved seeds.

Table 1 Descriptive statistics of unmatched samples (means)

Technology	Improved maize seeds			Tractor mechanization			Animal traction			Improved granary		
	Users	Non-users	Sig.	Users	Non-users	Sig.	Users	Non-users	Sig.	Users	Non-users	Sig.
Head's years of schooling	3.49	2.48	***	3.94	2.62	***	2.80	2.64	**	2.98	2.48	***
Female-headed (%)	23.38	26.57										
Widow headed (%)				13.93	17.96		14.59	19.61	***	4.87	12.96	***
Non-widow female headed (%)				15.33	18.21	**	14.41	20.24	***	17.72	14.11	
HH size (adult equivalent scale)	4.87	4.36	***	5.66	4.38	***	5.24	3.99	***	4.85	4.31	***
Head is engaged in off-farm (%)	67.64	57.62	*	67.19	58.26	***	54.58	61.38	***	55.88	59.00	
Distance to tarred road (km)	104.80	69.04	***	6.07	32.49	***	30.38	31.15	***	66.70	73.09	***
Tropical livestock units	3.01	1.92		2.93	1.85	***	3.41	1.00	***	2.93	1.82	***
Total cropped area (ha)	2.34	2.07	***	1.57	1.53		2.17	1.15	***	2.40	2.03	***
Membership in association (%)	11.59	4.91	***	20.93	7.02	***	7.73	7.96	***	10.25	4.49	***
HH received extension (%)	23.26	14.61	**	17.72	12.54		17.60	9.97	***	19.10	14.57	**
Household received credit (%)	5.94	4.23		7.01	1.70	***	1.58	2.29		6.97	3.84	**
HH hired permanent labor (%)	5.90	3.49	***	8.99	2.67	***	4.98	1.89	***	5.65	3.29	***
HH hired seasonal labor (%)	35.57	21.32	***	56.98	16.08	***	28.10	12.81	***	31.24	20.73	***
Number of observations	173	1,587		189	1,709		873	1,025		353	1,395	

Source: Authors' own calculations based on TIA05 data

Notes: For animal traction and tractor mechanization, only households in the southern provinces were included;
For improved maize seeds and improved granaries, only households in central provinces were included;
Due to lack of data for specific groups, not all variables are included for all technologies
Standard deviation not reported to save space;
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table 2 Results of the logistic regression

Technology	Improved maize seeds			Tractor mechanization			Animal traction			Improved granary		
	Coeff	Sig.	Sim.	Coeff	Sig.	Sim.	Coeff	Sig.	Sim.	Coeff	Sig.	Sim.
Head's years of schooling	0.12	***	0.12	0.03		0.03	0.02		0.02	0.03		0.03
Female-headed (1=yes)	0.34		0.35									
Widow headed (1=yes)				-0.31		-0.37	-0.25		-0.26	-0.66	*	-0.72
Non-widow female-headed (1=yes)				-0.08		-0.11	-0.23		-0.25	0.41		0.41
HH size (adult equivalent scale)	0.08	*	0.08	0.11		0.12	0.10	***	0.10	0.13	***	0.14
Head is engaged in off-farm (1=yes)	0.34		0.36	-0.07		-0.07	-0.17		-0.18	0.13		0.13
Distance to tarred road (km)	-0.01	*	-0.01	-0.06	***	-0.06	-0.01	**	-0.01	-0.01	**	-0.01
Tropical livestock units	0.02		0.02	-0.02		-0.02	0.17	***	0.18	0.01		0.01
Total cropped size (ha)	-0.02		-0.03	0.35	**	0.39	0.27	***	0.28	-0.03		-0.03
Membership in association (1=yes)	0.62		0.64	0.81	**	0.87	-0.10		-0.13	0.40		0.41
HH received extension (1=yes)				0.17		0.17	0.62	**	0.65	0.05		0.05
HH received credit (1=yes)	0.50		0.49	1.27		1.35	-0.83		-.090	0.24		0.23
HH hired permanent labor (1=yes)	0.41		0.41	0.22		0.25	-0.19		-0.19	-0.01		-0.03
HH hired seasonal labor (1=yes)	0.56	*	0.58	1.78	***	1.93	1.17	***	1.22	0.66	***	0.69
Constant	-3.38	***	-3.48	-22.9	***	-23.0	-0.56		-0.57	-1.87	***	-1.93
Number of observations	1729			1053			1898			1688		
Wald χ^2 (37)	177.1			344.3			274.3			135.9		
Prob > χ^2	0.00			0.00			0.00			0.00		
Pseudo R^2	0.15			0.37			0.27			0.13		
% predicted correctly	90.57			86.23			77.82			79.32		

Source: Authors own calculations based on TIA05 data.

Notes: HH stands for household;
District dummies were included but are not reported to save space;
Sim. are the coefficients based on 25,000 simulated data sets for each technology;
Due to lack of data for specific groups, not all variables are included for all technologies
***. **, and * denote significance at 1%, 5%, and 10%, respectively.

4.2 Variables associated with the use of improved technologies

The estimated logistic regression models seem to fit the data reasonably well. The percentage of correctly predicted/classified households is between 78% and 91%; the Pseudo R^2 varies between 0.13 for improved granaries and 0.37 for tractor mechanization (Table 2). The null hypothesis that the model coefficients are jointly equal to zero is rejected for each of the four improved technologies (Prob>χ^2=0.00). The coefficients obtained from the simulated data agree with those from the original data, both in terms of sign and magnitude. This suggests that the specification of the propensity score model is reasonable, and that the underlying assumption of 'selection on observables' is plausible.

The results from the logistic regression confirm the results from the descriptive statistics, and highlight three key factors influencing the use of improved technologies: road infrastructure, hired seasonal labor, and cropped area (Table 2). Indeed, road infrastructure, measured as the distance from the village to the nearest tarred road, was negatively and significantly correlated with the use of all four technologies. Labor availability, especially in the form of hired seasonal labor also played a statistically significant role for all four technologies, especially for tractor mechanization and animal traction, which had the largest coefficients. Family labor also played a role, mostly for animal traction and improved granaries. Finally, cropped area was significantly correlated to the use of tractors and animal traction, indicating that these two technologies may be more attractive for farmers with larger cropped areas. Unlike in the descriptive statistics presented earlier, cropped area was significant because in a regression framework other factors are taken into account, such as the distance to the tarred road.

Some variables played a significant role only for one of the technologies (e.g. gender for improved granaries; tropical livestock units for animal traction; the receipt of extension for improved maize seeds and animal traction). Other variables, for example access to credit were not significant at all. This might be associated with low variation in the data since few households had access to it.

Not all variables could be included in all the models due to lack of sufficient data for specific groups (Table 2). For example, the variable on whether the household is widow-headed was excluded from the model of improved seeds because too few surveyed widows used this technology. Instead, the broader gender variable was used (i.e., whether the household is female-headed). Likewise, the variable on access to credit was also excluded from the model on improved seeds because relatively few households had access to credit and used improved maize seeds.

4.3 The plausibility of the overlap and unconfoundedness assumptions

The users and the counterfactual comparison group of non-users indeed have similar observable variables (Table 3). Only the normalized differences for the variable on the distance to the nearest tarred road is fairly large. This might be due to the fact that this variable was recorded at the village level, and hence shows limited variation between households. Almost all other normalized differences are smaller than 0.25 in absolute values (Table 3), suggesting that the overlap assumption is reasonable.

The assessment of the overlap assumption can be improved by graphical representation. Imbens and Wooldridge (2009) argue that reporting normalized differences should be seen as a starting point, because inspecting differences one covariate at a time may not be sufficient. Therefore, the overlap assumption was also assessed through graphical representation, by comparing the distribution of propensity scores of the two groups (users and non-users). The two distributions are almost identical (Fig. 1). The graphical representation thus reinforces the results based on the normalized differences, suggesting that the overlap assumption is not a concern for any of the four technologies included in this analysis.

Table 3 Descriptive statistics for matches (means)

Technology	Improved maize seeds			Tractor mechanization			Animal traction			Improved granary		
	Users	Non-users	Δx[a]	Users	Non-users	Δx	Users	Non-users	Δx	Users	Non-users	Δx
Head's years of schooling	3.74	3.35	-0.11	3.86	3.79	0.09	2.80	2.41	-0.10	2.73	2.58	0.09
Female-headed (%)	0.17	0.25	0.03									
Widow female headed (%)				0.14	0.18	0.01	0.15	0.24	-0.05	0.05	0.04	0.01
Non-widow female headed (%)				0.16	0.21	-0.04	0.14	0.11	0.03	0.18	0.15	0.00
HH size (adult equivalent scale)	5.11	4.80	-0.06	5.57	5.44	-0.01	5.24	5.03	-0.17	4.81	4.96	-0.04
Head is engaged in off-farm (%)	0.69	0.66	-0.07	0.67	0.77	0.05	0.55	0.46	-0.04	0.54	0.49	0.03
Distance to tarred road (km)	82.53	100.91	1.07	6.19	8.45	0.09	30.30	38.13	0.28	69.28	81.81	-0.40
Tropical livestock units	2.30	2.95	-0.12	2.74	3.58	-0.20	3.41	2.73	-0.31	2.52	2.85	-0.16
Total cropped size (ha)	2.34	2.34	0.13	1.53	1.44	-0.33	2.17	1.84	-0.14	2.29	2.53	0.04
Membership in association (%)	0.19	0.10	0.00	0.21	0.13	0.07	0.08	0.10	-0.01	0.08	0.10	0.00
HH received extension (%)				0.18	0.10	0.07	0.18	0.18	0.01	0.17	0.20	-0.01
Household received credit (%)	0.24	0.23	-0.03	0.07	0.06	-0.01	0.02	0.02	-0.02	0.06	0.05	0.02
HH hired permanent labor (%)	0.04	0.05	0.00	0.07	0.07	-0.04	0.05	0.06	-0.03	0.03	0.04	0.01
HH hired seasonal labor (%)	0.33	0.32	0.01	0.56	0.45	0.05	0.28	0.21	-0.06	0.27	0.31	-0.05
Number of observations	161	161	322	171	171	342	871	871	1742	304	304	608

Source: Authors' own calculations based on TIA05 data

Notes: [a] Δx is the normalized difference;

Due to lack of data for specific groups, not all variables are included for all technologies

HH stands for household

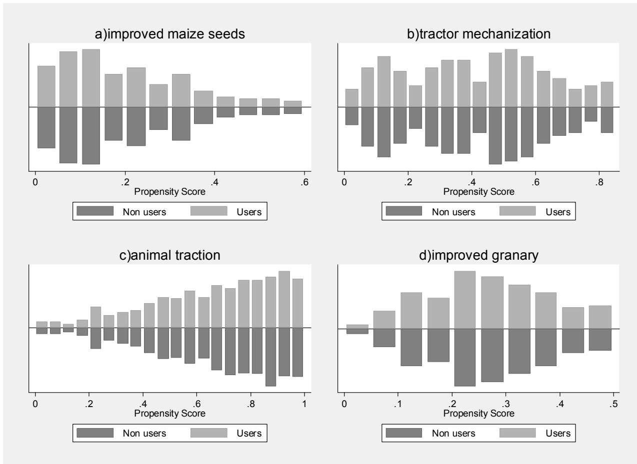

Figure 1 Propensity score distribution of matches by technology

The unconfoundedness assumption was tested using a placebo regression for each of the four technologies (Table 1A, appendix). The results from these placebo regressions are not necessarily the proof that the unconfoundedness assumption holds. But non-rejection of the null hypothesis that the coefficient on the use of an improved technology is zero suggests that there are no omitted variables correlated with the use of the technology. These results suggest that the assumption about “selection on observables” can be maintained, and that a causal interpretation of the results is reasonable.

4.4 Impact of technology use on household income

4.4.1 Results from matching and regression

The matching and regression models seem to fit the data reasonably well, with a R^2 in the range 0.26-0.41 (Table 4). Using tractor mechanization increased total household income by 5%, but using other technologies reduced household income. However, none of the improved technologies had a significant impact on household income. These results should be viewed in light of the fact that the 2004-05 agricultural season was characterized by a widespread drought, so that the quantities harvested in 2005 were the lowest in a 10-year period (Cunguara and Hanlon, 2010).

The results from matching and regression suggest that participation in off-farm income and size of cropped area had a significant impact on household income for households using any one of the four technologies (Table 4). On average, having a household head who engaged in off-farm activities significantly increased household income by 44-98% (Table 4). The number of household members (other than the head) engaged in off-farm activities also increased household income, by 10-35%. This result underscores the potential role of the off-farm employment in enhancing household incomes in rural Mozambique in a year of drought.

Asset endowments were also significant in enhancing household income. An additional cropped hectare increased income by 22%. Likewise, an additional tropical livestock unit increased household income by 5-6%. Finally, higher educational levels were also correlated with higher income (Table 4).

Table 4 Estimation of effect on household income based on matching and regression

Technology	Improved seeds		Tractor mechanization		Animal traction		Improved granary	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
HH adopted the technology (1=yes)	-0.11		0.05		-0.08		-0.10	
Head's age	-0.01		0.01		0.00		0.00	
Head's years of schooling	0.17	***	0.04		0.11	***	0.10	***
Female-headed (1=yes)	0.07							
Widow headed (1=yes)			-0.15		0.22		-0.53	
Non-widow female headed (1=yes)			-0.25		0.20		-0.08	
HH size (adult equivalent scale)	-0.01		0.04		0.00		-0.04	
Head is engaged in off-farm (1=yes)	0.44	**	0.98	***	0.84	***	0.58	***
N. of members engaged in off-farm	0.35	***	0.10		0.29	***	0.23	***
Tropical livestock units (TLU)	0.05	**	0.02		0.02		0.06	***
TLU (squared term)	0.00		0.00		0.00		0.00	***
Cropped area (ha)	0.23	**	0.21	***	0.22	***	0.41	***
Cropped area (squared term)	-0.01	*	0.00	***	0.00	***	-0.02	***
Membership in association (1=yes)	0.09		0.74	**	0.17		-0.27	
HH received extension (1=yes)	0.12		-0.88	*	0.18		-0.12	
Constant	7.98	***	7.28	***	7.07	***	7.66	***
R^2	0.37		0.29		0.26		0.41	
Number of observations	322		342		1741		607	

Source: Authors' own calculations based on TIA05 data

Notes: District dummies were included but are not reported to save space;

Due to lack of data for specific groups, not all variables are included for all technologies

***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

4.4.2 Results from the doubly robust estimator and sub-classification and regression

The results from the doubly robust estimator are similar to those from matching and regression, in that none of the four technologies significantly increased household income (Table 5). As discussed above, the lack of impact of improved technologies may be related to the severe drought in 2005.

Nevertheless, the sub-classification based on quintiles of the propensity score allows to assess whether there is heterogeneity within groups using a technology, despite the fact that the groups have similar characteristics. The sub-classification based on quintiles of propensity score shows that there are differences in the impact of using a technology on the household income (Table 5). The use of improved maize seeds had a statistically significant but negative impact on household income for the fourth quintile. This quintile was characterized by villages that are on average 152 km from a tarred road (Table 5), and by an intensive use of full-time hired workers. This suggests that the net benefit of using improved seeds in the central provinces in a drought year is negative. This is probably due to a combination of high production cost, low yields and high marketing costs.

A similar pattern can be identified for the use of tractors, modeled for the southern provinces, a region of better infrastructure but lower agricultural potential than the central provinces. The bottom quintile has a significant but negative effect of tractor use on household income (Table 5). This quintile is also characterized by larger distances to the nearest tarred road, compared to the top quintile, where the impact of tractor use is significant and positive. In addition, there is also a significant difference in the cropped area, with the bottom quintile cultivating significantly less land. This is consistent with Pingali et al. (1987) who argue that the use of tractor mechanization and animal traction may only be profitable with larger cropped area.

Table 5 Estimation results from the doubly robust estimator, and from sub-classification and regression by propensity score quintile

Technology	Econometric approach	Quintile	Coefficient	Sig.	Mean cropped area (ha)	Mean distance to nearest tarred road (km)
Improved maize seeds	Doubly robust		0.03		2.34	91.46
	Sub-classification and regression	1	0.38		1.73	39.88
		2	-0.06		2.12	49.93
		3	-0.39		2.23	65.77
		4	-1.45	***	2.68	152.05
		5	-0.26		2.95	152.54
Tractor	Doubly robust		-0.12		1.49	7.36
	Sub-classification and regression	1	-0.75	*	1.57	11.84
		2	0.86		0.78	8.36
		3	-0.29		1.54	3.99
		4	0.00		1.19	6.79
		5	0.98	***	2.36	5.52
Animal traction	Doubly robust		0.05		2.01	34.22
	Sub-classification and regression	1	-0.35	**	1.12	27.93
		2	-0.25		1.47	31.46
		3	-0.23		1.68	27.69
		4	0.03		1.72	41.16
		5	-0.08		4.06	42.92
Improved granaries	Doubly robust		-0.07		2.41	75.43
	Sub-classification and regression	1	0.53	*	2.03	91.79
		2	-0.78	***	1.99	55.18
		3	0.26		2.51	87.93
		4	-0.33		2.78	78.06
		5	-0.68	*	2.74	63.96

Sources: Authors' own calculations based on TIA05 data

Notes: District dummies were included but are not reported to save space;

***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Similarly, the lack of impact of animal traction on the income of households in southern Mozambique could be linked to the size of the cropped area. Indeed, households in the bottom quintile had a negative and significant impact, which might be associated with their smaller cropped area (Table 5). Although they are relatively closer to a market, their cropped area may be too small to fully benefit from the use of animal traction.

The use of improved granaries has a significant and negative impact on household income for the second and fifth quintiles (Table 5). The first quintile had a positive impact from using a granary, despite the fact that these households are located in a village fairly far from a tarred road (e.g., Zumbo, in Tete province). However, households in this village may be able to compensate the poor domestic infrastructure with access to markets in neighboring countries, i.e. Zambia and Zimbabwe. Indeed, many farmers in central Mozambique benefit from cross-border trade (Tschirley and Santos, 1999).

5 Concluding remarks and policy implications

This paper assesses whether a statistically significant relationship can be found between the use of four improved technologies and household income in rural Mozambique during a year of drought. Three econometric approaches (the doubly-robust estimator, sub-classification and regression, and matching and regression) were used to ensure that a range of potential biases are accounted for. The assumption of 'selection on observables' is assessed through a placebo regression, while the overlap assumption is assessed both through normalized differences and graphical representation of the distribution of the propensity scores. Furthermore, the model specification of the propensity score was assessed through sensitivity tests. The results show no concern for the assumptions used, suggesting that a causal interpretation of the results is plausible.

The results from matching and regression and from the doubly robust estimator show that, on average, using an improved agricultural technology did not have a significant impact on household income in rural Mozambique in 2005. This does not support the widespread assumption that improved technologies will increase household income (Panin, 1989; Oehmke and Crawford, 1996; Simalenga and Longisa, 2000). One key factor that might explain this discrepancy is that most improved technologies require an adequate rainfall to be effective. However, the year 2005 was characterized by a widespread drought which might have reduced the ability of the technologies to contribute to household income, especially directly through increasing crop production. Indeed, better seedbed preparation using animal traction or tractors might be of limited use during years of drought, as seeds, especially improved maize seeds, require adequate and timely water supply to be most productive. On the other hand, improved granaries are likely to reduce post-harvest losses even in years of drought. The analysis of TIA05 data thus reflects the weather-related risks associated with using improved technologies in a rain-fed agricultural system, which the overwhelming majority of farmers in Mozambique have to cope with.

Nevertheless, in years of drought improved technologies may still have an indirect impact on household income, through allowing shifts in resource allocation. For example, having an improved granary might allow for a better nutritional status of family members, which can thus engage in various activities on- and off-farm. Also, even in years of drought using tractors or animal traction is likely to free family labor, which can be used to engage in on-farm processing, handicraft production, petty trade or off-farm employment. However, to realize this potential and increase household income, farmers need access to markets through an adequate road network and transport services. Markets may also be crucial in allowing households to directly benefit from the improved technology by compensating for the effect of inadequate rainfalls (e.g., by purchasing new improved seeds if the first sowing failed due to lack of early rains).

The crucial role of access to markets is underlined by the fact that the impact of improved technologies on household income varied among users. Indeed, the results from the sub-classification and regression, which distinguishes between quintiles based on propensity score, show that some groups of users had a significantly negative, while others had a significantly positive impact, depending on the technology and on group characteristics. The results indicate that especially the distance to a tarred road, and thus access to markets, can play an important role on the ability of households to benefit from using an improved technology even in a year of drought. Households located in villages which are relatively closer to a tarred road tend to be able to benefit more, especially from using improved maize seeds or tractors. Indeed, even in years with adequate rainfall, farmers using an improved agricultural technology and producing a marketable surplus require a physical infrastructure to be able to reach markets, or for traders to reach their villages (Eriksen and Silva, 2009). However, in Mozambique most farmers are unable to profitably participate in markets because they lack the necessary assets, and because the road infrastructure is poor (Feder et al., 1985; Boughton et al., 2007; Mather, 2009). Thus, although the lack of impact of improved technologies during a year of drought seems overly pessimistic, it is plausible given the current situation in Mozambique which restricts the farmers' options to compensate for the effects of a drought.

This analysis of a nationally representative data set has provided empirical evidence for the assertion that, to break out of the semi-subsistence poverty trap (Barrett, 2008), the use of improved technologies alone is not enough. The use of these technologies may not have a significant effect on household incomes in years of drought. Thus, strategies to compensate for this effect are needed in order to reduce the vulnerability of the adopting households. In the meantime, to enable farmers to fully benefit from improved technologies in years of drought as well as years with adequate rainfall, they should be able to participate in markets. Thus, to allow improved technologies to have a positive impact on household income, entry barriers and structural impediments to market participation need to be reduced.

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References

Abadie, A., 2005. Semiparametric difference-in-differences estimators. Review of Economic Studies 72, 1-19.

Abadie, A., 2003. Semiparametric instrumental variable estimation of treatment response models. Journal of Econometrics 113, 231-263.

Abedaw, D, Fentie, Y., Kassa, B., 2010. The impact of a food security program on household food consumption in Northwest Ethiopia: A matching estimator approach. Food Policy 35: 286-293.

Abellana, R., Ascaso, C., Aponte, J., Saute, F., Nhalungo, D., Nhacolo, A., Alonso, P., 2008. Spatio-seasonal modeling of the incidence rate of malaria in Mozambique. Malaria Journal 7 (228) 1-11.

Angrist, J., 2004. Treatment effect heterogeneity in theory and practice. The Economic Journal 114, 52-83.

Barrett, C.B. 2008. Smallholder market participation: Concepts and evidence from eastern and southern Africa. Food Policy 33: 299-317.

Binswanger, H., 1978. The economics of tractors in south Asia: An analytical review. Agricultural Development Council, New York.

Boughton, D., Mather, D., Tschirley, D., Walker, T., Cunguara, B., Payongayong, E., 2006. Changes in Rural Household Income Patterns in Mozambique 1996-2002 and Implications for Agriculture's Contribution to Poverty Reduction. MINAG Working Paper, Maputo, Mozambique.

Boughton, D., Mather, D., Barrett, C., Benfica, R., Abdula, D., Tschirley, D., Cunguara, B., 2007. Market Participation by Rural Households in a Low-Income Country: An Asset-Based Approach Applied to Mozambique. Faith and Economics 50, 64-101.

Bowen, M., 2000. The state against the peasantry: Rural struggles in colonial and post-colonial Mozambique. The University Press of Virginia. University of Virginia.

Bryceson, D., 1999. African rural labour, income diversification and livelihood approaches: a long term development perspective. Review of African Political Economy 80, 171-189.

Cook, T., 2008. Waiting for life to arrive: a history of the regression-discontinuity design in psychology, statistics, and economics. Journal of Econometrics 142, 636-654.

Cunguara, B., Hanlon, J., 2010. Poverty is not being reduced in Mozambique. Working Paper No. 74, London School of Economics and Political Science.

Dehejia, R., Wahba, S., 2002. Propensity score-matching methods for nonexperimental causal studies. The Review of Economics and Statistics 84 (1), 151-161.

Deaton, A. 1997. The Analysis of Household Surveys. Washington, D.C.: World Bank.

Doss, C., 2006. Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. Agricultural Economics 34, 207-219.

Eriksen, S., Silva, J.A., 2009. The vulnerability context of a savanna area in Mozambique: household drought coping strategies and responses to economic change. Environmental Science and Policy 12: 33-52.

Feder, G., Just, R.E., Zilberman, D., 1985. Adoption of agricultural innovations in developing countries: a survey. Economic Development and Cultural Change 33 (2), 255–298.

Filho, A.S., 1997. The political economy of agrarian transition in Mozambique. Journal of Contemporary African Studies 15 (2), 191-218.

Fulginiti, L., Perrin, R., Bingxin Yu, 2004. Institutions and agricultural productivity in Sub-Saharan Africa. Agricultural Economics 31 (2), 169-180.

Gibson-Davis, C., Foster, M., 2005. Using propensity scores to estimate the effect of food stamps on food security. Discussion Paper no. 1293-05, Institute for Research on Poverty, University of Wisconsin, Madison.

Gilligan, D., Hoddinott, J., 2007. Is there persistence in the impact of emergency food aid? Evidence on consumption, food security, and assets in rural Ethiopia. American Journal of Agricultural Economics 89 (2), 225-242.

Government of Mozambique, 2006. Poverty Reduction Strategy Plan II. Council of Ministers, Maputo, Mozambique.

Heckman, J., Ichimura, H., Todd, P., 1997. Matching as an econometric evaluation estimator: evidence from evaluating a job training programme. Review of Economic Studies 64 (4), 605-654.

Heckman, J., Navarro-Lozano, S., 2004. Using matching, instrumental variables, and control functions to estimate economic choice models. The Review of Economics and Statistics 86, 30-57.

Horowitz, J., Manski, C.F., 2006. Identification and estimation of statistical functionals using incomplete data. Journal of Econometrics 132, 445-459.

Howard, J., Crawford, E., Kelly, V., Demeke, M., Jaime, J.J., 2003. Promoting high-input maize technologies in Africa: the Sasakawa-Global 2000 experience in Ethiopia and Mozambique. Food Policy 28, 335-348.

Imbens, G., Woolridge J., 2009. Recent developments in the econometrics of program evaluation. Journal of Economic Literature 47 (1), 5-86.

Imbens, G., 2004. Nonparametric estimation of average treatment effects under exogeneity: A review. The Review of Economics and Statistics 86 (1), 4-29.

Imbens, G., Lemieux T., 2008. Regression discontinuity design: a guide to practice. Journal of Econometrics 142, 615-635.

de Janvry, A., Sadoulet, E., 2002. World poverty and the role of agricultural technology: direct and indirect effects. Journal of Development Studies 38(4), 1-26.

Joubert, A., Tyson, P., 1996. Equilibrium and fully coupled GCM simulations of future southern African climates. Southern African Journal of Science 92, 471–484.

Kassie, M., Pender, J., Yesuf, M., Kohlin, g., bluffstone, R., Mulugeta, E., 2008. Estimating returns to soil conservation adoption in northern Ethiopian highlands. Agricultural Economics 38, 212-232.

Langyintuo, A., Mungoma, C., 2008. The effect of household wealth on the adoption of improved maize varieties in Zambia. Food Policy 33, 550-559.

Lee, D., Card D., 2008. Regression discontinuity inference with specification error. Journal of Econometrics 142, 655-674.

Lemieux, T., Milligan K., 2008. Incentive effects of social assistance: a regression discontinuity approach. Journal of Econometrics 142, 807-828.

Lewbel, A., 2007. Endogenous selection or treatment model estimation. Journal of Econometrics 14, 777-806.

Manski, C.F., 2002. Treatment choice under ambiguity induced by inferential problems. Journal of Statistical Planning and Inference 105, 67-82.

Mather, D., Cunguara, B., Boughton, D., 2008. Household income and assets in rural Mozambique 2002-2005: Can pro-poor growth be sustained? MINAG Working Paper n. 66E, Maputo, Mozambique.

Mather, D., 2009. Measuring the impact of public and private assets on household crop income in rural Mozambique, 2002-2005. MINAG Working Paper n. 67E, Maputo, Mozambique.

McCrary, J., 2008. Manipulation of the running variable in the regression discontinuity design: a density test. Journal of Econometrics 142, 698-714.

Mendola, M., 2007. Agricultural technology adoption and poverty reduction: a propensity-score matching analysis for rural Bangladesh. Food Policy 32 (3), 372–393.

MPD, 2010. Third poverty assessment in Mozambique.

Oehmke, J., Crawford, E., 1996. The impact of agricultural technology in sub-Saharan Africa. Journal of African Economies 5 (2), 271-292.

Panin, A., 1989. Profitability assessment of animal traction investment: The case of Northern Ghana. Agricultural Systems 30 (2), 173-186.

Pingali, P., Bigot, Y., Binswanger, H., 1987. Agricultural mechanization and the evolution of farming systems in Sub-Saharan Africa. The John Hopkins University Press, Baltimore, Mariland.

Reardon, T., 1997. Using evidence of household income diversification to inform study of rural nonfarm labor market in Africa. World Development 25, (5) 735-747.

Remington, T., Maroko, J., Walsh, S., Omanga, P., Charles, E., 2002. Getting off the seeds-and-tools treadmill with CRS seed vouchers and fairs. Disasters 26 (4), 316-328.

Rosenbaum, P., Rubin, D., 1983. The central role of the propensity score in observational studies for causal effects. Biometrika 70 (1), 41-55.

Savadogo, K., Reardon, T., Pietola, K., 1998. Adoption of improved land-use technologies to increase food security in Burkina Faso: Relating animal traction, productivity, and nonfarm income, Agricultural Systems 58 (3), 441-464.

Scharfstein, D., Manski, C.F., Anthony, J., 2004. On the construction of bounds in prospective studies with missing ordinal outcomes: an application to the good behavior game trial. Biometrics 60, 154-164.

Simalenga, T., Jongisa, E., 2000. Assessing the profitability of using animal traction under smallholder farming conditions. South African Journal of Agricultural Extension 29, 1-9.

Stephens, E., Barrett, C., 2008. Incomplete credit markets and commodity marketing behavior. Working Paper, Cornell University, Ithaka, New York.

Sunding, D., Zilberman, D., 2001. The agricultural innovation process: research and technology adoption in a changing agricultural sector. In: Gardner, B.L., Rausser, G.C. (Eds.), Handbook of Agricultural Economics, Volume 1A Agricultural Production. Elsevier, New York.

Thirtle, C., Beyers, L., Ismael, Y., Piesse, J., 2003. Can GM-technologies help the poor? The impact of Bt Cotton in Makhathini Flats, KwaZulu-Natal. World Development 31 (4), 717–732.

Tschirley, D., Santos, A., 1999. The Effects of Maize Trade with Malawi on Price Levels in Mozambique: Implications for Trade and Development Policy. Research Report No. 34. MAP/MSU Food Security Project, Ministry of Agriculture and Rural Development. Maputo.

Usman, M., Reason, C., 2004. Dry spell frequencies and their variability over southern Africa. Climate Research 26, 199-211.

Walker, T., Tschirley, D., Low, J., Tanque, M., Boughton, D., Payongayong, E., Weber, M., 2004. Determinants of Rural Income, Poverty and Perceived Well-Being in Mozambique in 2001-2002. MINAG Research Report No. 57E, Maputo, Mozambique.

Wooldridge, J., 2007. Inverse probability weighted estimation for general missing data problems. Journal of Econometrics 141, 1281-1301.

Yen, S.T., Andrews, M., Chen, Z., Eastwood, D., 2008. Food stamp program participation and food insecurity: an instrumental variable approach. American Journal of Agricultural Economics 90 (1), 117-132.

Table A1 Estimation results from the placebo regression

Dependent variable: Age of spouse of the household head (years)	Improved seeds		Mechanization		Animal traction		Improved granary	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
HH adopted the technology (1=yes)	0.39		3.09		0.59		0.24	
Head's years of schooling	-1.28	***	-1.15	***	-1.41	***	-1.67	***
Widow headed (1=yes)					-0.59			
Non-widow female-headed (1=yes)			11.23	***	9.12	***	6.27	***
Female-headed (1=yes)	7.40	**					0.38	
HH size (adult equivalent scale)	0.48		0.54	**	0.56	***	-4.17	***
Head is engaged in off-farm (1=yes)	-4.31	**	-9.45	***	-6.30	***	-0.01	
Distance to tarred road (km)	0.02		-0.44	***	0.03		0.12	
Tropical livestock units	0.11		0.09		0.03		0.30	
Total cropped size (ha)	0.26		-0.30		0.52	***	-2.38	
Membership to association (1=yes)	2.30		-1.31		-4.10	***	1.26	
HH received extension (1=yes)	4.08	**	2.43		0.69		-5.43	*
HH received credit (1=yes)			1.75		-9.75	***	-5.13	***
HH hired permanent labor (1=yes)	-2.06		6.65	**	3.78	**	-1.56	
HH hired seasonal labor (1=yes)	-2.04		0.79		-0.99		44.80	***
Constant	39.76	***	105.36	***	35.31	***	0.24	
R^2	0.33		0.46		0.33		0.30	
Number of observations	275		254		1251		525	

Source: Authors' own calculations based on TIA05 data
Notes: District dummies were used but are not reported to save space;
Due to lack of data for specific groups, not all variables are included for all technologies
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table A2 Estimation results from sub-classification and regression for improved maize seeds

Improved maize seeds	Quintiles of the propensity score									
	Bottom		2		Middle		4		Top	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
HH adopted the technology (1=yes)	0.38		-0.06		-0.39		-1.45	***	-0.26	
Head's age	-0.03		0.00		0.02		-0.01		-0.01	
Head's years of schooling	0.16		0.15		0.09		0.06		-0.02	
Female-headed (1=yes)	-1.16		0.17		-0.35		0.09		-0.28	
HH size (adult equivalent scale)	-0.17		0.04		-0.01		0.00		-0.20	***
Head is engaged in off-farm (1=yes)	0.66		1.38	**	0.46		-1.32	**	0.20	
N. of members engaged in off-farm	0.27		-0.07		0.97	**	0.14		0.25	*
Tropical livestock units (TLU)	0.24		-0.02		0.12		-0.23	*	0.00	
TLU (squared term)	0.00		0.00	*	0.00		0.01	*	0.00	
Cropped area (ha)	-0.24		2.05	***	-0.09		0.49	**	0.11	
Cropped area (squared term)	0.05		-0.22	***	0.01		-0.03	**	0.00	
Membership to association (1=yes)					-1.21		-4.07	***	0.11	
HH received extension (1=yes)	0.41		1.01		-0.74		-1.45	***	-0.30	
Constant	9.93	***	3.78	***	8.50	***	14.93	***	11.11	***
R^2	0.74		0.73		0.66		0.79		0.52	
Number of observations	49		51		69		62		91	

Source: Authors' own calculations based on TIA05 data
Notes: District dummies were included but are not reported to save space;
Due to lack of data for specific groups, not all variables are included for all technologies
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table A3 Estimation results from sub-classification and regression for tractor mechanization

Tractor mechanization	Quintiles of the propensity score									
	Bottom		2		Middle		4		Top	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
HH adopted the technology (1=yes)	-0.75	*	0.86		-0.29		0.00		0.98	***
Head's age	0.03	*	-0.04		0.00		-0.03	*	0.04	***
Head's years of schooling	-0.08		0.11		0.10		-0.21	**	0.17	***
Widow-headed (1=yes)	-0.47		2.73	*	0.07		-2.44	***	0.01	
No widow (female) headed (1=yes)	-0.15		1.57	*	0.64		-1.37	***	-2.13	***
HH size (adult equivalent scale)	-0.07		0.07		0.08		0.16		-0.01	
Head is engaged in off-farm (1=yes)	1.43	***	1.28	**	1.45	**	1.03		0.05	
N. of members engaged in off-farm	0.20		1.09	**	-0.08		0.12		0.11	
Tropical livestock units (TLU)	0.11		0.12		0.11		-0.21	***	0.02	
TLU (squared term)	0.00		0.00		0.00		0.00	***	0.00	
Cropped area (ha)	-0.56		1.29	**	-0.10		-0.41		0.18	***
Cropped area (squared term)	0.09	**	-0.15	*	0.14		0.07		0.00	***
Membership to association (1=yes)	2.18	***	1.70	*	0.16		0.29		-0.29	
HH received extension (1=yes)	-2.29	***	0.24		1.08		-2.12	***	0.62	
Constant	6.96	***	5.09	**	2.64		15.24	***	7.06	***
R^2	0.80		0.74		0.59		0.81		0.77	
Number of observations	50		50		74		76		91	

Source: Authors' own calculations based on TIA05 data
Notes: District dummies were included but are not reported to save space;
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table A4 Estimation results from sub-classification and regression for animal traction

Animal traction	Quintiles of the propensity score									
	Bottom		2		Middle		4		Top	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
HH adopted the technology (1=yes)	-0.35	**	-0.25		-0.23		0.03		-0.08	
Head's age	0.00		-0.01		-0.01		0.01	**	0.01	
Head's years of schooling	0.14	***	0.02		0.06		0.16	***	0.12	***
Widow-headed (1=yes)	-0.27		0.45		0.37		1.32	***	-0.31	
No widow (female) headed (1=yes)	0.15		-0.23		0.04		0.20		0.74	*
HH size (adult equivalent scale)	-0.03		0.01		-0.10	*	0.12	***	0.06	**
Head is engaged in off-farm (1=yes)	0.60	***	0.45		0.72	***	1.36	***	1.35	***
N. of members engaged in off-farm	0.28	**	0.16		0.28	**	0.27	**	0.16	***
Tropical livestock units (TLU)	0.07		0.07		0.08		0.05		0.00	
TLU (squared term)	0.00		-0.01	*	0.00		0.00		0.00	
Cropped area (ha)	0.68	***	0.64	***	0.30		0.00		0.30	***
Cropped area (squared term)	-0.11	***	-0.07	***	-0.02		-0.02		-0.01	***
Membership to association (1=yes)	-0.11		0.31		-0.53		1.63	***	0.15	
HH received extension (1=yes)	-0.73	**	-0.27		0.64		-0.82	**	0.33	
Constant	6.91	***	7.37	***	8.00	***	6.83	***	5.25	***
R^2	0.41		0.31		0.42			0.48		0.45
Number of observations	228		223		230			327		733

Source: Authors' own calculations based on TIA05 data
Notes: District dummies were included but are not reported to save space;
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table A5 Estimation results from sub-classification and regression for improved granaries

Improved granaries	Quintiles of the propensity score									
	Bottom		2		Middle		4		Top	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
HH adopted the technology (1=yes)	0.53	*	-0.78	***	0.26		-0.33		-0.68	*
Head's age	0.01		-0.01		-0.01		0.00		-0.01	
Head's years of schooling	0.13	*	0.03		-0.02		0.09		0.13	
Widow-headed (1=yes)	-0.85		-1.25		-0.45					
No widow (female) headed (1=yes)	0.07		-0.55		-0.41		-0.13		-0.09	
HH size (adult equivalent scale)	-0.13		0.19	**	-0.11		-0.06		-0.05	
Head is engaged in off-farm (1=yes)	0.07		1.01	***	-0.03		0.29		0.44	
N. of members engaged in off-farm	0.60	***	-0.33	*	0.24		0.42	**	0.10	
Tropical livestock units (TLU)	0.08		0.07	*	0.02		0.14	***	0.05	
TLU (squared term)	0.00		0.00	**	0.00		0.00	***	0.00	
Cropped area (ha)	0.64		0.20		0.91	***	0.12		0.38	*
Cropped area (squared term)	-0.08		0.00		-0.10	**	-0.02		-0.01	
Membership to association (1=yes)	0.45		-0.66		-1.21		-0.98	**	0.87	
HH received extension (1=yes)	-0.01		0.15		0.71		0.09		0.08	
Constant	7.02	***	8.29	***	8.39	***	7.72	***	8.02	***
R^2	0.54		0.63		0.55		0.57		0.83	
Number of observations	105		118		113		124		147	

Source: Authors' own calculations based on TIA05 data

Notes: District dummies were included but are not reported to save space;

***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Is agricultural extension helping the poor? Evidence from rural Mozambique

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Abstract

Mozambique remains predominantly poor. The official statistics show that poverty incidence barely changed from 54% in 2002-03 to 55% in 2008-09, which stands way above the government's target of 45% by the year 2009. This places the country off-target to cut hunger and poverty by half by 2015, despite an annual economic growth of about 7% in the period 1994-2010. In rural areas, poverty levels have slightly increased, due to the underperformance of the agricultural sector. Extension services can have a significant impact on poverty reduction through stimulating growth in agricultural productivity. Based on a nationally representative household survey from Mozambique, this paper uses three econometric models, namely an OLS regression, the doubly robust estimator and matching and regression to estimate the economic impact of receipt of extension. The results suggest that the receipt of extension increases farm incomes by 12%. However, rather than crafting resource-poor technologies, extension services tend to target wealthier households who are relatively more likely to adopt the existing technologies. This might increase income inequality. The impact of extension, and therefore its contribution to poverty reduction, can be enhanced through several mechanisms (e.g., programme design and the number of staff).

JEL Classification: O13, H34, I3.

Keywords: poverty reduction; impact assessment; targeting; Mozambique

1 Introduction

In Africa, the poverty literature can be loosely grouped into three strands of economic research: household diversification into nonfarm activities, growth in agricultural productivity, and the role of economic growth. In Mozambique, productivity growth has been identified as the primary route out of poverty (Arndt et al., 2010; MPD/DNEAP, 2010). Growth in agricultural production, through expansion of cropped area, was the main driving force for reducing poverty incidence from 69% in 1996-97 to 54% in 2002-03 (Arndt et al., 2006). In recent years, however, the decline in already low production of food per hectare was identified by the local government as being one of the main barriers to poverty reduction (MPD/DNEAP, 2010, p.65). This is particularly evident in central provinces where in 2008-09 about 60% of the population lived below the national poverty line, compared to 46% in 2002-03 (MPD/DNEAP, 2010, p.28).

The poor performance of the agricultural sector is associated in part with erratic rainfall, limited support to output market participation, disproportional aid to agriculture relative to non-agricultural sectors, and low use of improved technologies. In 2008, less than 4% of farmers used inorganic fertilisers or irrigated their fields, 5% used pesticides, 9% used animal traction, and less than 2% used tractors (Cunguara and Hanlon, 2010). Public investment in agricultural extension is likely to foster the adoption of improved technologies (World Bank, 2004), provided that output markets exist (Cunguara and Darnhofer, 2011). Agricultural extension provides farmers with information about cropping practices, optimal input use and high-yield varieties. It also supports farmers in the development of managerial skills, thus facilitating a shift to more efficient methods of production (Birkhaeuser et al., 1991).

A study conducted in Mozambique concludes that the receipt of extension services increases crop production by about 8% (ECON Analysis, 2005). By contrast, Walker et al. (2004) found no statistically significant effect of agricultural extension on household incomes in rural Mozambique. Mather (2009) also found that the receipt of extension does not improve crop incomes in the year in which the visit is made, but may lead to higher crop incomes over time. The lack of significant impact is because extension services do not succeed in promoting location-specific and adapted technologies (Eicher, 2002; Snapp et al., 2003; Walker et al., 2004). Household constraints on the access to existing technologies also reduce the impact of the receipt of extension services (van den Berg and Jiggins, 2007; Mather, 2009).

Nevertheless, methodological differences in the estimation of the economic impact of the receipt of extension may explain the differences in the results obtained in Mozambique. For instance, Walker et al. (2004) estimate the impact of the receipt of extension on household incomes by including a binary variable, indicating the receipt of extension, as one of the independent variables in an OLS regression of total household incomes. While implicitly assuming that wealthier households and their poorer counterparts are impacted the same by the receipt of extension services, which seems implausible, this approach does not take into account either the selection bias or endogenous programme placement.

The receipt of extension services is greater among wealthier farmers (Walker et al., 2004; ECON Analysis, 2005; Mather, 2009; Cunguara and Hanlon, 2010), and its impact is also likely to be greater among these farmers because they are financially more capable of implementing extension advices. The impact of the receipt of extension can also differ by geographical region. The local government usually allocates more extension workers to the central and northern provinces due to a higher agricultural potential in those two regions (Gêmo et al., 2005; Coughlin, 2006).

Therefore, there is a need to compare the incomes of farmers with similar or overlapping characteristics in terms of demographics, socio-economic aspects, and geographical location. For this purpose, several studies have used propensity score matching to deal with selection bias and endogenous programme placement (see for example, Godtland et al., 2004), under the assumption that potential outcomes are independent of the receipt of extension services. Based on a nationally representative household survey conducted in 2005 in Mozambique, this paper complements previous studies by estimating the economic impact of extension services while accounting for both selection bias and endogenous programme placement. Furthermore, unlike Mather (2009), Econ Analysis (2005), or Walker et al. (2004), the analysis presented in this paper is based on three econometric models, suggesting more robust results.

The rest of the paper is structured as follows. Section 2 describes the data used. It also describes extension services in Mozambique, provided that the design of the extension programme affects the estimation results. The estimation strategy and the choice of econometric approaches are presented in Section 3. The impact of extension services is modelled through an OLS regression. Then matching and regression methods are used as a series of robustness check. This section also discusses the selection of the variables used in the propensity score modelling. Section 4 discusses the results in the light of the available literature on Mozambique. This includes the discussion of targeting of extension services based on household typology and selected scenarios. Section 6 concludes with some policy remarks.

2 Data sources and description of extension services in rural Mozambique

This paper uses data from the National Agricultural Survey of 2005, commonly known as TIA05 (Portuguese acronym for *Trabalho do Inquérito Agrícola* 2005). The survey was implemented by the Department of Statistics within the Directorate of Economics of the Ministry of Agriculture in 2005. The survey was conducted from September to November 2005, and the data pertain to the agricultural season of 2004-05, which covers the period from September 2004 to August 2005. The sample was designed to be representative both at the provincial level and at the agro-ecological zone, and covered 94 out of Mozambique's 128 districts. Population weights were used throughout the paper (unless otherwise clearly specified) to make the analysis nationally representative. A total of 6,149 households were interviewed, of which 4,104 are panel households, interviewed both in 2002 and 2005.

Households were asked whether they had received agricultural extension advice in the last 12 months prior to the survey. Additionally, those who received extension visits were asked about the types of extension advice that they had received. At the national level, about 15% received extension visits (Table 1). Among those who received extension visits, more than 90% of households received advice on crop production, and about 39% received information about livestock rearing. Therefore, the outcome variable is crop and livestock (farm) income during the 2004-05 agricultural season, after logarithmic transformation. This ensures normality and allows the estimated coefficients to be interpreted as elasticities. Meticais was expectedly the main currency, although about 5% of households reported sales of staple crops in foreign currencies, such as the Malawian and Zambian Kwacha. These were converted into Meticais.

Table 1 Proportion of households receiving extension visits and types of extension advice

	Mean	Standard deviation
Household has received extension visits	0.15	0.35
Type of advice received		
Crop production	0.94	0.24
Livestock	0.39	0.49
Forestry	0.29	0.45
Fish farming	0.08	0.27
Agro-processing	0.08	0.27
Market participation	0.29	0.45

Source: Authors' calculations based on TIA05 data

Crop income includes the retained and sold value of food crops, cashew and coconut, sales of cash crops and horticultural and fruit crops. All costs of inputs are netted out from the gross crop income. Very few households purchase inputs in rural Mozambique, and among those few, some have incurred losses. Hence, the logarithmic transformation on the dependent variable comes at a cost of excluding the negative and zero income observations from analysis. A total of 165 households incurred net losses in farm income (although they might have had nonfarm income), reducing the number of observations from 6,149 to 5,984 households. The exclusion of these households may not be of major concern since it is likely that they experienced transitory decline in crop incomes, and hence they are not systematically different from some of the households included in the analysis.

Regarding livestock production, the income estimates are based on the value of live animals sold, and the sale of meat and dairy products, rather than livestock inventories. This is because livestock in Mozambique is used primarily for home consumption and income-generating activities (such as sales of live animals), and livestock investments are rather small. For instance, less than 9% of cattle herd size in 2005 is accrued to purchases over the previous 12 months among those who own cattle, less than 6% of the population. In addition, the purchase of livestock inputs is rather small. TIA05 data show that only 3% of farmers vaccinated their chickens, and two-thirds of them paid for the services. Furthermore, livestock inventories show a decline between 2002 and 2005 (Mather et al., 2008), which suggests that livestock investments are also declining. The estimate of livestock income is underestimated because neither livestock investments (although small) nor home consumption of livestock was accounted for. Nevertheless, excluding livestock inventories makes the results of the impact of the receipt of extension services comparable with other poverty studies on Mozambique, which use a similar approach (for example, Walker et al., 2004; Mather et al., 2008; Mather, 2009).

The national public extension system in Mozambique was established in 1987, but it did not become operational until the peace agreement was reached in 1992 (Gêmo et al., 2005). Although there are several approaches to extension, Mozambique was a late comer in adopting the farmer field school (FFS) approach. This approach was first introduced in the 2003-04 agricultural season in Namacurra and Nicoadala, two districts of Zambézia province (Dzeco et al., 2010). It is therefore unlikely that the estimates of the impact of extension in this paper reflect those of the FFS approach since those two pilot districts were not sampled in TIA05, and FFS was only a year old in 2004-05, which is the agricultural season covered in TIA05.

The national directorate of agricultural extension (DNER), which is the institution responsible for public extension in Mozambique, adopted the training and visit (T&V) extension model in 1988, and modified it in 1992 in the light of the shortcomings uncovered under local conditions (Eicher, 2002). The modified T&V model was in use at least till 2006 (Coughlin, 2006) and was based on a participatory rather than a top down approach, with a focus on interventions in the farming system, which include both crop and livestock production. Nevertheless, extension services remain predominantly a top down approach not geared towards responding to farmer needs on community requests (DANIDA, 2002).

The agricultural season of 2001-02, which is one of the two seasons covered in the TIA panel data, coincided with the completion of the 5-year Extension Master Plan (Eicher, 2002). Worth noting is that DNER is pursuing a learning-by-doing approach to building Mozambican models of agricultural extension (Eicher, 2002). This means that the implementation of the recommendations from its Master Plan evaluation report conducted in 2002 might have improved to some extent the extension approach in the following years. Simply put, it is likely that the extension model used in 2001-02 was different from the one used in 2004-05 agricultural season, with two implications.

First, this may explain in part the results found in Mather (2009), showing that the receipt of extension was only statistically significant over time, because the extension approach is equally improving over time. Second, the fact that panel households might have faced different extension approaches makes it harder to estimate the impact of extension in a panel data framework since the “treatment variable” is not the same in the two survey years. It is also possible that a farmer was visited by two different extension providers (of unequal effectiveness) in the two survey years.

Despite the advantages of panel data (e.g., it is possible to control for farmers’ skills), this paper uses TIA05 data as a cross-section data. This allows comparing the results with those from a panel data analysis reported in Mather (2009). The other advantage of estimating the impact of extension based in a cross-section framework is that the analytical approach presented in this paper can be extended to estimate the impact of other development projects in Mozambique, where panel data do not exist.

Besides DNER, there are two other providers of extension services, the private sector and NGOs. Private extension services differ significantly from the other providers. Their services are mainly funded through supply chains of specific cash crops, such as tobacco, cotton, and cashew. They provide agricultural extension services through input supply stores and through farming, processing or marketing companies and outgrowers’ schemes (Eicher, 2002). Unlike many subsistence farmers, cotton and tobacco producers usually have access to inputs through credit, may face a different extension model, and are financially more capable of implementing extension advices. Therefore, both cotton and tobacco producers were excluded from the analysis in an attempt to decrease the heterogeneity of extension approaches, which would otherwise affect the estimation results. The final number of observations declined from 5,984 to 5,067 households.

Although extension services provided by the public sector might differ to those from NGOs, both providers collaborate to some extent to extension programmes in Mozambique. For example, Ibis, a Danish NGO, was fully integrated with public extension in Zambézia province between 1988 and 1998 (Gêmo and Riveira, 2001). It is likely that both providers used a modified T&V extension model in the 2004-05 agricultural season, however with different degrees of farmers’ participation. Therefore, in this paper the estimate of the impact of extension reflects extension services provided by the public sector and NGOs, using a modified T&V approach.

3 Methods

The paper uses a combination of methods to assess the impact of the receipt of extension services on farm incomes in rural Mozambique. The empirical analysis starts with the estimation of an OLS regression. The motivation of using an OLS regression is to assess the plausibility of the impact of extension found in Walker et al. (2004), which uses a similar approach. The dependent variable is household farm income after logarithmic transformation. Independent variables include the receipt of extension services, demographics, risk factors to crop production, the use of improved technologies, access to public services, road infrastructure, and household location.

The binary variable indicating the receipt of extension services was included due to its expected positive impact on farm incomes (Birkhaeuser et al., 1991). However, since the receipt of extension is greater among wealthier farmers (Walker et al., 2004; ECON Analysis, 2005; Mather, 2009), the coefficient on the receipt of extension services obtained through a simple OLS model is likely to be overestimated, despite the fact that other variables affecting farm income are controlled for.

Demographic characteristics influence farm incomes through several mechanisms. A variable on the number of adult members was included because household size and composition influence labour availability (Doss, 2006). A second demographic variable pertained to years of education of the household head. Higher levels of education are likely to be associated with higher farm incomes, because better educated households are more capable of investing in improved technologies through participation in the nonfarm sector (Reardon, 1997; Barrett et al., 2001; Cunguara et al., 2011). In addition, participation in nonfarm activities was included both as a binary variable indicating whether the head is engaged in nonfarm activities, and as a continuous variable indicating the number of household members other than the head that are engaged in nonfarm activities. Finally, gender and age of the household head were included because several poverty studies on Mozambique have found widows and the elderly to be among the poorest (Walker et al., 2004; Boughton et al., 2006; Mather et al., 2008).

In addition to demographic variables and a binary variable indicating the receipt of extension, asset ownership comprised the third set of independent variables. These included a binary variable for bicycle ownership, and continuous variables for cropped area (in hectares) and livestock ownership, the latter expressed in tropical livestock units (TLU). Mozambique has one of the lowest road densities in Sub-Saharan Africa (Njoh, 2008), and many of the existing roads are in a state of disrepair and cannot be used year-round, especially during the rainy season. Therefore, ownership of bicycles often conditions farmers' participation in both input and output markets, which can raise farm incomes. As one would expect, larger cropped area are usually associated with higher crop income. Similarly, farmers can increase their incomes directly through sales of livestock, or indirectly through reinvestments of livestock sales into the adoption of improved technologies and thus enhance their farm incomes.

Conversely, there are several factors that can negatively affect farm incomes. These include, among others, drought, floods and animals (pests). Therefore, three risk variables were correspondingly included for drought, floods, and animals (Walker et al., 2004; Mather, 2009). Since these factors tend not to affect one, but several households in a given location, they were included as indices taking a null value if nobody reported them as affecting crop production in a given primary sampling unit (PSU), and a value of 1 if all households in a given PSU reported them. In other words, the indices are the proportions of households reporting crop failure due to a given risk factor in each PSU. The coefficients on these variables are expected to be negative, especially for drought risk, because 2005 was a year of widespread drought.

Yet the use of irrigation, drought-tolerant improved seeds and other improved technologies can minimise the impact of the risk factors, while at the same time enhancing farm incomes. Five binary variables were included to indicate whether or not the household used water pumps, improved maize seeds (maize is the most important staple crop), animal traction; inorganic fertilisers and tractors.

The use of improved technologies, however, depends on ownership of assets that can be easily turned into cash, such as livestock (Reardon, 1997; Bryceson, 1999; Thirtle et al., 2003). Cash income can also be used to hire labour. Labour shortage can impair the use of technologies that would require more labour than the family can provide (Doss, 2006). Hence, two binary variables were included to indicate whether the household hired seasonal or full-time workers.

The use of improved technologies also depends on the access to information regarding such technologies. A binary variable for membership to association was therefore included based on the premise that farmers must have information about improved technologies before they can consider using them (Doss, 2006). Likewise, access to price information is likely to affect agricultural related decisions, such as the area allocated to each crop, and whether to purchase modern inputs, which would then affect farm incomes. Hence, a binary variable was included to indicate the receipt of price information.

Moreover, a binary variable for road infrastructure was used to account for farmers' access to both input and output markets (Feder et al., 1985). This variable indicated whether a tarred road runs through or within the village where the household is located. Farmers close to a tarred road are more likely to use improved technologies. For instance, if improved seeds are not available locally, farmers may need to travel to the nearest township, which is more likely if there are adequate roads and transport services (Eriksen and Silva, 2009). Road infrastructure is not only likely to affect the use of an improved technology, but it is also likely to affect its attractiveness, since access to markets to sell surpluses is more likely where all-weather roads exist (Barrett, 2008).

Finally, district dummies were included to account for household location. In Mozambique, there are regional differences in terms of agricultural potential and access to nonfarm activities (Cunguara et al., 2011). The southern provinces have relatively better infrastructure and the education levels are also higher. This allows them to participate in nonfarm activities more often (Walker et al., 2004; Arndt et al., 2006), and nonfarm incomes can be invested into farm activities (Reardon, 1997; Barrett et al., 2001). District dummies are meant to control for these differences, including agro-ecological differences, which affect farm incomes.

The OLS model comprised one of the three econometric models used to estimate the impact of the receipt of extension services. Unlike the OLS model used in this paper, the other two models (doubly robust estimator and regression and matching) address selection bias and endogenous programme placement. One of the first steps in addressing selection bias and endogenous programme placement is to estimate a propensity score, which is basically used to identify farmers with similar observable characteristics that differ only by the 'treatment variable', which in this case is the receipt of extension (Rubin, 1974; Rosenbaum and Rubin, 1983; Heckman et al., 1998; Dehejia and Wahba, 2002).

3.1 Propensity score estimation

The propensity score is defined as the conditional probability of receiving treatment (Rosenbaum and Rubin, 1983), and can be expressed as

$$e(x) = \Pr(W_i = 1 \mid X_i = x) = E[W_i \mid X_i = x] \quad (1)$$

The binary variable W_i indicates the receipt of extension services. The conditional probability model [equation (1)] is usually estimated using flexible binary response models such as Logit or Probit. The main difference between using Probit or a Logit model is that the conditional probability of the receipt of extension approaches the extreme values of 0 or 1 at a slightly slower rate in a Logit than in a Probit model because the logistic distribution has slightly fatter tails. For ease of estimation, most applications have used the Logit model (Dehejia and Wahba, 2002). A weighted Logit model was therefore estimated.

Independent variables X_i include demographics, the use of improved technologies, membership to farmers' association, asset endowments, road infrastructure and district dummies. Since extension services are likely to target wealthier households, most of the independent variables in the weighted Logit model are similar to those used in the OLS regression of farm incomes. However, the inclusion of some of those variables is based on slightly different reasons.

Educational attainment, for instance, was included because extension programmes tend to be biased towards better educated farmers (Davidson et al., 2001). On the one side, better educated farmers usually have higher incomes and are thus financially more capable of implementing extension advices. On the other, education is known to be important in determining farmers' ability to understand and manage unfamiliar technology (Doss and Morris, 2001).

Similarly, age was included because extension workers may target farmers based on their age (Adesina and Baidu-Forson, 1995). Extension programmes may target older farmers, in which case the age coefficient would have a positive sign, because older farmers have more experience in cultivation and are better able to assess the characteristics of modern technologies advocated by extension workers. However, extension programmes may also target younger farmers, in which case the age coefficient would be negative, because younger farmers are less risk averse and hence have a higher likelihood of adopting new technologies (Adesina and Baidu-Forson, 1995).

One of the key assumptions in estimating the impact of extension is that, its receipt by one farmer does not affect farm incomes of farmers who did not receive extension. This is most likely to hold where there is no diffusion of knowledge. Yet farmers who received extension may share information on agricultural innovation with their neighbours who did not receive extension. Although technology variables are correlated with the receipt of extension because farmers in villages of high crop potential have better access to extension (Gêmo et al., 2005), their inclusion as independent variables (the use of animal traction, inorganic fertilisers, and improved maize seeds) might help controlling for diffusion of knowledge. Nevertheless, "to a great extent, even within the target districts, the extension system assists the same farmers in the same villages year after year while permanently ignoring others" (Coughlin, 2006, p.32). Thus, "most farmers in rural Mozambique get no extension services, directly or indirectly" (Coughlin, 2006, p3.0). Diffusion of knowledge would increase significantly if different farmers were visited over time.

Another independent variable that was included and is correlated to some extent with the receipt of extension is the access to livestock services, such as poultry vaccination. These services are usually provided by extension workers or community vaccinators that work closely with extension workers (Copland and Alders, 2005). Thus, the receipt of extension is likely to be higher among farmers who vaccinated their chickens against the Newcastle disease.

In addition to the asset variables included in the OLS regression, the weighted Logit model included radio ownership as another asset variable. The coverage of extension is supplied in part by mass media communication programmes (Eicher, 2002), and farmers who own a radio might be aware of the scheduled dates for extension workers to visit their villages. The likelihood of the receipt of extension in rural Mozambique is therefore greater among those who own a functional radio.

Membership to farmers' association was included because extension programmes might find it cheaper to target farmers' groups (Gêmo and Rivera, 2001). Similarly, due to significant budget constraints, it cost less to target farmers located close to a tarred road both in terms of time and fuel (Mather, 2009). The binary variable indicating whether a tarred road runs through or within the village was also included in the weighted Logit model. All regressions presented throughout this paper use district dummies as additional independent variables to control for household location and other unobserved variables.

The specification of the propensity score (the Logit model) is critical, since the results hinge on several assumptions, such as the overlap and unconfoundedness assumptions. The former implies that the conditional distributions of the covariates of farmers who received extension overlap completely with that of farmers who did not receive extension (Dehejia and Wahba, 2002; Imbens and Wooldridge, 2009). Viewed alternatively, based on the propensity score estimation, it is possible to identify farmers with similar observable characteristics that only differ by the receipt of extension.

There are two formal methods of testing the overlap assumption. The first method consists of plotting the distribution of the propensity scores of the two groups of farmers and visually assessing whether the overlap assumption holds, that is, the distributions are similar. The second method comprises the computation of normalised differences between farmers who received extension and the comparison group. Formally, the normalised difference is given by (Imbens and Wooldridge, 2009):

$$\Delta x = \frac{\bar{x}_1 - \bar{x}_0}{\sqrt{\sigma_1^2 + \sigma_0^2}} \qquad (2)$$

where $\bar{x}_i$ is the mean, and σ_i^2 is the sample variance. Imbens and Wooldridge (2009) consider a normalised difference greater than 0.25 (in absolute value) to be substantial. It bears noting that misspecification of the propensity can lead to a failure to detect any lack of overlap.

Another motivation for assessing the propensity score specification (for example, through sensitivity analysis) is that the doubly robust estimator, discussed in more detail in section 3.2, only requires that either the propensity score or the regression function be correctly specified in order to obtain consistent estimates (Imbens and Wooldridge, 2009; Wooldridge, 2007). By ensuring that the propensity score is well specified, results from the doubly robust estimator will therefore be consistent. However, the sensitivity analysis of the propensity score is challenging, as the literature provides little guidance on how it could be performed (Gibson-Davis and Foster, 2005; Gilligan and Hoddinott, 2007).

Using a random number generator, households were drawn from the original sample with replacement. Twenty five thousand new datasets were generated, each one of the same size as the original data (5,067 households). Population weights were not used in generating the artificial samples. This allowed each sampled household to be selected into the artificial data with equal probability. Nevertheless, population weights were used in the Logit model of

25,000 artificial data sets. The estimated coefficients from the weighted Logit model were saved to later calculate the means of these coefficients. The mean coefficients were then compared with the coefficients estimated from the original data. The concept behind this sensitivity test is that by drawing a large number of samples, the estimated parameters will be close to the "true" parameters. Since a t-test is not appropriate in this case in comparing these coefficients because they could be affected by the size of the simulated data, only the significance of the estimates from the original data, the means of coefficients from the simulated data along with the confidence intervals are presented.

Besides the overlap, the unconfoundedness is another important assumption that needs to be assessed. The unconfoundedness assumption implies that adjusting for differences in observed covariates removes bias in comparisons between the two groups of similar farmers that only differ by the receipt of extension. Although this assumption is not formally testable, this paper assesses its plausibility using a placebo regression approach. This is equivalent to estimating an OLS regression similar to the one used to estimate the impact of the receipt of extension. However, a different dependent variable is used, one that is known a priori that it cannot be caused by the receipt of extension, such as age of the spouse of the household head. If the coefficient on extension is significantly different from zero, then there are omitted variables that are correlated with the receipt of extension. Otherwise, the unconfoundedness assumption can be maintained and a causal interpretation of the results is reasonable. The results of the placebo regression are presented in the appendix section, and they give no reason for concern (Table A1), since there is no indication of the existence of omitted variables that are potentially correlated with the receipt of extension.

3.2 Doubly robust estimator and matching and regression

The interesting feature about the doubly robust estimation is that, as long as the parametric model for either the propensity score or the regression function is correctly specified, the resulting estimator for the average treatment effect is consistent (Wooldridge, 2007; Imbens and Wooldridge, 2009). Specifically, the doubly robust estimation can be represented as:

$$\hat{\Delta}_{DR} = n^{-1}\sum_{i=1}^{n}\left[\frac{W_i Y_i}{e(X_i,\beta)} - \frac{\{W_i - e(X_i,\beta)\}}{e(X_i,\beta)} m_1(X_i,\hat{\alpha}_1)\right] - n^{-1}\sum_{i=1}^{n}\left[\frac{(1-W_i)Y_i}{1-e(X_i,\beta)} + \frac{\{W_i - e(X_i,\beta)\}}{1-e(X_i,\beta)} m_0(X_i,\hat{\alpha}_0)\right] \quad (3)$$

where $e(X_i,\beta)$ is the postulated model for the propensity score, and $m_i(X_i,\hat{\alpha}_i)$ is the postulated regression model. The regression function is a linear (regression) model where the dependent variable is the outcome variable – crop and livestock income after logarithmic transformation. Independent variables in the regression model are the same as those used in the OLS regression of farm incomes. Also, the parametric model of the propensity score use the same independent variables described in section 3.1.

While all the regression models discussed so far use population weights, the doubly robust estimation does not. The statistical software used for the analysis, STATA 10.1, does not allow the use of weights in the doubly robust estimation. An alternative approach could be to weigh the sample 'manually', that is, the population weights could enter multiplicatively. In other words, each independent variable is multiplied by the weight variable and sample size, divided by the sum of all weights. This approach generated the same mean values as if the estimates were weighted non-manually, however the standard errors were slightly larger, which affects the statistical significance of the estimates, including the confidence interval.

Population weights were not used in the estimation of propensity scores. Nevertheless, this does not affect the validity of the results because the odds ratio estimated without any weights (thus ignoring the fact of choice-based or stratified samples) is a scalar multiple of the true odds ratio, which is itself a monotonic transformation of propensity scores (Caliendo and Kopeinig, 2008). Hence, matching can be done on the (miss-weighted or unweighted) estimate of the odds ratio. Clearly, with single nearest neighbour matching (which is the method used in this paper), it does not matter whether matching is performed on the unweighted propensity score, since ranking of the observations is identical and therefore the same neighbours will be selected (Smith and Todd, 2005). Population weights, however, were used after matching, for example in matching and regression.

The results from the doubly robust estimator were later used to assess the impact of the receipt of extension, based on some targeting scenarios. For example, empirical evidence suggests that the receipt of extension services in rural Mozambique is greater among wealthier households (Walker et al., 2004; ECON Analysis, 2005; Gêmo et al., 2005; Coughlin, 2006; Mather, 2009; Cunguara and Hanlon, 2010). However, an empirical question that arises is whether the impact of the receipt of extension is also greater among this group of households. By estimating the impact of extension based on selected household characteristics, this paper provides further insights on why extension programmes should (not) target wealthier households.

In addition to the doubly robust estimator and the OLS model, matching and regression was the third econometric approach used to estimate the impact of the receipt of extension services. Using matching and regression allows to improve the model results by correcting for possible remaining bias (Imbens and Wooldridge, 2009), and to compare the robustness of the estimation results given the econometric approach used. After matching farmers with similar characteristics that only differ by the receipt of extension, the following model was estimated:

$$Y_i = \alpha + W_i + \beta X_i + \varepsilon_i \tag{4}$$

where Y_i is farm income after logarithmic transformation, W_i is the binary variable indicating the receipt of extension and X_i is the same vector of independent variables as in the OLS regression. The difference is that, here, the estimation is conducted for matches only, rather than the whole TIA05 sample.

4 Results and discussion

4.1 Descriptive analysis

Starting with demographic characteristics, the results show that educational attainment remains very low (Table 2). On average, household heads have completed less than 3 years of formal education. However, households who received extension services are headed by significantly more educated people than those who did not receive extension. The differences are also statistically significant regarding household size and participation in nonfarm activities, both in favour of those who received extension services.

In terms of assets, increased endowments of land and livestock are associated with the receipt of extension. Bicycle ownership follows the same pattern. About 30% of those who did not receive extension own a bicycle, compared to 42% among households who received extension. It appears that extension services deliberately target wealthier farmers for several reasons. In Mozambique extension services face numerous constraints, such as the "unacceptable housing and transport conditions for front line extension workers" (World Bank, 2004, p.15). This would encourage extension workers to target farmers located close to a tarred road, who are usually among the relatively wealthy. However, the difference in the receipt of extension services was not statistically significant for tarred road.

Table 2 Descriptive statistics of variables used in the propensity score estimation

	All sample		Did not receive extension		Received extension		P-value
	Mean	SD	Mean	SD	Mean	SD	
Head's years of schooling	2.54	2.57	2.48	2.56	2.95	2.64	0.000
Head's age in years	44.19	14.89	44.31	15.03	43.41	13.96	0.697
HH is widow headed (1=yes)	0.09	0.28	0.09	0.29	0.06	0.24	0.004
HH is female non-widow headed (1=yes)	0.18	0.38	0.18	0.38	0.14	0.35	0.000
Household size (adult equivalent scale)	3.92	2.00	3.86	1.94	4.28	2.29	0.000
Number of members engaged in nonfarm	0.40	0.77	0.38	0.73	0.54	0.98	0.000
Head is engaged in nonfarm (1=yes)	0.61	0.49	0.60	0.49	0.68	0.47	0.000
Used inorganic fertilisers (1=yes)	0.01	0.12	0.01	0.10	0.04	0.20	0.000
Used improved maize seeds (1=yes)	0.04	0.20	0.04	0.19	0.07	0.26	0.002
Used animal traction (1=yes)	0.09	0.29	0.09	0.29	0.12	0.32	0.000
Cropped area in hectares	1.50	1.53	1.45	1.15	1.82	3.00	0.000
Tropical livestock units (TLU)	0.92	2.81	0.87	2.67	1.24	3.59	0.000
Household owns a bicycle (1=yes)	0.31	0.46	0.30	0.46	0.42	0.49	0.000
Household owns a radio (1=yes)	0.53	0.50	0.51	0.50	0.63	0.48	0.000
Membership to farmers' association (1=yes)	0.06	0.23	0.04	0.19	0.19	0.39	0.000
Household vaccinated chickens (1=yes)	0.02	0.14	0.02	0.12	0.04	0.21	0.000
Tarred road runs through the village (1=yes)	0.66	0.47	0.66	0.47	0.70	0.46	0.142
Number of observations	5,076		4,305		771		

Source: Authors' calculations based on TIA05 data.
Notes: *Ha: The difference between the mean of treated and untreated is not zero;
SD = Standard deviation;
Cotton and tobacco producers were excluded from the analysis.

Extension programmes may also target wealthier farmers due to their ability to adopt extension advices, and thus extension workers might want to use them as model or demonstration farmers (Mather, 2009). Targeting wealthier farmers, however, may increase income inequality since increase in farmers' incomes will be concentrated among the top income groups. While the demonstration of successful technologies eventually adopted by wealthier farmers may entice poorer farmers to also adopt them, the poor may not have the necessary means to implement all the recommendations. Instead of targeting wealthier farmers because they are relatively more likely to adopt the existing technologies, extension services in collaboration with research institutions should craft resource-poor technologies.

Some examples of resource-poor technologies include smaller packages of improved seeds and chemical fertilisers (Uttaro, 2002). These could be provided on a shared-risk basis, under which they are given on credit and the money is deducted from sales at the end of the season and does not need to be repaid if the crop fails. Since rain-fed agriculture is predominant in rural Mozambique, improved seeds should be selected for drought tolerance, especially in the (semi-) arid zones such as the southern provinces.

The use of improved technologies remains extremely low, but households who received extension services use inorganic fertilisers four times more often. The use of improved maize seeds is twice as high among this group, relative to those who did not receive extension. All these differences in terms of the use of improved technologies, demographics, asset endowment and others translate into differences in farm incomes that can be mistakenly attributed to the receipt of extension (Figure 1), unless selection bias and endogenous programme placement are accounted for. In other words, the receipt of extension is not causing all the difference in farm incomes.

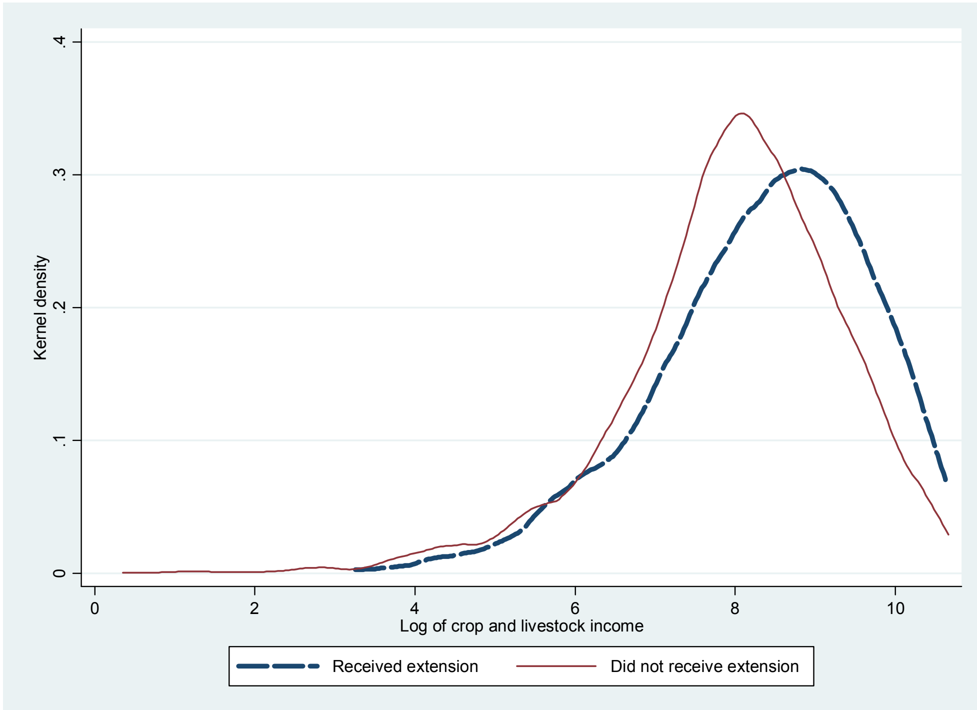

Figure 1 Kernel density of total household income by receipt of extension

4.2 Results from OLS regression

The results from OLS regression suggest that the receipt of extension is associated with higher farm incomes (Table 3). However, descriptive statistics showed that the receipt of extension is significantly greater among wealthier farmers than their poor counterparts. This suggests that both groups differ systematically in several aspects, and thus the estimation of the factors associated with farm incomes should be conducted separately. This is confirmed by the Chow statistic (*P-value* <0.001), which implies that the two groups follow different regression functions. The OLS regression indeed overestimates the impact of the receipt of extension. This suggests a bias in the impact of extension found in Walker et al. (2004), which is also based on OLS regression.

As expected, household size, household composition and gender of the household head have a statistically significant effect on farm incomes. Despite the importance of education in increasing farm incomes, its effect was not statistically significant. Although surprising, this is explained by low variation in the data. Most household heads are illiterate, and increasing 1 year of education from very low levels does not have a significant effect on farm incomes. Indeed, the squared term for education was significant, implying that educational levels have to increase significantly before it can have some effect on farm incomes. This assertion is later tested empirically by simulation methods used to assess the impact of targeting extension services based on several scenarios.

Asset variables were all significant, and the signs of the coefficients agree with the literature. An increase in cropped area by 1 ha results in farm income gains of 33%, and income gains decrease with further increase in cropped area. An additional tropical livestock unit, equivalent to acquiring one cow or about three goats, increases farm incomes by 7%. Bicycle ownership increases farm incomes by 17%.

Table 3 OLS results on farm incomes

Independent variables	Coeff.	Std. Error	P-Value
HH received extension (1=yes)	0.197	0.060	0.001
Head's years of schooling	0.029	0.021	0.175
Head's years of schooling (squared term)	-0.006	0.003	0.027
Head's age in years	0.006	0.007	0.388
Head's age (squared term)	0.000	0.000	0.341
HH is widow headed (1=yes)	-0.106	0.076	0.162
HH is female non-widow headed (1=yes)	-0.139	0.055	0.012
Household size (adult equivalent scale)	0.019	0.012	0.103
Number of members engaged in nonfarm	0.013	0.026	0.614
Head is engaged in nonfarm (1=yes)	-0.053	0.041	0.196
Cropped area in hectares	0.327	0.021	0.000
Cropped area in hectares (squared term)	-0.005	0.000	0.000
Tropical livestock units (TLU)	0.067	0.010	0.000
TLU (squared term)	-0.001	0.000	0.000
Household owns a bicycle (1=yes)	0.171	0.043	0.000
Drought risk index	-0.327	0.175	0.062
Flood risk index	0.095	0.316	0.763
Animal risk index	0.065	0.112	0.561
Membership to farmers' association (1=yes)	0.112	0.089	0.210
Used inorganic fertilisers (1=yes)	0.269	0.145	0.065
Used improved maize seeds (1=yes)	0.148	0.091	0.102
Used tractor (1=yes)	0.553	0.159	0.001
Used water pumps (1=yes)	-0.408	0.472	0.388
Used animal traction (1=yes)	0.138	0.083	0.095
HH hired full-time labour	0.105	0.169	0.535
HH hired seasonal labour	0.302	0.053	0.000
HH received price information (1=yes)	0.169	0.040	0.000
Tarred road runs through the village (1=yes)	1.223	0.278	0.000
Constant	6.414	0.329	0.000
Number of observations	5,067		
F(121, 4945)	13.35		
Prob > F	0.000		
R-squared	0.263		

Source: Authors' calculations based on TIA05 data.
Notes: District dummies were included but are not reported; HH stands for household.

In 2005, farmers in rural Mozambique were affected by a widespread drought. This is the reason why the coefficient on drought index is negative and statistically significant. Other risk variables were not significant. The central and northern provinces usually suffer from annual floods, but 2005 was particularly dry, and hence the flood index was insignificant. The use of animal traction and other improved technologies was associated with significantly higher farm incomes, although the direction of causality is unclear.

4.3 Results from the Logit model

The results from the weighted Logit model show that the coefficients from both the original and the simulated data are similar regarding the sign and magnitude. This suggests that the model specification of the propensity score is correct and stable, and that there is only selection on observables. In other words, there are no significant unobservable characteristics that affect the receipt of extension that were not accounted for. Worth noting is that the Logit model was used to identify matches, and therefore it uses the whole TIA05 sample (except farmers with negative farm income, and tobacco and cotton producers, see Section 2). The Logit model correctly predicted about 86% of farmers (Table 4).

Table 4 Logit model results

	Original data			Simulated data		
	Coeff.	Std. Error	P-Value	Mean	[95% CI]*	
Head's years of schooling	0.014	0.055	0.803	0.014	0.012	0.017
Head's years of schooling (squared term)	-0.002	0.006	0.797	-0.002	-0.002	-0.001
Head's age in years	0.013	0.021	0.529	0.016	0.015	0.017
Head's age (squared term)	0.000	0.000	0.415	0.000	0.000	0.000
HH is widow headed (1=yes)	-0.408	0.244	0.095	-0.447	-0.458	-0.436
HH is female non-widow headed (1=yes)	-0.118	0.174	0.497	-0.128	-0.135	-0.120
Household size (adult equivalent scale)	0.000	0.031	0.998	-0.002	-0.003	0.000
Number of members engaged in nonfarm	0.072	0.071	0.312	0.079	0.076	0.082
Head is engaged in nonfarm (1=yes)	0.200	0.126	0.111	0.206	0.200	0.211
Used inorganic fertilisers (1=yes)	0.845	0.360	0.019	0.889	0.872	0.906
Used improved maize seeds (1=yes)	0.635	0.259	0.014	0.658	0.646	0.669
Used animal traction (1=yes)	0.185	0.219	0.398	0.202	0.193	0.212
Cropped area in hectares	0.170	0.058	0.004	0.182	0.179	0.185
Cropped area in hectares (squared term)	0.000	0.001	0.948	-0.001	-0.001	-0.001
Tropical livestock units (TLU)	-0.006	0.026	0.816	-0.005	-0.007	-0.004
TLU (squared term)	0.000	0.000	0.913	0.000	0.000	0.000
Household owns a bicycle (1=yes)	0.207	0.132	0.116	0.216	0.210	0.221
Household owns a radio (1=yes)	0.315	0.128	0.014	0.320	0.314	0.326
Membership to farmers' association (1=yes)	1.681	0.178	0.000	1.771	1.763	1.779
Household vaccinated chickens (1=yes)	0.718	0.300	0.017	0.734	0.720	0.748
Tarred road runs through the village (1=yes)	-0.816	0.837	0.330	-3.906	-4.154	-3.658
Constant	-3.377	0.684	0.000	-2.707	-2.760	-2.654
Number of observations	4,967					
Wald chi-square(111)	434					
Prob > chi-square	0.000					
Pseudo R-squared	0.164					
Percent predicted correctly	85.71					

Source: Authors' calculations based on TIA05 data.
Notes: District dummies were included but are not reported;
*CI – Confidence interval.

Regarding demographic characteristics, gender of the household head was the only statistically significant variable. Widow-headed households are significantly less likely to be visited by extension workers. Because widows fare among the poorest in rural Mozambique, and there is evidence that extension workers tend to target wealthier farmers, this suggests that extension workers may deliberately decide not to target widows, with the risk of them remaining trapped in persistent poverty. Nevertheless, one could also argue that widow-headed households have less access to extension because they only represent about 9% of the total population. A large randomly drawn sample would probably show male-headed households having relatively better access to extension services because they represent more than 70% of the population.

The results also showed that it is more likely that farmers using improved technologies receive extension. Of note is that the coefficients on the use of improved seeds and inorganic fertilisers were quite large, and they were both significant at the 0.05 level. However, animal traction was not significant. This is because animal traction is predominantly used in southern Mozambique, while extension services are concentrated in central and northern provinces. The latter have a higher crop potential, but are severely affected by trypanosomiasis disease on cattle, preventing farmers from using animal traction.

The results suggest that extension services may be targeting farmers with larger cropped area and members of farmers' association (Table 4). There are fewer households cultivating relatively large fields in rural Mozambique. The average cropped area is about 1.5 ha per household (Table 2). There are also fewer households who are members of a farmers' association (Table 2). Yet, in a large random sample of households such as the TIA05, the receipt of extension is significantly higher among those few households.

4.4 Plausibility of the overlap and the unconfoundedness assumptions

By potentially accounting for selection bias and endogenous programme placement, Table 5 shows that the covariates of farmers who received extension and those who did not receive extension are well balanced. All normalised differences between households who received extension and their counterfactual group are small. The significance of the differences between receivers and non-receivers of extension, previously reported in Table 2, has vanished. As expected, the receipt of extension services has no influence on the age of the spouse of the household head (Table A1), suggesting that there are no significant omitted variables that influence the receipt of extension that were not accounted for, which makes it more plausible that the unconfoundedness assumption holds.

Table 5 Descriptive statistics of matches

	All sample		Did not receive extension		Received extension		
	Mean	SD	Mean	SD	Mean	SD	Δ *
Head's years of schooling	3.01	2.59	3.08	2.56	2.94	2.62	0.00
Head's age in years	43.77	14.16	44.05	14.35	43.49	13.98	0.00
HH is widow headed (1=yes)	0.06	0.24	0.07	0.25	0.06	0.24	0.00
HH is female non-widow headed (1=yes)	0.13	0.34	0.12	0.32	0.14	0.35	0.02
Household size (adult equivalent scale)	4.38	2.27	4.47	2.25	4.29	2.29	-0.02
Number of members engaged in nonfarm	0.56	0.95	0.58	0.92	0.55	0.98	-0.01
Head is engaged in nonfarm (1=yes)	0.68	0.47	0.68	0.47	0.67	0.47	0.00
Used inorganic fertilisers (1=yes)	0.04	0.21	0.05	0.22	0.04	0.19	-0.02
Used improved maize seeds (1=yes)	0.06	0.24	0.06	0.23	0.07	0.26	-0.02
Used animal traction (1=yes)	0.11	0.31	0.1	0.31	0.12	0.32	0.02
Cropped area in hectares	1.82	2.4	1.81	1.55	1.83	3.01	-0.02
Tropical livestock units (TLU)	1.32	3.78	1.4	3.96	1.24	3.6	-0.04
Household owns a bicycle (1=yes)	0.44	0.5	0.46	0.5	0.41	0.49	-0.04
Household owns a radio (1=yes)	0.65	0.48	0.66	0.48	0.63	0.48	-0.02
Membership to farmers' association (1=yes)	0.18	0.38	0.17	0.38	0.19	0.39	0.01
Household vaccinated chickens (1=yes)	0.06	0.23	0.07	0.25	0.04	0.21	-0.03
Tarred road runs through the village (1=yes)	0.73	0.45	0.75	0.44	0.71	0.46	-0.03

Source: Authors' calculations based on TIA05 data

Notes: Δ = *Normalized difference = [mean(x1)-mean(x0)]/(std. dev x0 + std. dev x1)^(1/2); SD = Standard Deviation

The assessment of the overlap assumption can be improved by graphical representation. Imbens and Wooldridge (2009) argue that reporting normalized differences should be seen as a starting point, because inspecting differences one covariate at a time may not be sufficient. Therefore, the overlap assumption was also assessed through graphical representation, by comparing the distribution of propensity scores of the two groups of farmers. The two distributions are almost identical (Figure 2). The graphical representation thus reinforces the results based on the normalized differences, suggesting that the overlap assumption is not a concern.

4.5 Results from the doubly robust estimator and regression and matching

The results from both the doubly robust estimator and matching and regression are statistically significant at the 0.10 level, compared to the OLS results which showed significance at the 0.01 level. Furthermore, the impact of the receipt of extension is equally positive, however significantly smaller. The results from matching and regression are more reliable than the OLS results, but those from the doubly robust estimator ensure more confidence (Wooldridge, 2007; Imbens and Wooldridge, 2009).

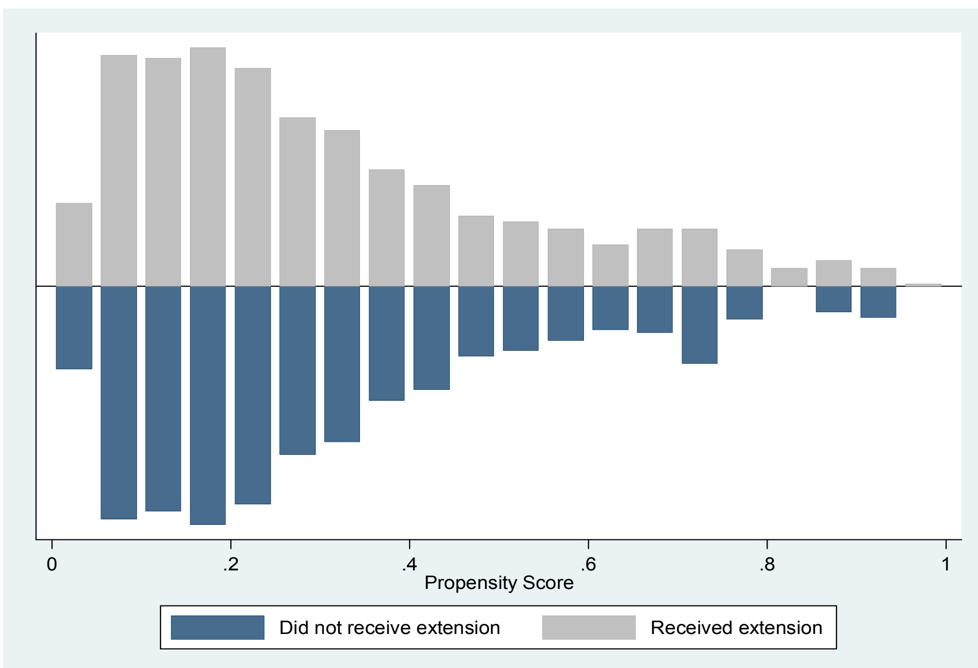

Figure 2 Distribution of propensity scores among treated and untreated households

Table 6 Estimates of the average treatment effect using different econometric approaches

Dependent variable:	Log of farm income (Meticais)		
	Coefficient	Std. Error	P-value
OLS with no control of endogeneity	0.197	0.060	0.001
Doubly robust estimator	0.120	0.060	0.051
Matching and regression	0.154	0.081	0.058

Source: Authors' calculations based on TIA05 data

The doubly robust estimator suggests that the receipt of extension services increases farm incomes by 12%. In an environment where more than half of the population lives below the national poverty line, and the fact that extension only reached 15% of farmers in 2005 (mostly wealthier farmers), the overall contribution of extension services to poverty reduction is undesirably low. However, this reflects the numerous constraints faced by extension services, the extension approach used by DNER and many NGOs (a modified T&V approach), and agricultural policies in place.

One significant constraint that affects extension services in Mozambique is the "lack of technology messages", mainly due to a weak link with agricultural research, which is perhaps the weakest link in the "agricultural knowledge triangle" (research, extension, and higher agricultural education) (Eicher, 2002). Extension services also face a shortage of staff, both in terms of quality and quantity. Mozambique has less than one agricultural researcher per 50,000 people, compared to 1:2,500 in neighbouring South Africa, and 1:400 in developed countries (Coughlin, 2006), and the density of extension workers is also low. Nevertheless, "in 1999 the World Bank actually blocked the government from hiring more agricultural extension workers, even though the total number was only one–tenth that recommended by the FAO" (Hanlon and Smart, 2008, p.168).

The Extension Master Plan chooses to maintain 700 public extension workers from 1998 to 2003, presumably because there is 'a satisfactory number of extensionists at the district level with specific training and professional experience in extension' (Eicher, 2002, p.17). Furthermore, many extension workers are on annual contracts, thus encouraging productive agents to seek jobs (sometimes non-agriculture related) with NGOs and the private sector (Eicher, 2002). This further reduces the number of staff, both due to contract problems and death of some extension workers.[3]

Indeed, extension services reached 8% of rural households in 2008, compared to 15% in 2005 (Cunguara and Hanlon, 2010). The decline in the coverage of extension services may have a bearing on regression in agricultural productivity. Production of food per capita and per hectare shows a negative trend between 2002 and 2008 (MPD/DNEAP, 2010). In addition, Boughton et al. (2006) show that between 1996 and 2002 the production of most crops fell per adult household member, suggesting that agricultural productivity in 2008 was actually lower than in 1996. There is an urgent need to improve agricultural productivity, and extension services can potentially contribute to reach that end.

There is reasonable evidence suggesting that the extension programmes usually target their beneficiaries based on, among other aspects, wealth (Walker et al., 2004; ECON Analysis, 2005; Gêmo et al., 2005; Mather, 2009; Cunguara and Hanlon, 2010). Descriptive analysis also showed that the receipt of extension is higher among wealthier households, for example, households that cultivate larger areas or own more livestock received extension more often (Tables 2 and 4). The empirical question that arises is whether the impact of extension is in fact greater among wealthier household.

Based on the results from the doubly robust estimator, simulation methods were used to assess several targeting scenarios. The initial impact of the receipt of extension, hereafter referred to as the benchmark, was compared to revised impacts obtained through targeting. The results showed that targeting households whose head is illiterate has smaller impact (Figure 3). Surprisingly, targeting widow headed households (usually the poorest households in rural Mozambique) had a greater impact, relative to the benchmark scenario of no

[3] It is estimated that 17% of employees of the Ministry of Agriculture are infected by HIV/AIDS (Coughlin, 2006).

targeting. However, the absolute change in incomes may be rather small, because widows have significantly lower incomes.

The greater percent change in farm incomes among widows is because about 53% of widow-headed households (among the matched sample) are located in the south, a region with a high tradition of livestock production. Widows can sell part of their livestock and thereby implement the technical recommendations provided by extension workers. Widows in the south may also have relatively higher cash incomes through remittances from family members working in the mining sector in neighbouring South Africa. In other words, access to cash (whether through remittances, livestock sales, credit, or off-farm employment opportunities) can enhance the contribution of extension services to poverty reduction.

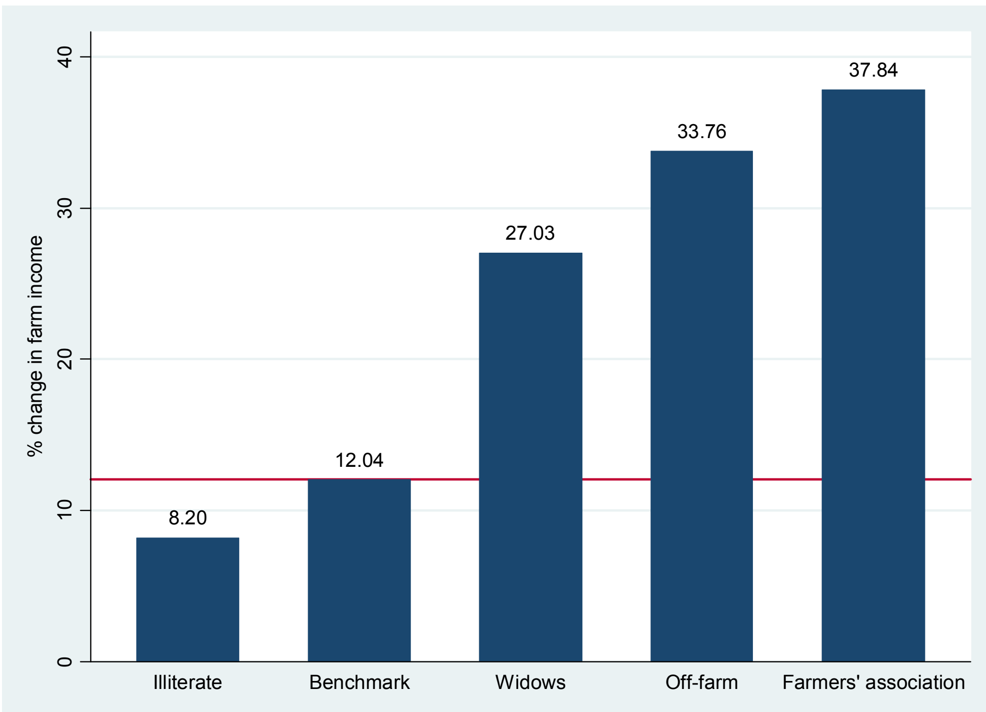

Figure 3 The impact of targeting farmers based on household typology

The impact of receipt of the extension was greater among members of farmers' association and households with at least one member engaged in off-farm activities. These households are also more capable of implementing extension advices. Worth noting is that members of farmers' association may have better access to output markets (for example, through collective action), which makes the use of improved technologies advocated by extension workers more profitable.

5 Concluding remarks and policy implications

This paper evaluates the impact of extension services in rural Mozambique. Using a nationally representative household survey conducted in 2005, three econometric approaches were used. An OLS regression was used to assess the plausibility of the results found in Walker et al. (2004). Then the doubly robust estimation and matching and regression were used to provide more robust results. The results suggest that extension services might have good reasons to target wealthier farmers, which is in line with the results found in several studies on extension in Mozambique (Gêmo et al., 2005; Mather, 2009). Due to severe budget constraints, extension services usually reach wealthier farmers the most because it costs less money and time. Moreover, wealthier farmers are more likely to implement the technical recommendations because they are financially more capable of purchasing modern inputs. Furthermore, wealthier farmers can be used as models or demonstration farmers (Mather, 2009). The results from the doubly robust estimation showed that the impact of the receipt of extension is also greater among this group of farmers. Nevertheless, targeting wealthier farmers is likely to increase income inequality.

The receipt of extension services increases farm incomes by 12%. This is consistent with the result found in ECON Analysis (2005), but does not support the results found in Walker et al. (2004) and Mather (2009). Walker et al. (2004) use an OLS regression model and do not control for either selection bias or endogenous programme placement. Meanwhile, Mather (2009) uses advanced panel methods to isolate the impact of the receipt of extension services, and concludes that the receipt of extension was only significant over time. However, the ‘treatment variable’ (the receipt of extension) may not be the same in both periods covered by the panel data because the extension approach used in 2004-05 is likely to be better than that used in 2001-02 agricultural season. In addition, it is also possible that farmers were visited by different extension providers (of unequal effectiveness) in the two survey years.

Targeting extension services to poorer households is likely to reduce poverty more rapidly, provided that these households can implement the technical recommendations. However, at the current stage of development in Mozambique the poor may lack the necessary means to implement extension advices. This is because they do not have access to credit or assets that can be easily turned into cash. One of the priorities of the local government should be to create a necessary asset portfolio among the poor. Livestock promotion programmes feature prominently among the potential candidates. This is supported by the fact that the impact of the receipt of extension services was noticeably greater among widow-headed households. These households were mostly located in the south, where cattle rearing are a predominant component of farmers’ livelihoods.

Rather than targeting wealthier farmers, the government should work on some enabling factors to improve the contribution of extension services to poverty reduction. So far, the contribution is relatively small because extension services only cover a small proportion of the poor, and access to extension declined by about 50% from its already low levels in just 3 years (Cunguara and Hanlon, 2010). Data limitations constrained detailed insights on service providers, programme design, and on cost/benefit analysis of extension services. Nevertheless, the results at hand showing a positive and significant impact of the receipt of extension, especially among farmers’ associations suggest that investments in extension services are likely to be worthwhile from a cost perspective.

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References

Adesina, A.A. and J. Baidu-Forson (1995) 'Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa', *Agricultural Economics*, 13: 1-9.

Arndt, C., Garcia, A., Tarp, F., Thurlow, J., 2010. Poverty Reduction and Economic Structure: Comparative Path Analysis for Mozambique and Vietnam. Working Paper No. 2010/122, UNU-Wider (United Nations University, World Institute for Development Economics Research).

Arndt, C., R. James and K. Simler (2006) 'Has Economic Growth in Mozambique been Pro-Poor?', *Journal of African Economies*, 15(4): 571-602.

Barrett, C., T. Reardon and P. Webb (2001) 'Nonfarm Income Diversification and Household Livelihood Strategies in Rural Africa: Concepts, Dynamics, and Policy Implications', *Food Policy*, 26(4): 315-31.

Barrett, C.B. (2008) 'Smallholder market participation: Concepts and evidence from eastern and southern Africa', *Food Policy*, 33: 299-317.

Birkhaeuser, D., R. Evenson and G. Feder (1991) 'The Economic Impact of Agricultural Extension: A Review', *Economic Development and Cultural Change*, 39(3):607-50.

Boughton, D., D. Mather, D. Tschirley, T. Walker, B. Cunguara and E. Payongayong (2006) Changes in Rural Household Income Patterns in Mozambique 1996-2002 and Implications for Agriculture's Contribution to Poverty Reduction, Working Paper 61E, Ministry of Agriculture, Maputo, Mozambique.

Bryceson, D (1999) 'African Rural Labour, Income Diversification and Livelihood Approaches: A Long Term Development Perspective', *Review of African Political Economy*, 80:171-89.

Caliendo, M., and S. Kopeinig (2008) 'Some practical guidance for the implementation of propensity score matching,' *Journal of Economic Perspectives*, 22(1): 31-72.

Copland, J.W. and R.G. Alders (2005) 'The Australian village poultry development programme in Asia and Africa', *World's Poultry Science Journal*, 61: 31-8.

Coughlin, P. (2006) Agricultural intensification in Mozambique: Infrastructure, policy, and institutional framework - when do problems signal opportunities, Report commissioned by the African Food Crisis Study, Department of Sociology, Lund University.

Cunguara, B., A. Langyintuo, and I. Darnhofer (2011) The role of nonfarm income in coping with the effects of drought in southern Mozambique. *Agricultural Economics*. (In press).

Cunguara, B., and I. Darnhofer (2011) Assessing the impact of improved agricultural technologies on household income in rural Mozambique. *Food Policy*. DOI: 10.1016/j.foodpol.2011.03.002.

Cunguara, B. and J. Hanlon (2010) Poverty is not being reduced in Mozambique, LSE Working Paper No. 74, London School of Economics and Political Science, UK.

Danida (2002) Review of Danida-supported Extension and Research activities within the Agricultural Sector Programme Support (ASPS): Mozambique, Working Paper, Copenhagen, Denmark.

Davidson, A.P., M. Ahmad and T. Ali (2001) Dilemmas of agricultural extension in Pakistan: Food for thought, Agricultural Research and Extension Network Paper No. 116.

Dehejia, R. and S. Wahba (2002) 'Propensity Score-Matching Methods for Nonexperimental Causal Studies', *The Review of Economics and Statistics*, 84(1): 151-61.

Doss, C.R. and M.L. Morris (2001) ‘How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana’, *Agricultural Economics*, 25: 27-39.

Doss, C. (2006) ‘Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement’, *Agricultural Economics*, 34: 207-19.

Dzeco, C., C. Amilai and A. Cristóvão (2010) Farm field schools and farmer’s empowerment in Mozambique: A pilot study, 9th European IFSA Symposium, 4-7 July 2010, Vienna, Austria.

ECON Analysis (2005) Impacts of Extension Services in Rural Mozambique, Report prepared for the World Bank, The World Bank, Washington DC.

Eicher, C.K. (2002) Mozambique: An analysis of the implementation of the extension master plan, Staff Paper 2002-31, Michigan State University, East Lansing, MI.

Eriksen, S. and J.A. Silva (2009) ‘The vulnerability context of a savanna area in Mozambique: household drought coping strategies and responses to economic change’, *Environmental Science and Policy* 12: 33-52.

Feder, G., R. Just, and D. Zilberman (1985) ‘Adoption of Agricultural Innovations in Developing Countries: A Survey’, *Economic Development and Cultural Change*, 33(2): 255-98.

Gêmo, H, and W.M. Rivera (2001) Mozambique’s move towards a pluralistic national system of rural extension, Agricultural Research and Extension Network Paper No. 110.

Gêmo, H, C.K. Eicher and S. Teclemariam (2005) *Mozambique’s experience in building a national extension system*, East Lansing, Michigan: Michigan State University Press.

Gibson-Davis, C., and M. Foster (2005) Using propensity scores to estimate the effect of food stamps on food security, Discussion Paper No. 1293-05, Institute for Research on Poverty, University of Wisconsin, Madison.

Gilligan, D., and J. Hoddinott (2007) ‘Is there persistence in the impact of emergency food aid? Evidence on consumption, food security, and assets in rural Ethiopia’, *American Journal of Agricultural Economics*, 89(2): 225-42.

Godtland, E., E. Sadoulet, A. de Janvry, R. Murgai and O. Ortiz (2004) ‘The Impact of Farmer Field Schools on Knowledge and Productivity: A Study of Potato Farmers in the Peruvian Andes’, *Economic Development and Cultural Change*, 53 (1): 63-92.

Hanlon, J. and T. Smart (2008) *Do Bicycles Equal Development in Mozambique.* Woodbridge: James Currey.

Heckman, J.J., H. Ichimura and P. Todd (1998) ‘Matching as an Econometric Evaluation Estimator’, *Review of Economic Studies*, 65: 261-94.

Heckman, J.J. and S. Navarro-Lozano (2004) ‘Using Matching, Instrumental Variables, and Control Functions to Estimate Economic Choice Models’, *The Review of Economics and Statistics*, 86: 30-57.

Heckman, J.J, L. Lochner and C. Taber (1999) ‘Human Capital Formation and General Equilibrium Treatment Effects: A Study of Tax and Tuition Policy’, *Fiscal Policy* 20(1): 25-40.

Imbens, G., and J. Wooldridge (2009) ‘Recent developments in the econometrics of program evaluation’, *Journal of Economic Literature*, 47(1): 5-86.

Leuven, E., and B. Sianesi (2003) PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing, http://ideas.repec.org/c/boc/bocode/s432001.html. Version 4.0.3 01oct2010.

Mather, D., B. Cunguara and D. Boughton (2008) Household income and assets in rural Mozambique, 2002-2005: Can pro-poor growth be sustained?, Working Paper 66E, Ministry of Agriculture, Maputo.

Mather, D. (2009) Measuring the impact of public and private assets on household crop income in rural Mozambique, 2002-2005, Working Paper 67E, Ministry of Agriculture, Maputo.

MPD (2010) Third Poverty Assessment in Mozambique, Ministry of Planning and Development, Maputo, Mozambique.

Njoh, A.J. (2008) 'Implications of Africa's Transportation Systems for Development in the Era of Globalization', *Review of Black Political Economy*, 35:147-62.

Reardon, T. (1997) 'Using Evidence of Household Income Diversification to Inform Study of Rural Nonfarm Labor Market in Africa', *World Development*, 25(5): 735-47.

Rosenbaum, P. and D. Rubin (1983) 'The Central Role of the Propensity Score in Observational Studies for Causal Effects', *Biometrika*, 70(1): 41-55.

Rubin, D. (1974) 'Estimating Causal Effects of Treatments in Randomized and Nonrandomized Studies', *Journal of Educational Psychology*, 66:688-701.

Smith, J. and Todd, P. (2005) 'Does matching overcome LaLonde's critique of nonexperimental estimators?' *Journal of Econometrics*,125(1–2): 305–353.

Snapp, S., M. Blackie and C. Donovan (2003) 'Realigning research and extension to focus on farmers' constraints and opportunities', *Food Policy*, 28:349-63.

Thirtle, C., L. Beyers, Y. Ismael and J. Piesse (2003) 'Can GM-technologies help the poor? The impact of Bt Cotton in Makhathini Flats, KwaZulu-Natal', *World Development*, 31(4):717-32.

Uttaro, R. (2002) 'Diminishing choices: Gender, small bags of fertilizer, and household food security decisions in Malawi', *African Studies Quarterly*, 6(1-2).

van den Berg, H. and J. Jiggins (2007) 'Investing in farmers - the impact of farmer field schools in relation to integrated pest management', *World Development*, 35(4):663-86.

Walker, T., D. Tschirley, J. Low, M. Tanque, D. Boughton, E. Payongayong and M. Weber (2004) Determinants of Rural Income, Poverty and Perceived Well-Being in Mozambique in 2001-2002, Working Paper 57E, Ministry of Agriculture, Maputo.

Walker, T., D. Boughton, D. Tschirley, R. Pitoro and A. Tomo (2006) Using Rural Household Income Survey Data to Inform Poverty Analysis: An Example from Mozambique, Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006.

Wooldridge, J. (2007) 'Inverse probability weighted estimation for general missing data problems', *Journal of Econometrics*, 141:1281-1301.

World Bank (2004) National strategy and reform policy: case studies of international initiatives. Agriculture and Rural Development, Discussion Paper 12, The World Bank, Washington DC.

Table A1 Results from the placebo regression

Dependent variable: age of head's spouse	Coeff.	Std. Error	P-value
HH received extension (1=yes)	0.23	0.37	0.522
Head's years of schooling	-0.36	0.13	0.007
Head's years of schooling (squared term)	0.02	0.01	0.099
Head's age in years	0.85	0.07	0.000
Head's age (squared term)	0.00	0.00	0.057
HH is widow headed (1=yes)	9.17	2.04	0.000
HH is female non-widow headed (1=yes)	12.05	0.66	0.000
Household size (adult equivalent scale)	-0.04	0.09	0.646
Number of members engaged in nonfarm	0.03	0.18	0.865
Head is engaged in nonfarm (1=yes)	-0.74	0.32	0.021
Cropped area in hectares	-0.03	0.14	0.824
Cropped area in hectares (squared term)	0.00	0.00	0.083
Tropical livestock units (TLU)	-0.07	0.07	0.304
TLU (squared term)	0.00	0.00	0.310
Household owns a bicycle (1=yes)	-0.14	0.29	0.638
Drought risk index	0.15	1.15	0.895
Flood risk index	1.49	1.79	0.406
Animal risk index	0.95	0.77	0.219
HH received credit (1=yes)	0.10	0.78	0.899
Membership to farmers' association (1=yes)	0.16	0.50	0.751
Used inorganic fertilisers (1=yes)	1.88	0.75	0.012
Used improved maize seeds (1=yes)	0.05	0.48	0.918
Used tractor (1=yes)	-2.10	1.39	0.133
Used water pumps (1=yes)	-6.06	3.82	0.113
Used animal traction (1=yes)	0.34	0.65	0.601
HH hired full-time labour	-0.74	0.95	0.432
HH hired seasonal labour	-0.02	0.35	0.951
HH received price information (1=yes)	0.28	0.29	0.339
Tarred road runs through the village (1=yes)	-0.26	1.76	0.883
Constant	1.64	2.22	0.460
Number of observations	3827		
F(121, 3705)	128.12		
Prob > F	0.000		
R-square	0.74		

Source: Authors' calculations based on TIA05 data
Notes: District dummies were included but are not reported

Whose wealth is it anyway? Mozambique's outstanding economic growth with worsening rural poverty

Benedito Cunguara and Joseph Hanlon

Wordcount: 10,556 words

ABSTRACT

Despite rapid economic growth and massive inflows of aid, in Mozambique rural poverty is worsening. Agricultural production and productivity have not increased in the last decade. Use of chemical fertilisers and other modern technology is low and decreasing. The present development model emphasises that the government and donor role is to provide human capital and infrastructure, while the private sector is responsible for economic development and ending poverty. The most recent national surveys confirm what is being seen elsewhere in Africa, that this non-interventionist strategy does not raise agricultural productivity or reduce poverty. Of Mozambique's population, 80 per cent is engaged in agriculture, but contributing only one fifth of the GDP. This suggests that investments in agriculture are likely to generate pro-poor growth, both to rural and urban dwellers. The policy failure is increasingly recognised, but donors and government have invested too much political capital in this policy to change easily.

INTRODUCTION

Mozambique has undergone significant structural changes in the 50 years up to 2010. First, it suffered from three decades of almost continuous war. Second, the implementation of the structural adjustment program from the mid 1980s started the transition from a socialist to a capitalism regime, with marked macroeconomic effects on employment, economic growth, and inflation and exchange rates (MacMillan et al., 2003). Third, the peace agreement signed in 1992 allowed once again the movement of people, which allowed migration from rural to urban areas (Silva, 2007). Fourth, the implementation of the poverty reduction strategy papers (hereafter PARPA, *Plano de Acção para a Redução de Pobreza Absoluta*) since 2001 contributed to further structural changes. But one thing did not change: poverty reduction has always been the government's overarching goal, as established in PARPA and other development strategies.

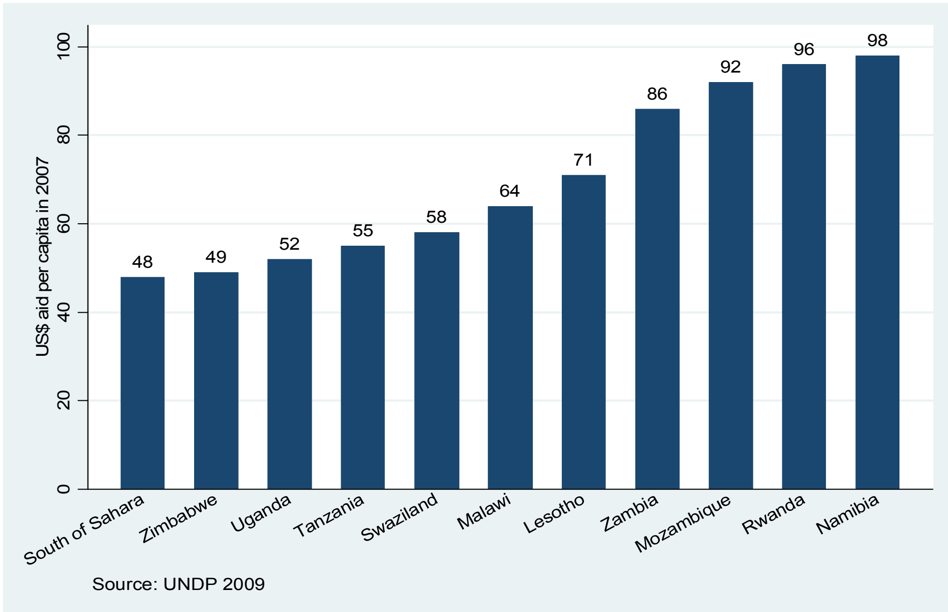
Mozambique has been one of the poorest countries in the world for more than two decades (UNDP, 2009). Its population is predominantly rural and 80 per cent is engaged in agriculture, but contributing only 20 per cent of the Gross Domestic Product (GDP) (INE, 2010), suggesting that labour productivity in the agricultural sector is significantly lower than in the non-agricultural sector. It also suggests that growth in agricultural productivity is critical for poverty reduction (Arndt et al., 2010). Nevertheless, as will be shown, agricultural productivity declined in the last decade, contributing to stagnant poverty levels.

In 1996-97 the mean consumption per capita was actually below the absolute national poverty line, implying that if the total consumption had been equally distributed among Mozambicans, all citizens would have lived in absolute poverty (Arndt et al., 2006). Economic growth was identified as the prime mover in poverty reduction in the World Bank's 'Washington Consensus', but relatively little attention was given to agricultural productivity growth. At the core of the 'Washington Consensus', as reflected in the PARPA, are macroeconomic policies presumed to lead to general economic growth, which in turn would trickle down to the poor (Dollar and Kraay, 2000).

In Mozambique, the official poverty statistics are derived from three consumption expenditure surveys. The first in 1996-97 showed an overwhelming 69 per cent of the population was poor. The second, in 2002-03, showed a sharp decline in poverty headcount to 54 per cent. This reflects the end of the war and an expansion of cultivated area (Arndt et al., 2006), but there is no evidence of improvement in agricultural productivity. Indeed, the production of most crops fell per hectare and per adult household member between 1996 and 2002 (Boughton et al., 2006). Moreover, caloric production per capita and per hectare declined in the subsequent period up to 2008 (MPD/DNEAP, 2010). The government had set a target of 45 per cent poverty by 2009, but the 2008-09 consumption expenditure survey (IOF) showed that 55 per cent of Mozambicans were poor (MPD/DNEAP, 2010), pointing to no poverty reduction in a decade. In particular, both the national annual agricultural survey (TIA, *Trabalho do Inquérito Agrícola*) and the IOF indicate that rural poverty is worsening.

Worsening rural poverty is puzzling both because national accounts show an outstanding economic performance since the end of the war in 1992, and because Mozambique became a donor darling and aid has been rising steadily for the past decade. Mozambique receives significantly more aid than neighbours at a similar level (Figure 1). Malawi (GDP rank 172, HDI 160) and Tanzania (GDP 157, HDI 151) receive only 60 per cent per capita of the aid to Mozambique. This may be because Mozambique is one of the few countries to be loyally following a neo–liberal, free market development policy, and was apparently also reducing poverty. But the 45 per cent target has proved a hostage to fortune. Both donors and government staked their prestige on a continuing huge fall in poverty. .

Figure 1 Aid per capita, $ per person in 2007



Four potential factors explain the weak correlation between rapid economic growth, massive international aid, and poverty stagnation. First, Arndt et al. (2010) consider Tanzania and Mozambique, two countries with rapid economic growth but little change in poverty levels, and argue that differences in the methods and accuracy of national growth and poverty accounting may explain this paradox. Indeed, Mozambique's official statistics show that on average the agricultural output is increasing by about 6 per cent a year in the last decade, even in a year of widespread drought such as 2005. However, the third national poverty assessment blames the underperformance of the agricultural sector for the lack of progress in poverty reduction (MPD/DNEAP, 2010), raising doubts on the accuracy of the official statistics and the national accounts.

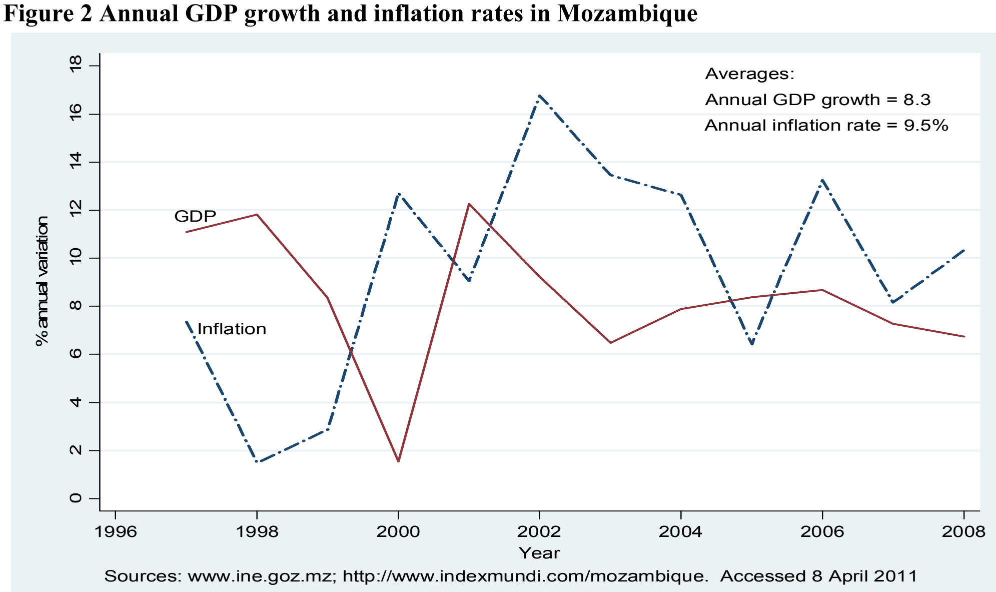
Second, the extent of the effect of economic growth on poverty reduction depends on the structural characteristics of the country, a feature often not accounted for in cross-country studies. Historically, Mozambique possesses two distinct zones of development, the relatively urban south and the predominantly rural areas in central and northern Mozambique (Silva, 2007). Most Portuguese settlers lived in the south where some urbanization took place, whereas agricultural production from the central and northern provinces was exported from the northern ports, leaving less incentives to connect the south to the north. Today, the southern provinces remain dependent on food imports and vulnerable to price fluctuations in the international markets (Tostão and Brorsen, 2005). Additionally, as a result of socio-economic imbalances between the urban and the rural areas, the urban population is growing rapidly, especially in the food-deficit southern provinces (INE, 2010).

Economic growth and population growth (entirely urban) combined with the stagnation of the agricultural sector may result in inflation of staple food prices, exacerbating poverty (Kalecki, 1976; Bhaduri, 2006). An increase in prices of staple food crops has a markedly negative impact on farmers' wellbeing because the demand for food is usually inelastic (Engel's law), and the majority of the population is net consumer of food (Boughton et al., 2007). For instance, Handa and Mlay (2006) found nearly unitary income elasticity for basic staple foods (e.g., cassava) among poor households in rural Mozambique.

Price instability discourages investment in staple food production by surplus households in northern Mozambique that have the assets and the favourable conditions to produce much more (Poulton et al., 2006). It also encourages deficit households in the southern provinces to devote scarce resources to staple food production to ensure their livelihoods, limiting diversification and the increased incomes that typically come with it (Tostão and Tschirley, 2010). Furthermore, it limits nonfarm investment in services such as input supply, provision of credit, and storage and processing, thus reinforcing behaviours that lead to continued price instability.

Cirera and Nhate (2007) argue that changes in the exchange rate in neighbouring countries tend to be fully transmitted to consumer prices in the domestic market. Although available statistics show that the GDP has been increasing rapidly, inflation rates tend to be higher (Figure 2). This suggests a worsening cost of living, which disproportionately affects the poor, who spend most of their income on food. A robust GDP growth and lack of progress in poverty reduction in the last decade suggest that most of the benefits of economic growth accrue to wealthier households. As a result, inequality levels would increase over time. Nevertheless, the Gini coefficient remained almost the same between 2002-03 and 2008-09, prompting questions about who is really benefiting from the economic growth.

Figure 2 Annual GDP growth and inflation rates in Mozambique



The third potential explanation for the weak correlation between rapid economic growth without significant changes in poverty or inequality is that the benefits of economic growth may accrue to foreign investors. Mozambique was successful in attracting foreign investment, mostly in 'mega projects' such as the aluminium smelter (Mozal). However, these 'mega projects' create few local jobs, have few local linkages, and have a small impact on poverty reduction. They benefit from huge tax exemptions, rely heavily on imported goods, and only a very small fraction of their production is consumed locally (Virtanen and Ehrenpreis, 2007). In 2006 Mozal contributed about 56 per cent of total exports and seven per cent of the GDP (Sonne-Schmidt et al., 2009). However, the standard income tax of 32 per cent that Mozal foundry would be entitled to bear has been replaced by a fixed turnover tax of $4 million, which is less than one per cent of Mozal's total export value in 2006 (Sonne-Schmidt et al., 2009).

The fourth potential explanation for the stagnant rural poverty despite increased international aid may lie in the structure of aid and government's expenditure. Only a small share of international aid is allocated to agriculture, a point discussed later. Additionally, government expenditure on agriculture is low (less than 10% of total government budget), and reflects both policy and development priorities, as well as political compromises (Zavale et al., 2009). Officially, 70 per cent of the Mozambican population is rural, yet agriculture employs about 80 per cent of the population, which suggests that even in urban areas agriculture is still an important economic activity. In rural areas, the smallholder sector accounts for 99 per cent of all farms, which means further reduction in poverty is dependent on enhancing farmers' incomes (Arndt et al., 2010).

The next section looks at the data and what they show about the way the lack of changes in farming contribute to the persistence of poverty, and then considers cash income and the poverty trap. The final section discusses the failure of the donor-led development model, while making a comparison between Mozambique and other countries for alternative policies which might reduce poverty and raise agricultural production. We also consider pressures for and against changing policy.

RURAL INCOME, POVERTY & TECHNOLOGY

This paper uses data from the national agricultural surveys (TIA) of 2002, 2003, 2005, 2006, 2007, and 2008. The surveys were implemented by the Department of Statistics of the Ministry of Agriculture. Except for the TIA08 sample, which draws on the Population Census of 2007, the TIA samples draw on the Census of Agriculture and Livestock of 1999–2000. TIA samples were stratified by province and agro–ecological zone. TIA02, TIA05, and TIA08 were the three most comprehensive surveys, with detailed information on household income components. All the TIA figures presented here are population weighted. Sample size was approximately 5,000 in 2002 and 2003, and 6,000 in subsequent years; coverage increased from 80 districts in 2002 to all 128 districts in 2008.

The analysis draws on four studies done as part of the donor–government evaluation of PARPA II (Cunguara and Kelly, 2009a and 2009b; Grupo de Estudo, 2009; Kelly, 2009) Two broadly based social surveys are also compared: the Demographic and Health Survey 2003 (IDS, Inquérito Demográfico e de Saúde), recalculated using as base the 2006 WHO standard population, was compared to the Multiple Indicator Cluster Survey 2008. Finally, we look at the third national poverty assessment report, which is based on the consumption expenditure surveys.

Table 1 focuses on food production because on average food crop income accounts for over 90 per cent of the median crop income (in 2002), and the share is even higher among smallholder farmers in the lowest income quintiles (Mather et al., 2008). Furthermore, between 2002 and 2005 participation in higher-value farm activities declined, as only a third of households had sold some high-value crops in 2005, and a quarter had sales of livestock products. Given subsistence requirement, risk management, and entry barriers to income activities, some households either do not have access to cash cropping or choose to focus their attention on meeting subsistence food requirements.

Table 1 Food production trends (2002- 2008) in Mozambique

Crop/year	2002	2003	2005	2006	2007	2008	% Δ 2002-08
Production per person (kg)							
Maize	90.0	92.9	67.3	101.7	80.7	80.7	-10.4
Rice	7.5	9.2	4.6	7.1	7.3	5.8	-22.5
Sorghum	11.2	15.0	8.2	14.7	11.9	8.4	-24.8
Millet	1.0	1.7	1.1	1.6	1.8	1.0	-1.5
Groundnuts – large husks	3.0	3.4	2.0	1.8	2.2	2.1	-32.1
Groundnuts – small husks	5.2	3.4	4.2	4.4	5.0	4.7	-8.7
Butter bean	2.9	3.2	3.6	3.6	3.9	3.5	21.0
Cowpea	4.3	5.0	3.5	5.2	4.4	4.1	-5.0
Bambara groundnut	1.8	1.4	0.6	0.8	1.4	0.8	-53.9
Cassava	278.2	376.1	341.7	399.5	353.0	269.4	-3.2
Sweet Potato	36.8	48.0	36.4	49.4	61.4	40.5	10.0
Caloric aggregate measures							
Total production index	100	124.2	111.3	140.9	128.6	113.8	13.8
Productivity (kcal/ha)	2,307	2,643	1,935	2,424	2,189	1,961	-15
Productivity index	100	114.6	83.9	105.1	94.9	85	-15
Calories per person/ day	2,135	2,583	2103	2717	2422	2000	-6.3

Source: Adapted from the Third National Poverty Assessment (2010), using TIA data.

Mozambique is a large country with variable and differentiated climatic conditions – most years have droughts and floods somewhere – but 2005 had widespread droughts and thus poorer crops than normal, while 2006 was a better than average year (Table 1). Per capita production of most staple crops declined between 2002 and 2008 and agricultural productivity (measured as calories produced per hectare) declined by 15 per cent.

Worsening rural poverty

The third consumption expenditure survey shows no improvement in poverty headcount: nationally, poverty incidence barely changed from 54.1 per cent in 2002-03 to 54.7 per cent in 2008-09 (Table 2). The increase was not statistically significant. Similar results had been reported a year earlier, in Cunguara and Kelly (2009a,b) using TIA data. The poverty gap and the squared poverty gap results suggest that the distribution of incomes worsened as the inequality increased, however not significantly. The change in the depth and severity of poverty was higher in rural areas. In general, poverty levels have worsened in the central provinces, especially in Zambézia and Sofala provinces, despite relatively high crop potential in that region.

Nutrition data also show that poverty levels are not changing very much. Nationally, chronic malnutrition (stunting) for children under five years old fell from 48 per cent in 2003 to 44 per cent in 2008, but this is still considered 'very high' by the World Health Organisation (Grupo de Estudo, 2009). Stunting is a good indicator for the well being of a population. If young children are exposed to sub-optimal nutrition at early stages in their development, they are unable to reach their full potential height and mental development; this opportunity is irreversibly lost, even if nutrition improves and a child gains weight. Ministry of Health figures also show that low birth weight rates are not improving; they were 10.9 per cent of births in 2006 to 11.3 per cent in 2008.

Table 2 Poverty statistics in Mozambique by survey year and location

Description/	Poverty headcount (%)			Poverty gap			Squared Poverty gap		
Survey year	1996-97	2002-03	2008-09	1996-97	2002-03	2008-09	1996-97	2002-03	2008-09
National	69.4	54.1	54.7	29.3	20.5	21.2	15.6	10.3	11.0
Urban	62.0	51.5	49.6	26.7	19.7	19.1	14.6	9.6	9.6
Rural	71.3	55.3	56.9	29.9	20.9	22.2	15.9	10.7	11.6
Niassa	70.6	52.1	31.9	30.1	15.8	12.3	16.1	6.7	6.5
Cabo Delgado	57.4	63.2	37.4	19.8	21.6	11.5	9.1	9.5	4.8
Nampula	68.9	52.6	54.7	28.6	19.5	20.0	15.3	9.3	9.8
Zambézia	68.1	44.6	70.5	26.0	14.0	27.9	12.3	6.1	13.9
Tete	82.3	59.8	42.0	39.0	26.3	16.5	22.5	15.3	8.9
Manica	62.6	43.6	55.1	24.2	16.8	21.1	11.7	9.2	11.1
Sofala	87.9	36.1	58.0	49.2	10.7	27.0	32.1	4.3	17.1
Inhambane	82.6	80.7	57.9	38.6	42.2	20.9	21.4	26.0	10.1
Gaza	64.6	60.1	62.5	23.0	20.6	28.3	10.9	9.3	16.7
Maputo Province	65.6	69.3	67.5	27.8	31.1	25.6	14.7	17.2	12.5
Maputo City	47.8	53.6	36.2	16.5	20.9	11.8	7.7	10.3	5.2

Source: Third National Poverty Assessment (2010) – MPD/DNEAP.

One reason for the very high levels of chronic malnutrition in Mozambique is that the average farmer produces enough food to feed their family adequately for less than eight months of the year, and this is not changing. The poorest families only produce enough to provide adequate food for half the year. Thus most smallholder farmers are deficit producers of food, selling some quantities soon after the harvest, and buying more food later in the agricultural season at prices significantly higher (Boughton et al., 2007). These households rely either on food aid or on cash income for their subsistence. Participation in nonfarm income activities is usually used as a coping strategy, and the poor usually engage in activities of low return (Cunguara et al., 2011).

Although income and nutrition are not improving, there are considerable improvements in human capital, notably education and health (UNICEF Stats). Although it remains extremely high, the under–five mortality rate was reduced from 153 deaths per 1,000 live births in 2003 to 142 in 2009 (compared to 110 and 108 deaths in Malawi and Tanzania, respectively). Positive trends were also observed with respect to literacy rates (54%) and primary school enrolment and attendance rates (80%). Literacy rates are higher in Malawi (73%) and Tanzania (73%), as well as primary school enrolment and attendance rates (91% in Malawi).

Child poverty, as measured through the deprivations-based approach[4], was reduced significantly from 2003 to 2008, from 59 per cent to 48 per cent. This measure responds more quickly to resource allocation, compared to consumption or income–based indicators of poverty. Therefore, increased funds for the rapid expansion of immunisation programmes had an immediate and direct impact on child poverty under the deprivations-based measure. Nevertheless, the evidence suggests that while Mozambique has been expanding and improving basic services to its citizens, it has been far less successful in promoting the agricultural sector, employment opportunities and the incomes of the rural population.

[4] A household is identified as poor if, and only if, it is deprived in some combination of indicators whose weighted sum exceeds a certain threshold. Indicators include health, education, and standard of living.

Low technology & little change

Maize is Mozambique's main staple crop. Table 1, which showed the bad year of 2005 and the unusually good year of 2006, also makes clear that maize production levels have not changed in the past decade. Furthermore, the poorest 20 per cent of rural people produce only 1 per cent of the country's maize, while the top 20 per cent produce more than half (result not tabled). Low productivity results in part from low and declining use of equipment and inputs (Table 3).

Table 3 Characteristics of agriculture production (2002-2008) in Mozambique

Description	2002	2003	2005	2006	2007	2008	% Δ 2002-08
Cultivated area ('000 hectares)	4,185	4,535	5,552	5,612	5,672	5,602	33.9
No. small and medium sized farms ('000)	3,127	3,210	3,333	3,396	3,619	3,725	19.1
Average farm size (ha.)	1.3	1,4	1.7	1.7	1.6	1.5	12.4
Household size (average)	5.0	5.0	5.3	5.1	4.9	5.1	2.0
Rural population (millions) [adjusted]	12.4	12.7	14.0	13.7	14.0	15.1	21.5
Household heads with 4th grade education (%)	31.1	32.9	36.4	36.2	36.6	42.3	36.0
Receipt of extension info. (% farms)	13.5	13.3	14.8	12.0	10.1	8.3	-38.5
Use of chemical fertiliser (% farms)	3.8	2.6	3.9	4.7	4.1	4.1	7.9
Use of pesticides (% farms)	6.8	5.3	5.6	5.5	4.2	3.8	-44.1
Use of irrigation (% farms)	10.9	6.1	6.0	8.4	9.9	8.8	-19.3
Receipt of credit (% farms)	-	2.9	3.5	2.9	4.7	2.6	-10.3

Source: Adapted from the Third National Poverty Assessment, using TIA data.

More detailed data from the TIAs show that improved technology is only used where there are special conditions. Northern Mozambique has the highest agricultural potential but, with a few exceptions, the lowest use of modern technology. For example, only 3 per cent of Mozambican farmers use chemical fertilisers, and that is largely on tobacco where it is supplied on credit by an international tobacco company. In the north, where expensive fertiliser can only be purchased in towns, only 0.2 per cent of farmers use fertiliser on maize. Only 2 per cent of farmers use tractors and 11 per cent use animal traction, and most are in the south, even though the most productive land is in the north.

Table 3 also shows that use of irrigation, chemical fertilisers and pesticides are all falling – in part due to higher input prices caused by higher fuel prices. Similarly, high fuel prices sharply cut the number of visits by agricultural extensionists. The decline in the use of pesticides may be related to a recent shift from cotton production to other cash crops (less vulnerable to pests) like sesame. In Mozambique, inputs are not, in general, subsidised, and the very low use creates a vicious cycle, with low sales causing low import volumes and thus higher prices.

The Ministry of Agriculture has not intervened sufficiently in rural areas. Many extensionists are on annual contracts, thus encouraging productive agents to seek jobs (sometimes non-agriculture related) with NGOs and the private sector (Eicher, 2002). The institutional weakness of the Ministry of Agriculture is also reflected in the number of publications. Between 2000 and 2005, the Directorate of Economics published 24 research reports and 27 policy briefs. In the subsequent period to 2010, the number of publications dropped by 50 per cent. Due to high cost of living, many employees of the Ministry of Agriculture search for better jobs in other places. For example, the Department of Policy Analysis, once a very functional unit of more than 15 analysts, at one point was reduced to two staff only – the head and her deputy. The government and Frelimo do not place, reward, or retain qualified people in the public sector.

Table 4 looks at chemical use by income; as expected, better off farmers are more likely to use chemicals, but the drop in even their use is noticeable. Better off farmers produce most of the maize, but they do it by farming more land, not by increasing productivity. Thus it appears that not only have none of the PARPA (2005-2009) targets to increase irrigation, extension, and use of improved seeds and fertiliser been met, but that the trend is actually the opposite.

Table 4 The use of improved technologies and hired labour, and membership to farmers' association

Income quintile	Chemical fertilisers (%)			Pesticides (%)			Member of association (%)			Hired seasonal labour (%)		
	2002	2005	2008	2002	2005	2008	2002	2005	2008	2002	2005	2008
Bottom	2	2	0	3	3	1	2	5	4	4	7	6
2	2	3	2	5	4	2	3	7	8	7	9	12
3	4	5	3	7	6	3	4	9	7	13	14	15
4	6	5	6	9	9	5	5	10	9	22	22	23
Top	10	10	7	13	10	5	9	13	10	35	39	38
Total	5	5	4	7	6	3	5	9	8	16	18	19

Source: Authors' calculations based on TIA data

Cash & the poverty trap

Cash income in rural Mozambique is low and hugely skewed (Table 5). The median cash income per capita in 2008 was about $25 per year, just $0.07 per day. This must be used to buy clothing, school books, cooking oil, medicines, and food in the lean season. And incomes are hugely skewed, with the top 20 per cent earning on average $174 per person per year – not a lot by global standards, but relatively wealthy by Mozambican standards. Cash income is derived from small crop sales, typically a few kilograms at a time, and small sales of charcoal or other forest products or locally produced beer. Some carry out some day labour on neighbours' fields. Total cash income per capita was significantly less in 2008 than in 2002.

Table 5 Annual per capita cash income by quintile of total maize production and year

Quintile of total maize production	Median per capita cash income (US$)			Mean per capita cash income (US$)		
	2002	2005	2008	2002	2005	2008
Bottom quintile	9.61	22.41	21.15	72.85	94.27	100.22
2	10.60	26.19	18.94	66.23	113.40	75.05
Middle quintile	13.18	28.30	21.67	81.61	104.18	88.78
4	22.88	36.09	31.37	99.82	118.28	90.12
Top quintile	41.48	86.87	58.46	152.01	200.16	174.50
Total	16.30	34.44	25.38	90.89	123.47	102.71

Source: Authors' calculations based on TIA data
Notes: Unofficial exchange rate in 2008: $1 = 26 Meticais;
All figures were converted into 2008 US$.

The income analysis is restricted to cash income (all cash received by households), because the bulk of food eaten in rural areas is produced by peasant farmers for their own consumption, and the value of crop production can be misleading. Total "income" may be higher in the drought year of 2005 because the farm gate prices of food consumed were higher in that shortage year – so higher imputed income does not necessarily mean greater welfare or more food eaten.

The bottom 60 per cent of farmers (based on cash income) have barely any food surplus. They are caught in what is known as the 'poverty trap' – that you cannot pull yourself up by your bootstraps if you have no boots. They are basically too poor to sell their produce, although they participate in the market as buyers. For the very poor with very little money, everything is more expensive (Addison et al., 2008). Buying in small quantities (usually when prices are high late in the season) is always more expensive than buying in bulk; selling maize by the 'lata' (a large can used as a measure) always earns less per kilo than selling by the sack or the lorry-load.

Risk is the biggest issue – the poorest have no savings, and must be conservative and reduce risk. Thus to use scarce cash to buy fertiliser is a huge risk when the investment may be lost due to poor or excessive rains or low output prices. The poverty trap works at community level too. When no one has money to buy, it makes no sense to produce more to sell on the local market. Even those who do trade are likely to sell only small quantities, and thus earn little for their day sitting in the market or by the roadside – as can be seen by the tiny average cash incomes of the poorest.

The top 40 per cent of farmers (based on cash income) earn more in cash than the value of what they produce for self–consumption. The large non–cash component means they are more productive farmers, even for their own consumption. These are also the farmers using chemical fertilisers and pesticides, and they are more likely to be in associations (Table 5). In effect, some are commercial farmers producing a cash crop. But it is off–farm income, both wage labour and self–employment, that lifts them into the upper income group (Cunguara et al., 2011).

FAILURE OF THE DONOR MODEL

For the past two decades, Mozambique has followed a development model largely set by the international community, which argues that donors and government should stress human capital, infrastructure, and more recently, 'governance'. Economic growth and poverty reduction were to be left to the private sector. The Millennium Development Goals (MDGs) have become an integral part of this policy, with emphasis put on MDGs 2 to 6 – education, gender, and health. The bias toward human capital has been pushed by the donors. For instance, aid to the social and governance sectors in Mozambique doubled in just six years, from \$477 million in 2003 to \$990 million in 2008. Budget support jumped from \$172 million to \$452 million between 2003 and 2008, and that also largely goes to social sectors (OECD Stat). A mark of the unquestioning promotion of this model was the 2005 statement by a visiting Norwegian aid official that 'everyone knows' that poverty is fought through investment in health, education, water and roads (Castel–Branco, 2007).

MDG 1 (to end poverty and hunger) has largely been ignored, and left to the private sector and foreign investment. Goal 1 has three targets: halve the proportion of people whose income is less than $1 a day, achieve full and productive employment and decent work for all, and halve the proportion of people who suffer from hunger. Mozambique seems not to be moving toward the Goal 1 targets (See Tables 1 through 4), yet both the government and donors treat the economic sectors (especially agriculture) as areas outside their concern.

GDP growth of more than 6 per cent a year for the past decade wins high praise from the international community, but has been driven by foreign investment in mineral and energy 'mega-projects' which create few jobs and have few local linkages. Over the next decade, mineral and energy exports will provide an increasing share of government revenue. However, Mozambique remains predominantly rural, and in the short and medium term, agriculture should remain a central component of development and poverty reduction (MPD/DNEAP, 2010).

The government talks much about the 'green revolution' which is supposed to end rural poverty. But it is not happening (Mosca, 2011). Half of Mozambicans are peasant farmers using only a hoe and no modern inputs, farming as their great grandparents did. The Chr Michelsen Institute (CMI) of Norway is doing a long term study of poverty funded by the UK Department for International Development (DfID). 'Our surveys confirm national data on improvements in education and health. However, we also show that people are in the process of losing faith in education as a vehicle for upward social mobility.' They continue: 'Above all, the surveys have confirmed the importance attached to employment, income and fair prices for agricultural products for alleviating poverty' (CMI Brief 8.1, Apr 2009).

Two decades of a donor–led, liberal, free–market rural development strategy have failed not just in Mozambique, but across Africa (Skarstein, 2005; Blackmon, 2008; Donaldson, 2008; Casse and Jensen, 2009). Countries were pushed to privatise state services and close marketing boards in the belief that if a truly free market was established, farmers would respond to price signals to produce the most profitable crops and pull themselves out of poverty. But the opposite happened, as production and productivity stagnated (Table 1) and the poorest peasants dropped back into subsistence production.

And the poverty trap came into play. Fertilisers and extension services supplied by marketing boards may have been more expensive, but farmers did not have to pay up-front – the cost was deducted from the payment for the crop. Most peasants have too little money to pay for inputs, even if they do cost less, and the marketing boards effectively provided insurance because if there was a generalised crop failure the input costs were not repaid. Hesselbein (2010b) identifies lack of markets as the biggest constraint in both Tanzania and Zambia. The same constraint applies to Mozambique (Cunguara and Darnhofer, 2011). The CMI study says that in Mozambique 'publicly supported local and adapted alternatives to the previous "marketing boards" should be considered' (CMI Brief 8.2, June 2009).

Mozambique's case is just one among dozens. Hesselbein (2010a) points to the lack of change in agricultural productivity across Africa. She notes that two of Mozambique's neighbours, Tanzania and Zambia, developed visions similar to Mozambique's 'green revolution,' based on market liberalisation and the private sector. As in Mozambique, the strategy failed; farmers are too poor to purchase seeds and fertiliser or invest in irrigation (Hesselbein, 2010b).

A recent short policy brief by the OECD notes that 'meeting the MDG poverty reduction goals needs growth to be more pro-poor', and that 'donors need to adapt to a changing landscape for development co-operation' (OECD, 2011). So, after 19 years, the OECD notices that the policy imposed on Mozambique after its war (and on other African countries) was 'unlikely' to work. And it did not (Hanlon, 2010).

The ahistorical nature of neo-liberal policies and their failures in Africa have led writers to look both at history and at the actions of other, more successful, countries. Hesselbein (2010a) argues that 'the initial conditions in Europe, before industrialisation, were very similar to those found in contemporary Sub-Saharan Africa.' There were complaints in mid-19th century Europe about lazy peasants. Agricultural stagnation was only overcome when farmers were given inputs, such as fertilisers and machines that made the work less back-breaking, plus consumer goods which made their lives less hard. And this tended to involve the active intervention of the state, particularly directing investment but also using tax policy to curb unproductive elite consumption and shift the money to investment. The state needs to be actively involved in the shift from subsistence to a market rural economy.

Chang (2008) looks back at both 19th century Europe and the Asian Tigers of the late 20th century. South Korea is often cited, because it had been colonised (by Japan) and then went through a war, and was similar in many ways to African countries in the late 20th century. A study by the US Congressional Budget Office (CBO, 1997) looked at what it saw as the success of aid to South Korea. (Non-military aid to South Korea in the 1970s was, in real per capita terms, double the aid to Mozambique now.) 'The South Korean government largely initiated, directed, and organised development by setting goals, establishing priorities, and backing them up with resources. Large, highly profitable private companies were clearly subordinate to the government, in part because the government controlled domestic credit as well as the right to borrow abroad.' The government also put in place a number of incentives such as subsidies and access to subsidised credit.

The CBO report pointed out that foreign aid was particularly important in upgrading South Korean agriculture, where it was used for research and agricultural extension, and to promote the use of fertilisers. US aid helped Korea build five fertiliser plants. Yet for the subsequent two decades, the international community prohibited exactly those successful policies in Africa, and in particular in Mozambique, which was forced to close its marketing board, dismantle agricultural research, and end state support for production of modern seeds. All protection and support, except for foreign multinational companies, was stopped. Subsidy was not allowed.

An alternative: reducing risk

Fertiliser subsidies are proving to be important in Africa as well (Hesselbein, 2010b). In contrast to many other African counties, Rwanda has a highly interventionist policy. A fertiliser subsidy pushed fertiliser use from 2 per cent to 62 per cent in just two years. Government guarantees credit to farmers. And it promotes farmer marketing associations and agribusiness, including companies that do peasant contract farming under which peasants grow an agreed crop and the company guarantees to buy, as with tobacco in Mozambique (Hesselbein, 2010b).

In Malawi, a fertiliser subsidy introduced with donor opposition turned the country from being dependent on food aid to being a maize exporter in just two years. Each household receives coupons allowing the purchase of two 50 kg bags of subsidised fertiliser, seed and storage pesticides; by 2007 the programme reached 1.7 million families. Partly helped by good rains, maize yields doubled and production jumped dramatically; in 2007 Malawi exported 300,000 tonnes of maize to Zimbabwe (Chinsinga and O'Brien, 2008).

In Mozambique, a similar fertiliser subsidy programme was implemented in 2009-10 and 2010-11 agricultural seasons, following the riots in 2008. About 25,000 farmers (less than 1% of the total farm households, compared to 70% in Malawi) received coupons allowing the purchase of fertilizers and improved seeds for about 30 per cent of the real price. However, many farmers are unable to purchase the subsidised package up front because they have little cash. Buffie and Atolia (2009) argue that 'input subsidies are highly effective in reducing smallholder poverty.' Input subsidies also 'buy a substantial increase (17–41 per cent) in the smallholder income along with a small but significant rise (2–5 per cent) in the real unskilled wage.'

Faced with the obvious success of the subsidy, donors could not impose any sanctions. But many remain opposed. Some argue that subsidies create market distortions while others argue that the money would be better spent on infrastructure. The IMF had been one of the most vociferous opponents, but the April 2010 issues of IMF Survey Magazine had unexpected praise for the fertiliser subsidy. 'Malawi's recent robust economic growth has enabled one of Africa's poorest countries to make real strides in reducing chronic food insecurity and progress toward poverty reduction.' This is partly because of 'several bumper harvests for tobacco, the principal cash crop, and maize, stemming from good rainfall and the distribution of subsidised fertilizer.'

Two important interventions in Mozambique show what can be done with a coordinated approach. The cashew nut sector's destruction by World Bank enforced liberalisation in 1995 became notorious (MacMillan et al., 2003), which created space for a quiet reversal of policy in the 2000s. A state agency, INCAJU, reintroduced protection (in direct and explicit violation of the World Bank rules) and discreetly worked with a domestic development agency and a handful of sympathetic donors to build the entire value chain – peasant production, state spraying and plant protection, marketing, new shelling and processing factories, and coordinated export – to create thousands of jobs and record production in the 2009–2010 season.

Tobacco is the other success. It has become Mozambique's most important export crop and has done more than any single intervention to reduce poverty. A single trans-national corporation, the US-based Universal Leaf Tobacco (ULT), has been given exclusive rights over tobacco production in much of the country. More than 150,000 farmers participate in its outgrower schemes, in which seeds, fertiliser and training are provided on credit, and there is a guaranteed market, but the tobacco must be sold to the company. Annual net profits for better farmers are over $730 (Benfica, 2006). The company has now built a tobacco processing factory, which created 1,600 jobs. ULT has created something similar to the old marketing boards, but no foreign investor has suggested similar schemes for other crops (Hanlon and Smart, 2008).

The core demands identified by CMI – income, jobs, and fair and assured market – are broadly agreed, so shared risk, guaranteed markets and subsidised technology will be central to reducing rural poverty. Jobs, even temporary day labour, should be created. It may also require cash transfers such a child benefit or non–contributory pension. Most important is to identify activities usually engaged in by the poor, and raise their profitability since participation in high-return activities is conditioned by entry barriers that require long-term investments, such as in education. Cunguara et al. (2011) argue that agro-processing and milling activities are usually carried out by female-headed households, which have systematically been ranked as poor. Raising the profitability of these activities is likely to generate pro-poor growth in the short-run.

There is also a need to raise technological levels to the point where working harder brings significant gains, so as to improve their own food production. Extension services could play a key role in fostering the adoption of improved technologies, provided markets exist. Cunguara and Moder (2011) estimate that in Mozambique the receipt of extension increases farm incomes by 12 percent. Nevertheless, rather than crafting resource-poor technologies, extension services tend to target wealthier households. This can increase income inequality in rural areas.

Resource-poor technologies include smaller packages of improved seeds and chemical fertilisers, which could be provided on a shared-risk basis, under which they are given on credit and the money is deducted from sales at the end of the season and does not need to be repaid if the crop fails. Seed packages should also include both early and late varieties to provide farmers with more flexibility in terms of when to plant, depending on the rainfall pattern in a given cropping season. Since rain-fed agriculture is predominant in rural Mozambique, improved seeds should be selected for drought tolerance. Packages of support should be tailored to the agricultural potential of different parts of Mozambique. Long term credit and technical support for up to seven years will be needed for the development of tree crops including nuts, mangoes and citrus fruit, and for farmer association owned marketing companies such as Ikuru in Nampula province (Hanlon and Smart, 2008).

The overwhelming majority of Mozambican farmers still use only a hand hoe, which means tillage and the amount of back pain a farmer can suffer is a key constraint. Animal traction and other tilling methods would allow the cropped area to be expanded, and land is available in the north. But this would require investment, especially the construction or rehabilitation of dip tanks and expansion of veterinary services in central and northern Mozambique. An alternative is small tractors, but that would require the establishment of machinery servicing and hiring networks appropriate for small farmers. Government would need to promote machinery hire companies that can rent tractors and harvesters to farmers too small to own their own.

Mozambicans speak out

The rising cost of living sparked riots in urban areas. Young people rioted in the capital Maputo on 5 February 2008; five people were killed and more than 100 injured, many shot by police. In response temporary subsidies were introduced for diesel, wheat, water, and electricity. But these measures are biased toward the growing urban population while agriculture is stagnant and the demand for food is increasing. Riots erupted again on 1 September 2010.

The dawning recognition that poverty is not being reduced is forcing some rethinking, but it is proving very slow. Prominent establishment Mozambicans are speaking out. Rogério Sitoe, editor-in-chief of the government owned daily newspaper, *Noticias*, wrote a remarkable column after the 2008 riots arguing that the root cause is ‘the religious way we applaud and accept the prescriptions of the World Bank and International Monetary Fund’, when these are really ‘poison prescriptions’ (*Notícias*, Maputo, 15 Feb 2008). These prescriptions have destroyed jobs (MacMillan et al., 2003) and failed to promote agricultural development (Mosca, 2011), thus contributing to the impoverishment of the countryside and forced a migration to the cities (Silva, 2007).

The government needs its own development policy and needs to stop treating World Bank and IMF statements as if they were 'bible verses', Sitoe continued. Later that year, Professor Firmino Mucavele, formerly Chief Executive of NEPAD, argued that Mozambique's much talked–about 'green revolution' cannot be simply providing a few inputs. Instead, it requires radical changes to the entire agricultural value chain, new ways of thinking about rural development, a hugely increased role for the state, and large amounts of money. He stressed that in previous green revolutions, the entire food production chain (choice of crops, inputs, extension, production systems and marketing) went through a revolution which was totally externally financed. The state would need to provide vastly expanded extension services, step up research particularly on pests and diseases, and would have to be buyer of last resort to guarantee a market (*Noticias*, 15 Sept 2008).

Then in early 2009 open criticism of the development model was voiced by the Mozambican Forum of the Peer Review Mechanism of the African Union. In a self evaluation report for the peer review, the Forum said that 'the most credible indicators point to an increase in absolute terms in the number of people below the minimum subsistence level.' The report is caustic about economic policy, pointing to the 'notorious way the economic programme ignored the question of income distribution, which means that the principle beneficiaries of growth are concentrated in tiny groups and restricted social strata.' It goes on to cite 'the failure to prioritise job creation in economic programmes' and says that the high levels of 'unemployment result from the application of neo–liberal economic programmes, which has a constraining effect leaving many families without the minimum level of subsistence' (Fórum Nacional do MARP, 2009: 50,82).

On 17 May 2010 in a speech in Maputo, the Executive Secretary of the Southern African Development Community (SADC) and former Mozambican Finance Minister, Tomás Salomão, said western institutions have been telling African governments 'do what I say and not what I do'. Developing countries had thus been obliged 'to comply with the recipes from structural adjustment programmes, often with heavy social costs and little impact on our socio–economic development'. The risk now was that attempts would be made 'to patch up the model of "structural adjustment" which has proven to be obsolete and outdated, and does not respond to the challenges that developing countries must overcome'. Salomão feared that Africa would be faced 'with the question: do you want aid? Then do what it says on this menu. Take it or leave it. A menu which often has nothing to do with us, or is produced by intellectuals who have recently come out of banks and universities, and don't know that Africa is a continent with more than 50 countries of differing socio–cultural realities' (AIM News, Maputo, 18 May 2010).

Is such a policy change possible?

The obvious question is why the Mozambican government does not simply stand up to the donors, as the government in Malawi did? The glib answer is provided by Table 1. Malawi stood up to the donors over fertiliser and still has a marketing board; Tanzania stood up to the donors in the early 1990s, and it now has an Independent Monitoring Group for aid (Harrison et al, 2009). Malawi and Tanzania received only 60 per cent as much aid as Mozambique, per capita, which in 2008 was worth nearly $800 million to Mozambique. A 2005 evaluation of aid to Mozambique, ironically titled ‘Perfect Partners’, said boldly: ‘aid dependency does not have to entail subservience’ (Killick et al, 2005: 50). But most Mozambican leaders disagree, and think Salomão rather than Killick is right; looking over the border at Malawi and Tanzania, they conclude the subservience pays extremely well.

Frelimo’s dealings with the international community reflect a long history in which the ‘West’ was not sympathetic to it. This was shaped by the Cold War. First NATO backed Portugal’s attempt to prevent independence and decolonisation. Then Mozambique became a Cold War battlefield, and in the 1982–92 proxy war, more than one million Mozambicans died; inevitably, many in the leadership see this as an extraordinarily high price that was paid for having an independent development policy. At the end of the Cold War, the victors in Washington used the Bretton Woods Institutions to impose harsh neoliberal policies on post–socialist governments which were still not trusted. During the 1980s there were two donor strikes, in which food aid was withheld first to force Mozambique to sign an agreement with the IMF and World Bank, and then to force it to agree a structural adjustment programme (Hanlon & Smart, 2008: 10).

The next confrontation came in 1995, when the World Bank imposed an unprecedented set of ‘necessary conditions’ on its programme to Mozambique. If the ‘necessary conditions’ were not satisfied, the programme would stop, and since all aid at that time was conditional on having a World Bank programme, violation of those conditions would end all aid. Two of those conditions were particularly controversial – privatisation of state banks to consortia known to be corrupt (which bankrupted the banks and created high level corruption which still plagues Mozambique) and a liberalisation of the cashew sector (which destroyed the sector, MacMillan et al., 2003). In a debate on cashew on 24 November 1997, Prime Minister Pascoal Mocumbi told parliament that when Mozambique asks money ‘from the World Bank, the Bank imposes its conditions. Sometimes we have to accept things which are not in our interest, because there is no other way out’ (Hanlon, 2000).

The second confrontation was over a campaign pledge by Armando Guebuza in 2004 to create a Mozambican development bank. In a response similar to that in Malawi in the same year, donors said they would not allow government to create such a bank – even though Mozambique was one of few countries without a development bank, and many donors have their own development bank. The newly elected government decided not to confront the donors, and instead quietly inserted a budget line to give seven million Meticais (about $250,000 by then) to each district per year as a development fund. Donors were angry, at least partly because they simply did not notice until the budget was passed by parliament. Their response was to insist on a change in the agreement between the budget support donors and government, in which the donors would see not only the final budget, but all preliminary drafts – to insure that nothing they did not agree with was ever again snuck into the budget.

The third and most complex confrontation is the on–going struggle over ‘governance’. In his article entitled ‘Do donors promote corruption?: the case of Mozambique’, Hanlon (2004) argued that there was an implicit compromise to maintain the myth of the Mozambican success story. Both sides claim poverty reduction, Mozambique accepts imposed neo–liberal policy prescriptions and the stress on social services, and the donors turn a blind eye to corruption and state capture (Hanlon, 2004). But at another level, ‘good governance’ is now seen as opening Mozambique to transnational corporations and to prevent the support of domestic capital which has been important in all successful national developments, such as the Asian Tigers, and which Mozambique is now doing. So Frelimo’s interests are complex, allowing some theft while also trying to promote a domestic developmental capital. Frelimo tries to avoid a frontal confrontation by each year promising actions which are never actually carried out. The deal seems to still be in place, because at the 19 May 2010 annual review of budget support, Kari Alanko (2010), Finnish ambassador and head of the budget support group, said that although government performance on governance was 'unsatisfactory', that its overall performance was 'satisfactory' because of expansion of services, economic growth and inflation control.

For two decades, donors have been deeply divided on agriculture and rural development policy; their attitudes have changed rapidly and there have been divisions within agencies. But the one constant has been to keep government out of the economy and agriculture. Thus they forced the closure to the marketing board and seed production and curbed agricultural research. In 1999 the World Bank actually blocked the government from hiring more agricultural extension workers, even though the total number was only one–tenth that recommended by the FAO (Hanlon & Smart, 2008: 168). Huge tax breaks and other *defacto* subsidies are permitted for foreign investors, particularly in the mineral energy sector. One of the world's largest tobacco companies can be given exclusive rights to control tobacco production in much of the country and set up what is, in effect, a marketing board, but the state is not allowed to create a similar system for other crops.

Another key to the puzzle is that Frelimo lacks a coherent agriculture and rural development strategy. There are two reasons why Frelimo cannot think outside the box and openly debate alternatives. First, the tradition is that policy issues should be debated first inside the party and in secret, but Frelimo has been unable to build that kind of internal debate. The second is that the budget support process means that donors are deeply embedded inside all the key ministries, and thus intervene actively in all policy discussions, which makes it impossible to even consider options that donors would oppose (de Renzio & Hanlon, 2009).

But the final key rests inside the Frelimo leadership. Frelimo has always stressed big farms (Mosca, 2011). States farms in the socialist era, and now trying to encourage foreign companies to invest in big farms (often the old state farms). There has always been distrust of the better off peasants who could be commercial farmers – dismissed as 'kulaks' in the socialist era, their role is still not accepted. In this, there is a curious alignment of interest between Frelimo and the donors – both want big foreign owned plantations as a development strategy and to help 'subsistence' peasant farmers almost as a form of social welfare. The final piece of the jigsaw is that throughout the 'greed is good' 1990s, donors promoted the idea that by getting rich, the elite was promoting development. Indeed, as recently as 2006 the IMF called for 'an agricultural and rural strategy to enhance the trickling down of growth to the poorest segments of the population' (IMF, 2006). And who in the elite will argue against 'trickle down' to help the poor, when the elite gain so much from the present policy?

Donors have pushed their development model very hard, and even used the budget support process to ensure that their officials are part of drafting key Mozambican documents such as the PARPA. But the Mozambican leadership has also accepted the donor line. Thus there seems no enthusiasm on either side for a change in policy. Mozambique has been a donor darling because of a combination of two factors – subservience to donor policy combined with apparently dramatic falls in poverty. If poverty is not falling, will that force a rethink on both sides? Can Mozambique and its donors pay more attention to MDG 1 – food, income and jobs? That is related to agricultural growth and the 'green revolution', which in turn requires a recognition that markets do not spring up by magic, but instead are created by the state. Will the government try to promote markets and the introduction of subsidised new technology (on credit) which would allow peasants to produce more and raise their living standards? Both donors and government have invested huge political capital in the current failed model and change is proving to be hard.

REFERENCES

Addison, T., C. Harper, M. Prowse, A. Shepherd et al. (2008) *Escaping Poverty Traps – The Chronic Poverty Report 2008–09*. London and Manchester: Chronic Poverty Research Centre.

Alanki, Kari (2010) 'Discurso proferido por Kari Alanka, Embaixador da Finlândia, por ocasião do encerramento da Revisão Anual de 2010', statement at a public meeting (19 May 2010). Maputo. http://www.pap.org.mz/ (accessed 25 May 2010).

Arndt, C., R. James, and K. Simler (2006) 'Has Economic Growth in Mozambique been Pro-Poor?', *Journal of African Economies* 15(4), 571-602.

Arndt, C., A. Garcia, F. Tarp, and J. Thurlow (2010) 'Poverty Reduction and Economic Structure Comparative Path Analysis for Mozambique and Vietnam'. UNU WIDER Working Paper No. 2010/122. Helsinki: World Institute for Development Research.

Benfica, R. (2006) 'An analysis of income poverty effects in cash cropping economies in rural Mozambique: Blending econometric and economy-wide models'. PhD Dissertation, Michigan State University, East Lansing, MI.

Bhaduri, A. (2006) 'Structural Change and Economic Development: On the Relative roles of Effective Demand and the Price Mechanism in a 'Dual Economy', pp. 110-123 in Bhaduri (2006) Employment and Development. *Essays from an Unorthodox Perspective*. New Dehli: Oxford University Press.

Blackmon, P. (2008) 'Rethinking poverty through the eyes of the International Monetary Fund and the World Bank', *International Studies Review* 10:179-202.

Boughton, D., D. Mather, C. Barrett, R. Benfica, D. Abdula, D. Tschirley, and B. Cunguara (2007) 'Market Participation by Rural Households in a Low-Income Country: An Asset-Based Approach Applied to Mozambique', *Faith and Economics* 50: 64-101.

Buffie, E.F., and Atolia, M., 2009. Agricultural input subsidies in Malawi: Good, bad or hard to tell. FAO Commodity and Trade Policy Research Working Paper N^{o}28. Rome: FAO.

Casse, T., and S. Jensen (2009) 'Do we understand the linkages between economic growth, poverty targets and poverty reduction?', *Review of African Political Economy* 36(122): 539-53.

Castel–Branco, Carlos Nuno (2007) 'Aid and Development: A Question of Ownership'. IESE Working Paper N^{0}1/2008. Maputo: Instituto de Estudos Sócio Económicos.

Chang, Ha-Joon (2008) *Bad Samaritans: The Guilty Secrets of Rich Nations & the Threat to Global Prosperity*. London: Random House.

Cirera, X., and V. Nhate (2007) 'An empirical estimation of the degree of price transmission from border to consumer prices in Mozambique'. Research Report No. 39E, Chapter 11. Maputo: DNEAP, Ministry of Planning and Development.

Chinsinga, Blessings and Aoiffe O'Brien (2008) *Planting Ideas: How Agricultural Subsidies are Working in Malawi*. London: Africa Research Institute.

CMI Brief. Bergen: Norway, Chr Michelsen Institute. www.cmi.no (accessed 25 May 2010).

Congressional Budget Office (CBO) (1997) 'The role of foreign aid in development: South Korea and the Philippines'. CBO Memorandum, Washington DC: CBO. http://www.cbo.gov/doc.cfm?index=4306&type=0 (accessed 25 May 2010).

Cunguara, B., and Kelly, B. (2009a) 'Trends in agriculture producers' income in rural Mozambique'. Maputo. http://www.open.ac.uk/technology/mozambique/p7_1.shtml; (accessed 15 March 2010).

Cunguara, B., and Kelly, B. (2009b) 'The impact of the PARPA II in promoting the agricultural sector in rural Mozambique'. Maputo. http://www.open.ac.uk/technology/mozambique/p7_1.shtml; (accessed 15 March 2010).

Cunguara, B., A., Langyintuo, and I. Darnhofer (2011) 'The role of nonfarm income in coping with the effects of drought in southern Mozambique', *Agricultural Economics*. (in press).

Cunguara, B., and I. Darnhofer (2011) 'Assessing the impact of improved agricultural technologies on household incomes in rural Mozambique', *Food Policy* 36(3): 378-90.

Cunguara, B., and K. Moder (2011) 'Is agricultural extension helping the poor? Evidence from rural Mozambique', *Journal of African Economies*. (in press).

de Renzio, P., and J. Hanlon (2009) 'Mozambique: Contested Sovereignty? The Dilemmas of Aid Dependence', in Lindsay Whitfield (ed) (2009) *The Politics of Aid: African Strategies for Dealing with Donors*, Oxford: Oxford University Press.

Dollar, D., and A. Kraay (2002) 'Growth is good for the poor', *Journal of Economic Growth* 7:195-225.

Donaldson, J. (2008) 'Growth is good for whom, when, how? Economic growth and poverty reduction in exceptional cases', *World Development* 36(11): 2127-43.

Eicher, C.K. (2002) 'Mozambique: An Analysis of the Implementation of the Extension Master Plan'. Staff Paper 2002–31. East Lansing: Michigan State University.

Fórum Nacional do MARP (2008) 'Mecanismo Africano de Revisão de Pares, Relatório de Auto–Avaliação do País'. Maputo. www.marp.org.mz (accessed 18 March 2010).

Grupo de Estudo de Aprofundamento na área de Nutrição (2009) 'Relatório de Avaliação de Impacto do PARPA II 2006–2009'. Maputo. http://www.open.ac.uk/technology/mozambique/p7_1.shtml (accessed 15 March 2010).

Handa, S., and G. Mlay (2006) 'Food consumption patterns, seasonality and market access in Mozambique', *Development Southern Africa* 23(4): 541-60.

Hanlon, J. (2000) 'Power without Responsibility: the World Bank & Mozambican Cashew Nuts', *Review of African Political Economy*, 83: 29–45.

Hanlon, J. (2004) 'Do donors promote corruption?: the case of Mozambique', *Third World Quarterly* 25(4): 747–63.

Hanlon, J. (2010) 'Mozambique: the war ended 17 years ago, but we are still poor', *Conflict, Security & Development* 10(1): 77–102.

Hanlon, J., and T. Smart (2008) *Do Bicycles Equal Development in Mozambique*?, Woodbridge, Suffolk, UK: James Currey.

Harrison, G., S. Mulley and D. Holtom (2009) 'Tanzania: A Genuine Case of Recipient Leadership in the Aid System?', in Lindsay Whitfield (ed) (2009) *The Politics of Aid*, Oxford: Oxford University Press.

Hesselbein, G. (2010a) 'The Economic Foundations of State–Building and State–Failure: A Political Economy of Sub–Saharan African States', forthcoming.

Hesselbein, G. (2010b) 'Economic Resource Mobilisation in DR Congo, Rwanda, Tanzania and Zambia: The Case of Agriculture', paper presented at a seminar of the: Crisis States Research Centre, London School of Economics.

IMF (International Monetary Fund) (2006) 'Country Report No. 06/46: Republic of Mozambique: Third review under the three–year arrangement under the poverty reduction and Growth Facility'. Washington DC: IMF. http://www.imf.org/external/pubs/cat/longres.cfm?sk=18874.0 (accessed 31 May 2010).

IMF Survey Magazine, Washington: IMF.

INE (Instituto Nacional de Estatística) (2010) Área de Estatística: Produto Interno Bruto. http://www.mozdata.gov.mz/pxweb2007/Database/INE/00/54/54.asp. (accessed 5 June 2010).

Kalecki, M. (1976) 'Problems of Financing Economic Development in a Mixed Economy', pp. 98-115 in M. Kalecki, *Essays in Developing Economies*. Brighton: Harvester Press.

Kelly, B. (2009) 'Trends in child poverty in Mozambique. A deprivations–based approach'. Maputo: Government of Mozambique and UNICEF Mozambique. http://www.open.ac.uk/technology/mozambique/p7_1.shtml (accessed 15 March 2010).

Killick, T., C. Castel-Branco, and R. Gerster (2005) 'Perfect Partners? The performance of programme aid partners in Mozambique 2004'. Report to the Programme Aid Partners in Mozambique. London: DFID.

MacMillan, M., K. Horn, D. Rodrik, I. Elbadawi, S. O'Connell (2003) 'When economic reform goes wrong: Cashews in Mozambique', *Brookings Trade Forum*, pp.97-165.

Mather, D. (2009) 'Measuring the impact of public and private assets on household crop income in rural Mozambique, 2002-2005'. MINAG Working Paper n. 67E. Maputo: Ministry of Agriculture.

Mather, D., B. Cunguara, and D. Boughton (2008) 'Household income and assets in rural Mozambique, 2002–2005: Can pro–poor growth be sustained.' MINAG Working Paper no. 66E. Maputo: Ministry of Agriculture.

Mosca, J. (2011) *Políticas Agrárias de (em) Mocambique (1975-2009)*. Lisboa: Livraria Escola Editora.

MPD/DNEAP (2010) 'Poverty and well–being in Mozambique: the third national assessment (2008–9)'. Maputo: Ministry of Planning and Development.

OECD (2011) 'Accelerating progress towards the MDGs through pro-poor growth policy messages from the DAC network on poverty reduction (POVNET)'. OECD Policy Brief. http://www.oecd.org/dataoecd/5/24/45132965.pdf (Accessed 27 May 2011).

Poulton, C., J. Kydd, S. Wiggins and A. Dorward (2006) 'State Intervention for Food Price stabilisation in Africa: Can It Work?', *Food Policy* 31(4): 342-56.

Silva, J. (2007) 'Trade and income inequality in a less developed country: The case of Mozambique', *Economic Geography* 83(2): 111-36.

Skarstein, R. (2005) ‘Economic liberalization and smallholder productivity in Tanzania: from promised success to real failure, 1985-1998’, *Journal of Agrarian Change* 5(3), 334-62.

Sonne-Schmidt, C., C.Arndt, and M. Magaua (2009) ‘Contribution of Mega-Projects to GPD in Mozambique.’ Paper presented at the II IESE Conference on “Dinâmicas da Pobreza e Padrões de Acumulação Económica em Moçambique.” Maputo, 22-23 April 2009.

Tostão, E., and B. Brorsen (2005) ‘Spatial price efficiency in Mozambique’s post-reform maize markets’, *Agricultural Economics* 33(2): 205-14.

Tostão, E., and D. Tschirley (2010) ‘On the role of government in food staples markets: Perspectives from recent research and implications for Mozambique’. Flash n. 54. Maputo: Ministry of Agriculture.

UNDP (United Nations Development Programme) (2009) *Human Development Report 2009*. New York: UNDP.

Virtanen, P. and D. Ehrenpreis (2007) ‚Growth, Poverty and Inequality in Mozambique’. Country Study 10. Brasilia: International Policy Centre for Inclusive Growth.

Zavale, H., G. Mlay, D. Boughton, A. Chamusso and P. Chilonda (2009) ‘The Structure and Trend of Agricultural Public Expenditure in Mozambique’. *ReSAKSS Southern Africa Working Paper.* Pretoria: International Water Management Institute.

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Trends in food security in rural Mozambique, 1996/2008

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1 Introduction

In 1992 about 83 percent of Mozambicans subsisted on food aid, largely because of war and drought (Tschirley et al., 1996). Since then nearly two decades have elapsed and a series of floods and droughts that occurred in the 2000s have left many rural households continuing to subsist on grain imports and food aid. This has caused Mozambique to be one of the largest recipients of global food aid flows (Abdulai et al., 2004). The worldwide food crises of 2007 and 2008 did not help the situation either, particularly in the southern provinces of Mozambique, a region dependent on grain imports due to lower crop potential (Arndt, et al., 2008; Tschirley and Jayne, 2010).

At the national level, it is estimated that an overwhelming 34 percent of the population is facing chronic hunger (WFP, 2010). There is, however, some evidence of glimmers of hope. To enable food purchases and dampen volatility in grain prices, the Mozambican government recently constructed silos with 50,000 metric ton capacity for grain storage in Tete province and there are plans to expand silo capacity to 143,000 metric tons by 2011 (Tschirley and Abdula, 2007; Tostão and Tschirley, 2010). In addition, there are some improvements in marketing infrastructure such as the bridge in Caia district, linking surplus agricultural production areas in the north to food markets in food deficit areas of the south (Tschirley and Jayne, 2010).

The government of Mozambique has developed a poverty reduction strategy paper (hereafter referred to by its Portuguese acronym PARPA, *Plano de Acção para a Redução da Pobreza Absoluta*), that has the potential to enhance food security through various mechanisms. For example, plans for more investments in irrigation, market infrastructure, extension services, commodity price information, animal traction, and other improved technologies are likely to increase crop yields (Mather, 2009). Also, investments in road infrastructure and education could reduce transaction costs in agricultural marketing and increase household cash incomes through the creation of rural non-farm employment.

While food security is a widely used concept that needs to be addressed in rural Mozambique, there is a longstanding debate on its measurement. Many indicators have been proposed, such as the dietary diversity index, coping strategies index, household caloric acquisition and individual intakes, among others (Maxwell and Frankenberger, 1992; Riley and Moock, 1995; Barrett, 2002). This is because food security entails multiple features such as the availability, access, and utilization of food that cannot easily be captured by a single measure, (Webb et al., 2006; Barrett, 2010). In this paper, food security is primarily measured by the amount of calories available to households in rural Mozambique, based on the dietary needs of each household member.

Two sources of caloric acquisition are considered, namely household own food production and household food purchases. The former has been shown to be negatively affected by low levels of farm productivity (Howard et al., 2003; Fulginiti et al., 2004). For instance, maize yield (the most important staple crop in Mozambique) is estimated to be 1.4 tons ha^{-1}; far below the potential yield of 5.5-6.0 tons ha^{-1} (Howard et al., 2003). This low level of productivity is intertwined with various factors, such as poor farmer health during the late dry season and at the beginning of the cropping season and HIV/AIDS related prime-age mortality (Abellana et al., 2008; Jayne et al., 2010); market failures in agricultural commodity and credit markets (Mather, 2009); very limited use of improved agricultural technologies

(Mather et al., 2008); and the occurrence of cyclical floods and droughts (Joubert and Tyson, 1996; Usman and Reason, 2004).

The second source of caloric acquisition that is considered in this manuscript is the amount of calories obtained through food purchases and this significantly depends on cash income available to the rural households, which in turn depends mainly on access to non-farm employment opportunities (Cunguara and Hanlon, 2010). Such opportunities have been shown to differ by geographical region, with households in the southern provinces having better access to non-farm activities due to better road infrastructure, relatively higher remittances, which can be invested in some non-farm activities (Walker et al., 2004), and better education levels (Government of Mozambique, 2006). Meanwhile, households in the central and northern provinces rely more on agricultural production, partly because of greater agricultural potential in these areas. Differences in geophysical, social, natural, and human capital in these areas are reflected in the differences in food security levels and poverty (Heltberg and Tarp, 2002; Donovan and Tostão, 2010).

The objective of this paper is twofold. First, using the national agricultural surveys from rural Mozambique, described in more detail in section two, the paper evaluates if PARPA has been effective in enhancing agricultural production and creating non-farm employment opportunities to address food security challenges in rural Mozambique. The focus is on PARPA II, which covers the period between 2006 and 2009, although the data used refer to a longer period (1996/2008) to better identify trends.

The evaluation starts in section three by tracking some of the agriculture-related targets set forth in PARPA, and relates these targets to food insecurity in rural Mozambique. The relevance of market participation both as a source of caloric acquisition through food purchases and as a potential source of income through farm output sales, justifies the discussion in section four on the priority agenda of output market participation. Given that the amount of calories acquired through food purchases often constitutes a greater proportion of total caloric intake and is highly dependent on cash income, section five addresses the relationship between cash incomes and other poverty measures that affect food security, while concluding the evaluation of PARPA with a heretical commentary on its success.

The second objective of this manuscript is covered in section six, and entails an econometric analysis of factors associated with food insecurity in rural Mozambique. This section first provides details on how the food security measure was constructed, while discussing its strengths and recognizing its weaknesses, then presents a Probit model estimated for each region (south, central, and north). The analysis is further disaggregated based on select household characteristics. Finally, section seven concludes with policy recommendations that are relevant for PARPA III, which will cover the period 2010-2014.

2 Data description and sources

The data analyzed were drawn from all available national agricultural surveys in Mozambique, commonly known as TIA, which is the Portuguese acronym for *Trabalho do Inquérito Agrícola*[5]. The surveys were conducted by the Department of Statistics within the Directorate of Economics of the Ministry of Agriculture. The TIA samples are stratified by province and agro-ecological zone, making them representative at both levels. Therefore, all results presented in this paper are population-weighted to account for the stratified sampling. Sample size varies between 3891 households in 1996 and 6248 households in 2006. The surveys differ slightly in terms of the questions that were asked. For example, the data on use of improved seeds and access to credit were only collected starting in 2005. Also, specification of the crops that received fertilizer application was only recorded in the latest round of surveys, TIA08.

Worth noting is that TIA96 had serious methodological drawbacks. Most importantly, the data on cassava production, the second most important crop in Mozambique, were collected using a single recall question. This is inadequate for a crop that is harvested several times throughout the year. Therefore, TIA96 data are used sparingly in this study. TIA02, TIA05, and TIA08 are the three most comprehensive surveys. They combine the annual household demographic and agricultural and livestock production components with detailed data on household income components. Total household incomes are obtained from five sources, namely livestock sales, remittances and pensions, wages, self-employment earnings, and crop production. Meanwhile, cash income refers to all cash received by the household (e.g. salaries in cash, crop and livestock cash sales, net revenues in cash from small businesses, and cash transfers).

TIA02, TIA05, and TIA08 also provide data on non-farm activities. These include (i) unskilled agricultural wage on small or large farms; (ii) unskilled non-agricultural wage (e.g. domestic worker); (iii) skilled or specialized non-agricultural wage (teaching, management positions, government clerk, trained non-agricultural workers with at least 10 years of schooling, and mining); (iv) extraction of flora and fauna products of low returns, which includes cutting firewood, sticks, grass and palm tree leaves, collecting honey and bush fruits, and hunting; (v) extraction of flora and fauna products of high returns, which comprises charcoal production and fishing; (vi) other self-employment activities of low returns, which includes handcrafting, carpentry, cloth making, bicycle and radio repairing, blacksmith, and brick production; and (vii) other self-employment activities of high returns, such as production and sale of home-made beverages, trading in food and non-food products, trading in livestock, agro-processing and milling activities.

All income data were inflated to 2008 prices and for consistency and comparability purposes, the inflators used to adjust the 2005 income levels to 2008 prices are similar to those described in Mather et al. (2008), where 2002 income levels were inflated to reflect the prices in 2005. Household consumption quantities, defined in terms of the food basket in the region-specific consumption expenditure surveys (IAF), were also used in adjusting incomes. These consumption quantities were valued using 2002 Agricultural Market Information Systems (SIMA) retail prices, then the basket was revalued with 2005 and 2008 SIMA prices to update the cost of an identical (fixed) consumption basket. The consumption quantities are therefore weights for the commodity prices. Thus the inflators were fixed because the weights were not allowed to change over time.

[5] A brief description of the TIA surveys can be found at the following website address: http://www.aec.msu.edu/fs2/mozambique/survey/index.htm

3 Tracking PARPA's achievements on agriculture-related targets

Descriptive analysis of the TIA data show that between 2005 and 2008, the coverage of extension services in rural Mozambique steadily declined (Table 1). This was partly because extension workers did not have fuel for their motorbikes. Similarly, the market information system recently experienced a decline in funding available to pay for radio broadcasts (Mather, 2009), which resulted in a decline in the percentage of households receiving price information. This suggests that PARPA did not provide adequate support for public market information services, which farmers and rural traders could have taken advantage of to improve their incomes and food security.

Table 1 Evolution of some of the agriculture-related indicators set in PARPA

	TIA96	TIA02	TIA03	TIA05	TIA06	TIA07	TIA08
Received extension visits (%)	NA	13.53	13.52	14.77	11.97	10.15	8.27
Farmers' association (%)	NA	3.67	4.45	6.39	6.50	8.25	7.22
Received price info (%)	NA	34.52	47.15	40.32	36.27	33.12	34.19
Hired seasonal labour (%)	NA	15.51	15.32	17.60	23.81	20.76	19.57
Used chemical fertilisers (%)	1.26	3.72	2.46	3.76	4.58	3.63	3.02
Used chemical pesticides (%)	NA	6.76	5.12	5.41	5.29	6.51	2.60
Used poultry vaccine (%)	NA	1.92	3.22	3.00	4.12	NA	4.39
Used animal traction (%)	6.55	11.22	10.90	9.29	12.38	11.48	10.92

Source: Authors' calculations based on all available TIAs
Notes: NA – Not available

Statistics on land tilling methods show a slight decline in the use of animal traction in recent years. Due to the occurrence of trypanosomiasis disease, animal traction is limited to the southern provinces and few villages in central provinces. Dipping services are sparse because many dip tanks were destroyed during the war and have not been rehabilitated. In addition, there is a shortage of staff (i.e., dip tank attendants) and a lack of accessible water to operate the dip tanks (Alfredo et al., 2005). Little effort has been made to address trypanosomiasis disease and expand the use of animal traction in high agricultural potential zones. It is revealing that animal traction is not mentioned at all in PARPA II, despite its potential to increase crop production (Pingali et al., 1987; Mather, 2009). An effective measure of dealing with trypanosomiasis could be the combination of dipping services, application of vaccines in endemically unstable conditions, and the use of tick-resistant breeds of cattle (Norval et al., 1992). The use of tractor mechanization is another alternative, but only two percent of farmers currently use tractors in rural Mozambique and mostly in areas of lower agricultural production potential.

Statistics from the TIA data also show that agricultural production is unevenly distributed. In the case of maize, the bottom quintile accounted for less than two percent of total production, while the top quintile accounted for more than half the total production. This pattern barely changed between 1996 and 2008. Overall, total maize production was five percent higher in 2008, relative to 2002, but a trend could not be discerned because of high fluctuation in production (Table 2).

On the one hand, households in higher quintiles achieved higher production levels because they cultivated larger areas of land (i.e., technical efficiency). On the other hand, they also had higher productivity levels because their production increased at a faster rate than the increase in cropped area when moving from a lower quintile to the upper quintiles (i.e., allocative efficiency). For example, total maize production in the top quintile in 2008 was approximately 44 times greater than that in the bottom quintile (Table 2), but total cropped area (of maize and all other crops) was roughly two times greater (last column of Table 3).

Table 2 Share of maize production by farm size and year (percentage of total maize grown)

Year	Quintiles (%)					Total production (Tons)
	Bottom	2	Mid	4	Top	
1996	1.78	5.29	9.51	20.06	63.36	919,644
2002	1.23	5.62	11.49	22.45	59.21	1,155,538
2003	0.97	5.16	11.83	22.24	59.81	1,145,303
2005	0.14	3.90	10.54	22.60	62.82	945,831
2006	1.39	5.71	11.26	22.85	58.78	1,469,087
2007	0.86	5.22	11.35	22.29	60.29	1,133,306
2008	1.39	5.49	12.30	20.17	60.65	1,214,255

Source: Authors' calculations based on all available TIAs
Notes: Farms have been ranked in quintiles by the total amount of maize produced

Both the mean and median per capita cash income increased significantly between 2002 and 2005, which is in line with the increase observed in household incomes during the same period (Mather et al., 2008; Cunguara and Kajisa, 2009; Cunguara, 2009), but decreased in the following period. The results also show a large variation in cash income both across time and quintiles of maize production (see Table 3). Moreover, there is a considerable disparity between the mean and the median, which reflects a high degree of skewness in the distribution of per capita cash income among rural households.

Table 3 Annual per capita cash income by quintile of total maize production and year

Quintile of total maize production	Median per capita cash income in 2008 US$			Mean per capita cash income in 2008 US$			Mean cropped area in 2008
	2002	2005	2008	2002	2005	2008	
Bottom quintile	9.61	22.41	21.15	72.85	94.27	100.22	1.29
2	10.60	26.19	18.94	66.23	113.40	75.05	1.45
Middle quintile	13.18	28.30	21.67	81.61	104.18	88.78	1.63
4	22.88	36.09	31.37	99.82	118.28	90.12	2.05
Top quintile	41.48	86.87	58.46	152.01	200.16	174.50	3.15
Total	16.30	34.44	25.38	90.89	123.47	102.71	1.83

Source: Authors' calculations based on TIA08
Notes: Unofficial exchange rate $1 = 26 Meticais;

Among the top quintile households, productivity levels increased because households engaged in non-farm income generating activities more often, and hence had cash to purchase improved farm inputs. Households in the top quintile also used fertilizers about 14 times more frequently than their counterparts in the bottom quintile. In addition, households in the top quintile were found to employ a considerable amount of non-family labor, suggesting that they also helped other households to move out of poverty (Table 4). Ellis and Freeman (2004) have argued that the success of poverty reduction strategy plans such as PARPA in reducing poverty in Africa is related to their ability to stimulate creation of employment opportunities and generating creative solutions for technical extension and market infrastructure development.

Table 4 The use of improved technologies, hired labour, and access to public services by farm size in 2008

Quintile of total maize production	Percentage of households					
	Improved maize seeds	Chemical fertilisers	Animal traction	Receipt of extension	Receipt of price info	Hired seasonal labour
Bottom quintile	8.20	0.75	15.25	4.93	28.93	11.48
2	8.21	1.42	16.60	6.51	34.27	17.83
Middle quintile	9.29	2.63	12.99	9.03	36.65	17.91
4	11.43	7.37	14.24	9.49	39.01	25.78
Top quintile	12.74	10.25	19.86	12.20	44.20	34.47
Total	9.74	4.00	15.62	8.11	35.93	20.41

Source: Authors' calculations based on TIA08

Notes: Analysis restricted to maize growers, 78% percent of the total sample
Farms have been ranked in quintiles by the total amount of maize produced

4 Participation in the output market

Most smallholder farmers were found to be net buyers of food but participated in food markets as both buyers and sellers, depending on the season. Usually smallholder farmers sell their produce right after harvesting season (between May and July) at prices that are significantly lower than the food prices they pay when they participate as buyers during the dry season (Stephens and Barrett, 2008). Profitable participation in the output market has been linked to participation in input markets and the use of storage and post-harvest marketing services. For example, Howard et al. (2003) show that in Mozambique farmers using improved maize seeds earn 24 percent more than non-users if they are able to delay their maize sales until November.

The type of crops as well as the amount sold varied significantly by farmer's income. The poorest farmers, defined as those in the lowest quintile of per capita cash income, tended to sell staple crops such as maize, whereas wealthier farmers sold cash crops in addition to staple crops (see Table 5). Of note is that once the farmer was able to sell, the poorest would sell extremely low quantities compared to wealthier farmers. It is also interesting to note that farmers in the top quintile did not sell cotton (a traditional cash crop in Mozambique) as frequently as those in the other quintiles, except the bottom quintile. This finding lends support to previous results in Pitoro et al. (2009), where non-cotton growers were found to be wealthier than cotton growers. Conversely, farmers in the bottom quintile rarely cultivated tobacco or sesame, and thus could not sell tobacco in 2008.

There are also regional differences in output market participation. Maize and cotton were sold more frequently in the northern provinces, whereas sales of tobacco, sesame, and tomatoes[6] was predominant in the central provinces. However, farmers in the central provinces had the largest volumes of sales, including sales of maize and cotton. The quantity of tobacco sold in the southern provinces (reported in Table 5) can be misleading because a closer look at the data shows that there were only three large sellers, and all of them were located in Maputo province. The relatively lower quantities of maize sold in the northern provinces, despite its agricultural potential, could be associated with poor road infrastructure and low market access. Indeed, the development of rural markets is identified by the government as one of the main challenges in promoting rural development (Government of Mozambique, 2006: p70).

[6] Tobacco and sesame are two of the most important cash crops in Mozambique, while tomatoes are the most widely sold horticultural crop.

Table 5 Output market participation by quintile of per capita cash income, region and crop in 2008

Quintile/ region	% of households who sold the following crops*					Mean quantity sold in kilograms per household				
	Maize	Cotton	Tobacco	Sesame	Tomatoes	Maize	Cotton	Tobacco	Sesame	Tomatoes
Bottom	5.01	0.46	0.00	0.44	1.13	59.89	42.45	-	18.73	197.20
2	17.65	4.87	0.39	5.35	2.57	132.96	213.12	44.74	51.23	309.24
Mid	20.38	6.54	2.20	7.38	4.50	192.60	448.85	198.73	83.35	520.15
4	19.64	4.54	4.25	9.02	5.87	301.38	658.27	369.64	112.66	1,471.00
Top	18.87	2.38	4.89	7.74	5.23	952.20	1,041	986.04	407.43	2,088.28
North	20.45	5.01	2.20	6.12	2.85	228.54	416.87	409.40	131.98	585.07
Centre	14.05	3.53	3.72	9.49	6.50	802.42	730.17	745.75	197.54	1,806.01
South	4.88	0.17	0.11	0.00	3.07	182.77	33.90	1,412	-	827.23
Total	16.21	3.82	2.21	5.88	3.77	346.79	484.13	555.22	157.63	1,129.19

Source: Authors' calculations based on TIA08

Notes: * The percentages are based in the whole sample, including those who did not cultivate the crop. If non-growers were excluded from the analysis, there wouldn't be any variation, i.e., the percentages would be similar across quintiles. For instance, 159 farmers sold tobacco out of 167 growers;

Farms have been ranked in quintiles by the per capita household income.

Rural development and food security would benefit from policies and programs that address missing rural financial markets and other limiting factors, such as access to animal traction (Boughton et al., 2007). Unfortunately, analysis of the TIA data shows a statistically significant decline in rural households' access to credit, from 2.9 percent in 2006 to 2.6 percent in 2008. The limited access to credit is also highly skewed, with the poorest households having no access at all. While government has been providing funds for investment into local credit initiatives at the district level, the selection criteria used to allocate these funds is unclear and its impact on beneficiaries is still unknown.

Rural development programs should also include investments in road infrastructure and market information, which are necessary but not sufficient conditions for increasing crop market participation at this early stage of Mozambique's smallholder agricultural development (Boughton et al., 2007). This is consistent with the result found in Cunguara and Darnhofer (2010), where road infrastructure played a crucial role in the profitability of the use of improved technologies. However, the relationship between market infrastructure and the adoption of improved technologies is barely explored in PARPA. Instead, the government expects the private sector to co-participate in the investment of market infrastructure through what is called "the development of public-private partnerships" (Government of Mozambique, 2006: p126).

Since not all smallholders are likely to be commercially viable in the short to medium term, households that cannot build the necessary asset portfolios may fail to escape poverty through output market participation. Therefore, there will be a need for policies and programs that enable more remunerative participation of such households in non-farm labor markets and entrepreneurial opportunities (Boughton et al., 2007). Since poor households are often confined to low return non-farm activities, breaking barriers to entry in high return non-farm activities will be critical. This may require substantial investments in education (Reardon, 1997), which can only be accomplished in the medium to long-term.

Rural markets could also take advantage of the current rapid changes in communication technologies and the rapid spread of mobile phones. There is an opportunity in the market information system to develop innovative services that rapidly and efficiently deliver information to farmers (see for an example, Aker, 2008 for the case of Niger). Sadly, as evinced by the results in the previous section, government investment in the market information system has recently declined, perhaps because of government's belief that the private sector has enough incentives to co-participate.

5 Cash income, assets, and farmers' perceptions of economic conditions

As much as it is challenging to improve food security, measuring it is an equally difficult task. The results presented so far suggest that household incomes did not improve between 2002 and 2008. During the same period, official poverty estimates for rural areas suggest an increase in poverty headcount from 55 percent to 58 percent. Although both the TIA surveys and the official poverty estimates show no improvements, it is important to look at other welfare measures to determine if a similar pattern exists. One such measure is the household's perception of the present economic condition, relative to that of three years before. In 2008, households were asked whether their economic condition had improved since 2005, and in 2005 the same question had been asked, relative to 2002, and so on. Figure 1 illustrates the results on these perceptions. In 2005 there were significantly more households that perceived a worsening economic condition, relative to 2002. This result may be explained by the excessive drought of 2005. Mozambique frequently suffers from both floods and droughts in the same agricultural year, but in 2005 the drought was much more severe (especially in the southern provinces).

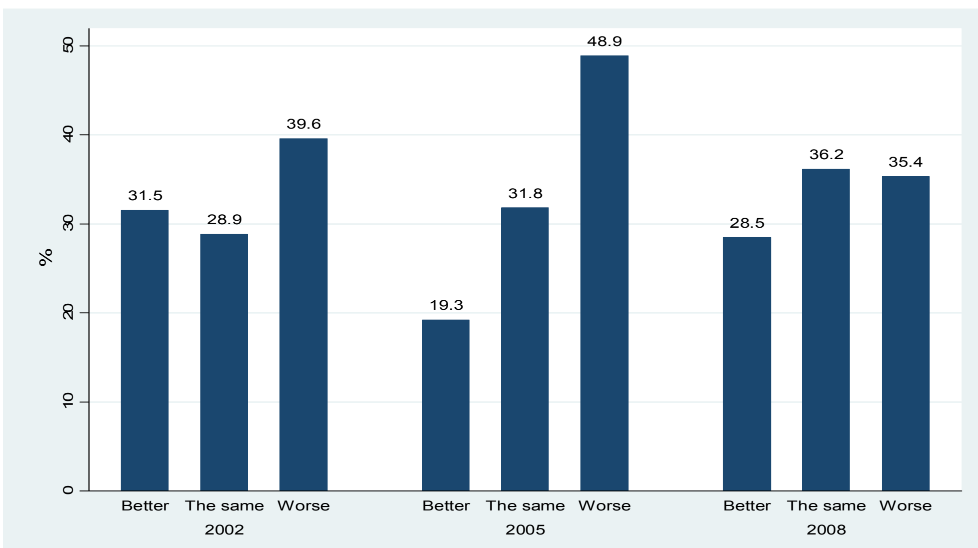

Figure 1 Household perception of the economic condition, relative to three years before

In 2008 households perceived their economic conditions as significantly better than in 2005, but not as good as in 2002. This suggests that overall, between 2002 and 2008, their economic condition had worsened. Results on perceptions are consistent with household welfare trends. However, they may seem paradoxical since data on asset ownership (e.g. bicycles) show improvements (Figure 2). Researchers have asked the question whether the increase in bicycle ownership is really indicative of poverty reduction and concluded that it is not necessarily the case (Hanlon and Smart, 2008). A prominent explanation has to do with asset distribution.

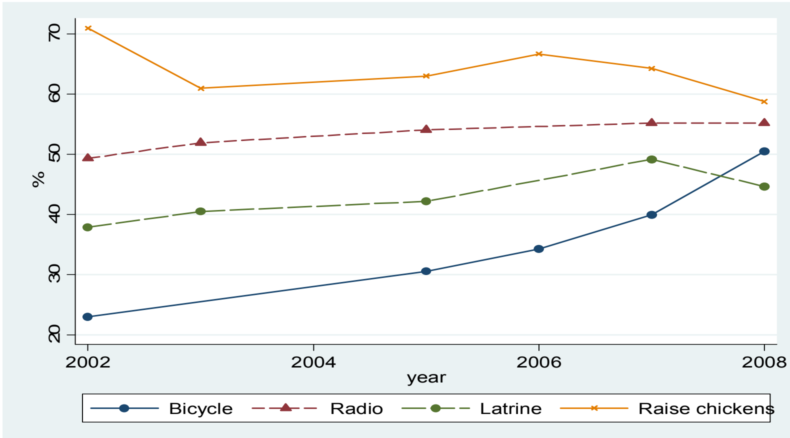

Figure 2 Percentage of ownership of selected assets by year

Other assets were equally considered, such as cropped area, type of housing, and ownership of chickens (Table 6). The percentage of households raising chickens has declined, especially among the lowest three quintiles of per capita cash income. While the top two quintiles experienced a decline between 2002 and 2005, in 2008 there were more households raising chickens among these two groups, relative to 2005. One reason for the decline in the number of households raising chickens could be the occurrence of Newcastle disease. A study conducted in 11 villages in the southern province of Gaza found that "unvaccinated chickens are approximately five times more at risk to die of Newcastle disease" (Harrison and Alders, 2010). However, in 2008 only four percent of farmers vaccinated their chickens (see Table 1).

In terms of cropped area, all quintiles experienced an increase between 2002 and 2005, which is consistent with changes observed in household incomes between these two periods. However, in the period 2005 to 2008 all quintiles experienced a decline in the cropped area, and the decline was relatively greater among the lowest quintiles of per capita cash income. A similar pattern recurs for the type of housing in rural Mozambique. Although on average the percentage of households with thatched roofs has declined, the change was greater among the top quintile.

Table 6 Asset ownership by quintiles of per capita cash income and year

Quintiles of per capita cash income by year	% HH raising chickens			Mean cropped area (hectares)			% HH with thatched roof		
	2002	2005	2008	2002	2005	2008	2002	2005	2008
Bottom quintile	60.80	58.23	50.37	1.14	1.60	1.42	87.04	88.27	82.99
2	72.10	65.63	58.77	1.17	1.80	1.63	93.19	88.98	89.49
Mid quintile	75.95	66.10	59.03	1.33	1.98	1.83	91.97	87.40	83.61
4	77.10	63.10	64.02	1.54	2.04	1.93	88.95	79.92	77.90
Top quintile	68.57	61.77	62.53	1.59	2.32	2.20	74.90	68.34	55.28
Total	70.97	63.02	58.76	1.34	1.92	1.77	87.87	83.54	78.82

Source: Authors' calculations based on TIA08

Some assets show a positive trend (type of houses, bicycle and radio ownership), but most of the improvements are concentrated among the relatively wealthy households. Looking at household incomes, asset ownership, and household's own perception of the economic condition based on TIA data, and the official poverty estimates, a similar pattern can be identified. Between 2002 and 2008, the interventions set forth in PARPA did not significantly enhance household incomes, consumption, and asset accumulation among the poor.

6 Measuring food security

The use of caloric acquisition as a measure of food security has been criticized for two main reasons. First, it is not possible to uncover intra-household allocations of food (Hoddinott, 1999). Second, by focusing on macronutrient such as the caloric sufficiency, micronutrient deprivation is ignored, although it is just as serious an issue (Barrett, 2002). Nevertheless, in a country where 44 percent of the population suffers from chronic malnutrition (low height for age or stunting) and about a third faces chronic hunger (Grupo de Estudo, 2009; WFP, 2010), the lack of macronutrients is likely to be a reasonable indicator of food security.

Rural households can be defined as food secure if they are able to obtain the required calories either from their own production or purchase of food, although other food sources may exist, such as food aid. In this paper, the focus is on the first two food sources assuming that food aid is only made available when farmers are food insecure and unable to obtain the required calories either from agricultural production or purchase of food. Thus, the following equation is estimated, indicating whether or not a household is food insecure ($food^s = 1$ if food secure, and 0 otherwise):

$$food^s = D * [(Q_r + fs * Y_{cash}/P_{retail}) \geq Cal_{req}] \quad (1)$$

where fs is the share of food expenditure, and varies between 0.7 in Maputo province to 0.8 in Tete and Manica provinces, depending on the household location (MPF/UEM/PU, 2004: p37). D is a dummy variable taking on the value of one if the left hand side of the inequality is unsatisfied, and zero otherwise. Q_r & Cal_{req} represent the amount of calories produced and retained for home consumption, and household caloric requirements, respectively. Y_{cash} is the total cash income, and P_{retail} is the maize retail price from SIMA.

The above proposed measure of food security captures two aspects, namely the availability and access to food. Some households are likely to obtain most of their caloric requirement through purchase (e.g., tobacco producers and households whose head is relatively more educated) either because they allocate relatively smaller portions of their land to crop production or due to their greater participation in non-farm income generating activities. Others are likely to meet their caloric needs exclusively from own crop production (and food aid) because they are completely subsistence farmers without any cash income.

A food composition table was used to convert the physical quantities of food that were retained by the household for home consumption. The crops used in this computation included: grains (maize, rice, sorghum, and millet); pulses (peanuts, cowpeas, common beans, pigeon peas, green beans, mung beans, and earth peas); and roots and tubers (sweet potatoes and cassava). These crops represent the overwhelming majority of Mozambican peasant production[7]. Likewise, cash incomes were converted into caloric values using SIMA maize prices, and added to the retained calories from farmers' own production. Median provincial prices were used to account for regional differences in prices. The analysis was restricted to TIA02, TIA05, and TIA08 because other TIAs did not collect information on cash income sources, with the exception of TIA96, which was excluded

[7] Horticultural crops were not included in the computation of caloric availability because horticultural yield data are not collected by the agricultural surveys used in this paper.

because the data on cassava production are not reliable, as previously explained in section 2.

Table 7 shows that food insecurity was lowest in 2002, but has been increasing ever since. About 43 percent of rural households were food insecure in 2002, which implies that they had to rely on food aid. In 2008 the percentage of households in need of food aid had increased to approximately 48 percent. These results resonate well with the official poverty incidence estimates in rural Mozambique, which show an increase from 55 percent in 2002 to 57 percent in 2008 (MPD, 2010).

The results also show that an overwhelming majority of households in the bottom three quintiles were food insecure. As expected food insecurity decreases, as one moves from the bottom quintile to the upper quintiles, but the change is noticeably greater from the fourth to the top quintile. This is because the median per capita cash income in the top quintile is about twice as high as the median among households in the fourth quintile (See Table 3), and maize production is about three times higher among those in the top quintile (Table 2). Therefore, food security strategies are likely to differ between households in the top quintile and those in the bottom four quintiles.

Table 7 Percentage of food insecure households by year

Quintiles of total maize production	Percentage of food insecure households			Food security gap per capita/day in 2008 US$		
	2002	2005	2008	2002	2005	2008
Bottom quintile	55.81	61.09	60.38	0.10	0.11	0.11
2	52.96	56.55	59.63	0.08	0.09	0.09
Middle quintile	46.43	48.47	51.35	0.07	0.09	0.08
4	37.33	42.24	41.32	0.05	0.07	0.05
Top quintile	12.18	14.43	16.39	0.04	0.05	0.04
Total	42.93	45.44	47.79	0.08	0.09	0.08

Source: Authors' calculations based on TIA08
Notes: Farms have been ranked in quintiles by the amount of maize produced.

In order to close the food security gap, each Mozambican in rural areas needs an average of \$0.08 per day. This might seem very low at first glance, but is actually greater than the median per capita cash income per day in 2008 (See Table 3: \$25.38/365days=\$0.07), and is also roughly about a quarter or a fifth of the official poverty line, depending on the region in the country. For those in the bottom quintile, adoption of improved technologies alone might not be sufficient to close this gap. A family of five, the average household size in rural Mozambique, would have to adopt an improved technology that increases their incomes by about \$241 per year, almost 10 times the median cash income in 2008, which seems difficult. In addition to the adoption of improved technologies, farmers in the bottom quintile would have to expand their cropped areas, while seeking employment opportunities outside the agricultural sector. In turn, those in the top quintile can either adopt improved technologies or engage in non-farm income activities. This is because food insecure households in this group lie perilously below the 'food insecurity line,' and thus require relatively smaller changes in either agricultural production or cash income.

A closer look at the results presented in Table 7 reveals that the food security gap slightly increased among those in the lowest quintile of maize production. While the Food Security and Nutrition National Strategy described in PARPA II aims at increasing food availability from farmers' own production and improving farmers' ability to purchase food, the results shown indicate that this is not happening. On the contrary, food insecurity is increasing, consistent with the results obtained from other welfare measures. Whether the measure is per capita cash income, consumption expenditure, or the food security measure presented in this paper, the receipt of public services (e.g., extension services or price information), poultry production, or the use of improved agricultural technologies such as chemical fertilizers and animal traction, the results consistently show that PARPA II has not reduced food security and has not been effective in achieving its goals.

6.1 Probability estimation of household food insecurity

A Probit model was used to assess the factors associated with the likelihood of being food insecure. The dependent variable is thus binary; whether or not the household was able to obtain sufficient calories, either from own production or purchases from the market, to meet the dietary requirements of all members. The analysis was conducted for each region in the country because there are substantial systematic differences in terms of agricultural potential and livelihood strategies, with households in the southern provinces relying relatively less frequently on crop production. In addition, separate models were estimated for households in the top income quintile of maize production because their food security strategies are likely to differ from those in the bottom four quintiles. The analysis discussed below is based primarily on TIA08 because the data provide more recent details on some of the key agricultural-related variables, which were not collected in the previous household income surveys (e.g., access to credit was not collected in TIA02 and TIA05; the use of improved seeds was not collected in TIA02). Nevertheless, a pooled model was also estimated using the variables that are common to the three TIA surveys and a trend variable denoting the survey period was included in this model. TIA02 was set as the baseline year.

The vector of independent variables includes household demographics, participation in non-farm income generating activities, asset ownership, agricultural technology variables, and access to public services. Pertaining to demographic characteristics, the education level of the household head has been shown to influence cash income earned by the household (Reardon, 1997; Garrett and Ruel, 1999). The coefficient was thus expected to be negative, implying that more educated households are less likely to be food insecure because they are able to purchase food. A variable on gender of household head was included based on other poverty studies in Mozambique showing that female-headed households tend to be worse-off than their male counterparts (Walker et al., 2004; Boughton et al., 2006; Boughton et al., 2007; Mather et al., 2008). Household size, expressed in terms of the adult equivalent scale (Deaton, 1997), was included as a proxy for labor availability, both for agricultural and non-agricultural activities. Cunguara et al. (2010) show that increasing the household size by adding one adult member usually results in lower outcomes because the marginal gain in net income per capita is smaller than the average net income per capita. Thus, the coefficient on household size was expected to be positive. Finally, the age of household head was expected to have an impact on labor supply for food production, and the ability to seek and obtain non-farm employment opportunities (Babatunde et al., 2007).

A second set of independent variables comprised of participation in non-farm activities by the household head. Here two proxies were used, namely whether the household head was engaged in salaried or self-employment activities. Previous work has revealed that household head's participation in non-farm activities increases farmers' ability to purchase food (Garrett and Ruel, 1999; Babatunde et al., 2007). Therefore, the coefficient was expected to be negative, implying that households with such sources of income are less likely to be food insecure. The magnitude of the coefficient, however, was likely to differ noticeably by region and quintile of maize production.

A third set of independent variables consisted of household asset ownership. Here, two proxies were also used: cropped area and livestock ownership. Households cultivating larger fields were expected to be more food secure (Tschirley and Weber, 1994), and thus the sign of the coefficient would be expected to be negative while its magnitude would most likely vary by region, reflecting differences in agricultural potential. A squared term was included for the variable on cropped area to capture potential diminishing marginal returns from land. In terms of livestock, three animal species were included. Cattle are relatively predominant in the southern provinces, goats are found more frequently in the central provinces, particularly in Tete, and chickens are widespread throughout the country. The coefficient on each of these three variables was expected to be negative, implying that households can sell some of their animals to purchase food, invest in agricultural activities through purchase of improved inputs, or invest in small-businesses and hence increase their cash incomes (Reardon and Taylor, 1996; Dercon, 1998).

With regard to agricultural technology, animal traction was included as an independent variable in the models for the southern and central regions, but excluded from the northern provinces due to the occurrence of tse-tse fly disease on cattle. Mather (2009) estimates that the use of animal traction increases crop income by 33 percent in the central provinces. In central provinces the gains from animal traction use are related to increases in both agricultural productivity and expansion of area cropped, whereas in the southern provinces its impact is only related to area cropped (Mather, 2009). The coefficient was thus expected to be negative. The use of improved seeds and chemical fertilizers was also expected to have a negative sign, suggesting that households adopting these technologies would be less likely to suffer from food insecurity. A variable on the use of hired labor was included to capture the heterogeneity of family and hired labor (Deolalikar and Vijverberg, 1987).

The last set of independent variables pertained to access to public services, such as the receipt of credit, extension services, price information, and household membership to a farmers' association. Generally, these variables were expected to have a negative sign, implying that access positively influences either agricultural production or participation in non-farm income generating activities. In addition, district dummies were included to control for differences in agricultural potential and access to non-farm activities.

The results of the Probit estimation for TIA08 are presented in the appendix section, Tables A1 and A2. The model seems to fit the data fairly well, especially among the top 20 percent of the households, with a pseudo R^2 of 0.80, and about 91 percent of households predicted correctly. Most of the signs of the estimated coefficients were also in agreement with the literature. In what follows, a discussion is provided emphasizing the differences between the top 20 percent of households and the bottom 80 percent, while also looking at regional differences. A discussion of the results from the pooled model is also provided, and the discussion emphasizes the trends in food insecurity.

In the northern provinces the use of improved technologies (improved maize seeds and chemical fertilizers) was not significant for the bottom 80 percent of households, but was found to be significant for the top 20 percent. A similar pattern was observed in the southern provinces. One possible explanation for this result is that households in the bottom 80 percent cultivate smaller parcels of land, and most of the times in intercropping systems. The average impact of adopting these technologies was therefore small, and households in this category should expand their cropped area first to realize significant gains to technical change. Indeed, the coefficient in cropped area is significant for the northern provinces and the bottom 80 percent of households, but statistically insignificant for the top 20 percent of households in the same region. The results on the effect of animal traction are slightly different, suggesting that all households in the southern provinces would benefit from its adoption. Use of animal traction, however, was not statistically significant for the central provinces, probably due to lower variation in the data.

In terms of livestock, goats and cattle were significant factors enhancing food security among the top 20 percent, but not significant among the bottom 80 percent, perhaps because the latter do not own them (see the means presented in Tables A1 and A2). For the poor, at present chickens are the most important livestock in all three regions. However, cattle herd size was also significant among the bottom 80 percent in the central provinces, although the magnitude of the coefficient was small, relative to that among the top 20 percent in the same region. At present, chicken sales among the bottom 80 percent are unable to raise the required cash to either purchase sufficient food or invest in the agriculture so as to increase the agricultural productivity and production to ensure food security.

The statistically significant coefficient on whether the head is engaged in non-farm activities signals the importance of non-farm cash income in ensuring food security. For the bottom 80 percent of households, the magnitude of the coefficient on self-employment (and head's education) was larger for the southern provinces, which reflects the lower agricultural potential in that region, and non-farm employment should be a long term strategy for coping with food insecurity and poverty (Cunguara et al., 2010).

Finally, with the exception of the receipt of credit in the central provinces, access to public services was not statistically significant among the bottom 80 percent. With regard to the receipt of extension, the lack of statistical significance might be related to the farmers' inability to adopt the technical recommendations provided by the extension workers (Walker et al., 2004; Mather, 2009; Cunguara and Moder, 2010). Low variation in the data could also explain the lack of effect of credit (in the northern and southern provinces only 2% received credit and the impact was not significant, compared to 7% in the central provinces, where the impact was significant). The result on the receipt of price information was somewhat surprising, and contradicted the results found by Mather (2009), who estimated that its receipt increases crop income by 23 percent and 31 percent in the central and southern provinces, respectively. For the top 20 percent of households, the receipt of credit and extension was statistically significant both in the northern and central provinces.

Results of the Probit estimation for the pooled model are presented in the appendix section, Tables A3 and A4. The results are consistent with those obtained in the Probit model for TIA08 and the descriptive statistics presented earlier. For example, food insecurity in 2008 was significantly worse than in 2002 and 2005. Similarly, chickens were more effective in enhancing food security among the bottom 80 percent of household ranked by the amount of maize produced, while goats were more effective among the top quintile.

7 Conclusions and policy implications

Using a set of seven nationally representative household surveys from rural Mozambique, the objective of this paper was twofold. The first goal was to evaluate whether or not PARPA, the poverty reduction strategy in Mozambique, has been effective in enhancing agricultural production and creating rural non-farm employment opportunities to address food security challenges in rural Mozambique. The results consistently show that this did not happen and findings are robust to the welfare indicator used. Whether it is cash income, consumption expenditure, asset endowments, receipt of public services, agricultural production or food security, results suggest that PARPA missed its goals, and food insecurity increased between 2002 and 2008.

The second objective was to analyze the factors associated with food insecurity in rural Mozambique. Results differed noticeably by quintile of total maize production and region. In the short run, adoption of improved technologies should be promoted more rigorously, especially among households in the top quintile of maize production. This recommendation stems from the finding that top quintile households were more likely to adopt improved technologies and be less food insecure while at the same time employing those in the bottom quintiles. Because the food security gap is relatively large among households in the bottom quintile, non-farm employment opportunities would be beneficial in addition to the adoption of improved technologies.

Likewise, the main strategy to reduce food insecurity in the southern provinces should be creation of non-farm activities for all quintile categories of households. Nevertheless, the use of some improved technologies also proves to be of great importance. In particular, animal traction and/or mechanization are likely to enhance food security among those in the top quintile of maize production because they cultivate relatively larger fields. Meanwhile, the use of animal traction was not significant among the poorest households partly because they farm smaller fields and land area is the binding constraint for these households. Therefore, if the poor in the south are to realize significant gains from adoption of improved technologies they will need to first expand their cropped area.

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References

Abdulai, A., Barrett, C., Hazell, P., 2004. Food aid for market development in Sub-Saharan Africa. DSGD Discussion Paper n. 5, International Food Policy Research Institute, Washington DC.

Abellana, R., Ascaso, C., Aponte, J., Saute, F., Nhalungo, D., Nhacolo, A., Alonso, P., 2008. Spatio-seasonal modeling of the incidence rate of malaria in Mozambique. Malaria Journal 7 (228) 1-11.

Aker, J., 2008. Does digital divide or provide? The impact of cell phones on grain marketing in Niger. University of California, Berkeley.

Alfredo, A., Jonsson, N., Finch, T., Neves, L., Molloy, J., Jorgensen, W., 2005. Serological Survey of Babesia bovis and Anaplasma marginale in cattle in Tete Province, Mozambique. Tropical Animal Health and Production 37(2):121-131.

Arndt, C., Benfica, R., Maximiano, N., Nucifora, A., Thurlow, J., 2008. Higher fuel and food prices: impacts and responses for Mozambique. Agricultural Economics 39 supplement: 497–511.

Arndt, C., James, R., Simler, K., 2006. Has Economic Growth in Mozambique been Pro-Poor? Journal of African Economies 15(4): 571-602.

Babatunde, R., Omotesho, O., Sholotan, O., 2007. Factors influencing food security status of rural farming households in north central Nigeria. Agricultural Journal 2(3)351-357.

Barrett, C., 2010. Measuring food insecurity. Science 327(5967): 825-828.

Barrett, C., Reardon, T., Webb, P., 2001. Non-farm Income Diversification and Household Livelihood Strategies in Rural Africa: Concepts, Dynamics, and Policy Implications. Food Policy 26(4):315-331.

Barrett, C., 2008. Smallholders' market participation: concepts and evidence from eastern and southern Africa. Food Policy 33: 299-317.

Barrett, C., 2002. Food security and food assistance programs. In: BL Garner, GC Rausser, editors. Handbook of agricultural economics. Amsterdam: Elsevier Science; 2002.

Boughton, D., D. Mather, D. Tschirley, T. Walker, B. Cunguara, E. Payongayong. Changes in Rural Household Income Patterns in Mozambique 1996-2002 and Implications for Agriculture's Contribution to Poverty Reduction. MINAG Working Paper, Maputo, Mozambique, 2006.

Boughton, D., D. Mather, C. Barrett, R. Benfica, D. Abdula, D. Tschirley and B. Cunguara. Market participation by rural households in a low-income country: an asset-based approach applied to Mozambique. Faith and Economics 50(2007): 64-101.

Canagarajah, S., Newman, C., Bhattamishra, R., 2001. Non-farm Income, Gender, and Inequality: evidence from rural Ghana and Uganda. Food Policy 26: 405-420.

Cunguara, B., Hanlon, J., 2010. Poverty is not being reduced in Mozambique. Crisis States Research Centre, Working Paper No. 74, London School of Economics and Political Sciences.

Cunguara, B., Langyuntuo, A., Darnhofer, I., The role of non-farm income in mitigating drought risk among farmers in rural Mozambique. Manuscript submitted to Agricultural Economics in July 2010.

Cunguara, B., Darnhofer, I., The impact of improved agricultural technologies on household incomes in rural Mozambique. Manuscript resubmitted to Food Policy in June 2010.

Cunguara, B., Moder, K., Is agricultural extension helping the poor? Evidence from rural Mozambique. Manuscript submitted to Journal of African Economies in May 2010.

Cunguara, B., Kajisa, K., 2009. Determinants of income and schooling investments in rural Mozambique, 2002-2005: A panel and cross-section analysis of the rice growing provinces. Chapter 8. In Otsuka, K., J. Estudillo, and Y. Sawada (eds). Poverty and income dynamics in rural Asia and Africa. New York: Routledge.

Cunguara, B., 2009. Pathways out of poverty in rural Mozambique. Lambert Academic Publishing, Germany.

Deaton, A. 1997. The Analysis of Household Surveys. Washington, D.C.: World Bank.

Deolalikar, A., Vijverberg, W., 1987. A Test of Heterogeneity of Family and Hired Labour in Asian Agriculture. Oxford Bulletin of Economics and Statistics 49(3): 291-305.

Dercon, S., 1998. Wealth, risk, and activity choice: cattle in western Tanzania. Journal of Development Economics 55:1-42.

Donovan, C., Tostão, E., 2010. Staple food prices in Mozambique. Prepared for the Comesa policy seminar on "Variation in staple food prices: Causes, consequence, and policy options", held in Maputo, Mozambique, 25-26 January 2010.

Ellis, F., Freeman, H., 2004. Rural Livelihoods and Poverty Reduction Strategies in Four African Countries. Journal of Development Studies,40(4):1-30.

Fulginiti, L., Perrin, R., Yu, B., 2004. Institutions and agricultural productivity in Sub-Saharan Africa. Agricultural Economics 31(2): 169-180.

Garrett, J., Ruel, M., 1999. Are Determinants of Rural and Urban Food Security and Nutritional Status Different? Some Insights from Mozambique. World Development 27(11), 1955-1975.

Government of Mozambique, 2006. Plano de Acção de Redução de Pobreza Absoluta 2006-2009. Conselho de Ministros, Maputo, Mozambique.

Grupo de Estudo (Grupo de Estudo de Aprofundamento na área de Nutrição), 2009. Relatório de avaliação de impacto do PARPA II 2006-2009. Study as input to Impact Evaluation Report (RAI) of PARPA II, Maputo, at http://www.open.ac.uk/technology/mozambique/p7_1.shtml; accessed July 25, 2010.

Hanlon, J., Smart, T., 2008. Do Bicycles Equal Development in Mozambique. Woodbridge: James Currey.

Hanlon, J., 2004. Do donors promote corruption? The case of Mozambique. Third World Quarterly 25(4): 747–763.

Harrison, J., Alders, R., 2010. An assessment of chicken husbandry including Newcastle disease control in rural areas of Chibuto, Mozambique. Tropical Animal Health and Production 42(4).

Heltberg, R., Tarp, F., 2002. Agricultural supply response and poverty in Mozambique. Food Policy 27:103-124.

Hoddinott, J., 1999. Choosing outcome indicators of household food security. Technical Guide No. 7, International Food Policy Research Institute, Washington, D.C.

Howard, J., Crawford, E., Kelly, V., Demeke, M., Jaime, J.J., 2003. Promoting high-input maize technologies in Africa: the Sasakawa-Global 2000 experience in Ethiopia and Mozambique. Food Policy 28, 335-348.

INE (Instituto Nacional de Estatística), 2004. Anuário Estatístico. 2004. Maputo, Mozambique.

Jayne, T. S., Mather, D., Mghenyi, E. Principal Challenges Confronting Smallholder Agriculture in Sub-Saharan Africa, World Development (2010), doi:10.1016/j.worlddev.2010.06.002

Joubert, A., Tyson, P., 1996. Equilibrium and fully coupled GCM simulations of future southern African climates. Southern African Journal of Science 92:471–484.

Mather, D., 2009. Measuring the impact of public and private assets on household crop income in rural Mozambique, 2002-2005. MINAG Working Paper n. 67E, Maputo, Mozambique.

Mather, D., D. Boughton, B. Cunguara, Household income and assets in rural Mozambique 2002-2005: Can pro-poor growth be sustained? MINAG Working Paper n. 66E, Maputo, Mozambique, 2008.

Maxwell, S., Frankenberger, T., 1992. Household food security: Concepts, indicators, measurements. IFAD and UNICEF, Rome.

MPD (Mozambique Ministry of Planning and Development), 2010. Poverty and well-being in Mozambique: the third national assessment (2008-9). Maputo.

MPF/IFPRI/PU (Mozambique Ministry of Planning and Finance/International Food Policy Research Institute/Purdue University), 2004. Poverty and well-being in Mozambique: the second national assessment (2002–3). Maputo.

Norval, R., Fivaz, B., Lawrence, J., Dailecourt, T., 1983. Epidemiology of tick-borne diseases of cattle in Zimbabwe I Babesiosis. Tropical Animal Health and Production 15: 87-94.

Oehmke, J., Crawford, E., 1996. The impact of agricultural technology in sub-Saharan Africa. Journal of African Economies 5 (2): 271-292.

Pingali, P., Bigot, Y., Binswanger, H., 1987. Agricultural mechanization and the evolution of farming systems in Sub-Saharan Africa. The John Hopkins University Press, Baltimore, Mariland.

Pitoro, R, Walker, T., Tschirley, D., Swinton, S., Boughton, D., de Marrule, H., 2009. Can Bt technology reduce poverty among African cotton growers? An ex ante analysis of the private and social profitability of Bt cotton seed in Mozambique. Contributed Paper prepared for presentation at the International Association of Agricultural Economists' Conference, Beijing, China, August 16-22, 2009.

Reardon, T., 1997. Using evidence of household income diversification to inform study of rural non-farm labor market in Africa. World Development 25, (5) 735-747.

Reardon, T., Taylor, J., 1996. Agroclimac shock, income inequality, and poverty: Evidence from Burkina Faso. World Development 24(5):901-914.

Riley, F., Moock, N., 1995. Inventory of Food Security Impact Indicators. In Food security indicators and framework: A handbook for monitoring and evaluation of food aid programs, IMPACT, Arlington, Va., U.S.A.

Stephens, E., Barrett, C., 2008. Incomplete credit markets and commodity marketing behavior. Working Paper, Cornell University, Ithaca, New York.

Tostão, E., Tschirley, D., 2010. On the Role of Government in Food Staples Markets: Perspectives from Recent Research and Implications for Mozambique. Flash series, Volume 54e. Michigan State University, East Lansing, MI

Tschirley, D., Jayne, T., 2010. Exploring the Logic behind Southern Africa's Food Crises. World Development 38(1):76-87.

Tschirley, D., Abdula, D. 2007. Toward improved maize marketing and trade policies to promote household food security in central and southern Mozambique: 2007 update. In Prepared for trade policy for food products conducive to development in eastern and southern Africa, March 2007. Rome: Food and Agriculture Organization of the UN.

Tschirley, D., Donovan, C., Weber, M.T., 1996. Food aid and food markets: lessons from Mozambique. Food Policy 21(2): 189–209.

Tschirley, D., Weber, M.T., 1994. Food Security Strategies under Extremely Adverse Conditions: The Determinants of Household Income and Consumption in Rural Mozambique. World Development 42(2): 159–173.

Usman, M., Reason, C., 2004. Dry spell frequencies and their variability over southern Africa. Climate Research 26:199-211.

Walker, T., D. Boughton, D. Tschirley, R. Pitoro, A. Tomo. Using Rural Household Income Survey Data to Inform Poverty Analysis: An Example from Mozambique. Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006.

Walker, T., D. Tschirley, J. Low, M. Tanque, D. Boughton, E. Payongayong, M. Weber. Determinants of Rural Income, Poverty and Perceived Well-Being in Mozambique in 2001-2002. MINAG Research Report No. 57E, Maputo, Mozambique, 2004.

Webb, P., Coates, J., Frongillo, E.A., Rogers, B.L., Swindale, A., Bilinsky, P., 2006. Measuring household food insecurity: Why it's so important and yet so difficult to do? Journal of Nutrition 136: 1404-1408.

WFP (World Food Program), 2010. Mozambique Country Overview. Available at: http://www.wfp.org/countries/mozambique. Accessed on August 3, 2010

Appendix

Table A1 Probit model results for the bottom 80% by region in 2008

	North: bottom 80%			Centre: bottom 80%			South: bottom 80%		
	Coeff.	Sig.	Mean	Coeff.	Sig.	Mean	Coeff.	Sig.	Mean
Head's gender (1=male)	-0.32	**	0.80	-0.18		0.75	-0.05		0.61
Head's years of completed education	-0.07	***	2.74	-0.05	**	3.05	-0.10	***	2.79
Head’s age (years completed)	0.00		40.03	0.02		43.10	-0.01		48.49
Head’s age (squared term)	0.00		1786	0.00		2072	0.00		2589
HH size in adult equivalent scale (AE)	1.31	***	2.84	0.42	***	3.27	0.23	***	3.57
HH size in AE (squared term)	-0.12	***	9.02	-0.03		12.69	-0.01	**	16.72
Head is engaged in salaried act. (1=yes)	-0.22	**	0.24	-0.39	***	0.36	-0.51	***	0.34
Head is self-employed	-0.37	***	0.42	-0.44	***	0.36	-0.63	***	0.29
Cropped area in hectares	-0.45	***	1.61	-0.25	**	1.94	0.08		1.50
Cropped area in hectares (squared term)	0.03	***	3.74	0.04	***	5.80	-0.01		3.96
Cattle herd size	-0.03		0.03	-0.04	*	0.51	0.00		0.77
Number of goats owned by the HH	0.00		0.63	-0.01		2.37	0.00		1.32
Number of chickens owned by the HH	-0.03	***	3.09	-0.01	**	6.89	-0.02	**	5.35
HH used improved maize seeds (1=yes)	0.13		0.05	-0.02		0.18	-0.01		0.09
HH used animal traction (1=yes)			0.00	-0.02		0.11	-0.22	*	0.44
HH used fertilisers (1=yes)	0.11		0.02	-0.08		0.04	-0.14		0.02
HH hired permanent labour (1=yes)			0.01	-0.57		0.04	-0.39		0.03
HH hired seasonal labour (1=yes)	-0.47	***	0.18	-0.59	***	0.17	-0.53	***	0.20
HH received extension services (1=yes)	-0.05		0.08	-0.02		0.10	-0.01		0.05
HH received price information	-0.12		0.34	-0.08		0.39	-0.16		0.32
Member of a farmers' association (1=yes)	0.10		0.08	-0.06		0.05	0.25		0.09
HH received credit (1=yes)	-0.49		0.02	-0.43	*	0.03	0.07		0.02
Constant	-1.11	*		-0.53			1.49	**	
Number of observations	1581			1106			1330		
Wald chi2	306			179			211		
Prob>chi2	0			0			0		
Pseudo R2	0.21			0.18			0.17		
Percent predicted correctly	72.87			70.71			69.85		

Source: Authors’ calculations based on TIA08
Notes: District dummies are included but not reported to save space
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table A2 Probit model results for the top 20% by region in 2008

	North: bottom 80%			Centre: bottom 80%			South: bottom 80%		
	Coeff.	Sig.	Mean	Coeff.	Sig.	Mean	Coeff.	Sig.	Mean
Head's gender (1=male)	1.71	**	0.90	-0.88	**	0.91	1.14	**	0.75
Head's years of completed education	0.16		3.32	-0.04		4.01	-0.19	**	2.73
Head's age (years completed)	0.78	***	42.27	0.04		42.58	0.10		50.52
Head's age (squared term)	-0.01	***	1943	0.00		1985	0.00		2721
HH size in adult equivalent scale (AE)	14.84	***	3.39	1.60	***	3.73	0.46	**	5.17
HH size in AE (squared term)	-1.66	***	13.16	-0.09	***	16.16	-0.02		33.55
Head is engaged in salaried act. (1=yes)	-3.55	***	0.19	-0.95	***	0.28	-0.84	*	0.28
Head is self-employed	-1.65	***	0.43	-0.92	***	0.39	-0.01		0.31
Cropped area in hectares	-0.73		3.10	-0.41	***	3.46	-0.31	**	2.80
Cropped area in hectares (squared term)	-0.05		13.98	0.01	***	21.48	0.01	**	12.43
Cattle herd size	0.65	***	0.11	-0.07	*	1.38	-0.02		3.50
Number of goats owned by the HH	-0.38	***	1.37	-0.07	***	3.67	0.01		3.31
Number of chickens owned by the HH	-0.06	*	6.33	-0.01		11.11	-0.10	***	13.53
HH used improved maize seeds (1=yes)	-2.06	*	0.10	0.75	*	0.18	-2.28	***	0.11
HH used animal traction (1=yes)			0.01	0.05		0.24	-1.06	**	0.66
HH used fertilisers (1=yes)	-3.65	***	0.07	-0.57		0.13			0.05
HH hired permanent labour (1=yes)			0.09	1.20	**	0.11	-0.51		0.09
HH hired seasonal labour (1=yes)			0.32	-0.99	***	0.36	-0.89	**	0.45
HH received extension services (1=yes)	-2.74	***	0.11	-0.84	*	0.13	1.51	***	0.08
HH received price information	-0.93		0.31	0.12		0.53	-0.54		0.36
Member of a farmers' association (1=yes)	3.34	***	0.11	0.75	*	0.09	-0.85		0.19
HH received credit (1=yes)	-2.67	**	0.05	-1.28	*	0.06			0.02
Constant	-54.23	***		1.00			-1.24		
Number of observations	219			433			164		
Wald chi2	126.56			156.53			83.66		
Prob>chi2	0			0			0		
Pseudo R2	0.80			0.50			0.53		
Percent predicted correctly	90.87			88.22			80.49		

Source: Authors' calculations based on TIA08
Notes: District dummies are included but not reported to save space
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table A3 Pooled Probit model results for the bottom 80% by region

	North: bottom 80%		Centre: bottom 80%		South: bottom 80%	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Head's gender (1=male)	-0.12	*	-0.08		-0.01	
Head's years of completed education	-0.06	***	-0.05	***	-0.08	***
Head's age (years completed)	0.00		0.02	**	-0.01	
Head's age (squared term)	0.00		0.00	**	0.00	
HH size in adult equivalent scale (AE)	0.83	***	0.30	***	0.22	***
HH size in AE (squared term)	-0.06	***	-0.01	***	-0.01	***
Head is engaged in salaried act. (1=yes)	-0.38	***	-0.37	***	-0.64	***
Head is self-employed	-0.35	***	-0.41	***	-0.50	***
Cropped area in hectares	-0.32	***	-0.11	***	-0.04	
Cropped area in hectares (squared term)	0.02	***	0.01	***	0.00	**
Cattle herd size	-0.03		-0.02	*	-0.02	***
Number of goats owned by the HH	-0.01		-0.01	*	0.00	
Number of chickens owned by the HH	-0.02	***	-0.01	***	-0.01	**
HH used animal traction (1=yes)	0.52		-0.25	**	0.01	
HH used fertilisers (1=yes)	0.07		-0.43	***	-0.26	
HH hired permanent labour (1=yes)	-0.72	**	-0.56	**	-0.24	*
HH hired seasonal labour (1=yes)	-0.42	***	-0.57	***	-0.49	***
HH received extension services (1=yes)	-0.16	**	0.03		-0.09	
HH received price information	-0.11	**	-0.13	*	-0.15	**
Member of a farmers' association (1=yes)	-0.09		-0.04		0.06	
Dummy for year=2005	0.22	***	0.10		-0.03	
Dummy for year=2008	0.31	***	0.14	*	0.26	***
Constant	-1.04	**	-0.75		1.02	*
Number of observations	4779		3270		4405	
Wald chi2	701.72		436.54		454.95	
Prob>chi2	0.00		0.00		0.00	
Pseudo R2	0.15		0.17		0.15	
Percent predicted correctly	69.09		70.67		68.63	

Source: Authors' calculations based on TIA02, TIA05, and TIA08
Notes: District dummies are included but not reported to save space
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.

Table A4 Pooled Probit model results for the top 20% by region

	North: bottom 80%		Centre: bottom 80%		South: bottom 80%	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Head's gender (1=male)	-0.26		-0.20		0.22	
Head's years of completed education	-0.01		-0.04		-0.13	**
Head’s age (years completed)	0.13	***	0.06	*	-0.06	
Head’s age (squared term)	0.00	***	0.00	*	0.00	
HH size in adult equivalent scale (AE)	1.60	***	0.63	***	0.34	***
HH size in AE (squared term)	-0.13	***	-0.02	***	-0.01	*
Head is engaged in salaried act. (1=yes)	-0.67	**	-0.60	***	-0.47	*
Head is self-employed	-0.67	***	-0.19		-1.08	***
Cropped area in hectares	-0.38	***	-0.12	**	-0.09	
Cropped area in hectares (squared term)	0.02		0.00		0.00	
Cattle herd size	-0.06		-0.01		0.01	
Number of goats owned by the HH	-0.02		-0.02	**	-0.04	**
Number of chickens owned by the HH	0.00		-0.01		-0.03	**
HH used animal traction (1=yes)			-0.17		-0.54	*
HH used fertilisers (1=yes)	-0.94	**	-0.58	**	-1.48	***
HH hired permanent labour (1=yes)			0.32		-0.62	*
HH hired seasonal labour (1=yes)	-0.61	***	-0.85	***	-0.24	
HH received extension services (1=yes)	-0.12		-0.19		0.74	**
HH received price information	-0.22		-0.10		-0.44	
Member of a farmers' association (1=yes)	0.59	**	0.37	*	-0.36	
Dummy for year=2005	0.84	***	-0.09		0.27	
Dummy for year=2008	0.98	***	0.09		1.00	***
Constant	-13.70	***	-1.81	*	2.34	*
Number of observations	789		1495		511	
Wald chi2	214.11		245.66		129.35	
Prob>chi2	0.00		0.00		0.00	
Pseudo R2	0.34		0.30		0.35	
Percent predicted correctly	88.21		86.89		82.19	

Source: Authors’ calculations based on TIA02, TIA05, and TIA08
Notes: District dummies are included but not reported to save space
***, **, and * denotes significance at 1%, 5%, and 10%, respectively.