

INTENSIFICATION & ASSET DYNAMICS: INTRAHOUSEHOLD
DECISION-MAKING IN BURKINA FASO

By

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ABSTRACT

INTENSIFICATION & ASSET DYNAMICS: INTRAHOUSEHOLD DECISION-MAKING IN BURKINA FASO

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With a population of over one billion people, Sub-Saharan Africa represents one of the poorest regions of the world. Efforts to eradicate global poverty require substantial economic growth in this region. Similar to other developing countries, a large percent of the population in this region is engaged in agriculture. Hence, increasing agricultural productivity is crucial for improving the well-being of the people of this region.

My dissertation is motivated by two key observations that hold across most developing countries. The first is that a majority of the population derives at least part of their income from agricultural activities. Therefore, any efforts to reduce poverty will require greater agricultural productivity. This requires understanding how farmers make productivity-enhancing and other agricultural decisions. The second observation is that while policy-makers have been concerned with poverty across households, there is considerable variation in well-being within households. Women have historically been disadvantaged within households, and continue to be in many parts of the world. A greater emphasis needs to be placed on measuring intrahousehold welfare, and understanding the heterogeneous impact of policies on different household members. Poverty reduction policies should consider individuals within a household, rather than the household itself, as the appropriate unit of observation.

My dissertation focuses on understanding the agricultural decisions of households in Burkina Faso. Adopting an intrahousehold decision-making approach, I study how input allocation decisions are made between family members and how they can affect each other. I

also analyze how weather shocks can affect agriculture and access to productive assets necessary for income generation.

In chapter two, I study the fertilizer subsidy program in Burkina Faso. I find that while it increases fertilizer use and productivity of farmers, the increase is concentrated amongst male farmers. In fact, fertilizer use for female farmers in the same households decreases. Therefore, men mostly benefit from the program.

The third chapter develops a theoretical model of how agricultural inputs, such as fertilizer, are allocated between fields managed by different family members. The model shows that individuals can engage in strategic behavior to influence the labor allocation decisions of other family members. In the empirical analysis, I find there is substantial allocative inefficiency within households. Reallocating inputs from the household head's fields can substantially increase agricultural production and improve equity within the family. Therefore, the fertilizer subsidy program and similar initiatives should consider targeting women and younger males.

Given increasing climate variability in Burkina Faso, the fourth chapter studies the effects of floods and droughts on agriculture, and how households cope with these shocks. I find that droughts lead to less land being cultivated and lower crop yields, while floods lead to lower crop yields. Households sell and consume livestock during floods, but mostly rely on other strategies during droughts. During these weather shocks, the gender asset gap increases due to substantial sale of female-owned livestock. This leads to the ill-effects of weather shocks persisting for women over time. I also find that while households liquidate more livestock if they have a baby boy to sustain consumption levels, they do not do so if a baby girl is present. This suggests that baby girls are more vulnerable to negative economic shocks early in their lives.

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This dissertation is dedicated to my loving grandmother, Bilquis Raza.

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CHAPTER 1: INTRODUCTION

With a population of over one billion people, Sub-Saharan Africa represents one of the poorest regions of the world. The poverty rate is about 41 percent (World Bank, 2013), and efforts to eradicate global poverty require substantial economic growth in this region. Similar to other developing countries, a large percent of the population in this region is engaged in agriculture. Hence, increasing agricultural productivity is crucial for improving the well-being of the people of this region.

The use of modern agricultural technologies is crucial for increasing agricultural productivity. The Green Revolution in other parts of the world, such as Asia, led to substantial increases in crop yields in the 1960s and 1970s. This was largely driven by adoption of improved crop varieties and increased use of fertilizer (Evenson and Gollon, 2003). In other regions, such as North America, mechanization has been extremely important in modernizing agriculture (Cochrane, 1979).

The induced innovation theory suggests that adoption of new technologies depends on relative factor availability, and that the same technologies will not be adopted everywhere. Erenstein (2006) notes that Sub-Saharan countries have historically relied on extensification for increasing agricultural production. But over the last century, due to growing population and depleting soil quality, less land is available for agriculture. This has resulted in a growing need for agricultural intensification – more output is necessary on each unit of land. Increased use of modern inputs, such as fertilizer, is necessary to increase agricultural productivity. Many governments have responded by increasing support for input subsidy programs. Jayne and Rashid (2013) state that ten countries in Sub-Saharan Africa spend over \$1 billion annually on

input subsidy programs. Yet the adoption of fertilizer and other modern inputs generally remains low in the region.

My dissertation is motivated by two key observations that hold across most developing countries. The first is that a majority of the population derives at least part of their income from agricultural activities. Therefore, any efforts to reduce poverty will require greater agricultural productivity. This requires understanding how farmers make productivity-enhancing and other agricultural decisions.

The second observation is that while policy-makers have been concerned with poverty across households, there is considerable variation in well-being within households (Haddad, Hoddinott & Alderman, 1994). Women have historically been disadvantaged within households, and continue to be in many parts of the world. A greater emphasis needs to be placed on measuring intrahousehold welfare, and understanding the heterogeneous impact of policies on different household members. Poverty reduction policies should consider individuals within a household, rather than the household itself, as the appropriate unit of observation.

My dissertation focuses on understanding the agricultural decisions of households in Burkina Faso. Adopting an intrahousehold decision-making approach, I study how input allocation decisions are made between family members and how they can affect each other. I also analyze how weather shocks can affect agriculture and access to productive assets necessary for income generation.

In chapter two, I study the performance of a fertilizer subsidy program in Burkina Faso. I first assess whether it is accessible to all types of households. Next, I evaluate whether it achieves its main goal of increasing fertilizer use amongst farmers. Lastly, I analyze whether the benefits of the program are equally distributed among male and female farmers.

The third chapter develops a theoretical model of how agricultural inputs, such as fertilizer, are allocated between fields managed by different family members. The model shows how individuals can engage in strategic behavior to influence the labor allocation decisions of other family members. In the empirical analysis, I find there is substantial allocative inefficiency within households. Reallocating inputs from the household head's fields can substantially increase agricultural production and improve equity within the family. Therefore, the fertilizer subsidy program and similar initiatives should consider targeting women and younger males.

Given increasing climate variability in Burkina Faso (Burkina Faso National Climate Change Adaptation Plan, 2015), the fourth chapter studies the effects of floods and droughts on agriculture, and how households cope with these shocks. I quantify the extent to which households liquidate livestock during weather shocks to sustain consumption levels. The loss of productive assets reduces future income-generating potential. I use gender-disaggregated livestock ownership data to analyze whether the livestock sold belonged to men or women, and whether the gender asset gap increases during such negative economic shocks. I also test whether households sell more assets if there are young children present in the household. Since the first 1000 days from conception till a child's second birthday are crucial (Cusick and Georgieff, 2012), we expect households with young children to be willing to sell more assets to stabilize consumption. If households do not do so, young children would be identified as an important sub-population that is especially vulnerable during weather shocks, especially since they cannot participate in the decision-making of the family.

Since my main data source is a household panel survey, I rely on fixed effects estimation in all the chapters. However, the type of fixed effects I use differs based on the econometric challenge of each research question. In the second chapter, I use household fixed effects to test

how fertilizer use and productivity varies as households access a fertilizer subsidy program. In the next chapter, I use household-year-crop fixed effects (and restrict the sample only to male farmers) to compare input-use and productivity of plot managers that are very similar to one another. In the fourth chapter, I use variation in rainfall to quantify agricultural losses from droughts and floods, and understand household coping strategies. I use household fixed effects to control for any systematic differences in where households choose to locate. This allows me to treat the rainfall variation as exogenous.

In all of the chapters, I estimate behavioral response functions (as opposed to factor demand functions or production functions) and mostly use linear approximations to understand the relationship between the main explanatory variables and the dependent variable. Therefore, I am estimating average relationships which would be applicable for a typical unit of observation.

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CHAPTER 2: FERTILIZER SUBSIDIES AND INTRAHOUSEHOLD EFFECTS

Abstract

Burkina Faso instituted a fertilizer subsidy program in 2008 to increase fertilizer use and boost agricultural productivity. Farmers can purchase subsidized NPK and urea fertilizers for their cotton, rice and maize crops. I use a three-year panel survey to analyze the effect of the subsidy program on fertilizer use and productivity. I also test whether the effects of the subsidy program are similar for male and female farmers within the same households.

Using a household fixed effects approach, I find that farmers increase their fertilizer use by about 2 nitrogen kg/ha when they access the subsidy program. This increased use is concentrated amongst male farmers; in fact, the fertilizer use among female farmers decreases. This may be because greater fertilizer use on collective plots managed by men requires more female labor for crop maintenance and cultivation, leading to less time available for women to work and generally invest on their own fields.

The subsidy program is associated with higher fertilizer application (by 5.8 nitrogen kg/ha) on cotton, rice and maize plots. This increase mainly comes from fertilizer applied to maize. However, the fertilizer application rate does not increase for staple crops (millet and sorghum). Yields are higher on plots for households that receive subsidized fertilizer by about 5.5 percent. Conditional on receiving subsidized fertilizer, men and women achieve similar yields for cotton, rice and maize. However, women have significantly lower yields on millet and sorghum plots than men.

This chapter adds to the limited literature that explores how the benefits of an input-subsidy program are shared across household members. The evidence suggest that men disproportionately benefit from the subsidy program, strengthening their bargaining power.

Input-subsidy programs and other programs should consider their impact on intrahousehold resource allocation since it has efficiency and equity implications.

2.1 Introduction

There is a growing recognition in many African countries that higher use of modern agricultural inputs is necessary for increasing food security and overall economic growth. In 2006, the Abuja Declaration recognized that a Green Revolution is needed in Africa¹. Higher fertilizer use is noted as crucial to increasing crop yields. With growing populations and soil nutrient depletion, the use of fertilizer along with other inputs is critical to sustain higher agricultural output.

There has been a resurgence in Input Subsidy Programs (ISPs) in Sub-Saharan Africa since the early 2000s (Morris et al., 2007). Ten African governments spend roughly US\$1 billion annually on input subsidy programs, amounting to 28.6 percent of their public expenditures on agriculture (Jayne and Rashid, 2013). Most of these programs subsidize inorganic fertilizer in an attempt to increase its use among farmers. Jayne et al. (2018) explain that if farmers have little experience with fertilizer use, a subsidy may increase its exposure to farmers, who may be willing to continue using fertilizer even after the subsidy is phased out.

However, fertilizer use remains significantly lower than other parts of the world. While farmers in West Africa in 2010 used about 2.9 nitrogen nutrient kg/Ha, this was significantly lower than 40.0 nitrogen nutrient kg/Ha in South America and 92.2 nitrogen nutrient kg/ha in Southern Asia (FAOSTAT). Not surprisingly, crop yields are significantly lower in West Africa than other parts of the world. For example, maize yields are only 1.4 tons/ha in Sub-Saharan Africa, compared to 3.8 tons/ha in Brazil and 3.9 tons/ha in Thailand (Smale, Byerlee and Jayne, 2011).

¹ <http://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/african-fertilizer-financing-mechanism/abuja-declaration/>

Burkina Faso instituted an ISP in 2008, following the 2007-08 food price shocks. The subsidy is universal for farmers growing specific crops: rice, maize and cotton (Druilhe and Barreiro-Hurle, 2012). About half a million farmers receive a 15-30 percent subsidy for NPK and urea (Druilhe and Barreiro-Hurle, 2012). The ISP funding is national, as opposed to other countries such as Tanzania and Mali which rely on 50 percent and 30 external donor funding respectively (Druilhe and Barreiro-Hurle, 2012). Since the demand for subsidized fertilizer is high across the country but the government's budget is limited, a relatively small proportion of households are able to access the program. The government's priorities change across regions year by year, leading to large temporal heterogeneity in the availability of subsidized fertilizer (Wanzala-Mlobela, Fuentes and Mkumbwa, 2013). Therefore, a household that receives subsidized fertilizer in one year may not be able to access the subsidy the following year due to misallocation or simply insufficient supplies.

Wanzala-Mlobela, Fuentes and Mkumbwa (2013) provide a detailed description of the fertilizer supply chain of Burkina Faso. 95 percent of fertilizer used in Burkina Faso is imported by five major importers, which also act as wholesalers and distributors. The remaining fertilizer is locally produced by Industrial Company of Agricultural and Tradable Productions (CIPAM). There are 4 supply chains of fertilizer. The first involves the importers acquiring and distributing fertilizer themselves or through a thin network of wholesalers and retailers. In the second supply chain, CIPAM manufactures and sells fertilizer mainly to farmer groups, wholesalers/retailers and the cotton companies. The third involves commercial farmers and plantations, mainly the cotton companies, procuring fertilizer from importers with financial support from the government. The fourth supply chain is the government fertilizer operation program, in which fertilizer is distributed to farmers at subsidized rates. The subsidized fertilizer under the

government operation program accounted for 17 percent of fertilizer used in Burkina Faso in 2010.

The government provides financial support to three cotton companies to purchase fertilizers, which they provide to farmers on credit (Wanzala-Mlobela, Fuentes and Mkumbwa, 2013). The government also directly procures, stores, transports and retails fertilizer to farmers and farmer organizations.

Across Sub-Saharan Africa, the effectiveness of the ISPs is controversial. The apparent success of ISPs, especially Malawi's fertilizer subsidy program, received a lot of attention in the mass media. In 2007, the New York Times ran a story titled "Ending famine, simply by ignoring the experts". Policy-makers also sought to replicate the Malawi input subsidy model in other African countries, and were convinced that supporting input subsidies works and the "cost of achieving food security is fiscally manageable and responsible" (Denning et al., 2009). However, subsequent literature showed that many ISPs disproportionately help wealthier farmers (Lunduka, Ricker-Gilbert and Fisher, 2013; Dorward and Chirwa, 2011), crowd out commercial fertilizer use (Jayne et al., 2013) and can be very costly to implement (Jayne and Rashid, 2013). There is limited evidence on the effectiveness of the fertilizer subsidy program in Burkina Faso. Sabo, Siri and Zerbo (2010) use a computable general equilibrium model to show that the subsidies have a large impact on increasing maize production, though the effect on rice and cotton production is more limited. They also find that the program also moderately increases household income and reduces poverty.

Alia (2017), accounting for the endogeneity of receiving subsidized fertilizer, finds that the subsidy program increases fertilizer use on maize fields by about 1.4 kg/ha. He also finds that the program crowds in use of hybrid maize and crop protecting chemicals (pesticides and herbicides)

while crowding out manure use. However, the increased use of fertilizer can be considered modest, considering the large subsidy provided to farmers and the implementation costs incurred by the government. Also, since Alia (2017) focuses on studying maize production, it is unclear how the subsidies affect other crops that they are intended to affect (cotton and rice) and other major crops (e.g. millet and sorghum).

In this chapter, I present additional evidence on the performance of the subsidy program. The main objectives of the program are increasing fertilizer use and improving productivity. Since two important indicators of the effectiveness of the subsidy program are quantity of fertilizer use and crop yields (Theriault, Smale & Assima, 2018), I analyze how they change when households access the subsidy program. Next, I study how yields of targeted (cotton, rice and maize) and other crops vary when households receive the subsidy. Druilhe and Barreiro-Hurle (2012) note that farmers may divert subsidized fertilizer from the crops they are intended for to other crops. For example, households in Mali diverted fertilizer from cotton to maize (Laris, Foltz and Voorhees, 2015). Hence, the program may affect the input use of other crops.

This chapter contributes to a better understanding of the effects of an ISP in Francophone Africa. Moreover, the intrahousehold effects of ISPs are largely ignored in the literature. While the differential effects of ISPs for male and female headed households have been studied (see Jayne et al., 2018, for a review), a discussion of how the effects vary between male and female members of the same household are largely ignored. There is limited evidence on whether such programs reduce the gender gap in input use and productivity. Some studies from Malawi suggest that the subsidized inputs are shared equally between men and women. Chirwa et al. (2011) use a probit model to find that amongst households that received the Farm Input Subsidy Program (FISP), plots managed by men and women had similar probabilities of applying

fertilizer. However, they did not test whether similar quantities of fertilizer were applied on male and female managed plots. Karamba and Winters (2015) use matching methods and spatial fixed effects, and find that the FISP increases the probability that fertilizer is applied to a female managed plot relative to a male managed plot. They also do not test whether similar quantities of fertilizer were applied. Moreover, they find that the subsidy program leads to similar improvements in male and female managed plots. They suggest that females may be constrained in other non-labor inputs, which limits their ability to increase productivity.

I study gender differentials in the effect of the program in Burkina Faso, and whether the benefits appear to be concentrated towards men or women or equally balanced between the two. In specific, I test whether the fertilizer application and productivity of male and female managed plots in same household is similar when households benefit from the subsidy program. To access the subsidized fertilizer, farmers need to be part of a farmer organization or travel to the Provincial Directorate of Agriculture to present their fertilizer needs, and transport the fertilizer from the Provincial Town Hall to their farms (Wanzala-Mlobela, Fuentes and Mkumbwa, 2013). In rural Burkina Faso, this usually requires a man traveling and dealing with members of the farmer organization or government officials. By incurring the transaction cost of acquiring the subsidized fertilizer, the subsidized fertilizer may implicitly be owned by the man. He may be less inclined to share the fertilizer with women in the household, and may rather use it at his discretion. Having a source of cheap fertilizer may also improve his bargaining position, which may affect the allocation of other inputs and decisions beyond agricultural production. The next chapter discusses such intrahousehold resource allocation considerations in detail, and helps conceptualize how decisions are made by families in rural Burkina Faso.

I find that the subsidy program is associated with about 2.5 nitrogen kg/ha more fertilizer applied to an average plot. This increase is driven by greater fertilizer use of plots managed by men. In fact, there is lower use of fertilizer on plots managed by women. Two possible explanations for this finding are increased intrahousehold bargaining power of men due to the subsidy program, and greater output on male plots requiring more female labor, leaving less time for women to work on their own plots and apply fertilizer. Households receiving the subsidy apply more fertilizer to cotton, rice and maize; however, they do not apply more fertilizer to sorghum and millet. I also find that the subsidy program is associated with a 5.5 percent increase in crop yields. These yield increases are mostly driven by the plots managed by men.

2.2 Agricultural Context

Agriculture has an important role in rural Burkina Faso, employing 90 percent of the workforce and contributing to 30 percent of GDP in 2012². In a typical household, multiple family members engage in joint agricultural production. This include men, women and children providing their labor and working together. Collective plots are managed by the household head or a designate, and all family members are expected to provide labor to this field. The proceeds of these plots are used to meet the family needs, such as providing commonly consumed goods like such as food. These are the main fields the household cultivates, and contributes to the food security of the family.

Family members can also manage private plots, which allow them to earn personal income. They are expected to spend as much time as needed on the collective plot, and spend any remaining time they have on their private plots. They are allowed to spend their private income

² <http://www.fao.org/docrep/field/009/i3760e/i3760e.pdf>

at their discretion, though they may be expected to contribute to household expenses in times of need (Thorsen, 2002). In practice, these norms are evolving, and younger men admit to prioritizing their own fields in a similar farming system in Mali (Guirkingner & Platteau, 2013).

Since the household head is usually male, collective plots which are more intensively cultivated are managed by men. Therefore, plots managed by men typically use more inputs and achieve higher yields. As noted by Kazianga and Wahhaj (2013), private plots managed by men and women have similar levels of input-use and productivity.

Historically, land has been fairly abundant in Burkina Faso and households have relied on extensification for producing more crops (Gray, 1999; Reij, Tappan & Belemvire, 2005). As populations have grown and there is greater pressure to produce more, there has been a greater emphasis on producing more from a given amount of land. Land degradation, particularly in some parts of the country, has made it crucial that farmers produce more efficiently.

Production of rain-fed cereals, such as sorghum, millet, and maize, account for over 70 percent of total cultivated land (INSD, 2014). Needing less moisture, millet and sorghum are well adapted to drylands and are cultivated throughout the country (INSD, 2014). Both cereals play an important role in achieving food security, since they constitute the basis of the diet for a vast majority of Burkinabe. In contrast, maize is mostly grown in the wetter zones of the country (INSD, 2014). Cotton, the country's main export, is also produced in the wetter zones (INSD, 2014) and is typically grown in rotation with maize and millet/sorghum.

Greater fertilizer use, along with using improved seed varieties, has been at the center of intensification efforts in Sub-Saharan Africa and in Burkina Faso in specific. As mentioned earlier, fertilizer use is still considerably lower than that in other parts of the world. This may partly be due to lack of complementary inputs, such as irrigation which is considered a game-

changer in the economics of fertilizer use (Jayne and Rashid, 2013). With soil degradation in Burkina Faso, this may also partly be due to low responsiveness to fertilizer because soils lack complementary inputs.

2.3 Data

The data used in this chapter comes from the Continuous Farm Household Survey/ Enquête Permanente Agricole (EPA), collected by the Ministry of Agriculture and Food Security of Burkina Faso. The sampling frame for the EPA is based on the 2006 Population Census. The EPA generates production, area and yield data for rain-fed crops, serves as an early warning system for food insecurity, and also furnishes general information about livestock holdings, income and expenditures of rural households, and farm input use, using a nationally representative sample across all 45 provinces from 2009/10 to 2011/12.

In this chapter, I utilize data from 2009-10, 2010-11 and 2011-12 (referred to as 2010, 2011 and 2012 in the remaining dissertation) on 65,214 plots in 2775 households across the three years. 41,399 of these plots are managed by men while 23,804 are managed by women (the sex of the manager is missing for 11 plots). The survey has plot level output and input information. However, information on the sources of the inputs is gathered at the household level. This is typical for such surveys since inputs are purchased together in most developing countries for the entire household and not separately for plots. Thus, we know whether a household received subsidized fertilizer but not which plot that fertilizer was applied to. Similarly, the survey did not gather disaggregated purchase data (quantity and price) for commercial and subsidized fertilizer separately. This limits the scope of the analysis in this chapter; for example, I am unable to test for crowding in or crowding out of commercial fertilizer.

The module on source of agricultural inputs asks how each major input was acquired. These include seeds, organic manure, NPK, urea, pesticide, fungicide and herbicide. The input can be acquired by subsidy, purchased from a commercial source, received as a gift or produced by the household itself. In this essay, I consider households that acquire any quantity of subsidized NPK or urea as beneficiary of the fertilizer subsidy program for that year.

Table 2.1 shows that a relatively small proportion of households receive subsidized fertilizer. In 2010, about 3.5 percent of households benefited from the subsidy program. This number dropped to 3 percent the following year before increasing to 4 percent in 2012. The variations were mostly due to changes in funding available from the government's budget.

The households receiving the fertilizer across the years were not the same either. Only 39 percent of the households that received the subsidy in 2010 also benefited from it in 2011. Similarly, 33 percent of households that received the subsidy in 2011 also benefited from it in 2012. In our sample of 2775 households, 92 percent never accessed subsidized fertilizer, 5 percent received subsidized fertilizer only one of the three years, 2 percent got it two out of three years while less than 1 percent received it all three years. Table 2.2 shows that there was significant variation in the number of surveyed households receiving the subsidy within a province across the three years.

These differences were driven by fertilizer needs assessments of the Provincial Directorate of Agriculture and the Regional Directorate of Agriculture, along with availability of government resources for the program (Wanzala-Mlobela, Fuentes & Mkumbwa, 2013). Fertilizer quantity is measured by adding the nitrogen content in NPK (14%) and urea (46%), similar to Koussoubé and Nauges (2017). The quantity applied to a plot is divided by plot size to calculate the nitrogen (kg/ha) applied. Plots managed in households that receive the fertilizer

subsidy use considerably more fertilizer (16.4 N kg/ha) as compared to plots in households that do not receive the subsidy (5.8 N kg/ha). However, this increase cannot be attributed to the subsidy program. Households that receive subsidized fertilizer may be intrinsically different from those that do not. They may be more inclined to using fertilizer because they have plots more responsive to fertilizer or because they have experience using fertilizer effectively. Even within households that receive the subsidized fertilizer, only 36 percent of plots have fertilizer applied to them. This may be due to differences in fertility and crop response across plots. But it may also reflect in bargaining power between family members. In households that did not receive subsidized fertilizer, 85 percent of plots do not have any fertilizer applied to them.

Table 2.3 compares crop yields between households that benefit from the subsidy and those that do not. The p-value is for the hypothesis that yields are higher on the plots managed in households that receive subsidized fertilizer. We may expect their yields to be higher because they have access to cheaper fertilizer, which they can potentially apply in greater quantity. While the subsidy program targets rice, maize and cotton, farmers may divert subsidized fertilizer to other food crops (Druilhe and Barreiro-Hurle, 2012). For this reason, cotton farmers receive fertilizer on credit for their cotton and maize hectares (Theriault and Serra, 2014), to reduce diversion away from cotton. Through this mechanism, yield of other crops may increase too. For most of the major crops, the yields are higher on plots belonging to households that receive the fertilizer subsidy. The yield is 26 percent higher for groundnut and 23 percent higher for white sorghum, while the differences are less prominent for cash crops such as peanuts (7 percent), cotton (7 percent) and sesame (5 percent). This may be because households growing these crops use fertilizer even if it is not subsidized. While the subsidy program targets maize,

rice and cotton, there seems to be a greater increase in the yield of some food crops (such as white sorghum) associated with the subsidy program.

2.4 Analytical Framework

In this chapter, I want to quantify the effect of the fertilizer subsidy on the amount of fertilizer used. The subsidy program reduces the price farmers have to pay by 15 to 30 percent. If households choose F^* amount of fertilizer by equating marginal revenue and marginal costs of fertilizer, a reduction in the price of fertilizer will change the optimal quantity of fertilizer to $F^{**} > F^*$.

However, if a household buys 100 kgs of subsidized urea, it is unlikely that their total fertilizer use increases by 100 kgs (or more). The subsidized fertilizer will crowd out some of the commercial fertilizer. This is obvious from the first order condition discussed above. First of all, there are transaction costs incurred in procuring subsidized fertilizer. This decreases the price reduction from the subsidy. Secondly, the extra fertilizer that is bought due to the subsidy depends on the price elasticity of fertilizer rather than the amount of subsidized fertilizer allocated to farmers under the government policy. Fertilizer demand in most developing countries is generally considered price inelastic (Fulginiti and Perrin, 1993; Croppenstedt, Demeke & Meschi, 2003; Olwande, Ngigi & Nguyo, 2009). If F^{**} is greater than the amount of subsidized fertilizer allocated to households, they can simply purchase that allocated amount of subsidized fertilizer and the remaining amount at commercial prices. Therefore, we expect some crowding out of commercial fertilizer.

The subsidized fertilizer is intended to be used for cotton, rice and maize production. However, since there is no enforcement mechanism to ensure the subsidized fertilizer is used on

these crops, households can divert fertilizer to other crops for diversification. Given concave crop production functions, the marginal physical product of fertilizer decreases as more fertilizer is applied. Thus, households have incentive of applying their fertilizer across multiple plots growing different crops. On the other hand, the target crops are most responsive to nitrogen fertilizer. Therefore, there may be little diversion to crops like sorghum and millet because they are much less responsive to fertilizer.

I conceptualize the problem of fertilizer allocation across plots using the agricultural household model. The standard Singh, Squire and Strauss (1986) model allows us to derive a household's fertilizer demand function. However, given incomplete land (Brasselle et al, 2002) and labor markets (Dumas, 2007) in Burkina Faso, separability is unlikely to hold. Therefore, household characteristics are also likely to affect the fertilizer demand of a household (de Janvry and Sadoulet, 2006).

In the empirical analysis, I quantify the extent to which the subsidy program increases fertilizer use and how this effect is distributed across crops. The fertilizer is also unlikely to be shared equally across household members. I also test whether the increase in fertilizer use from subsidized fertilizer is distributed across plots managed by men or women, or concentrated among the plots of either. Since the fertilizer subsidy program in Burkina Faso is gender-blind (Wanzala-Mlobela, Fuentes & Mkumbwa, 2013), and may be more accessible to males since it is easier for men to participate in farmer organizations or deal with government officials to request subsidized fertilizer, the subsidized fertilizer may generally be acquired by men. In that case, it may be treated as their private good that they can use upon their discretion. This would lead to more fertilizer being applied to plots managed by men rather than women.

As described earlier, there is significant variation in the quantity of subsidized fertilizer made available in different geographic regions of the country. These differences are primarily driven by availability in government funding and forecasts by the Provincial Directorate of Agriculture (Wanzala-Mlobela, Fuentes & Mkumbwa, 2013). A significant portion of self-selection into the subsidy programs happen due to differences in the demographics, wealth and social networks of a household. Many of these factors do not significantly change over a short period of time. Therefore, I use panel data methods to control for these time-invariant household characteristics to significantly reduce the self-selection problem. This allows me to assess how access to subsidized fertilizer affects fertilizer use and productivity in Burkina Faso.

Other techniques for estimating the impact of the subsidy program are matching methods (often combined with difference-in-differences) or instrumental variables techniques. However, there are always concerns that matching methods fail to adequately control for unobserved factors that determine access to the subsidy program and also affect fertilizer use and productivity. Similarly, finding valid instruments is challenging and finding ones that vary across time at the household-level (to combine instrumental variables with household fixed effects) is difficult. The literature uses instruments such as number of years spent in the village or number of family members that are leaders of a farmer organization (Alia, 2017), or locality election variables (Mason and Ricker-Gilbert, 2013). However, it would be reasonable to expect that these variables affect input allocation and productivity from pathways other than the subsidy program. For example, early settlers in villages may have acquired the best quality land. Or leadership in a farmer organization may indicate wealth or larger social networks, increasing credit or knowledge of agricultural practices. Similarly, election results are also likely lead to investment in other public goods, which may affect input-use and productivity. Since using weak

instruments may exacerbate the endogeneity problem (Wooldridge, 2010), I use fixed effects to understand how the subsidy program is associated with fertilizer use and productivity. Mason et al. (2017) compare results from different estimators of an ISP in Kenya, and find that the fixed effects estimator provides similar results to various matching- difference-in-differences estimators.

2.5 Empirical Strategy

I first discuss the factors that are associated with a household receiving subsidized fertilizer. The outcome variable is a binary variable for whether a household received subsidized fertilizer in a given year. The model is estimated as a linear probability model for incorporating fixed effects and since it is a good approximation of the average relationship between household characteristics and access to the subsidy program (Angrist and Pischke, 2008). Province fixed effects estimation will be used to compare households within the same geographic region. This allows us to analyze whether the benefits of the subsidy are concentrated among certain types of households. Household fixed estimation will also be used to better understand how household characteristics affect access to the subsidy program. Since some household characteristics may not vary over much over this three-year survey period, the province fixed effects estimation will allow us to understand how those factors correlate with access to the subsidy program.

While households that benefit from the subsidy program use more fertilizer, I conduct the same test in a regression framework controlling for plot, manager and household level characteristics. Given that there is low correlation in a household receiving the subsidy across years, and this is mostly due to government decisions that are not significantly affected by household characteristics or behavior, I exploit the panel nature of the data to test how fertilizer

application and productivity changes as households drop in and out of the subsidy program. This is implemented by household fixed effects estimation. By doing so, I control for many time-invariant household level characteristics such as size of social networks (factors which are unlikely to vary much across the three years of the panel).

$$Y_{iht} = \beta_0 + \beta_1 \text{Subsidy}_{ht} + \gamma \mathbf{X}_{iht} + \boldsymbol{\theta}_h + \varepsilon_{iht}$$

The dependent variable is fertilizer use (N kg/ha) or crop yield (kg/ha) on plot i . The main variable of interest is *Subsidy*, which indicates whether the plot i belonged to a household h which received subsidized fertilizer at time t . The vector $\mathbf{X}$ contains plot, manager and (time-variant) household-level characteristics.

Since the underlying conceptual model is a non-separable household model, I use household fixed effects to control for time-invariant household level socio-economic characteristics that affect fertilizer demand. Additionally, I control for time-varying household characteristics that may affect fertilizer demand.

The coefficient β_1 will indicate whether household access to the subsidy is associated with greater fertilizer use and higher productivity. It essentially captures the change in fertilizer use and productivity comparing a household that received subsidized fertilizer in a given year with itself in a year in which it did not receive subsidized fertilizer. This allows us to better understand the effect of the subsidy program.

I also test whether any potential increase in fertilizer use and crop yields are concentrated to plots managed by men or women, or if they are balanced equally across both types of plots. This is done by interacting the subsidy indicator with an indicator for sex of plot manager.

$$Y_{iht} = \beta_0 + \beta_1 \text{Subsidy}_{ht} + \beta_2 \text{Female}_{iht} + \beta_3 \text{Subsidy} * \text{Female}_{iht} + \gamma \mathbf{X}_{iht} + \boldsymbol{\theta}_h + \varepsilon_{iht}$$

The marginal effect of the subsidy now is $\beta_1 + \beta_3 * Female_{iht}$. β_3 indicates whether the effect of the subsidy differs by the sex of the plot manager.

In all of these models, standard errors are clustered at the household level to account for correlations in the outcome variables between different plots managed within the same household across the three years.

Table 2.4 defines the dependent and explanatory variables used in the analysis, and presents their mean values and standard deviations. Since factors like plot, manager and (time-variant) household characteristics along with other inputs can affect fertilizer allocation and productivity, I control for them in the empirical analysis.

2.6 Results

I first analyze what kind of households are most likely to receive subsidized fertilizer. In the province fixed effects estimation, I include latitude and longitude (and their interactions) to further control for geographic differences within provinces. By doing so, I compare households in the same province and geographic region with different household-level characteristics. In the household fixed effects regression, these are implicitly controlled for.

Table 2.5 shows that female headed households are much less likely to receive the subsidy program. In the sample, almost all recipients of the subsidized program are from male headed households. As opposed to ISPs in Ghana, Kenya, Zambia, Nigeria and Malawi (Jayne et al, 2018), subsidized fertilizer in Burkina Faso is rarely accessible to female headed households. Households that grow more cotton are also more likely to benefit from the subsidy program. This is because cotton is one of the crops prioritized by the program, and credit is often available for farmers to purchase fertilizer for growing cotton. Having a household member that is a member of a farmer organization also seems to increase the probability of receiving subsidized fertilizer.

This is because farmer organizations can approach the Provincial Directorate of Agriculture to request subsidized fertilizer. Being a member of a farmer organization may also reduce the transaction cost of acquiring subsidized fertilizer and transporting it to the farm for use.

I now present results from household fixed effects estimation on the effect of the subsidy program. Table 2.6 shows the effect of the subsidy program on fertilizer use. Column 1 is the base model, column 2 controls for additional control variables. Column 3 is the base model with an interaction term between subsidy and sex of the plot manager, while column 4 includes this interaction and additional control variables. The third and fourth columns allow me to test whether the subsidy program has a similar effect across plots managed by men and women. I find that when households have access to the subsidy, they apply about 2.5 nitrogen kg/ha more fertilizer to their plots. This is a 40 percent increase in the fertilizer application rate. The interaction term of subsidy receipt and sex of the plot manager shows that the subsidy is associated with greater inequality of fertilizer use within the household. The benefits of the subsidy program appear to be concentrated to plots managed by men. In model 4, the specification with the full set of controls, I find that the marginal effect of the subsidy program is increasing fertilizer use by 2.17 N kg/ha (35 percent increase in the fertilizer application rate); however, the subsidy program actually decreases the fertilizer use on female managed plots and increases it substantially on male managed plots. This suggests that not only does the subsidy program provide cheaper fertilizer to the household, but it affects the allocation of fertilizer between household members.

One reason for the reduction in fertilizer use on female managed plots may be that fertilizer application on male plots requires more labor. Moreover, higher yield requires more labor for maintaining and harvesting plots managed by men. Since these are often collectively managed

fields, women are expected to provide labor for these plots. This may leave insufficient labor for their own plots to apply fertilizer, and maintain and harvest the crops they grow.

Alternatively, the subsidy program could improve the bargaining position of men within the household and allow them to influence the input allocation decisions of other family members.

Chapter 3 discusses this hypothesis in more detail.

The regression in table 2.6 pools plots growing all crops. This leads to more noisy estimates with larger standard errors. In table 2.7 and table 2.9, I restrict the sample to plots growing the main crops targeted by the subsidy program (cotton, rice and maize) and main staple crops (millet and sorghum).

The subsidy program aims to increase fertilizer use for cotton, rice and maize. However, farmers can divert subsidized fertilizer to other crops to improve their yield. I test whether the subsidy is associated with greater fertilizer use on millet and sorghum plots. I choose these crops because they are commonly grown in Burkina Faso, and considered important crops for food security. Even though they have lower crop response than cotton, rice and maize (Yanggen et al., 1998), farmers employing a safety-first approach or diversifying their portfolio to reduce risk may choose to do so.

Table 2.7 suggests that access to the subsidy increases the fertilizer application on cotton, rice and maize by about 5.8 nitrogen kg/ha. This is a 60 percent increase in the fertilizer application rate. However, there is no increase in fertilizer application to sorghum and millet. While there is no difference in fertilizer application rate across plots managed by men and women for cotton and rice, there is a large difference maize plots (results available on request). This may be because cotton and rice fields are cultivated more commercially, regardless of

whether they are managed by men or women. However, access to the subsidy program makes fertilizer use on maize plots more profitable.

Table 2.8 shows that access to the subsidy program is associated with 5.5 percent higher yields. In these specifications, I do not find evidence that these yield increases are concentrated to plots managed by men. However, this may be because this model is estimated with noise from pooling multiple crops. Also, yield differentials may not exist on cash crops since they appear to have similar levels of fertilizer (and perhaps other inputs) applied to them. Instead, yield differentials may exist on staple crops grown by males and females.

In table 2.9, I find that the subsidy program has a larger effect on the yields of cotton, rice and maize compared to millet and sorghum. This is not surprising, since cotton, rice and maize are known to be more responsive to nitrogen fertilizer than millet and sorghum (Yanggen et al., 1998). Females have lower yields on the target and staple crops. Even though the subsidy program is not associated with more fertilizer being applied to male managed staple crops, I find that those male managed plots achieve higher yields. This may be because more female labor is required on male managed cotton, rice and maize plots, which leaves less labor for their own plots. This would lead to lower yields on the sorghum and millet plots they manage.

2.7 Conclusion

In this chapter, I discuss the fertilizer subsidy program in Burkina Faso. It is intended to increase NPK and urea fertilizer use on three important crops: cotton, rice and maize. The 15 to 30 percent price subsidy is likely to increase fertilizer use, but the increase depends on the price elasticity of demand of fertilizer. The literature suggests that fertilizer demand is not very price

elastic. Also, high transaction costs of procuring subsidized fertilizer can reduce the effective discount farmers get.

The data shows that many households that procure fertilizer in one year do not receive it in the following year. There is significant variation in the supply of subsidized fertilizer across provinces. This is mostly driven by the government's budgetary allocations and forecasts by the Provincial Directorate of Agriculture. I find that the subsidy program is very inaccessible to female headed households, raising concerns about its targeting. It also appears to be more accessible to households that grow cotton and farmers that are members of farmer organizations.

Using a household fixed effects model, I estimate that the subsidy program increases fertilizer application on a plot by 2.5 nitrogen kg/ha. This increase is concentrated among plots managed by men. In fact, female managed plots have less fertilizer applied to them when the household receives subsidized fertilizer compared to when it does not. This may be because more labor is required to maintain and harvest the collective plot where most of the fertilizer may be applied. This may leave insufficient labor for women to work on their own plots. It may also be due to changes in the intrahousehold bargaining positions of men and women. Further research is required to explore exactly why female managed plots receive less fertilizer when a households accesses the fertilizer subsidy program.

I find that the subsidy program is associated with higher fertilizer application on the target crops (cotton, rice and maize) but not for millet and sorghum. Yields increase when a household receives subsidized fertilizer. Men and women achieve similar yields for cotton, rice and maize. However, women have significantly lower yields on millet and sorghum plots than men.

This chapter emphasizes the need to understand how subsidized fertilizer is used within a household, and whether the benefits are concentrated among certain household members. The subsidy program can also change the bargaining position of family members, which has an effect on allocative efficiency, productivity and other non-agricultural decisions made within the household.

APPENDIX

Table 2.1: Access to the Subsidy Program

	2010	2011	2012
Number of HHs Not Receiving Subsidized Fertilizer	2615	2636	2424
Number of HHs Receiving Subsidized Fertilizer	96	79	108
Total	2711	2715	2539

Source: Author's calculations

Table 2.2: Number of Households Receiving Subsidized Fertilizer by Province

Province	2010		2011		2012	
	No Subsidy	Subsidy	No Subsidy	Subsidy	No Subsidy	Subsidy
Bam	56	0	56	0	55	1
Bazega	28	1	38	0	36	1
Bougouriba	62	2	62	2	60	2
Boulgou	81	0	82	0	79	2
Boulkiemde	58	0	56	0	60	1
Comoe	60	7	67	0	62	5
Ganzourgou	62	1	55	6	61	7
Gnagna	35	0	35	0	35	0
Gourma	76	1	75	2	55	0
Houet	155	6	140	11	134	7
Kadiogo	81	2	82	0	79	4
Kenedougou	93	1	86	2	84	3
Kossi	58	5	63	0	53	0
Kouritenga	55	1	54	1	53	0
Mouhoun	54	2	53	4	50	2
Nahouri	62	4	66	3	62	2
Namentenga	95	0	96	0	89	0
Oubritenga	68	0	68	0	67	0
Oudalan	61	0	60	0	59	0
Passore	32	0	66	0	59	0
Poni	59	4	62	1	54	2
Sanguie	72	0	71	1	71	1
Sanmatenga	68	0	69	0	55	0
Seno	18	0	18	0	0	0
Sissili	43	6	45	4	38	10
Soum	31	2	35	0	35	0
Sourou	65	0	63	1	58	0
Tapoa	26	0	22	0	23	3
Yatenga	49	4	43	0	44	0
Zoundweogo	31	0	31	0	30	1
Bale	66	37	73	31	81	8
Banwa	62	2	61	0	46	3
Ioba	40	5	36	9	28	11
Komandjoari	30	0	30	0	27	0

Table 2.2 (cont'd)

Kompienga	34	0	34	0	26	3
Koulpelogo	61	0	59	0	57	5
Kourweogo	60	0	55	0	60	0
Leraba	73	1	74	0	56	14
Loroum	64	0	62	1	57	1
Nayala	45	2	47	0	46	0
Noumbiel	71	0	71	0	60	0
Tuy	67	0	67	0	60	5
Yagha	57	0	57	0	35	0
Ziro	43	0	43	0	39	4
Zondoma	48	0	48	0	46	0

Source: Author's calculations

Table 2.3: Crop Yields Across Households that Do & Do Not Receive Subsidized Fertilizer

	No Subsidy	Subsidy	Percentage Difference	p-value
Maize	759	837	10.25	0.0047
Millet	1250	1414	13.09	0.0000
Rice	1281	1532	19.60	0.0000
White Sorghum	855	1053	23.11	0.0000
Red Sorghum	1023	1077	5.30	0.0898
Cotton	1192	1278	7.25	0.009
Peanuts	741	793	7.01	0.0222
Sesame	568	596	4.83	0.3111
Cowpea	724	707	-2.34	0.643
Groundnut	751	946	26.01	0.004
Okra	1835	2043	11.35	0.2697

Source: Author's calculations

Table 2.4: Definitions and Descriptive Statistics of Dependent & Explanatory Variables

Variable	Definition	Mean	S.D.
Fertilizer	Nitrogen fertilizer applied to the plot (kg/ha)	6.20	34.11
Yield	Crop Yield (kg/ha)	962.62	725.08
Subsidy	Household received subsidized fertilizer (0/1)	0.04	0.19
Female	Plot manager is female (0/1)	0.37	0.48
Plot Size	Size of the plot (ha)	0.47	0.72
Collective	Plot is collectively managed (0/1)	0.56	0.50
Far from home	Plot is located far from house (0/1)	0.57	0.50
Lowland	Plot is a lowland (0/1)	0.09	0.29
Slope	Plot is sloped (0/1)	0.07	0.25
Tenure	Plot has secure tenure (self-reported) (0/1)	0.51	0.50
Intercrop	Two crops grown on the plot (0/1)	0.35	0.48

Table 2.4 (cont'd)

Labor	Total number of labor days (person days/ha)	512.16	2526.81
Manure	Quantity of manure applied (kg/ha)	1533.83	77624.34
Herbicide	Quantity of herbicide applied (liters/ha)	54.32	439.21
Fungicide	Quantity of fungicide applied (kg/ha)	11.58	124.89
Pesticide	Quantity of pesticide applied (kg/ha)	6.75	214.00
Raticide	Quantity of raticide applied (kg/ha)	7.54	338.88
Ratio of Children to Women	Ratio of children to women in household	2.60	1.44
HH Livestock	Number of livestock owned (TLUs)	6.78	13.78
HH Area Owned	Total agricultural land owned by household (ha)	3.69	3.94
HH Cotton Area Cultivated	Area on which household grows cotton (ha)	0.46	1.82
Non-Farm Income	Non-Farm income of household (ln CFA Francs)	175.05	533.88
HH Head Age	Age of the head of household (years)	51.51	14.76
HH Head Female	Household head is female (0/1)	0.043	0.20
HH Head Literate	Household head is literate (0/1)	0.23	0.42
FO Member	At least one member of the household is a member of a farmer organization	0.40	0.49

Source: Author's calculations

Table 2.5: Determinants of Receiving Subsidized Fertilizer

	(1)	(2)
Latitude	-0.0898 (0.189)	
Longitude	0.0573 (0.0892)	
Latitude*Latitude	0.00365 (0.00730)	
Longitude*Longitude	0.00697* (0.00370)	
Latitude*Longitude	-0.00402 (0.00656)	
HH Head Age	-0.000190 (0.000206)	0.000115 (0.000307)
HH Head Female	-0.0240*** (0.00669)	-0.0299** (0.0150)
HH Head Literate	-0.0108 (0.00821)	-0.0179 (0.0137)
HH Size	0.000108 (0.000585)	-0.000889 (0.000913)
HH Area Owned	-0.000551 (0.00145)	-0.000634 (0.00204)

Table 2.5 (cont'd)

HH Cotton Area Cultivated	0.0126** (0.00507)	0.0153** (0.00662)
HH Livestock	-0.000506* (0.000281)	0.00106** (0.000486)
HH Farmer Organization Member	0.0392*** (0.00733)	0.00633 (0.00783)
Year 2011	0.00132 (0.00493)	-0.00521 (0.00463)
Year 2012	0.0174** (0.00677)	0.0114* (0.00657)
Constant	0.552 (1.220)	0.0330 (0.0205)
Observations	58,070	63,076
Fixed Effects	Province	Household

Fixed effects estimation

Standard errors are clustered at the household level

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 2.6: Fertilizer Use (N kg/ha) Equation

	(1)	(2)	(3)	(4)
Subsidy	1.927* (1.032)	2.484** (1.065)	4.037*** (1.327)	4.765*** (1.379)
Female	-0.496 (0.437)	-0.519 (0.463)	-0.285 (0.439)	-0.293 (0.467)
Subsidy*Female			-7.097*** (2.266)	-7.584*** (2.139)
Plot Size	-2.278*** (0.492)	-1.566*** (0.392)	-2.305*** (0.500)	-1.597*** (0.401)
Collective	1.085** (0.440)	0.859* (0.442)	1.046** (0.437)	0.814* (0.441)
Far from home	1.612*** (0.354)	1.465*** (0.335)	1.576*** (0.352)	1.427*** (0.335)
Lowland	0.690 (0.520)	0.892 (0.555)	0.688 (0.520)	0.887 (0.555)
Slope	0.355 (0.654)	0.204 (0.669)	0.340 (0.655)	0.188 (0.671)
Tenure	-0.450 (0.308)	-0.546* (0.320)	-0.468 (0.308)	-0.562* (0.319)
Intercrop	0.284 (0.270)	0.389 (0.291)	0.322 (0.271)	0.432 (0.292)
Ratio of Children to Women	0.0610 (0.155)	0.0681 (0.163)	0.0556 (0.155)	0.0633 (0.163)

Table 2.6 (cont'd)

HH Livestock	-0.0170 (0.0456)	-0.00657 (0.0486)	-0.0168 (0.0456)	-0.00648 (0.0487)
HH Area Owned	-0.290 (0.202)	-0.176 (0.208)	-0.292 (0.202)	-0.177 (0.208)
Non-Farm Income	-0.000589* (0.000309)	-0.000607** (0.000306)	-0.000581* (0.000309)	-0.000602** (0.000305)
HH Cotton Area Cultivated	-0.594* (0.349)	-0.502 (0.320)	-0.588* (0.348)	-0.498 (0.319)
Total Labor		0.00104** (0.000468)		0.00104** (0.000468)
Manure		2.08e-05 (6.39e-05)		2.13e-05 (6.39e-05)
Herbicide		0.0122** (0.00591)		0.0122** (0.00590)
Fungicide		0.00968** (0.00489)		0.00966** (0.00489)
Pesticide		0.000731 (0.00139)		0.000748 (0.00139)
Raticide		0.0102*** (0.00364)		0.0102*** (0.00365)
Constant	2.301** (1.095)	0.831 (1.370)	2.303** (1.095)	0.824 (1.370)
Year 2011	1.371*** (0.461)	1.132** (0.478)	1.364*** (0.461)	1.124** (0.478)
Year 2012	2.257*** (0.338)	1.823*** (0.451)	2.261*** (0.338)	1.829*** (0.450)
Observations	62,350	56,819	62,350	56,819
Number of Households	2,768	2,765	2,768	2,765
Marginal Effect of Subsidy			1.516 (1.016)	2.038** (1.039)

Household fixed effects estimation

Standard errors are clustered at the household level

Coefficients on crop indicator variables omitted

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 2.7: Fertilizer Use (N kg/ha) Equation Across Plots Growing Target and Staple Crops

	Target	Target	Staple	Staple
Subsidy	5.310* (3.088)	6.512** (3.182)	0.0244 (0.515)	-0.106 (0.588)
Female	-2.984* (1.754)	-4.106** (1.800)	-0.270* (0.158)	-0.149 (0.161)
Subsidy*Female	-5.128 (5.883)	-6.284 (5.045)	0.384 (0.429)	0.284 (0.420)
Plot Size	-9.630*** (2.214)	-7.476*** (1.533)	-0.481*** (0.104)	-0.169 (0.120)
Collective	4.478*** (1.531)	3.031** (1.519)	0.669*** (0.217)	0.528** (0.217)
Far from home	2.695** (1.327)	1.382 (1.418)	0.323 (0.235)	0.519** (0.249)
Lowland	3.546** (1.603)	4.371** (1.701)	0.171 (0.211)	0.0853 (0.217)
Slope	1.763 (2.620)	0.733 (2.746)	0.240 (0.327)	-0.0607 (0.149)
Tenure	-0.184 (1.241)	-1.086 (1.381)	0.115 (0.163)	0.167 (0.155)
Intercrop	-5.521*** (1.630)	-5.403*** (1.869)	-0.0135 (0.0931)	-0.0284 (0.103)
Ratio of Children to Women	-0.103 (0.528)	0.119 (0.624)	-0.113 (0.0829)	-0.0947 (0.0890)
HH Livestock	0.0100 (0.0975)	0.0195 (0.0909)	-0.0159 (0.0147)	-0.00888 (0.0156)
HH Area Owned	-1.477*** (0.477)	-1.291*** (0.401)	-0.0612 (0.0549)	-0.0176 (0.0557)
Non-Farm Income	-0.00113 (0.000763)	-0.00134* (0.000718)	-0.000303 (0.000321)	-0.000180 (0.000306)
HH Cotton Area Cultivated	-0.0535 (0.537)	-0.167 (0.539)	-0.137 (0.126)	-0.0536 (0.0961)
Total Labor		0.00295** (0.00120)		0.000485 (0.000342)
Manure		3.74e-05 (8.81e-05)		0.000250 (0.000159)
Herbicide		0.0255** (0.0127)		0.000305 (0.000197)
Fungicide		0.0173* (0.00972)		0.0124 (0.0117)
Pesticide		0.000478 (0.00153)		0.00650** (0.00324)
Raticide		0.0150** (0.00612)		0.00878* (0.00526)

Table 2.7 (cont'd)

Year 2011	2.398** (1.119)	2.134* (1.132)	0.664*** (0.160)	0.587*** (0.178)
Year 2012	5.403*** (1.114)	4.199*** (1.548)	0.914*** (0.212)	0.808*** (0.215)
Constant	26.13*** (2.758)	21.86*** (2.935)	0.742 (0.489)	-0.181 (0.607)
Observations	15,287	13,843	27,088	24,645
Number of Households	2,408	2,376	2,667	2,648
Marginal Effect of Subsidy	4.431 (2.750)	5.423* (2.852)	0.127 (0.436)	-0.0292 (0.492)

Household fixed effects estimation

Standard errors are clustered at the household level

Coefficients on crop indicator variables omitted

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 2.8: Crop Yield (kg/ha) Equation

	(1)	(2)	(3)	(4)
Subsidy	65.26** (28.45)	69.94** (29.16)	68.94** (30.27)	72.07** (30.96)
Female	-12.68 (9.084)	-15.06 (9.469)	-12.31 (9.143)	-14.85 (9.519)
Subsidy*Female			-12.62 (35.77)	-7.218 (36.06)
Plot Size	93.64*** (5.553)	97.47*** (5.959)	93.59*** (5.554)	97.45*** (5.964)
Collective	23.93** (9.703)	19.11* (10.13)	23.86** (9.701)	19.07* (10.13)
Far from home	-0.204 (9.148)	-8.508 (9.595)	-0.272 (9.148)	-8.546 (9.597)
Lowland	52.65*** (15.52)	51.37*** (15.67)	52.64*** (15.52)	51.36*** (15.68)
Slope	-18.26 (13.17)	-20.66 (13.88)	-18.30 (13.17)	-20.68 (13.88)
Tenure	-12.84 (11.10)	-10.58 (11.60)	-12.87 (11.10)	-10.60 (11.60)
Intercrop	-64.47*** (7.629)	-63.82*** (7.997)	-64.40*** (7.635)	-63.78*** (8.005)
Ratio of Children to Women	-2.936 (6.541)	-0.0779 (6.811)	-2.945 (6.542)	-0.0823 (6.812)
HH Livestock	2.165**	1.698*	2.166**	1.697*

Table 2.8 (cont'd)

	(0.983)	(1.011)	(0.983)	(1.011)
HH Area Owned	-13.11*** (3.787)	-13.35*** (3.916)	-13.11*** (3.788)	-13.35*** (3.917)
Non-Farm Income	-0.0151 (0.0113)	-0.0152 (0.0108)	-0.0151 (0.0113)	-0.0152 (0.0108)
HH Cotton Area Cultivated	1.388 (7.852)	4.269 (7.924)	1.399 (7.856)	4.273 (7.926)
Total Labor		-0.0135*** (0.00468)		-0.0135*** (0.00468)
Manure		-0.00139** (0.000566)		-0.00139** (0.000566)
Herbicide		0.0143 (0.00955)		0.0142 (0.00955)
Fungicide		-0.0457 (0.0295)		-0.0458 (0.0295)
Pesticide		0.0516 (0.0351)		0.0516 (0.0351)
Raticide		0.0710 (0.0447)		0.0710 (0.0447)
Year 2011	16.20 (9.913)	16.27 (10.24)	16.19 (9.913)	16.27 (10.23)
Year 2012	-116.0*** (11.02)	-113.5*** (11.38)	-116.0*** (11.02)	-113.5*** (11.38)
Constant	860.3*** (26.88)	860.2*** (28.11)	860.3*** (26.88)	860.2*** (28.11)
Observations	58,764	53,516	58,764	53,516
Number of Households	2,768	2,763	2,768	2,763
Marginal Effect of Subsidy			64.49** (28.58)	69.50** (29.28)

Household fixed effects estimation

Standard errors are clustered at the household level

Coefficients on crop indicator variables omitted

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 2.9: Crop Yield (kg/ha) Equation Across Plots Growing Target and Staple Crops

	Target	Target	Staple	Staple
Subsidy	121.0** (48.33)	147.6*** (50.19)	62.12* (34.45)	66.31* (35.75)
Female	-75.21*** (26.38)	-72.85*** (26.47)	-19.19* (10.16)	-21.84** (10.80)
Subsidy*Female	124.2 (84.97)	127.9 (87.28)	-83.43** (39.45)	-82.48** (40.28)
Plot Size	85.95*** (12.07)	94.91*** (12.52)	60.36*** (4.411)	64.16*** (4.775)
Collective	31.33 (24.49)	11.51 (25.60)	33.83*** (10.06)	31.01*** (10.64)
Far from home	14.45 (20.84)	-9.248 (22.21)	-14.27 (9.093)	-15.72* (9.495)
Lowland	37.13 (32.35)	46.81 (33.85)	5.208 (12.71)	6.383 (13.41)
Slope	-10.49 (32.52)	-19.11 (34.43)	-0.0204 (13.34)	-3.319 (14.34)
Tenure	-40.81* (24.65)	-41.29 (26.42)	14.20 (11.89)	16.09 (12.55)
Intercrop	-139.5*** (22.34)	-142.0*** (23.97)	-58.13*** (8.783)	-56.96*** (9.147)
Ratio of Children to Women	-5.826 (12.90)	4.287 (13.63)	3.094 (7.612)	6.025 (8.000)
HH Livestock	1.906 (1.270)	1.343 (1.267)	1.741 (1.102)	1.243 (1.185)
HH Area Owned	-13.46* (7.296)	-14.47* (7.894)	-13.55*** (3.833)	-15.25*** (4.015)
Non-Farm Income	-0.0174 (0.0205)	-0.0198 (0.0201)	0.00460 (0.0139)	0.00985 (0.0147)
HH Cotton Area Cultivated	-5.702 (10.36)	-3.966 (11.34)	12.60* (7.345)	15.17** (7.344)
Total Labor		-0.0169** (0.00669)		-0.0101** (0.00484)
Manure		0.000962 (0.000843)		0.00170* (0.000922)
Herbicide		0.0276** (0.0117)		0.00347 (0.0124)
Fungicide		-0.106* (0.0603)		-0.0298 (0.0226)
Pesticide		0.0748 (0.0522)		-0.0344 (0.0851)
Raticide		0.175** (0.0720)		-0.0313 (0.0345)

Table 2.9 (cont'd)

Year 2011	-73.07*** (19.70)	-67.10*** (20.67)	45.94*** (10.79)	48.53*** (11.28)
Year 2012	-173.1*** (20.98)	-163.6*** (21.73)	-87.93*** (12.33)	-86.54*** (12.67)
Constant	1,438*** (51.46)	1,435*** (55.24)	785.5*** (28.98)	786.1*** (30.41)
Observations	14,555	13,167	26,055	23,693
Number of Households	2,356	2,316	2,656	2,637
Marginal Effect of Subsidy	142.2*** (46.06)	169.6*** (48.02)	40.03 (31.10)	44.17 (32.23)

Household fixed effects estimation

Standard errors are clustered at the household level

Coefficients on crop indicator variables omitted

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

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CHAPTER 3: AGRICULTURAL INTENSIFICATION & INTRAHOUSEHOLD DECISION-MAKING

Abstract

In most West African countries, agricultural production is a complex process that involves multiple household members managing land. This chapter explores the allocation of agricultural inputs within households in rural Burkina Faso. The theoretical model derives the efficient allocation of resources across plots managed by the household head and other members. The model also describes how resources will be distributed in the absence of full cooperation between household members. A key implication is that the household head can exploit the complementarity in production between material inputs and labor to influence how other household members choose to allocate their own labor. For instance, by applying a large amount of fertilizer on his own plot, the household head can increase the marginal productivity of labor on his plot and incentivize other household members to supply labor to his plot rather than to their own.

The model leads to testable predictions of whether allocation of inputs within the household is efficient. The hypotheses are tested using a 3 year nationally-representative panel survey for rural Burkina Faso. The identification strategy compares plots managed by the household head with those managed by other males in the same household for the same year growing the same crop. I find that efficient allocation of inputs is not achieved; plots managed by the household head receive about 55 percent more fertilizer and about 25 percent more labor than the optimal amount. Redistribution of fertilizer and labor from the household head's plots to those of other household members would lead to higher agricultural production for the household. There is, however, evidence of some fertilizer and labor sharing within households. I

also provide evidence that input complementarity is an important mechanism through which the labor allocation decisions of junior members are influenced. The results are robust to various sample restrictions and empirical specifications.

The findings highlight the importance of bargaining positions of household members, and that access to certain inputs will allow individuals to influence input allocation decisions of others. Policies aimed at increasing use of modern agricultural inputs should consider its impact on bargaining positions within the household. Providing inputs to household members other than the head will increase their influence on other intrahousehold resource allocation decisions, leading to greater equity within the household. It will also increase total production by increasing allocative efficiency, since inputs are currently overallocated on collective plots. Hence, input-subsidy programs and similar programs should target younger household members to increase agricultural production and improve equity.

3.1 Introduction

Two types of plot management systems are prevalent in the dryland farming systems of West Africa. Collective plots are cultivated by the entire family under the management and supervision of the household head. Proceeds from these plots are mostly spent on the entire household. Individual plots allow family members to manage their own plots, and earn personal income. While individual plots proliferate, production on large collective plots continues to serve as the basis for family food security.

Most applied microeconomic studies on consumption and labor supply decisions assume that the household acts as a single unit with a well-behaved utility function (Bourguignon et al., 2009). Yet, this unitary model assumption is not supported by theory (e.g. Arrow's impossibility theorem) or by empirical studies. Browning and Chiappori (1998) find that the Slutsky symmetry

conditions are violated for two-person households in Canada but not for single men or single women households. They also reject income pooling for two-person households, providing evidence against the unitary model. Lundberg et al. (1997) show that when child benefit payments in the U.K. shifted from fathers to mothers, it led to significant increases in demand for children and women's clothing rather than men's clothing. This refutes a key implication of the unitary model that sources of income do not affect household decisions. These studies pointed to the need to better understand decision-making within the household.

Subsequent research developed the collective model (Chiappori, 1988), which assumes that despite having multiple household members, individuals can bargain and agree to efficient allocation of resources within the household. While some studies fail to reject Pareto-efficiency (Bobonis, 2009; Chiappori et al., 2002), studies in various African contexts provide evidence of inefficiency within the household. Dercon and Krishnan (2000) find in rural Ethiopia that women suffer more when the household faces negative economic shocks, a result inconsistent with the collective model. Goldstein and Udry (2008) also show inefficiency in following decisions in Ghana as evidence against the collective model, with women's plot being left fallow for fewer years and being less productive.

A large literature shows that in many West African countries, there is inefficiency in allocation of agricultural inputs within households (Udry, 1996; Akresh, 2008; Kazianga and Wahhaj, 2013), which is evidence against the collective model. Udry (1996), using a 4-year panel survey in Burkina Faso (1981-85), showed that plots managed by women were less intensively cultivated, leading to lower crop yields on the plots of females compared to males. Given diminishing marginal productivity, a reallocation of inputs from male to female plots would increase overall agricultural production of the household.

Kazianga and Wahhaj (2013) show that the differential access to inputs across gender can entirely be attributed to the difference in input access between collectively and individually managed plots. Collective plots are mostly managed by men in Burkina Faso, and failing to control for plot management system leads to its effect being attributed to gender. They find that individually managed male and female plots have similar access to inputs and have similar yields. While Guirkinger et al. (2015) find that individually managed plots are more intensively cultivated in Mali, few studies recognize plot management system as the major reason for differences in productivity within households.

Kazianga and Wahhaj (2013) show that household members provide much more labor to the collective plot than what is optimal. These empirical findings motivate the question: why do household members (perhaps voluntarily) provide large amounts of their labor to the collective plot? Since proceeds from the collective plot are mostly shared with the entire household, but individual plot proceeds are kept for oneself, we may expect rational individuals to free-ride and not work on the collective plot. Instead, they would prefer to work on their own land and keep the income from it for themselves.

Understanding the intrahousehold decision-making process is important in most developing country contexts, given that the household is usually the primary unit for organizing economic and social activities. It is especially important in the case of rural Burkina Faso, where most households are poor and have access to limited resources. Additionally, labor markets are weak and credit markets virtually non-existent (Kazianga and Udry, 2006; Wouterse and Taylor, 2008), and people rely on their families for generating livelihoods. By recognizing inefficiencies within the household, resources can be reallocated to increase the income of the household.

Given the low levels of income, small increases in income can result in a large improvement in welfare.

This chapter explores the allocation of agricultural inputs across collectively and individually managed plots in Burkina Faso. In specific, I study the allocation of inorganic fertilizer and family labor. I first present a theoretical model that describes how resources will be distributed between the household head and a junior member. The Pareto-efficient allocation of inputs is benchmarked by the collective model. The non-cooperative equilibrium differs significantly from this allocation, with much less input-sharing between the household members. The model also notes that other allocations could occur as a result of negotiation between household members.

Similar to Kazianga and Wahhaj (2013), this model assumes that social norms require the household head to spend part of his income on a public good³ shared by all household members. This social norm acts as a commitment mechanism, allowing the junior member to provide labor to the collective plot and benefit from greater public good consumption.

I show input complementarity as another mechanism through which the household head can influence the labor allocation decisions of other household members. By applying large amounts of fertilizer to his own plot, the household head can increase the marginal product of labor on his own plot compared to other plots in the household. Such strategic behavior allows the household head to manipulate the incentive structure of other household members, leading them to voluntarily choose input allocations that he prefers.

³ As explained in Kazianga and Wahhaj (2013), public goods loosely refer to commonly consumed goods, such as food and housing. Since these goods are not non-rival and non-excludable, they are strictly speaking not public goods. However, I stick to the convention of referring to commonly consumed goods as public goods.

Predictions of the model are then tested using a 3-year panel survey from Burkina Faso. There is strong evidence that the allocation of inputs within the household is not efficient. More fertilizer and labor are used on the household head's plot than what is optimal. The household can increase its overall production by reallocating fertilizer and labor from the plots of the household head to plots managed by others. I also provide evidence that the strategic behavior of the household head enables him to exert control on the labor of other family members.

This essay contributes to the literature by showing that the household head can act strategically and alter the incentive structure of other household members. This allows the household head to manipulate decisions made by others. Another difference from the previous studies (Udry, 1996; Akresh, 2008; Goldstein and Udry, 2008; Kazianga and Wahhaj, 2013) is that they only distinguish between efficient and inefficient allocation of inputs. I explicitly note that partial cooperation may exist between household members; even if they are unable to sustain the Pareto-efficient allocation of inputs, they may agree to an allocation that differs from the non-cooperative equilibrium. This emphasizes that cooperation should not be viewed as a binary concept.

Section 2.1 describes the agricultural context of Burkina Faso. The theoretical model and predictions of input allocation decisions are discussed in Section 2.2. Section 2.3 explains the empirical strategy to test for Pareto-efficiency, non-cooperative behavior and partial cooperation. The results are described in Section 2.4 along with robustness tests in Section 2.5, followed by some concluding remarks in Section 2.6

3.2 The Burkinabe Farming Context

Over two-thirds of the Burkinabe population depends on agriculture as their primary source of livelihood (World Bank, 2016). Production of rain-fed cereals, such as sorghum, millet, and

maize, account for over 70 percent of total cultivated land (INSD, 2014). Needing less moisture, millet and sorghum are well adapted to drylands and are cultivated throughout the country (INSD, 2014). Both cereals play an important role in achieving food security, since they constitute the basis of the diet for a vast majority of Burkinabe. In contrast, maize is mostly grown in the wetter zones of the country (INSD, 2014). Cotton, the country's main export, is also produced in the wetter zones (INSD, 2014) and is typically grown in rotation with maize and millet/sorghum.

Inorganic fertilizer use remains low in Burkina Faso despite its ability to significantly increase crop yields. While on average 15.8 kg/ha fertilizer is applied to arable land in Burkina Faso, it is 127.9 kg/ha in Latin American and Caribbean and 158.5 kg/ha in South Asia (World Bank, 2016). The government of Burkina Faso instituted a fertilizer subsidy in 2008 in an effort to stimulate use, particularly on maize and rice (Druilhe and Barreiro-Hurlé, 2012) because they are more fertilizer-responsive than sorghum or millet (Yanggen et al., 1998). Heads of households are mostly recipients of the subsidy and of any fertilizer received through official programs. Official sources still dominate fertilizer supply in Burkina Faso because of the scarcity of fertilizer and underdevelopment of commercial markets. Hence, family members are typically reliant on the household head for access to fertilizer.

Social norms in most of Burkina Faso are patriarchal and patrilineal (West, 2010). The senior male head has ultimate responsibility for ensuring the household's food security, and supervises agricultural activities on collective plots. Harvests from collective plots are shared as meals consumed together by the family. Often, families eat meals together while working on the collective plot, incentivizing family members to show up and work on the common plot. The patriarch 'holds the keys' to the family granaries and distributes their content (Kevane and Gray,

1999). Sales revenues serve to purchase commonly consumed goods, such as food. While nuclear households, constituting of a household head, spouse(s) and children, are common, extended households are also prevalent. These are multiple nuclear households living and eating together, and organizing agricultural production under the supervision of a patriarch. Common examples of extended households are when married sons and their wives live with their parents.

Many ethnic groups exist in Burkina Faso. The Mossi are a prominent ethnic group; about 52 percent of Burkinabe are Mossi (CIA-Factbook, 2017). Other major ethnic groups include Fulani, Gurma and Bobo. Norms of working on the collective plot and sharing its proceeds are most prevalent amongst Mossi households.

Alongside the collective plot, the head may also allocate plots among individual members of the household according to both norms and negotiation. Following patrilocal norms, women after marriage join the family of their husband and gain the right to cultivate a plot, on which they grow crops needed for food preparation (West, 2010; Guirkinger et al., 2015). This suggests that different types of crops are grown on collective plots and those managed by junior members. Kevane and Gray (1999) note that among many ethnic groups in Burkina Faso, proceeds from these plots belong to the women without encumbrance. In addition to the married sons and their wives, they note that unmarried sons and younger brothers of the head, as well as widows, may be allocated plots to supplement their personal needs. They also find that in times of duress when the family granaries are low, individuals may also be called upon to contribute to the common good from their individual proceeds.

The right to manage production on individual plots is negotiable. Kevane and Gray (1999) describe how women's indirect rights to the plots are obtained through marriage, are mediated by the broader range of duties and responsibilities undertaken by both men and women

in the household, and are often linked directly to provision of her labor. Household members are expected to supply labor to the collective plots before their own plots. Yet, young male plot managers interviewed by Guirkinger and Platteau (2014) admit to prioritizing their individual plots.

Ethnographic literature suggests that the amount of labor household members need to provide to the collective plot is flexible. Fiske (1991) writes:

“In these cultivating groups [farming the common plot] what really matters is participation, even token participation — if a member is making an effort, people do not assess the amount. Complete failure to participate in the collective farming, however, produces tension and results in critical gossip, although the group in fact continues to feed a member who does not work”.

This motivates the question, why do household members (perhaps voluntarily) provide large amounts of labor on collectively managed plots instead of free-riding? Kazianga and Wahhaj (2013) show how social norms requiring the household head to spend his income on public goods can explain such behavior. While they studied allocation of a single input, labor, I analyze allocation of both labor and fertilizer. This allows for a richer model that allows for strategic interplay between household members. In specific, I show how strategic behavior of the household head can exploit the complementarity of inputs to manipulate the input allocation decisions of other household members. This allows the household head to influence the labor allocation decisions of other household members and make them apply more labor to the collective plot.

3.3 Theoretical Model

This essay extends the intrahousehold decision-making models proposed by Kazianga and Wahhaj (2013) in order to understand the allocation of fertilizer, a modern, divisible input, and labor

between plots managed by the household head and those managed by other household members. The model shows how the intrinsic complementarity of fertilizer and labor has implications for the input allocation decisions of all household members.

The model examines the simple case of a household composed of only a head (h) and a junior member (m). The household head and junior member each manage one plot of land (collective and individual plot, respectively), growing the same crop Y that has a price normalized to 1. Similar to Kazianga and Wahhaj (2013), I assume that the junior member has $E_l^m > 0$ hours of productive labor endowment while the head has none of his own and must rely on labor from the junior member ($E_l^h = 0$). Unlike labor, the household head has a positive fertilizer endowment ($E_z^h > 0$), while the junior member does not ($E_z^m = 0$). These assumptions are based on typical resource endowments and decision-making rules described in Section 2. Access to a scarce and costly input like fertilizer is generally the privilege and the responsibility of the senior head, while junior members usually provide labor to the production process. While the zero-labor endowment of the household head and zero fertilizer endowment of the junior member may be a strong assumption, it can be considered a normalization.

The common production technology uses labor (L) and fertilizer (Z) inputs to produce Y . Output also depends on plot characteristics (A), such as soil quality. Since each individual has only one plot, the crop output, labor, fertilizer and plot characteristics can be subscripted by the member. Hence $Y^i = F(L^i, Z^i, A^i)$ for $i = h, m$, where F is a strictly concave function. Labor is more productive on plots where more fertilizer is applied ($\frac{\partial^2 F}{\partial L \partial Z} > 0$). This complementarity in production has interesting and meaningful effects on the optimal allocation of inputs because it allows household members to exert influence on others' decisions.

On the consumption side, there is one private good x with price p_x , and one public good q with price p_q . The junior member is free to spend his income on x or q . However, the household head is compelled by social norms to spend a fixed proportion, α , of his income on q . This acts as a commitment mechanism for the household head and incentivizes the junior member to provide labor to the head's plot. Utility is a function of the public and private good i.e. $U^i(x^i, z)$ for $i = h, m$. Since there are no savings in this model, the entire income is spent on the two goods.

Since the model assumes fixed endowments for fertilizer and labor, it essentially suggests both markets are missing. Kazianga and Udry (2006) note that apart from harvesting cotton, markets for hired agriculture labor are virtually absent in Burkina Faso. Our data also suggests that family labor constitutes the largest portion of labor used, and that exchanged and hired labor are used less often. The zero-labor endowment of the household head can be considered as a normalization. In the fertilizer market, the government is highly involved in all aspects from importation to retail (Wanzala-Mlobela et al., 2013). Subsidized fertilizer accounts for about 17 percent of all fertilizer consumed in Burkina Faso, and most fertilizer is acquired through farmer groups or cooperatives based on a fixed quantity per unit land cultivated (Wanzala-Mlobela et al., 2013). While anyone can purchase fertilizer for agricultural production, the household head is often member of a farmer organization that enable him to access fertilizer. Hence, farmer cooperatives remain the primary source of fertilizer (Theriault and Tschirley, 2014), and provide households fertilizer in proportional amounts to land cultivated (primarily for cotton).

The model also assumes that the household head has to spend a fixed proportion of proceeds from the collective plot on commonly consumed goods, which can be accessed by all family members. While the household head could restrict access of these goods to junior

members, in the social context it is unlikely that he withholds food or basic necessities from them. As Fiske (1991) notes, junior members who fail to work on the collective field will be subject to ridicule and gossip, but will continue to be fed by the family. As mentioned earlier, the norms of working together on the collective plot and consuming its proceeds jointly are most prevalent amongst Mossi families. In the empirical part of this study, I exploit this heterogeneity of social norms across different households.

Another mechanism to discipline junior members is not allocating them a plot in the following season. This also allows the household head to exert influence on the labor allocation decisions of junior members. However, in practice most junior members continue to cultivate the same plots (Kevane and Gray, 1999). This is especially true for male junior members (Akresh et al., 2016). Hence, this decision is not modeled into the theoretical model.

3.3.1 Collective Model

First, I use the collective model, where λ denote the Pareto weights, to benchmark the efficient allocation of resources. Then, similar to Fafchamps (2001), I explore conditions under which an efficient allocation could be sustained voluntarily over time.

$$\max_{x^h, x^m, q, L^h, Z^h, L^m, Z^m} \lambda U^h(x^h, q) + (1 - \lambda) U^m(x^m, q) \text{ s.t. } (1)$$

$$p_x(x^h + x^m) + p_q q \leq Y \quad (1a)$$

$$\frac{p_q q}{Y^h} \geq a \quad (1b)$$

$$Y = Y^h + Y^m = F(L^h, Z^h, A^h) + F(L^m, Z^m, A^m) \quad (1c)$$

$$L^h + L^m \leq E_L^m \quad (1d)$$

$$Z^h + Z^m \leq E_Z^h \quad (1e)$$

Equation 1a is the budget constraint for the household, while 1b denotes the social norm that requires the household head to spend a percent of his income on the public good. Y , the total household income, is defined in 1c as the sum of output on the head and junior member's plots. Equations 1d and 1e describe how the labor and fertilizer endowments respectively can be used on the two plots.

In the case that 1b binds, a percent of the income is spent on the public good and the remaining is allocated between the private goods of the head and junior member to equate weighted marginal utilities. If the public good is sufficiently desired by household members, a greater percentage is spent on the public good - up to the point where the per dollar marginal utility is equated between the public and private good.

My particular concern is the production side. When production is accomplished with Pareto efficiency, labor and fertilizer are allocated across the head and junior member's plots to maximize production given a fixed endowment of inputs. Hence the marginal product of labor and marginal product of fertilizer is equated across plots ($\frac{\partial F(L^h, Z^h, A^h)}{\partial L^h} = \frac{\partial F(L^m, Z^m, A^m)}{\partial L^m}$ and $\frac{\partial F(L^h, Z^h, A^h)}{\partial Z^h} = \frac{\partial F(L^m, Z^m, A^m)}{\partial Z^m}$). An implication is that $Z^h = Z^m$ if $L^h = L^m$ and $A^h = A^m$. In other words, use of fertilizer is the same across plots if labor inputs and land characteristics are the same. In the empirical estimation, we will test whether fertilizer is applied equally across plots, conditional on both plots having similar plot characteristics and plot manager characteristics.

3.3.2 Non-Cooperative Model

Next, I find the allocation of resources when the household head and junior member are unable to commit resources to one another. The household head, who in the local context is given the overall authority for farm production in the household, moves first. As explained in

Section 2, the household head as the patriarch has considerable influence over the household agricultural activities, and typically junior members play a more reactive role to his actions. This assumption is also based on the fact that there are multiple junior members in most households, which allows heads to negotiate with them and exert bargaining power.

The household head's problem is:

$$\max_{x_h^h, x_h^m, q^h, Z_h^h, Z_h^m} U^h(x_h^h + x_h^m, q^h + q^{m*}) \text{ s.t.} \quad (2)$$

$$p_x(x_h^h + x_h^m) + p_q q^h \leq Y^h \quad (2a)$$

$$\frac{p_q q^h}{Y^h} \geq a \quad (2b)$$

$$Y^h = F(L_m^h, Z_h^h, A^h) \quad (2c)$$

$$Z_h^h + Z_h^m \leq E_z^h \quad (2d)$$

while the junior member's problem is:

$$\max_{x_m^m, x_m^h, q^m, L_m^m, L_m^h} U^h(x_m^m + x_m^h, q^m + q^{h*}) \text{ s.t.} \quad (3)$$

$$p_x(x_m^m + x_m^h) + p_q q^m \leq Y^m \quad (3a)$$

$$Y^m = F(L_m^m, Z_h^m, A^m) \quad (3b)$$

$$L_m^m + L_m^h \leq E_L^m \quad (3c)$$

x_h^h , x_m^h , x_h^m and x_m^m are the amounts of the private good purchased and consumed by the head, purchased by the junior member and gifted to the head, purchased by the head and gifted to the junior member, and purchased and consumed by the junior member respectively. q^h and q^m are the public good purchased by the head and junior member respectively. Additionally, Z_h^h and Z_h^m are the amount of fertilizer applied to the head and junior member's plots respectively, while L_m^m and L_m^h are the amount of labor applied to the junior member and head's plots respectively.

Equations 2a and 3a are the budget constraints of the household head and junior member respectively, 2c and 3b are their production technology while 2d and 3c are their resource endowments. 2b is the constraint requiring public good provision due to the social norm.

The head will optimally allocate fertilizer across the plots so that $\frac{1}{p_q} \frac{\partial F}{\partial Z_h^h} + \frac{\partial q^{m*}}{\partial Z_h^h} = 0$. The

additional income from using an extra unit of fertilizer on the head's plot, $\frac{\partial F}{\partial Z_h^h}$, can be used to

purchase $\frac{1}{p_q} \frac{\partial F}{\partial Z_h^h}$ units of q . At the optimum, this will equal $\frac{\partial q^{m*}}{\partial Z_h^h}$, the loss in public good

contributed by the junior member due to more fertilizer applied on the head's plot (which leads

to less fertilizer applied on the junior member's plot). $\frac{\partial q^{m*}}{\partial Z_h^h} \leq 0$ since the junior member is not

required to contribute to the public good. In case the junior member does not purchase the public

good, $\frac{\partial q^{m*}}{\partial Z_h^h}$ equals zero and the head will apply all the fertilizer to his own plot i.e. $Z_h^h = E_z^h$.

This is because the head does not benefit from higher income on the junior member's plot, since all of it is spent on the private good. Even if the junior member contributes to the public good, this contribution is likely to be low and the head will allocate a larger portion of fertilizer on his own plot rather than the junior member's plot.

The junior member will allocate labor so that $\frac{1}{p_q} \frac{\partial F}{\partial L_m^m} + \frac{\partial q^{h*}}{\partial L_m^m} = 0$. The additional income

gained by the junior member from using an extra unit of labor on his plot, $\frac{\partial F}{\partial L_m^m}$, can be used to

purchase $\frac{1}{p_q} \frac{\partial F}{\partial L_m^m}$ units of q . At the optimum, this will equal $\frac{\partial q^{h*}}{\partial L_m^m}$, the loss in public good

contributed by the household head due to less labor applied to the head's field. But $\frac{\partial q^{h*}}{\partial L_m^m} \neq 0$

rather $\frac{\partial q^{h*}}{\partial L_m^m} < 0$, since the head is obliged to spend a share of the income from his plot on the public good due to social norms that he protects food security in the household.

While we expect more fertilizer to be allocated to the head's plot than the junior member's plot, we expect labor to be even more evenly distributed - more labor may actually be allocated to the collective plot - for two reasons. First, social norms act as a commitment mechanism to ensure that the head spends a fixed proportion of his income on the public good. Second, the marginal product of labor will be higher on the head's plot due to higher application of fertilizer. We may have naively expected the non-cooperative equilibrium to result in each household member allocating their entire productive resource endowment on their own plots. However, input complementarity in production enables the head to exert some control over labor allocation despite not having any labor endowment.

3.3.3 Sustaining Cooperation

I now present conditions under which the household can voluntarily achieve the efficient allocation of resources and emulate a cooperative solution through bargaining. Since there is repeated interaction, action over time between the head and the junior member, they can sustain the efficient solution in the collective model. From the second welfare theorem, we know that a Pareto efficient resource allocation can be represented as a price system combined with lump-sum transfers (Fafchamps, 2001).

Let U_c^h and U_c^m be the household head and junior member's single period utility under the collective solution while U_a^h and U_a^m are defined as their single period autarky solution. The collective solution can be sustained under the following condition:

$$\sum_{t=0}^{\infty} \delta_t^i U_c^i > U_s^i + \sum_{t=1}^{\infty} \delta_t^i U_a^i \quad \text{for } i = h, m \quad (4)$$

U_s^i denotes the single period utility of i from unilaterally deviating from the collective model allocations. The condition above suggests that the collective model solution can be sustained if the discounted lifetime utility from the collective solution occurring forever is higher than the utility of deviating for one period and then receiving the non-cooperative equilibrium utility.

Alternatively, the household members may try to sustain allocations other than the efficient one using a similar condition as equation 4. The non-cooperative equilibrium determines the reservation utility of the household head and the junior member. Other equilibrium may exist that involve some exchange of fertilizer and labor that is less than that the optimal amount. In this equilibrium, the utility of both players should be greater than the reservation utility. Additionally, a no-deviation condition similar to equation 4 will ensure neither player has an incentive to shirk.

There are a few reasons why household members could want to sustain an allocation different from the most efficient allocation. The efficient allocation of resources may require significant exchange of inputs between household members. This leads to a hold-up problem, increasing the benefit from a one period unilateral deviation. Instead, it may be easier to sustain an allocation which has substantial input-sharing, but does not go as far as the efficient allocation of inputs. This reduces the benefit of a one period deviation, and discourages players from shirking. Another reason may be high transaction cost of bargaining (Akresh, 2008). Endowment effects and status quo bias (Kahneman et al., 1991) may also cause household members to not want to exchange the input they are endowed it.

Given that household members live together for a large number of years, the folk theorems (Abreu et al., 1994) suggest that some level of cooperation is quite likely to exist

within the household. There is also less asymmetric information and hidden actions, increasing the ability of household members to cooperate. Comparative advantage for different types of labor also increases the incentive to trade labor. Men are often assigned tasks that require more strength, such as plowing, while women are tasked with tedious activities such as weeding. For all of these reasons, we expect household members to work together and have some level of cooperation. The empirical analysis will specifically test for such a partial cooperative allocation.

Another fact to note is that junior members are not necessarily better off even if the efficient allocation of inputs exists within the household. This is because to sustain this equilibrium, they may need to make side transfers to the household head for his provision of fertilizer to the individual plot. But this may leave them no better off than they are in the non-cooperative solution. Hence, an efficient allocation of resources does not necessarily increase the welfare of all individuals within the household.

3.3.4 Predictions

In principle, we would like to observe the bargaining process between household members to test the theoretical model. However, since the process is unobservable, the data is used to test the predictions of the models to assess which one is better explain observed behavior. The theoretical model is used to make predictions about input allocation and production for Pareto-efficiency and non-cooperative behavior. Predictions are also derived for a partial cooperative equilibrium.

Under Pareto-efficiency, we expect:

$$Z^h = Z^m \text{ if } L^h = L^m \text{ and } A^h = A^m \quad (5)$$

$$L^h = L^m \text{ if } Z^h = Z^m \text{ and } A^h = A^m \quad (6)$$

$$Y^h = Y^m \text{ if } A^h = A^m \quad (7)$$

Under non-cooperative behavior, the allocation of fertilizer and labor depends on multiple parameters in the model. Similar to Kazianga and Wahhaj (2013), I assume that the junior member makes zero contribution to the public good. In normal circumstances, this is a close approximation to how households in rural Burkina Faso operate since proceeds from the collective plot is used to feed the family while income from individual plots is spent by the plot manager.

In this case, the household head applies all the fertilizer to his own plot. Hence:

$$Z_h^h = E_z^h \text{ and } Z_h^m = 0 \quad (8)$$

In turn, the junior member will apply large amount of labor on the collective plot and lower amount of labor on his own plot. The precise amount of labor on the collective and individual plots depends on the production function and utility functions, and is defined as:

$$L_0 \ni \frac{1}{p_z} \frac{\partial F}{\partial L_m^m} + \frac{\partial z^{h*}}{\partial L_m^m} |_{L_m^m=L_0} = 0 \quad (9)$$

Allocations that differ from the Pareto-efficient allocation (equations 5 and 6) and the non-cooperative allocation (equations 8 and 9) would suggest a partial cooperative equilibrium.

Two more implications based on the theoretical model are discussed⁴. One is based on the fact that at different points of the agricultural season, the marginal productivity of labor is different. Early in the season, before costly inputs such as fertilizer and herbicide are applied, different plots have relatively similar marginal product of labor. As the season progresses and these inputs are applied, the plots where these are applied more have higher marginal product of labor. Essentially, junior members will realize that the output gained from working on their individual plots will not be greater than what they stand to gain from working on the collective

⁴ These predictions are not formally derived to keep the theoretical model tractable

plot. At this point, it is in the self-interest of the junior member to work more on the collective plot. Since the labor data disaggregates between plowing, sowing, maintenance, harvest and transportation activities, I test whether the overallocation of labor to the collective plot increases later in the season.

Ideally, the survey would indicate the date on which fertilizers and other inputs are applied to each plot. Unfortunately, such data is rarely gathered in any survey and not available in this dataset. Instead, I will test whether the labor allocation to the collective plot increases later in the season when agricultural inputs are applied, compared to early season activities (plowing and sowing) when these inputs have not been applied.

Since the junior members can foresee the head allocating most fertilizer to his own plot, they will reduce labor allocation to their own plot even in early parts of the season. This suggests that the effect we observe is a lower bound on the true influence the higher marginal productivity on the collective plot has. The information gained later in the season is useful though, since there is much less uncertainty later in the season. Hence, I do expect the allocation to change later into the season.

The actual application of fertilizer also requires labor, which may partially explain why labor allocation is higher on the collective plots. This factor will be accounted for in the empirical analysis. I also test for overallocation of labor being greater in Mossi households compared to households of other ethnicities. Since the social norms of joint farming and consumption are more prevalent in Mossi households, I expect more labor to be allocated to the collective plot for these households compared to other households. This should result in more overallocation of fertilizer and labor to the collective plot in regions where there is a greater proportion of Mossi households.

3.4 Data & Empirical Strategy

This essay utilizes data from the Continuous Farm Household Survey (*Enquête Permanente Agricole* (EPA)) of Burkina Faso. The dataset contains detailed plot level information on crops grown, inputs applied and the quantity of each crop harvested. The quantity of crop harvested is estimated by taking a random sub-sample of each plot and measuring the output from that sub-plot. This leads to more accurate estimates of output and yields. The survey is not a plot level panel. Hence, plots cannot be matched across rounds and plot fixed effects cannot be used to control for time-invariant plot level characteristics.

Other modules include a household roster, which contains person level demographic information, and others that contain information on livestock, household grain stocks, nutritional status and off-farm incomes. GPS coordinates are also available for each village, which allows me to match the data with other geo-spatial datasets to find measures of distance to towns and cities.

Since my main dataset, the Continuous Farm Household Survey, does not contain information on the ethnicity of households, I use the Burkina Faso LSMS dataset for year 2014 for such data. The LSMS survey does not explicitly ask for the ethnicity of households, but notes the language the interview was conducted in. Moore is the language of Mossi people (Grootaert et al., 2002); households that respond in Moore are identified as Mossi households. In order to match this information with my sample, I calculate the proportion of Mossi households in each province in the LSMS data. I use these as the proportion of Mossi households in each province in my analytical dataset. This allows me to use the variation in prevalence of Mossi households across the 45 provinces to test whether there are differences in patterns of input allocation across ethnicity.

To check for Pareto-efficient allocation of inputs, I test whether input allocation is affected by plot management system. The theoretical model suggests that inputs should be shared equally across collective and individual plots, controlling for factors that affect productivity. However, there are a large number of factors that determine input allocation - some of which are correlated with plot management system. Identifying the effect of plot management system on the quantity of inputs applied to different plots requires adequately controlling for these factors. I am able to use several features of the data, described below, to test for allocative efficiency. Among the 62,603 plots in the data, 36,901 are collectively managed while 25,702 are individually managed. The collective plots are predominantly managed by men; only 2,643 are managed by women. 93 percent of collective plots are managed by the household head themselves; 4 percent are managed by his/her spouse and 2 percent by a son.

As expected in the Burkinabe context, majority (96 percent) of household heads are male. Access to productive resources differs significantly by gender (Theriault et al., 2017; Peterman et al., 2011; Quisumbing et al., 2001). Given that very few women manage the collective plot and even fewer are the household head, and that there is a large gender differential in access to inputs, it will be challenging to isolate the gender effect from that of the plot management system. Hence, I follow (Guirking et al., 2015; Ouedraogo, 2016) and restrict the sample to plots managed by males. By comparing collective and individual plots managed by men, I ensure that the effect of plot management system on inputs application rates is not confounded by gender effects.

On average, a household cultivates 8 plots - 4.7 of which are collective and 3.3 of which are individual. The total number of plots ranges from 1 to 46, with large variability across household structure (e.g. nuclear vs. extended households) and geographic regions. Households with more

members generally have more plots, while Ouedraogo (2016) suggests that collective farm management is an ex-ante risk management technique to cope with weather variability.

Collective plots exist in most households; only 2 percent of households exclusively cultivate individual plots. On the other hand, 28 percent of households cultivate collective plots and no individual plots. Thus, the vast majority of households cultivate both individual and collective plots.

Figure 3.1 shows how the proportion of collective and individual plots within a household differs across regions of Burkina Faso. The area of each pie chart is proportional to the average number of plots of a household in the region. The gray and white areas denote the average number of collective and individual plots in a household, respectively. Overall, there are more collective plots than individual plots within households in most regions. In South-Western Burkina Faso, collective farming dominates individual farming. In other parts of the country, collective and individual plots are cultivated in relatively similar proportions within the household. Hence, comparing collective and individual plots cultivated by males within the same household may be a sensible empirical strategy.

Typically, different crops are grown on collective and individual plots. The primary crop on 33 percent, 26 percent and 19 percent collective plots is sorghum, maize and millet respectively. However, the primary crop on 27 percent, 9 percent and 12 percent of individual plots is sorghum, maize and millet respectively. Instead, 20 percent of individual plots are used to grow peanuts while an additional 11 percent primarily grow rice.

In general, plot management systems differ across geographic regions and types of households, both of which are likely to affect agricultural intensification and productivity. Also, different types of crops are grown on collective and individual plots. This is likely to be

problematic due to different input requirements and responsiveness of various crops. To control for factors that affect input choices and productivity, I use a household-year-crop fixed effects approach following Udry (1996), Kazianga and Wahhaj (2013) and Ouedraogo (2016).

Hence, the model to be estimated is:

$$I_{hjt} = \beta_0 + \beta_1 \text{collective}_{hjt} + \beta_2 \mathbf{X}_{hjt} + \delta_{hkt} + \varepsilon_{hjt} \quad (10)$$

I_{hjt} is the input per hectare applied on plot j of household h growing crop k at time t . In the case of fertilizer, it is the total nitrogen nutrient kg per hectare applied to the plot. For labor, it is the total number of labor days divided by area (hectares) of the plot. Since there is large heterogeneity in plot sizes and the model describes the intensity of input use, the relevant quantity for analysis is input per hectare (rather than the total quantity of the input). The total nitrogen nutrient kg is calculated by summing the nitrogen content of urea (46%) and NPK (14%), same as Koussoubé and Nauges (2017).

The main explanatory variable of interest is *collective*, which equals one if the plot is a collective plot and zero if it is an individual plot. $\mathbf{X}$ includes plot level characteristics that affect input choice. All the explanatory variables are defined in Table 3.2.

A number of factors can affect input use decisions. Economic theory suggests that the price of fertilizer and wage rates will affect quantity used of fertilizer and labor respectively. In case of missing fertilizer and labor markets, as suggested by Wanzala-Mlobela et al. (2013) and Kazianga and Udry (2006) respectively, their demand will depend on shadow prices, which will be a function of household characteristics. The prices of other complementary and substitute inputs will also be important determinants of quantities of fertilizer and labor used.

Regional characteristics affect input decisions since some areas have greater access to fertilizer through the subsidy program or from commercial supply chain (Wanzala-Mlobela et

al.,2013). The geographic location of households will also affect input choices; area with climate conducive to agriculture might have higher use of inputs, and areas with soil more responsive to fertilizer would have greater application of fertilizer (Koussoubé and Nauges, 2017). If any of these factors are correlated with plot management system and are not adequately controlled for, β_1 will be inconsistent due to omitted variables bias.

Household-level characteristics can also affect input use decisions. Households with more members may have more individual plots (Akresh et al., 2016), and also greater availability of labor. Hence, household structure may be correlated with plot management system and with input allocation, leading to inconsistent estimation of β_1 .

Other important factors may depend on time; in years of low rainfall, household members may prefer to consolidate resources and work on the collective plot (Ouedraogo, 2016), resulting in fewer individual plots being cultivated. Fertilizer use may be low in such years, since fertilizer is less effective without adequate supply of water.

Another important difference between collective and individual plots are the type of crops that are grown. While cereals and cash crops are usually grown on collective plots, vegetables and crops needed for food preparation, like condiments, are often grown on individual plots of females.

By using a household-year-crop fixed effects model, I compare inputs allocated to collective and individual plots growing the same crop in the same household in the same year. This controls for many crop-choice, household, market, geographic and time varying factors that may affect input choice. Fertilizer price and labor wage rates are controlled for by comparing input allocation of people within the same household. However, if these prices vary

systematically across household members the household-year-crop fixed effects model will not adequately control for them.

I additionally control for plot characteristics. These include plot area, whether the plot is located far from the dwelling, whether it is a lowland plot, if it is flat or sloped plot, whether the plot has a secure tenure and whether the plot is intercropped.

Plot area is included as indicator variables for decile, following the specification in the literature (Udry, 1996; Kazianga and Wahhaj, 2013; Ouedraogo, 2016). This allows a highly non-linear relationship between plot size and input intensity/crop yield, and is much less restrictive compared to a level, square or logarithmic specification. The tenth decile is the reference group, and its indicator variable is omitted in $\mathbf{X}$. The model is re-estimated for robustness using a level term, which imposes a linear effect of plot size. The equation is also estimated with a level and quadratic term for plot size, and using the natural logarithm of plot size⁵.

Tenure security may be an important determinant of how much a household invests in a plot. The tenure security indicator variable is based on a self-reported response. Since farmer actions are more likely to depend on their own perceptions (rather than objective measures of tenure security), it is the appropriate measure.

The main coefficient of interest in equation 10 is β_1 . If the estimated coefficient is different from zero, there is evidence of inefficient allocation of labor. $\beta_1 > 0$ suggests that the input is overallocated to collective plots, while $\beta_1 < 0$ means the input is overallocated to individual plots.

Equation 10 is also estimated with yield (kg/ha) as the dependent variable. Controlling for characteristics that explain agricultural productivity, the yield should be similar on collective

⁵ The natural logarithm of plot size + 1 is taken to ensure that the variable only takes on positive values

and individual plots. This test is similar to those in Udry (1996) and Kazianga and Wahhaj (2013).

However, I additionally control for material inputs, which may be an important mechanism through which the productivity differential exists, and test whether a differential still remains. If β_1 is statistically significantly different from zero, there is evidence of Pareto-inefficiency. The collective model, or a cooperative equilibrium that emulates the efficient allocation of inputs, would then be rejected.

If Pareto-efficiency is rejected, some tests are conducted to check whether observed behavior is more consistent with the non-cooperative model or a partial cooperative equilibrium. In some specifications, I also control for the use of other agricultural inputs (measured in kg/ha or liters/ha). Since there may be complementarity in use of inputs, this might be a source of omitted variables bias. For example, if plots that receive more fertilizer also receive more quantity of seed, not controlling for the quantity for seed will lead to the coefficient of fertilizer also capturing the effect of greater quantities of seed. Controlling for these inputs will reduce omitted variables bias.

I first present some descriptive statistics to show the extent to which different household members work on each other's plots. Labor exchange is common if all plots benefit from all types of labor (male, female and child). I also test whether a collective plot receiving fertilizer is highly predictive of all individual plots within the same household receiving some fertilizer. This is suggestive evidence of input-sharing between household members.

The model is also tested by noting that it predicts that the overallocation of labor to the collective plot increases later in the agricultural season. Land preparation and sowing are defined as early agricultural season activities - these are done before fertilizer and other material inputs

are applied to plots, which increases the marginal productivity of labor and the expected return from working on the collective plot. The later-season activities include crop maintenance, harvest and transportation.

$$L_{h j k t}^{early} = \alpha_0 + \alpha_1 Collective_{h j k t} + \alpha_2 X_{h j k t} + \gamma_{h k t} + \nu_{h j k t}$$

$$L_{h j k t}^{later} = \beta_0 + \beta_1 Collective_{h j k t} + \beta_2 X_{h j k t} + \delta_{h k t} + \epsilon_{h j k t}$$

L^{early} is the quantity of labor applied to a plot for land preparation and sowing. L^{later} is the quantity of labor applied to a plot for crop maintenance, harvest and transportation. The other variables are defined earlier. The theoretical model suggests that $\beta_1 > \alpha_1 > 0$. $\beta_1 > \alpha_1$ because the difference in marginal productivity of labor on the collective and individual plots is higher later in the agricultural season, once productivity-enhancing investments have been made. $\alpha_1 > 0$ since early in the agricultural season, the junior member foresees that the head will apply more fertilizer on his own plot.

Since the analysis depends heavily on application rates of labor and fertilizer, I trim the sample to ensure outliers do not overly affect the results. For each year, the smallest and largest 1 percentile labor application rates (person days per ha) of collective and individual plots are presented in Table 3.1. There are some very small and very large values for the labor application rate in the data. The lowest 1 percentile labor application rates are close to zero and improbable, since some labor is required for agricultural activities. The highest 1 percentile values are also extremely high (equivalent to about 40 people working 100 days in a season on a single plot).

For the fertilizer application rate, a large proportion of plots do not use any fertilizer. Hence, the zero application rate is a common occurrence, and those observations are retained in the analytical sample. On the other end of the distribution, the highest 1 percentile values are considered plausible. In the Burkina Faso LSMS survey, the 99th percentile quantity of fertilizer

is about 94 N kg/ha, suggesting that the 99th percentile values we find are possible. The fertilizer data is likely to have less measurement error since most farmers purchase fertilizer in bags and are likely to know the total quantity, especially since it is a fairly large purchase for them. Also, fertilizer is applied to plots on a few number of days - unlike labor, which is applied consistently throughout the agricultural season. This suggests that the fertilizer quantity data might be more reliable with fewer misreporting or errors in the data. Hence, I trim only the higher 0.1 percentile values to ensure that extreme observations do not drive the results. In the remaining chapter, the statistics presented and regression models estimated are based on the analytical sample.

Table 3.2 shows that the size of an average collective plot is 0.63 ha, about twice as large as an individual plot. Typically, collective plots are closer to home and have more secure tenure, as reported by the survey respondent. A slightly higher proportion of collective plots are intercropped compared to individual plots.

The data also suggests that material inputs are applied more intensively on collectively managed plots. For example, the fertilizer application rate is 8.19 nitrogen kg/ha on collective plots, as opposed to 5.51 nitrogen kg/ha on individual plots. Similarly, manure, herbicide, fungicide and raticide application rates are higher on collective plots. The seed application rates are, however, higher on individual plots.

Labor application rates are also higher on individually managed plots - which may suggest that managers of individual plots try to compensate for lower access to material inputs by working on their fields harder. Individual and collective plots receive relatively similar amounts of male labor. However, individual plots receive about 10 days/ha more female labor and 13 days/ha more child labor. Since these are all individual plots operated by men, it suggests they are able to access labor from their wives and children. The data also shows that crop maintenance, which

includes fertilizing, irrigating, weeding etc., is the most labor-consuming activity, followed by crop harvest.

Table 3.3 shows the crop yields on individually and collectively managed plots. The last column is the p-value that the yield on the individual and collective plot is unequal. At the 5 percent statistical significance level, crop yields of millet, white sorghum and peanuts are greater on collective plots than individual plots. For all of the other crops, the yield is not statistically different across collective and individual plots.

Table 3.4 shows that in the analytical sample, the average household has 3.96 collective and 0.56 individual plots. The low number of individual plots is because we dropped female managed plots from the sample as part of the identification strategy. This translates to 2.28 hectares of cultivated area for each household. The average household size is 10.65 members; about 40 percent of households are extended households.

Since these are all (unconditional) descriptive statistics, the differences across collective and individual plots can be due to many reasons - such as differences in plot characteristics or crops grown on the plots.

3.5 Results

I now present results from the formal tests described in the previous section. Table 3.5 shows estimates from estimating equation 10 for fertilizer and labor. The dependent variable in columns 1-4 is the quantity of fertilizer applied to the plot (nitrogen kg/ha), and in columns 5-8 is the quantity of labor used on the plot (total labor days/ha). Columns 1 and 5 are estimates from the household-year-crop fixed effects model with *Collective* being the only explanatory variables. Other explanatory variables are sequentially added across specifications. Columns 2 and 6 control for plot characteristics that may affect input choice. Column 3 includes the quantity of fertilizer

applied to the plot as an explanatory variable, while column 7 includes the quantity of labor applied to the plot as an explanatory variable. Columns 4 and 8 include other material inputs that are applied to the plot.

Column 2 shows that comparing collective plots with individual plots cultivated by men within the same household in the same year growing the same crop, additionally controlling for observable plot characteristics, the collective plot receives 87 additional labor days per hectare. This is about 25 percent higher labor allocation to the collective plot, statistically significant at the 1 percent level. Even when we control for other inputs, the collective plot receives 85 extra labor days, significant at the 1 percent level.

Similarly, column 6 shows that collective plot receive 3.50 nitrogen kg per hectare more fertilizer than individual plots. This amounts to a 55 percent higher allocation on the collective plot. In the most robust specification, column 8, the collective plot receives 2.21 nitrogen kg per hectare (35 percent) more fertilizer than the individual plot. For all specifications, the coefficient is significant at the 1 percent level.

Both labor and fertilizer are overallocated to the collective plot in large quantities. This leads to the rejection of Pareto-efficiency, since the household can increase production by reallocating both inputs from the collective plot to those of junior males.

The coefficients of the area decile variables suggest that the effect of plot size on input allocation is fairly non-linear. The smallest plots have higher rates of fertilizer and labor allocation, while larger plots have considerably lower application rates.

Since there is greater allocation of labor on the collective plots even when controlling for material inputs (such as the quantity of fertilizer), it suggests that they are not the only factors the household head can use to make the junior members allocate labor to the collective plot. Other

mechanisms include altering allocation of individual plot the following year (Akresh et al., 2016) or using social pressure (Kazianga and Udry, 2006). The quality of inputs is not homogeneous either, especially since the timing of the labor and fertilizer application has a large impact on how effective it is. Since the collective plot has first right to access labor, it might be able to use labor at the most productive time (e.g. after rainfall) while the individual plot receives labor at a later point in time. In that case, even if the individual plot receives the same amount of labor as the collective plot, the collective plot will be advantaged and may achieve higher yields.

Despite benefiting from the allocation of large amounts of labor and fertilizer, Table 3.6 shows that collectively managed plots achieve about 38 kg/ha (only 4 percent) higher yield compared to individually managed plots. This is similar to Udry (1996), who finds that yields can be increased by 6 percent by reallocating inputs from plots managed by men to those managed by women. When the quantity of labor and fertilizer is controlled for, the coefficient decreases, suggesting they are key mechanisms through which the higher yield is achieved on the collective plot. When the quantity of other inputs is controlled for, the coefficients reduces to 24 kg/ha - statistically significant at the 10 percent level. This suggests that these inputs are important contributors of the yield differential. The yield differential exists even when all these inputs are controlled for. This may be due to heterogeneity in the quality of the inputs and the timing at which they have been applied.

The small yield differential suggests that the labor and fertilizer allocated to the collective plot is not being used very effectively. In general, we would expect there to be some diminishing returns to scale due to concavity of production functions. However, if there is a very large overallocation of inputs on collective plots, the farm may be operating at a fairly flat part of the production function.

To explore the heterogeneity of labor available to collective and individual plots, I estimate equation 10 with male labor, female labor and child labor (each in number of labor days per hectare) as the dependent variables. Table 3.7 shows that the overallocation on the collective plots is there for all types of labor. The results are significant at the 1 percent level. Female labor is the most unevenly distributed across collective and individual plots; collective plots receive 35 extra labor days of female labor compared to individual plots. As expected, the sum of the coefficients for male, female and child labor equals the labor overallocation amount estimated in table 3.5, since these are all the types of labor that can be used.

Next, I test the implication of the model that suggests that junior members will allocate more labor to the collective plot as the season progresses. Table 3.8 shows the labor allocation across collective and individual plots early and late in the season. While the overallocation of labor on the collective plot exists early in the season, it is nearly three times greater later in the season. This suggests that as the season progresses, junior members realize that the marginal product of labor is higher on the collective plot - and they allocate more labor on those plots. In all specifications, the coefficients are statistically significant at the 1 percent level. Also, for each specification, the coefficient in the early season and late season specifications are statistically significantly different from one another at the 1 percent level.

I also test whether the overallocation of labor to the collective plots is more prevalent in regions with greater Mossi populations. In table 3.9, *Collective * Mossi* is the coefficient of interest. It suggests that a household residing in a province with only Mossi population has 110 more labor days allocated to the collective plot relative to the individual plot, compared with a province with no Mossi households. Households in provinces with no Mossi population do not have a statistically significant overallocation of labor on the collective plot.

The *Collective*Mossi* coefficient ranges between -2.5 and -1.6. While these coefficients are not precise estimates (p-values range between 0.19 and 0.25), it could suggest that in regions with greater Mossi population, household heads are more willing to share fertilizer with junior members in exchange for their labor. This suggests that some level of cooperation (as described in section 2.2) is being sustained by household members - though this is clearly not enough to sustain an efficient allocation of inputs within the household.

The main threat to identification is unobserved plot characteristics that are correlated with fertilizer and labor allocation. If the collective plot is of higher quality i.e. more responsive to inputs, more inputs should be allocated to it. This would mean the optimal allocation requires more fertilizer and labor be allocated to the collective field. Our results would then no longer be evidence of inefficiency within the household. However, unobserved plot characteristics are unlikely to lead to such large overallocation of fertilizer and labor on the collective plot. The regression already controls for basic plot characteristics, such as slope and location on the toposequence.

Since the collective and individual plots belong to males in the same households in the same area, they are likely to be of relatively similar quality. Moreover, previous studies (Udry, 1996) show that based on observable plot characteristics, individual plots are of better or same quality as the individual plots.

While the theoretical model predicts the household head can allocate all the fertilizer on his own plot, we see a significant amount of fertilizer allocated to the plots managed by junior members. In previously discussed ways in which the household head can influence the actions of junior members. There are also ways in which the household head's actions are also disciplined, to ensure that he does not act in a completely dictatorial or selfish manner.

Junior members can create coalitions with one another to counter the bargaining power of the household head. For the coalition to be viable, each junior member must receive at least as much utility from staying in the coalition than the utility outside the coalition. If a coalition can be sustained in which junior members limit the labor available to work on collective plots, it may be able to exert some pressure on the household head to require him to share more fertilizer with junior members.

Another mechanism restricting the household head's actions are altruism and social norms. The household head may be altruistic towards his family members, thus incorporating their utility into his own utility function. That would lead to him want to share inputs with junior members, so that their incomes increase and they can purchase private goods. Such behavior would be expected amongst family members who care about their consumption but also of others.

Junior members may also be able to access material inputs from other sources, which allows them to not be completely dependent on the household head. For example, they may be able to purchase some fertilizer from nearby markets. They may also have outside options, such as working in the non-farm sector, which increases their reservation utility and requires the household head to compensate them more in order for them to work on the collective plot.

3.6 Robustness

Next, I conduct a series of robustness tests to ensure that the results are not driven by the sample selection, data trimming or the empirical specification.

The results above were based on an analytical sample from which female farmers were removed. This helped identify the effect of plot management from the effect of gender. However, since females constitute a large majority of individual plot managers, I want to test whether retaining them in the sample changes the main findings.

The results from estimating equation 10 are presented in Table 3.10. The findings are qualitatively the same; labor and fertilizer is overallocated on collective plots. All coefficients are significantly different from zero at the 1 percent significance level. The coefficients are slightly smaller than those in 5, suggesting that junior females have slightly greater access to agricultural inputs than junior males.

In the main analytical sample, I trimmed the largest one percentile of labor quantity observations but only the largest 0.1 percentile of fertilizer quantity observations. I re-estimate the results trimming the largest one percentile of fertilizer quantity observations (to be consistent with the trimming based on labor quantities) and with no trimming of the sample based on labor or fertilizer quantities. Tables 3.11 and 3.12 show that the results remain qualitatively unchanged in each case. The results are still precisely estimated, at the 1 percent significance level. Trimming more of the sample based on fertilizer quantities leads to smaller coefficients estimated for *collective* in the fertilizer equations. Not trimming any of the sample leads to larger estimated coefficients of *collective*.

Both of these results are expected. By trimming more of the fertilizer data, some of the larger fertilizer quantities are removed from the sample for collective and individual plots. This leads to smaller estimated difference in the mean application rates across the two types of plots. Even though the magnitude of the difference is smaller, about 1.8 nitrogen kg/ha, it is still a large difference (about 30 percent) across the two types of plots.

Similarly, not trimming any of the sample based on labor and fertilizer quantities suggests a greater overallocation on collective plots. This is because the sample retains the largest values of labor and fertilizer application rates.

Another somewhat arbitrary choice in the empirical specification was using quartiles of plot size rather than a more standard level, quadratic or logarithmic specification. While the main results were presented in quartiles for consistency with the literature, I show in Tables 3.13, 3.14 and 3.15 that the results remain qualitatively the same. Each of the point estimates are very similar to those in table 3.5. The only estimates that are meaningfully different in magnitude are the labor regressions for the specifications using a level plot size term. That is the most restrictive specification, and while the coefficient is 25 percent smaller than in the specification using plot size quartiles, the results are qualitatively the same. Hence, the main results use the most flexible specification using plot size quartiles, which keep the specification consistent with those in the literature.

All these regressions suggest that the results are not based on arbitrary choices of sample selection or empirical specification. Hence, we have very robust evidence that labor and fertilizer are both overallocated on collective plots.

3.7 Conclusion

A large literature has identified inefficient allocation of resources within households. In this article, I study the allocation of inputs across plots managed by different household members in Burkina Faso. I find that the plots managed by the household head receive more fertilizer and more labor. The initial endowment of resources and bargaining positions are important determinants of resource allocation within the household. The theoretical model shows that even if the efficient allocation of inputs can be sustained, it does not imply that all members of the household are better off. To sustain the cooperative equilibrium under repeated interaction, household members may have to make other transactions and household members with better bargaining positions

may accrue most benefits. Even if input allocation is efficient within the household, interventions may be needed to address equity issues within the household.

In West Africa, many countries have input subsidy programs that attempt to increase the use of modern agricultural inputs to boost productivity (Jayne et al., 2018). In Burkina Faso, these subsidies are often more accessible to the household head than junior members, especially women. This is partly because subsidized fertilizer is mainly available through farmer cooperatives (Theriault and Tschirley, 2014), and the household head is often the representative of the household in these cooperatives. Along with fertilizer, these subsidies provide the household head with more bargaining power. This allows him to influence decisions made by others in the household.

The design and implementation of agricultural programs and policies can be improved by better understanding decision-making within households. A large literature has shown that increasing incomes of junior members, particularly women, leads to better nutrition and education outcomes for the entire household (Fiszbein and Schady, 2009 ; Hoddinott and Haddad, 1995). There is an overall consensus in the literature that women are more efficient in utilizing cash transfer funds than men and, therefore, virtually all conditional cash transfer programs target females as recipients (see Fiszbein and Schady (2009) for a review). Such targeting, however, does not exist in programs that aim to increase agricultural input use. Directly targeting junior members to receive input subsidies or vouchers could lead to more efficient use of inputs within the household. The results suggest that agricultural output will increase if more inputs were allocated to the plots of junior members rather than the household head. A recent study by (Theriault et al., 2017) shows that the likelihood of fertilizer adoption is significantly lower for junior members than older men in Burkina Faso. Therefore, greater access to inputs will improve the intrahousehold bargaining position of junior members while reducing the gap in technology

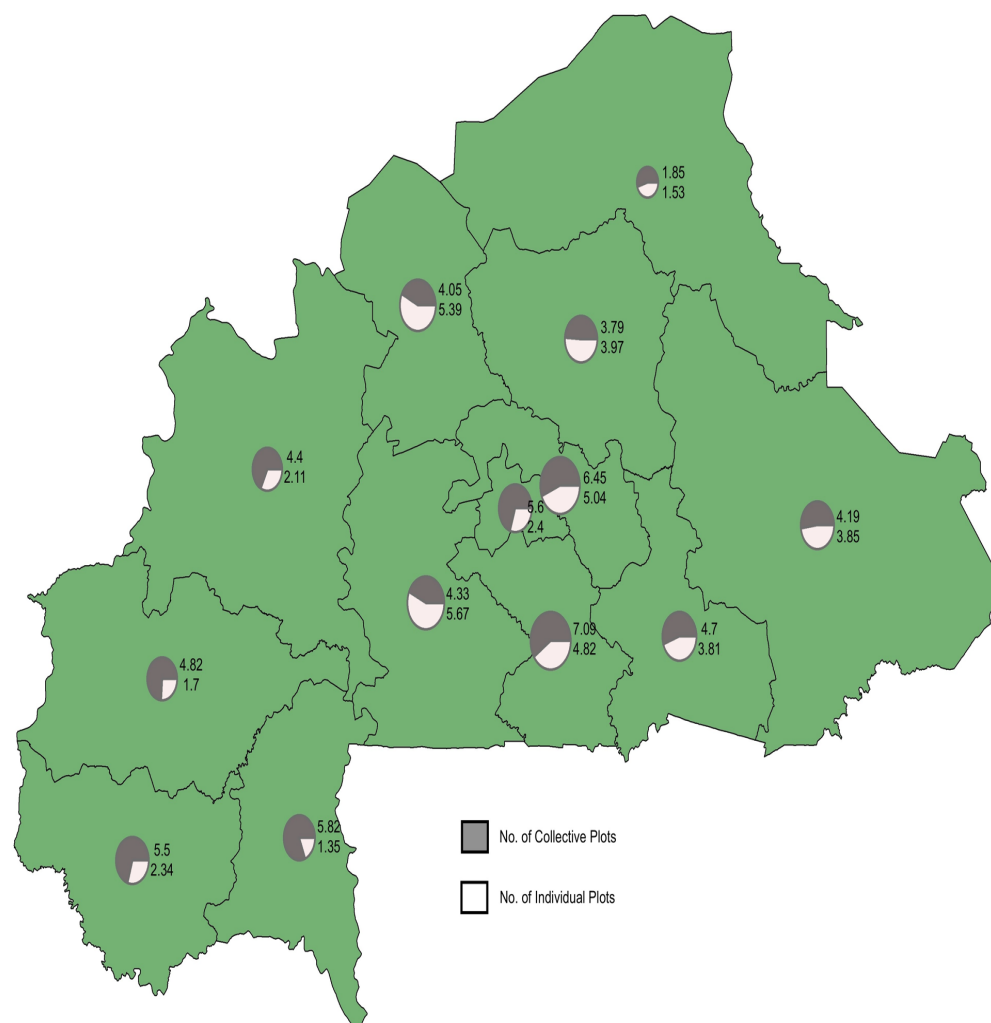
adoption. Targeted programs have the potential to increase both efficiency and equity within household members. Hence, policy-makers should consider changing the design and implementation of programs that attempt to increase modern agricultural input use. By explicitly targeting junior members, or at least making these programs more accessible to them, the income of rural households can be increased and equity between household members can be improved.

In practice, such policies can be difficult to implement. Even if subsidized fertilizer is earmarked for women and young men, it may be transferred to the household head once received by junior members due to local customs and traditions. This would limit the positive effects of targeting junior members. However, similar concerns existed before women were targeted as recipients of cash transfer programs. The changes to the design of cash transfer programs has proved effective in increase the influence of women in the household decision-making process, and improved expenditure allocations of households.

On the other hand, if the targeting is effective it could significantly affect social ties between family members, and potentially have unintended consequence (e.g. conflict) in the short-run. Any possible cultural disruption needs to be understood, as it may have large consequences. Therefore, further research is necessary to understand how junior members can be appropriately targeted with agricultural interventions to improve the effectiveness of those programs.

APPENDIX

Figure 3.1: Average Number of Collective & Individual Plots in a Household by Region



Source: Author's calculations

Table 3.1: Data Trimming

Year	Plot Type	Labor			Fertilizer	
		p1	p99	p1	p99	p99.9
2010	Collective	0.44	4949	0.00	112.7	479.23
2010	Individual	0.00	6177	0.00	66.7	125.12
2011	Collective	0.79	4840	0.00	117.2	687.18
2011	Individual	0.00	3473	0.00	85.0	225.73
2012	Collective	0.56	4325	0.00	147.1	632.65
2012	Individual	1.14	3859	0.00	206.6	1276

Source: Author's calculations

Table 3.2: Plot and Plot Manager Characteristics

Variable	Definition	Individual	Collective
<i>Plot Characteristics</i>			
Area	Plot area (ha)	0.34	0.63
Far from home	Plot is reported to be far from home (0/1)	0.66	0.52
Lowland	Plot is on lowland (0/1)	0.14	0.071
Sloped	Plot is sloped (0/1)	0.064	0.072
Tenure	Plot tenure is secure (0/1)	0.43	0.66
Intercrop	Plot has two or more crops grown on it (0/1)	0.32	0.38
<i>Material Inputs</i>			
Fertilizer	Nitrogen fertilizer applied to plot (N kg/ha)	5.51	8.12
Manure	Organic fertilizer applied to plot (kg/ha)	412.55	1142.34
Seed	Quantity of seed applied to plot (kg/ha)	170.23	80.75
Herbicide	Quantity of herbicide applied to plot (litres/ha)	36.9	62.97
Fungicide	Quantity of fungicide applied to plot (kg/ha)	8.59	9.11
Pesticide	Quantity of pesticide applied to plot (kg/ha)	6.27	5.7
Raticide	Quantity of raticide applied to plot (kg/ha)	3.59	6.02
<i>Labor</i>			
Total Labor	Number of labor days worked on plot (days/ha)	273.89	243.6

Table 3.2 (cont'd)

Family Labor	Number of labor days worked on plot by family members (days/ha)	195.9	175.03
Male Adult Labor	Number of male labor days worked on plot (days/ha)	94.55	88.44
Female Adult Labor	Number of female labor days worked on plot (days/ha)	95.42	84.62
Child Labor	Number of child labor days worked on plot (days/ha)	83.92	70.54
Plowing Days	Number of labor days worked on plowing land (days/ha)	31.2	25.96
Sowing Days	Number of labor days worked on sowing land (days/ha)	42.07	37.03
Maintenance Days	Number of labor days worked on maintaining crop (days/ha)	115.4	103.51
Harvest Days	Number of labor days worked on harvesting crop (days/ha)	50.63	46.12
Transportation Days	Number of labor days worked on harvesting crop (days/ha)	34.66	31.12

Source: Author's calculations

Table 3.3: Average Crop Yields by Plot Management Type

Crop	Individual	Collective	p-value
Millet	726	776	0.027
Maize	1216	1244	0.596
Rice	1258	1235	0.695
Fonio	927	794	0.538
White Sorghum	812	900	0.00
Red Sorghum	1019	1031	0.725
Cotton	1152	1215	0.286
Peanuts	720	841	2E-04
Sesame	552	576	0.524
Soya	869	904	0.778
Yam	8661	7460	0.196
Potato	8367	7635	0.559
Irish Potato	429	160	0.547
Niebe	657	690	0.328

Table 3.3 (cont'd)

Vouandzo	711	864	0.549
Tomato	10440	5880	0.411
Egg Plant	3697	4902	0.429
Chilli Pepper	2017	700	0.05
Okra	3270	3548	0.797

p-value provided for t-test that the yield is not equal across collective & individual plots.

Source: Author's calculations

Table 3.4: Household Characteristics

Variable	Mean	S.D.
No. of plots in household	4.51	2.99
No. of collective plots in household	3.96	2.65
No. of individual plots in household	0.56	1.19
Area cultivated (ha)	2.28	1.99
Household size	10.65	6.31
Extended household (0/1)	0.41	0.49
Mossi household (0/1)	0.43	0.33

Source: Author's calculations

Table 3.5: Input Use by Plot Management Type

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	1.670 (11.67)	87.41*** (12.03)	84.32*** (12.03)	84.52*** (12.15)	1.387** (0.624)	3.486*** (0.822)	3.259*** (0.821)	2.206*** (0.707)
Area Decile 1		635.6*** (23.12)	624.4*** (23.30)	622.6*** (23.97)		12.68*** (1.836)	11.02*** (1.840)	8.895*** (1.688)
Area Decile 2		430.4*** (19.59)	421.4*** (19.73)	418.0*** (19.91)		10.22*** (1.474)	9.105*** (1.541)	7.344*** (1.369)
Area Decile 3		315.9*** (14.79)	308.7*** (15.04)	308.9*** (15.21)		8.089*** (1.310)	7.267*** (1.331)	5.423*** (1.145)
Area Decile 4		241.1*** (14.51)	234.5*** (14.94)	233.8*** (15.06)		7.505*** (1.259)	6.878*** (1.309)	5.458*** (1.135)
Area Decile 5		186.3*** (12.00)	180.7*** (12.21)	180.3*** (12.36)		6.262*** (1.125)	5.778*** (1.129)	4.464*** (0.974)
Area Decile 6		136.9*** (10.41)	131.7*** (10.55)	131.5*** (10.66)		5.858*** (1.003)	5.502*** (1.005)	4.297*** (0.841)
Area Decile 7		101.3*** (9.865)	96.81*** (10.06)	96.68*** (10.04)		5.099*** (1.153)	4.836*** (1.151)	3.662*** (0.812)
Area Decile 8		71.12*** (9.237)	68.74*** (9.329)	69.74*** (9.308)		2.693*** (1.018)	2.508** (1.022)	1.576* (0.874)
Area Decile 9		44.73***	42.87***	42.32***		2.100**	1.983**	1.273*

Table 3.5 (cont'd)

		(8.623)	(8.654)	(8.698)		(0.907)	(0.905)	(0.767)
Far from home		15.36	14.83	11.72		0.595	0.555	0.329
Lowland		(10.31)	(10.28)	(10.37)		(0.739)	(0.740)	(0.711)
		18.31	17.89	19.09		0.471	0.424	0.713
Slope		(18.18)	(18.20)	(18.51)		(0.698)	(0.700)	(0.751)
		-2.164	-0.775	-1.764		-1.566	-1.561	-1.486
Tenure		(15.39)	(15.47)	(15.85)		(1.217)	(1.220)	(1.206)
		12.19	12.50	9.383		-0.350	-0.382	0.0128
Intercrop		(16.15)	(16.19)	(16.37)		(0.755)	(0.759)	(0.801)
		-5.052	-5.153	-5.323		0.114	0.127	0.168
Fertilizer		(11.51)	(11.53)	(11.64)		(0.537)	(0.537)	(0.537)
			0.887**	1.005**				
Seed			(0.369)	(0.395)				
				0.0499				0.00371**
Manure				(0.0317)				(0.00154)
				-0.00171				9.02e-05
Herbicide				(0.00112)				(0.000160)
				-0.00980				0.00886***
Fungicide				(0.0170)				(0.00223)
				0.0411				0.00453
Pesticide				(0.0570)				(0.00423)
				-0.0260				0.0131*
Raticide				(0.0347)				(0.00767)
				-0.0850*				0.0146*
Total Labor				(0.0470)				(0.00802)
							0.00260**	0.00270**
Constant	246.3*	-73.63***	-72.40***	-69.84***	6.644***	-1.387	-1.196	-0.311
	**							
Observations	(10.23)	(19.77)	(19.71)	(19.59)	(0.547)	(1.557)	(1.558)	(1.369)
	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063
Number of groups	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.6: Yield by Plot Management Type

	(1) Yield	(2) Yield	(3) Yield	(4) Yield
Collective	68.65*** (19.01)	37.62* (20.91)	33.29 (20.84)	24.29* (14.71)
Area Decile 1		-265.4*** (43.23)	-286.8*** (42.18)	-308.4*** (23.57)
Area Decile 2		-175.1*** (44.51)	-191.0*** (42.90)	-239.8*** (23.05)
Area Decile 3		-174.8*** (54.79)	-187.1*** (54.44)	-215.9*** (22.56)
Area Decile 4		-173.4*** (36.92)	-183.8*** (36.59)	-204.0*** (20.00)
Area Decile 5		-139.0*** (35.65)	-147.2*** (35.34)	-168.6*** (19.87)
Area Decile 6		-145.4***	-152.4***	-167.4***

Table 3.6 (cont'd)

		(33.75)	(33.49)	(18.42)
Area Decile 7		-89.83***	-95.67***	-124.5***
		(32.63)	(32.45)	(17.92)
Area Decile 8		-82.08**	-85.43***	-88.58***
		(32.37)	(32.24)	(17.58)
Area Decile 9		-17.93	-20.40	-49.51***
		(30.76)	(30.65)	(18.34)
Far from home		-50.80***	-51.59***	-48.28***
		(13.50)	(13.50)	(12.52)
Lowland		51.08	50.59	21.84
		(55.42)	(55.30)	(39.70)
Slope		26.34	27.36	22.36
		(27.45)	(27.53)	(27.18)
Tenure		-15.38	-15.33	-7.297
		(21.56)	(21.59)	(17.78)
Intercrop		-44.44***	-44.46***	-51.08***
		(16.93)	(16.91)	(16.88)
Fertilizer			0.745**	0.590**
			(0.362)	(0.287)
Total Labor			0.0188	0.0178*
			(0.0115)	(0.00927)
Seed				0.0220
				(0.0144)
Manure				0.00179**
				(0.00086)
Herbicide				0.00671
				(0.0110)
Fungicide				-0.0491
				(0.0511)
Pesticide				-0.0212
				(0.0172)
Raticide				0.0473
				(0.0367)
Constant	1,019***	1,211***	1,214***	1,144***
	(16.69)	(46.05)	(45.80)	(24.97)
Observations	31,507	30,279	30,279	29,378
Number of groups	20,231	19,612	19,612	18,923

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.7: Labor Use by Type

	(1) Male Labor	(2) Male Labor	(3) Male Labor	(4) Male Labor	(5) Female Labor	(6) Female Labor	(7) Female Labor	(8) Female Labor	(9) Children Labor	(10) Children Labor	(11) Children Labor	(12) Children Labor
Collective	-1.771 (6.030)	28.72*** (6.277)	27.44*** (6.238)	26.38*** (6.314)	8.980* (5.162)	35.40*** (5.588)	34.96*** (5.595)	35.06*** (5.588)	-5.539 (5.023)	23.30*** (4.581)	21.91*** (4.595)	23.09*** (4.646)
Area Decile 1		222.7*** (12.10)	218.0*** (12.16)	217.6*** (12.35)		219.1*** (11.15)	217.6*** (11.39)	216.6*** (11.61)		193.8*** (9.842)	188.8*** (9.795)	188.3*** (10.23)
Area Decile 2		155.1*** (8.694)	151.4*** (8.729)	150.6*** (8.873)		147.8*** (8.266)	146.5*** (8.340)	145.4*** (8.440)		127.5*** (7.858)	123.5*** (7.905)	121.9*** (7.985)
Area Decile 3		120.5*** (7.180)	117.5*** (7.193)	116.9*** (7.248)		103.1*** (6.282)	102.1*** (6.394)	101.7*** (6.438)		92.37*** (5.958)	89.15*** (6.033)	90.36*** (6.142)
Area Decile 4		89.34*** (6.374)	86.60*** (6.489)	85.64*** (6.518)		77.06*** (5.747)	76.13*** (5.895)	76.38*** (5.958)		74.71*** (6.033)	71.72*** (6.156)	71.78*** (6.269)
Area Decile 5		69.57*** (5.447)	67.29*** (5.504)	66.46*** (5.525)		61.25*** (5.285)	60.47*** (5.367)	61.00*** (5.409)		55.47*** (4.683)	52.98*** (4.728)	52.85*** (4.813)
Area Decile 6		50.46*** (4.810)	48.32*** (4.865)	48.10*** (4.899)		43.24*** (4.443)	42.52*** (4.488)	42.72*** (4.511)		43.15*** (4.064)	40.82*** (4.091)	40.64*** (4.143)
Area Decile 7		38.21*** (4.407)	36.35*** (4.455)	35.91*** (4.407)		32.43*** (4.163)	31.80*** (4.219)	31.92*** (4.233)		30.69*** (3.971)	28.66*** (4.052)	28.85*** (4.062)
Area Decile 8		29.05*** (4.246)	28.07*** (4.288)	28.74*** (4.213)		21.09*** (3.614)	20.75*** (3.643)	21.21*** (3.629)		20.98*** (3.876)	19.91*** (3.893)	19.79*** (3.918)
Area Decile 9		21.20*** (3.895)	20.43*** (3.918)	20.10*** (3.908)		9.840*** (3.548)	9.581*** (3.554)	9.694*** (3.580)		13.69*** (3.420)	12.86*** (3.418)	12.52*** (3.436)
Far from home		6.909* (4.196)	6.692 (4.181)	5.335 (4.227)		8.656* (4.718)	8.583* (4.720)	8.124* (4.763)		-0.208 (4.118)	-0.445 (4.094)	-1.739 (4.105)
Lowland		-2.405 (7.733)	-2.577 (7.744)	-2.035 (7.826)		15.15* (7.915)	15.09* (7.914)	15.79* (8.193)		5.568 (7.189)	5.381 (7.200)	5.326 (7.245)
Slope		-1.403 (6.394)	-0.831 (6.432)	-2.704 (6.514)		2.174 (6.912)	2.367 (6.913)	2.024 (7.048)		-2.935 (5.966)	-2.312 (6.009)	-1.084 (6.081)
Tenure		7.974 (7.205)	8.101 (7.220)	8.020 (7.264)		5.145 (7.765)	5.188 (7.772)	4.119 (7.863)		-0.931 (7.077)	-0.792 (7.080)	-2.756 (7.196)
Intercrop		-1.813 (5.371)	-1.855 (5.380)	-2.976 (5.373)		-1.119 (4.853)	-1.133 (4.857)	-0.315 (4.909)		-2.120 (4.991)	-2.166 (4.988)	-2.031 (5.002)
Fertilizer			0.365** (0.145)	0.353** (0.148)			0.124 (0.130)	0.157 (0.136)			0.398*** (0.140)	0.495*** (0.148)
Seed				0.00894 (0.0104)				0.0238* (0.0136)				0.0171 (0.0111)
Manure				-0.000554 (0.000496)				-0.000662 (0.000471)				-0.000491 (0.000617)
Herbicide				-0.00698 (0.00746)				0.00173 (0.00619)				-0.00454 (0.00568)

Table 3.7 (cont'd)

Fungicide				0.00501 (0.0251)				0.00124 (0.0239)				0.0349 (0.0289)
Pesticide				-0.00935 (0.0139)				-0.0140 (0.0136)				-0.00266 (0.0218)
Raticide				-0.0272* (0.0154)				-0.0223 (0.0189)				-0.0354* (0.0188)
Constant	90.90*** (5.288)	-28.35*** (9.018)	-27.84*** (8.974)	-25.27*** (8.873)	78.21*** (4.527)	-29.93*** (9.191)	-29.76*** (9.198)	-29.73*** (9.184)	77.24*** (4.405)	-15.35* (7.902)	-14.79* (7.870)	-14.85* (7.888)
Observations	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063
Number of groups	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.8: Labor Use Early & Late in the Agricultural Season

	(1) Early	(2) Early	(3) Early	(4) Early	(5) Late	(6) Late	(7) Late	(8) Late
Collective	-0.597 (3.196)	21.54*** (3.279)	20.55*** (3.290)	20.75*** (3.347)	2.244 (8.891)	65.94*** (9.213)	63.74*** (9.189)	63.75*** (9.244)
Area Decile 1		175.9*** (7.076)	172.3*** (6.961)	170.8*** (7.174)		460.3*** (17.62)	452.3*** (17.81)	452.1*** (18.32)
Area Decile 2		111.1*** (5.670)	108.2*** (5.658)	107.0*** (5.836)		319.7*** (14.95)	313.2*** (15.08)	311.0*** (15.14)
Area Decile 3		77.05*** (4.241)	74.77*** (4.290)	75.00*** (4.358)		239.5*** (11.44)	234.3*** (11.62)	234.4*** (11.73)
Area Decile 4		60.56*** (4.016)	58.44*** (4.066)	58.18*** (4.116)		180.7*** (11.19)	175.9*** (11.54)	175.6*** (11.63)
Area Decile 5		43.35*** (3.205)	41.58*** (3.219)	41.19*** (3.262)		143.1*** (9.455)	139.1*** (9.637)	139.1*** (9.752)
Area Decile 6		31.24*** (2.697)	29.58*** (2.688)	29.32*** (2.701)		105.8*** (8.278)	102.1*** (8.404)	102.2*** (8.496)
Area Decile 7		24.05*** (2.575)	22.60*** (2.576)	22.39*** (2.571)		77.01*** (7.782)	73.79*** (7.951)	74.00*** (7.940)
Area Decile 8		16.93*** (2.443)	16.17*** (2.435)	16.50*** (2.410)		54.18*** (7.303)	52.48*** (7.387)	53.18*** (7.383)
Area Decile 9		11.62*** (2.146)	11.03*** (2.118)	10.79*** (2.121)		32.93*** (6.875)	31.60*** (6.919)	31.31*** (6.960)
Far from home		6.408** (2.878)	6.240** (2.848)	5.386* (2.876)		9.017 (7.924)	8.641 (7.912)	6.375 (7.983)
Lowland		1.454 (4.320)	1.320 (4.317)	1.501 (4.456)		16.83 (14.47)	16.54 (14.49)	17.56 (14.68)
Slope		-1.847 (4.074)	-1.404 (4.090)	-1.863 (4.181)		-0.273 (11.87)	0.717 (11.92)	0.198 (12.21)
Tenure		6.625 (4.460)	6.724 (4.478)	5.900 (4.522)		5.589 (12.53)	5.810 (12.55)	3.547 (12.69)
Intercrop		-0.594 (3.222)	-0.626 (3.233)	-0.366 (3.257)		-4.613 (8.753)	-4.685 (8.760)	-5.129 (8.855)
Fertilizer			0.283*** (0.106)	0.325*** (0.115)			0.632** (0.285)	0.710** (0.302)
Seed				0.0146 (0.0105)				0.0351 (0.0213)
Manure				-0.000424 (0.000340)				-0.00129 (0.000827)
Herbicide				-0.00193 (0.00436)				-0.00819 (0.0129)
Fungicide				-9.88e-05 (0.0152)				0.0387 (0.0455)
Pesticide				-0.00819 (0.00937)				-0.0182 (0.0268)
Raticide				-0.0165* (0.00998)				-0.0691* (0.0383)
Constant	64.85** (2.803)	- (5.767)	-21.04*** (5.711)	-20.76*** (5.702)	181.6** (7.796)	-52.27*** (15.15)	-51.39*** (15.14)	-49.15*** (15.06)
Observations	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063
Number of groups	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.9: Input Use by Ethnicity

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	-49.80** (21.20)	29.25 (19.85)	25.09 (19.83)	17.14 (19.47)	2.183** (1.063)	4.660*** (1.256)	4.584*** (1.250)	3.067*** (1.040)
Area Decile 1		634.6*** (23.10)	623.3*** (23.28)	621.4*** (23.95)		12.70*** (1.836)	11.03*** (1.839)	8.902*** (1.688)
Area Decile 2		429.4*** (19.58)	420.2*** (19.72)	416.7*** (19.88)		10.25*** (1.475)	9.122*** (1.542)	7.355*** (1.370)
Area Decile 3		314.5*** (14.73)	307.2*** (14.98)	307.2*** (15.14)		8.118*** (1.313)	7.294*** (1.333)	5.441*** (1.147)
Area Decile 4		239.4*** (14.45)	232.6*** (14.88)	231.8*** (14.99)		7.541*** (1.260)	6.914*** (1.309)	5.479*** (1.135)
Area Decile 5		184.4*** (11.95)	178.8*** (12.16)	178.2*** (12.30)		6.300*** (1.126)	5.818*** (1.130)	4.488*** (0.974)
Area Decile 6		135.2*** (10.39)	129.9*** (10.53)	129.5*** (10.63)		5.891*** (1.003)	5.537*** (1.005)	4.319*** (0.841)
Area Decile 7		99.28*** (9.863)	94.69*** (10.06)	94.29*** (10.02)		5.141*** (1.154)	4.881*** (1.152)	3.691*** (0.813)
Area Decile 8		69.74*** (9.220)	67.31*** (9.312)	68.12*** (9.281)		2.721*** (1.021)	2.538** (1.024)	1.595* (0.874)
Area Decile 9		43.88*** (8.625)	41.99*** (8.656)	41.32*** (8.691)		2.117** (0.906)	2.002** (0.904)	1.285* (0.767)
Far from home		15.68 (10.29)	15.15 (10.25)	12.07 (10.35)		0.589 (0.739)	0.548 (0.739)	0.324 (0.710)
Lowland		17.98 (18.16)	17.55 (18.17)	18.68 (18.49)		0.478 (0.699)	0.431 (0.701)	0.718 (0.752)
Slope		-1.416 (15.40)	-0.00571 (15.48)	-0.788 (15.86)		-1.581 (1.218)	-1.578 (1.220)	-1.498 (1.207)
Tenure		8.640 (16.26)	8.888 (16.30)	5.277 (16.47)		-0.278 (0.761)	-0.301 (0.765)	0.0652 (0.805)
Intercrop		-4.641 (11.53)	-4.735 (11.55)	-4.813 (11.66)		0.105 (0.537)	0.118 (0.537)	0.161 (0.537)
Fertilizer			0.892** (0.369)	1.009** (0.394)				
Seed				0.0500 (0.0316)				0.00370** (0.00154)
Manure				-0.00176 (0.00111)				9.09e-05 (0.000160)
Herbicide				-0.00973 (0.0171)				0.00886*** (0.00223)
Fungicide				0.0430 (0.0565)				0.00451 (0.00424)
Pesticide				-0.0266 (0.0354)				0.0132* (0.00767)
Raticide				-0.0802* (0.0475)				0.0145* (0.00802)
Collective*Mossi	97.74*** (36.15)	109.8*** (33.58)	111.8*** (33.63)	126.6*** (33.38)	-1.512 (1.782)	-2.218 (1.930)	-2.505 (1.945)	-1.620 (1.443)
Total Labor							0.00262** (0.00113)	0.00272** (0.00113)
Constant	253.2*** (10.18)	-62.79*** (19.90)	-61.36*** (19.82)	-57.58*** (19.57)	6.538*** (0.545)	-1.606 (1.571)	-1.442 (1.570)	-0.467 (1.386)
Observations	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063
Number of groups	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.10: Input Use by Plot Management Type - Including Females

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	-56.10*** (7.891)	54.94*** (9.270)	53.27*** (9.293)	52.60*** (9.447)	1.008*** (0.224)	2.544*** (0.361)	2.503*** (0.360)	2.072*** (0.316)
Area Decile 1		957.2*** (24.47)	951.0*** (24.57)	943.9*** (25.28)		9.481*** (1.199)	8.764*** (1.178)	7.511*** (1.085)
Area Decile 2		570.1*** (17.67)	565.1*** (17.80)	560.4*** (17.78)		7.594*** (1.036)	7.167*** (1.037)	6.331*** (0.987)
Area Decile 3		411.5*** (14.97)	407.5*** (15.05)	404.9*** (15.07)		6.114*** (0.882)	5.805*** (0.895)	4.949*** (0.836)
Area Decile 4		297.2*** (12.30)	293.5*** (12.40)	293.7*** (12.51)		5.609*** (0.827)	5.386*** (0.824)	4.540*** (0.757)
Area Decile 5		230.0*** (11.06)	226.7*** (11.21)	227.0*** (11.22)		5.058*** (0.755)	4.885*** (0.760)	4.150*** (0.694)
Area Decile 6		168.3*** (9.994)	165.2*** (10.08)	165.3*** (10.05)		4.760*** (0.705)	4.634*** (0.705)	3.970*** (0.642)
Area Decile 7		126.8*** (8.584)	124.1*** (8.669)	124.8*** (8.600)		4.220*** (0.659)	4.125*** (0.658)	3.539*** (0.595)
Area Decile 8		85.36*** (8.214)	83.12*** (8.310)	83.10*** (8.248)		3.434*** (0.689)	3.370*** (0.688)	2.777*** (0.554)
Area Decile 9		56.70*** (7.401)	55.52*** (7.450)	56.27*** (7.387)		1.809*** (0.596)	1.766*** (0.596)	1.370*** (0.530)
Far from home		-16.35* (9.044)	-16.47* (9.030)	-15.09* (8.982)		0.188 (0.395)	0.201 (0.393)	0.0854 (0.377)
Lowland		12.86 (15.09)	12.43 (15.10)	16.06 (15.22)		0.651 (0.418)	0.641 (0.419)	0.598 (0.436)
Slope		14.34 (14.29)	15.00 (14.30)	17.27 (14.51)		-1.004 (0.688)	-1.015 (0.688)	-0.984 (0.684)
Tenure		-4.384 (12.90)	-4.501 (12.89)	-3.884 (13.05)		0.179 (0.339)	0.183 (0.339)	0.263 (0.336)
Intercrop		-1.001 (10.76)	-1.021 (10.76)	-0.857 (10.80)		0.0309 (0.350)	0.0316 (0.350)	0.0680 (0.346)
Fertilizer			0.654** (0.309)	0.784** (0.328)				
Seed				0.0236 (0.0146)				0.000393 (0.000307)
Manure				0.000103*** (4.12e-06)				1.75e-07 (4.43e-07)
Herbicide				-0.0124 (0.0143)				0.00697*** (0.00156)
Fungicide				-0.000837 (0.0428)				0.00126 (0.00183)
Pesticide				0.0126 (0.0428)				0.0117* (0.00621)
Raticide				-0.0711 (0.0488)				0.0109* (0.00624)
Total Labor							0.000750** (0.000365)	0.000848** (0.000369)
Constant	368.8*** (4.586)	6.177 (14.41)	6.822 (14.42)	2.881 (14.37)	4.974*** (0.130)	-0.986 (0.886)	-0.991 (0.886)	-0.645 (0.808)
Observations	52,581	50,459	50,459	48,858	52,581	50,459	50,459	48,858
Number of groups	28,247	27,424	27,424	26,317	28,247	27,424	27,424	26,317

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.11: Input Use by Plot Management - Trim Top 1 Percentile of Fertilizer Quantities

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	-0.874 (11.68)	82.99*** (12.08)	81.98*** (12.12)	82.06*** (12.30)	1.009*** (0.282)	1.849*** (0.349)	1.814*** (0.350)	1.569*** (0.350)
Area Decile 1		625.7*** (23.05)	623.3*** (23.12)	620.1*** (23.97)		4.283*** (0.688)	4.023*** (0.700)	3.237*** (0.676)
Area Decile 2		426.7*** (19.41)	424.6*** (19.36)	421.2*** (19.60)		3.683*** (0.589)	3.506*** (0.599)	3.050*** (0.591)
Area Decile 3		303.6*** (14.51)	301.8*** (14.66)	302.2*** (14.82)		3.269*** (0.569)	3.143*** (0.581)	2.714*** (0.580)
Area Decile 4		230.4*** (14.53)	228.7*** (14.63)	227.4*** (14.80)		3.208*** (0.575)	3.112*** (0.577)	2.791*** (0.575)
Area Decile 5		179.8*** (11.87)	177.9*** (12.01)	177.4*** (12.20)		3.465*** (0.588)	3.390*** (0.589)	3.030*** (0.583)
Area Decile 6		131.4*** (10.42)	129.4*** (10.47)	128.4*** (10.59)		3.528*** (0.560)	3.474*** (0.559)	3.179*** (0.559)
Area Decile 7		93.84*** (9.773)	92.43*** (9.856)	91.56*** (9.883)		2.569*** (0.544)	2.530*** (0.544)	2.391*** (0.537)
Area Decile 8		71.46*** (9.086)	70.55*** (9.130)	70.05*** (9.179)		1.665*** (0.529)	1.635*** (0.529)	1.521*** (0.527)
Area Decile 9		40.72*** (8.510)	40.15*** (8.514)	39.02*** (8.611)		1.036** (0.472)	1.019** (0.473)	0.935** (0.467)
Far from home		14.69 (10.12)	14.24 (10.12)	11.26 (10.19)		0.834*** (0.306)	0.828*** (0.307)	0.747** (0.304)
Lowland		20.21 (18.05)	20.29 (18.05)	18.45 (18.61)		-0.148 (0.545)	-0.156 (0.545)	-0.00728 (0.553)
Slope		0.382 (15.32)	0.327 (15.34)	0.165 (15.76)		0.101 (0.523)	0.101 (0.523)	0.130 (0.521)
Tenure		11.80 (16.36)	11.81 (16.38)	7.772 (16.61)		-0.0102 (0.501)	-0.0151 (0.501)	0.0787 (0.514)
Intercrop		-4.195 (11.62)	-4.253 (11.63)	-4.209 (11.72)		0.107 (0.320)	0.109 (0.320)	0.126 (0.317)
Fertilizer			0.548 (0.396)	0.726* (0.395)				
Seed				0.0490 (0.0318)				0.00150** (0.000639)
Manure				-0.00105 (0.00110)				1.86e-06 (5.06e-05)
Herbicide				-0.0107 (0.0200)				0.00397*** (0.00114)
Fungicide				0.0242 (0.0590)				0.00244 (0.00168)
Pesticide				-0.0202 (0.0355)				0.00305 (0.00190)
Raticide				-0.0678 (0.0422)				0.00765* (0.00424)
Total Labor							0.000415 (0.000300)	0.000543* (0.000297)
Constant	246.3*** (10.24)	-65.97*** (19.69)	-66.61*** (19.67)	-63.49*** (19.62)	5.102*** (0.247)	1.179* (0.667)	1.206* (0.666)	1.305* (0.666)
Observations	32,002	30,711	30,711	29,816	32,002	30,711	30,711	29,816
Number of groups	20,482	19,841	19,841	19,149	20,482	19,841	19,841	19,149

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.12: Input Use by Plot Management Type - Untrimmed Sample

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	23.33 (24.10)	151.2*** (24.81)	149.8*** (24.84)	144.8*** (24.34)	1.619** (0.819)	4.726*** (0.976)	4.598*** (0.981)	2.774*** (0.690)
Area Decile 1		997.7*** (51.21)	991.0*** (51.24)	965.8*** (51.36)		21.81*** (5.013)	20.96*** (5.075)	13.32*** (2.000)
Area Decile 2		570.2*** (35.12)	565.2*** (35.08)	548.1*** (35.62)		15.96*** (3.288)	15.47*** (3.324)	10.07*** (1.568)
Area Decile 3		395.7*** (26.27)	391.9*** (26.26)	382.0*** (26.26)		12.21*** (2.990)	11.88*** (3.031)	7.057*** (1.346)
Area Decile 4		284.3*** (22.43)	280.8*** (22.47)	269.9*** (22.61)		11.10*** (2.724)	10.86*** (2.753)	6.948*** (1.207)
Area Decile 5		216.2*** (20.00)	212.9*** (20.09)	204.2*** (20.25)		10.41*** (2.669)	10.23*** (2.688)	6.616*** (1.182)
Area Decile 6		161.5*** (17.40)	158.7*** (17.40)	151.3*** (17.56)		9.148*** (2.416)	9.011*** (2.432)	5.514*** (0.991)
Area Decile 7		121.0*** (15.93)	118.5*** (15.95)	115.6*** (16.09)		8.226*** (2.406)	8.123*** (2.421)	4.642*** (1.074)
Area Decile 8		76.64*** (15.52)	74.86*** (15.56)	73.75*** (15.50)		5.739** (2.251)	5.674** (2.263)	2.953*** (1.030)
Area Decile 9		54.64*** (10.75)	53.22*** (10.77)	49.89*** (10.84)		4.576** (2.031)	4.530** (2.038)	1.960** (0.879)
Far from home		-0.894 (16.25)	-1.061 (16.24)	0.849 (16.62)		0.539 (0.908)	0.540 (0.908)	0.139 (0.793)
Lowland		32.47 (32.05)	32.49 (32.05)	32.40 (32.57)		-0.0590 (0.693)	-0.0866 (0.693)	0.319 (0.726)
Slope		-37.32 (32.05)	-37.14 (32.01)	-45.24 (31.72)		-0.563 (1.396)	-0.531 (1.398)	-1.296 (1.136)
Tenure		-39.07 (25.69)	-39.32 (25.74)	-43.10* (26.17)		0.826 (1.415)	0.859 (1.415)	1.123 (1.414)
Intercrop		29.68 (18.51)	29.49 (18.51)	28.21 (18.68)		0.594 (0.699)	0.569 (0.701)	0.561 (0.673)
Fertilizer			0.310 (0.245)	0.513* (0.289)				
Seed				0.0750* (0.0421)				0.00676** (0.00278)
Manure				0.00484 (0.00349)				9.32e-05 (0.000162)
Herbicide				-0.0181 (0.0156)				0.00923*** (0.00231)
Fungicide				0.259 (0.220)				0.0105 (0.00976)
Pesticide				-0.0509 (0.0487)				0.0140* (0.00807)
Raticide				0.000799 (0.108)				0.0232* (0.0131)
Total Labor							0.000849 (0.000532)	0.000773* (0.000448)
Constant	353.0*** (21.16)	-121.2*** (39.77)	-119.2*** (39.77)	-116.7*** (40.15)	7.743*** (0.719)	-6.471* (3.465)	-6.368* (3.477)	-2.438 (1.664)
Observations	35,386	33,653	33,653	32,589	35,386	33,653	33,653	32,589
Number of groups	22,074	21,263	21,263	20,456	22,074	21,263	21,263	20,456

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.13: Input Use by Plot Management Type - Level Area Variable

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	1.670 (11.67)	68.12*** (12.36)	63.95*** (12.36)	62.15*** (12.45)	1.387** (0.624)	3.252*** (0.817)	3.016*** (0.815)	1.963*** (0.700)
Area		-185.2*** (7.319)	-178.8*** (7.410)	-170.7*** (7.360)		-4.946*** (0.640)	-4.303*** (0.646)	-3.336*** (0.537)
Far from home		-7.423 (10.67)	-7.824 (10.62)	-8.399 (10.64)		0.313 (0.757)	0.338 (0.753)	0.154 (0.718)
Lowland		17.79 (19.70)	17.17 (19.70)	18.09 (20.08)		0.480 (0.698)	0.418 (0.699)	0.690 (0.749)
Slope		-11.14 (16.13)	-8.994 (16.21)	-8.906 (16.73)		-1.677 (1.223)	-1.638 (1.225)	-1.541 (1.206)
Tenure		8.126 (16.39)	8.609 (16.42)	5.630 (16.71)		-0.376 (0.757)	-0.404 (0.761)	-0.00462 (0.800)
Intercrop		-28.89** (12.34)	-28.63** (12.34)	-27.82** (12.35)		-0.202 (0.529)	-0.102 (0.525)	-0.0318 (0.523)
Fertilizer			1.283*** (0.374)	1.381*** (0.400)				
Seed				0.148*** (0.0435)				0.00451** (0.00180)
Manure				0.00165 (0.00123)				0.000121 (0.000160)
Herbicide				-0.0104 (0.0160)				0.00890*** (0.00223)
Fungicide				0.143*** (0.0489)				0.00542 (0.00418)
Pesticide				-0.0209 (0.0348)				0.0131* (0.00773)
Raticide				-0.0452 (0.0370)				0.0150* (0.00824)
Total Labor							0.00347*** (0.00110)	0.00344*** (0.00111)
Constant	246.3** (10.23)	281.3*** (14.67)	271.4*** (14.73)	258.1*** (14.83)	6.644*** (0.547)	7.761*** (0.815)	6.785*** (0.812)	5.810*** (0.779)
Observations	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063
Number of groups	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.14: Input Use by Plot Management Type - Quadratic Area Variable

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	1.670 (11.67)	82.30*** (12.40)	78.48*** (12.41)	76.68*** (12.51)	1.387** (0.624)	3.482*** (0.822)	3.231*** (0.820)	2.154*** (0.703)
Area		-553.3*** (19.86)	-541.3*** (19.96)	-521.4*** (19.84)		-10.92*** (1.562)	-9.229*** (1.590)	-7.556*** (1.522)
Far from home		163.8*** (7.472)	160.9*** (7.455)	154.3*** (7.366)		2.658*** (0.544)	2.157*** (0.548)	1.834*** (0.532)
Lowland		7.209 (10.44)	6.606 (10.39)	4.808 (10.45)		0.550 (0.754)	0.528 (0.753)	0.308 (0.719)
Slope		17.91 (19.22)	17.38 (19.22)	18.59 (19.59)		0.482 (0.701)	0.427 (0.702)	0.701 (0.751)
Tenure		-5.588 (15.91)	-3.848 (15.95)	-3.699 (16.45)		-1.586 (1.225)	-1.569 (1.226)	-1.479 (1.209)
Intercrop		8.570 (16.29)	8.974 (16.32)	5.811 (16.58)		-0.369 (0.758)	-0.395 (0.761)	-0.000553 (0.799)
Fertilizer		-18.50 (12.03)	-18.47 (12.04)	-18.04 (12.08)		-0.0333 (0.534)	0.0232 (0.531)	0.0750 (0.530)
Seed			1.097*** (0.376)	1.209*** (0.404)				
Manure				0.119*** (0.0380)				0.00421** (0.00170)
Herbicide				0.000564 (0.00113)				0.000108 (0.000159)
Fungicide				-0.0138 (0.0160)				0.00884*** (0.00223)
Pesticide				0.0940* (0.0493)				0.00488 (0.00420)
Raticide				-0.0147 (0.0375)				0.0132* (0.00767)
Total Labor				-0.0491 (0.0450)				0.0149* (0.00805)
Constant							0.00306*** (0.00112)	0.00309*** (0.00113)
Observations	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063
Number of groups	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 3.15: Input Use by Plot Management Type - Natural Logarithm of Area Variable

	(1) Labor	(2) Labor	(3) Labor	(4) Labor	(5) Fertilizer	(6) Fertilizer	(7) Fertilizer	(8) Fertilizer
Collective	1.670 (11.67)	84.50*** (12.38)	80.50*** (12.38)	78.42*** (12.48)	1.387** (0.624)	3.507*** (0.821)	3.242*** (0.820)	2.160*** (0.703)
Area		-422.3*** (14.50)	-410.5*** (14.73)	-394.6*** (14.67)		-10.34*** (1.286)	-9.017*** (1.311)	-7.106*** (1.125)
Far from home		5.535 (10.55)	4.924 (10.50)	3.411 (10.55)		0.536 (0.756)	0.519 (0.754)	0.298 (0.719)
Lowland		17.84 (19.40)	17.29 (19.41)	18.32 (19.79)		0.483 (0.699)	0.427 (0.700)	0.699 (0.750)
Slope		-8.165 (15.97)	-6.323 (16.04)	-6.296 (16.55)		-1.615 (1.222)	-1.590 (1.223)	-1.501 (1.206)
Tenure		9.742 (16.26)	10.14 (16.29)	7.082 (16.56)		-0.346 (0.758)	-0.376 (0.761)	0.0164 (0.800)
Intercrop		-21.48* (12.17)	-21.41* (12.18)	-20.92* (12.21)		-0.0622 (0.532)	0.00527 (0.529)	0.0553 (0.528)
Fertilizer			1.140*** (0.376)	1.255*** (0.403)				
Seed				0.130*** (0.0399)				0.00428** (0.00173)
Manure				0.00103 (0.00117)				0.000112 (0.000160)
Herbicide				-0.0125 (0.0159)				0.00886*** (0.00223)
Fungicide				0.108** (0.0497)				0.00497 (0.00419)
Pesticide				-0.0231 (0.0356)				0.0131* (0.00770)
Raticide				-0.0554 (0.0387)				0.0148* (0.00814)
Total Labor							0.00314*** (0.00111)	0.00318*** (0.00112)
Constant	246.3*** (10.23)	313.8*** (14.48)	304.0*** (14.58)	292.4*** (14.69)	6.644*** (0.547)	8.540*** (0.821)	7.555*** (0.822)	6.461*** (0.782)
Observations	32,295	30,991	30,991	30,063	32,295	30,991	30,991	30,063
Number of groups	20,617	19,969	19,969	19,257	20,617	19,969	19,969	19,257

Household-year-crop fixed effects estimation

Standard errors clustered at household-year-crop level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

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CHAPTER 4: ASSET SMOOTHING & COPING STRATEGIES IN BURKINA FASO

Abstract

Households in rural Burkina Faso are highly dependent on favorable weather for their livelihood. Dynamic household models suggests that when faced by negative economic shocks, they will sell assets in order to meet consumption needs. However, many factors determine the extent to which households are willing to sell their assets. Households at key asset thresholds may choose to protect their assets and reduce consumption. The presence of young children is also likely to induce greater sale of assets, since their nutritional status early in life has long term consequences (Cusick and Georgieff, 2012).

Data from a three-year panel survey is used to study the effect of weather shocks on agriculture, and then test the extent to which households sell their assets. Droughts and floods reduce crop yields by 8 and 11 percent respectively, while 7 percent less land is cultivated in drought seasons. This reduction in land cultivated comes from non-cereal crops; staple cereal crops remain unaffected as they are crucial for the household's food security.

To overcome these adverse economic shocks, households sell livestock to meet short-term needs. I find evidence that households sell small animals such as pigs and broilers, but not larger animals such as oxen. This may be because the weather shocks were not large enough to require the sale of large animals.

Even though more male owned livestock are liquidated during floods, a significant amount of female owned livestock is sold and consumed. This leads to an increase in the gender gap for assets. During droughts, even more female-owned livestock are sold and consumed. The asset gender gap worsens significantly more during droughts. This will limit the ability of

women to generate income, and worsen their bargaining position within the household. This will lead to ill-effects of the weather shocks persisting for them over time.

Households liquidate more livestock when there are baby boys, presumably to stabilize consumption and ensure their nutritional needs are met. However, they often do not do so in the presence of baby girls in the household. Both men and women seem to engage in this preferential treatment for boys.

4.1 Introduction

Rural households in most developing countries rely on agriculture for a significant portion of their income. Yields and crop prices are usually highly volatile (Jensen, 2000; Bellemare et al., 2013) and affect most of the population. Household's livelihood can be adversely affected by many factors, such as insufficient rainfall or falling crop prices. Other unforeseen expenditures, such as illness, can also negatively affect household welfare. In the absence of formal safety nets, households often depend on local risk-pooling to cope with negative economic shocks (Townsend, 1994). While such mechanisms can be effective in dealing with idiosyncratic risks, they fail to insure against aggregate risks that affect entire communities. Households may have to reduce current consumption if their incomes are sufficiently reduced. Alternatively, they may use savings or seek loans to meet current consumption needs.

In developing countries such as Burkina Faso, most households have low levels of savings. Assets often play the role of a store of value (Deaton, 1991). Productive assets play a doubly important role; not only are they needed to generate income, they can also be sold when needed. A large literature discusses the use of livestock as buffer stock to smooth consumption over time (Binswanger and McIntire, 1987; Swinton, 1988; Fafchamps et al., 1998; Kazianga and Udry, 2006). Since livestock is used for agriculture activities (e.g. plowing) and produces output (e.g. milk), it is an important economic asset demanded by most households and markets exist for their sale and purchase. Hence, households can buy and sell assets to manage their consumption levels over time.

In places with missing credit and insurance markets, Binswanger and McIntire (1987) suggest that livestock is the major form of wealth and a substitute for insurance. Rosenzweig and Wolpin (1993) show that Indian farmers buy and sell bullocks, which are an important

productive asset, to smooth consumption across time. Swinton (1988) notes that cattle, sheep and goats were sold by households in response to a large drought in Niger. Fafchamps et al. (1998) provide one of the first formal tests of livestock inventories being used smooth consumption over time. While they find that Burkinabe households sold cattle, sheep and goats in response to droughts, the sales were much less than what theory would predict. Similarly, Hoogeveen (2002) and Fafchamps and Lund (2003) find lower than expected assets sales and consumption smoothing. Households seem willing to reduce current consumption, even though they have assets that can be liquidated to maintain current consumption levels at the expense of future consumption.

Carter and Lybbert (2012) attempt to explain this empirical regularity with a poverty traps model; they suggest that households at critical asset thresholds would be less willing to sell that asset. Such households would asset smooth rather than consumption smooth, because selling the asset reduces their ability to generate income in the future. Under the poverty traps model, it is optimal for some households to smooth consumption but for others to maintain their asset stock. This leads to lower levels of average consumption smoothing over all households, and can explain previous findings. Using the same Burkina Faso data as Fafchamps et al. (1998) and Kazianga and Udry (2006), they find that only households with a large herd size sell livestock to off-set income shocks.

Lybbert et al. (2004) and Santos et al. (2006) had previously found evidence of multiple equilibrium and poverty traps amongst pastoralists in Southern Ethiopia, while Carter et al. (2007) find behavior consistent with poverty traps for households in Ethiopia and Honduras. Barrett et al. (2006) find evidence of asset-based poverty traps in Northern Kenya and Southern Madagascar, but not in the central highlands of Madagascar. This is suggestive that poverty traps

exist in remote areas with few livelihood generating opportunities and limited access to credit and markets. Adato et al. (2006) also find a large number of South Africans lack the means to find a way out of poverty, and discuss how the lack of social capital for the poorest restricts their upward economic mobility.

Most of these studies use flexible semi/non-parametric techniques (Lybbert et al., 2004; Adato et al., 2006; Barrett et al., 2006; Santos et al., 2006; Lybbert and McPeak, 2012) or Hansen's threshold method (Carter et al., 2007; Carter and Lybbert, 2012; Janzen and Carter, 2013) to find an asset threshold above and below which two different regimes exist. One exception is Hoddinott (2006), which notes the importance of a pair of oxen in agricultural production to compare oxen sales of households with one or two oxen with those with more oxen.

However, a number of studies in different geographic settings fail to find similar evidence. Naschold (2013) finds that households in rural Pakistan and Ethiopia face static and structural poverty, while Naschold (2012) and Dercon and Outes (2009) share similar findings for India. Similarly, Quisumbing and Baulch (2013) for Bangladesh, Lokshin et al. (2004) for Hungary and Russia, Jalan and Ravallion (2004) for China and Antman and McKenzie (2007) for urban Mexico fail to find evidence of poverty traps.

This essay uses data from Burkina Faso to better understand how households cope with negative economic shocks. In the local context, agriculture is mostly rain-fed and droughts can significantly impact crop output and household incomes. Excessive rain can also destroy crops and inundate fields. Both droughts and floods have been very common in Burkina Faso in the last few decades. The World Bank (2011) notes that between 1991 and 2009, the country

experienced eleven major floods (affecting 383,203 people) and three major droughts (affecting 96,290 people). The floods left inundated fields, destroying standing crop, and caused damage to dwellings and other assets. Floods early in the agricultural seasons also carry away parts of the fertile top soil, leaving the land barren. Droughts led to insufficient moisture for crops, and lower crop yields. These events increase the vulnerability of agricultural households in Burkina Faso, who often need to resort to ex-post strategies to deal with losses due to bad weather.

Similar to other developing countries, most rural Burkinabe households own some livestock. Livestock is one of the most important assets, and is more liquid (and more commonly owned) than other assets such as farm machinery. Oxen are commonly owned and used as a traction animal, primarily for ploughing. Smaller animals, such as goats and sheep, are common and may be easier to sell in times of need. Many households also own poultry, while other animals such as donkeys may be used as draft animals.

This essay contributes to the consumption smoothing/asset stock management literature by analyzing intrahousehold aspects of asset sale decisions. After identifying weather shocks that adversely affect household income, I test whether livestock is sold in response to these shocks. Asset sale patterns are also compared with predictions of a poverty traps model.

Next, I test whether the presence of young children leads to more assets being sold in response to a negative shock. Since the first 1000 days from conception till the child's second birthday are crucial for their development and have lifelong effects (Cusick and Georgieff, 2012), households may choose to sell assets to ensure that the nutritional needs of the children are met. However, the intrahousehold resource allocation literature suggests that the adults in the household may not fully internalize the benefits to children in their decision-making (Doss,

2013; Baez and Santos, 2007). Girls may be more vulnerable than boys in times of need (Behrman, 1988), so I test for asset sales in the presence of children between the ages of zero and two, and also test for differential asset sales when the child is a boy rather than a girl.

Women are often more vulnerable than men during times of need. Sabarwal et al. (2010) note that women increase participation in the labor force more than men. I explore a different channel - sale of livestock owned by women rather than men - through which women may be disadvantaged and have sustained ill-effects of the weather shocks. If assets owned by women are consistently sold more than those owned by men, their bargaining position within the household will weaken and their vulnerability will persist over time, as they lose assets needed for generating income.

4.2 Theoretical Framework

In this section, I describe a model of how households manage their stock of assets. The model is fairly general, and allows for the existence of poverty traps. I discuss the predictions that can be empirically tested. Next, I extend the model to an intrahousehold resource allocation framework, where household members make their own consumption and asset accumulation decisions while engaging in joint production. I then discuss insights from this richer model on how men and women may manage assets differently, and how that behavior can be interpreted.

4.2.1 Standard Model

The following model is based on Carter and Lybbert (2012), and it describes the intertemporal optimization problem of households:

$$\max_{c,L} E_0 \left[\sum_{t=0}^{\infty} \left(\frac{1}{1+\delta} \right)^t u(c_t + q_t) \right] \quad (1)$$

subject to
$$x_t(L, \theta) = F(L_t) + (1 - \tau)\theta_t L_t \quad (1a)$$

$$L_{t+1} = x_t - c_t - q_t \quad (1b)$$

$$L_t \geq 0 \quad \forall t \quad (1c)$$

$$F(L_t) = \max[F^h(L_t), F^l(L_t)] \quad (1d)$$

$$\frac{\partial F^h}{\partial L} > \frac{\partial F^l}{\partial L} \quad \forall L \quad (1e)$$

$$F^l(L) > F^h(L) \quad \forall L \leq \tilde{L} \quad (1f)$$

c_t and q_t are the household consumption of private and public goods at time t , L_t is the household's asset holdings, $u(\cdot)$ is the time-invariant utility function, δ is the discount rate while τ is the depreciation rate of assets. F is the production function, which is a function of household assets. The asset stock produces positive output with diminishing returns. θ_t is an iid stochastic term that shocks the asset stock. The depreciation and stochastic shock occur after production has taken place, since the production function uses all L_t assets to create output. Cash-on-hand at time t , x_t , is defined as the sum of the value of output and remaining assets.

Equation 1b states that the cash in hand not spent in consumption becomes next period's asset stock. This asset stock is non-negative; under the standard assumption that return to assets approaches infinite as the asset stock approaches zero, the household will accumulate assets for productive along with precautionary measures (Carter and Lybbert, 2012).

Households have access to a high and a low type of technology. The marginal return to assets is greater under the high type technology compared to the low type technology ($\frac{\partial F^h}{\partial L} >$

$\frac{\partial F^l}{\partial L} \forall L$). However, the high type technology is subject to fixed costs so the total output is higher under the low type technology until a minimum level of assets, $\tilde{L}$, is reached: $F^l(L) > F^h(L) \forall L \leq \tilde{L}$. These properties of the production function create a discontinuous jump in the marginal returns to assets at the point $\tilde{L}$.

Under this framework, households try to maximize their lifetime utility by choosing their consumption and asset stocks over time. In the absence of credit markets, they can only invest in their productive assets by foregoing current consumption.

Missing credit markets are a central feature of all poverty traps models. If credit markets were complete, households would simply borrow to purchase enough assets to engage in the high technology production. Hence, the poverty trap would essentially not exist. Thus, missing credit markets are an important assumption. Given that formal credit is virtually non-existent in rural Burkina Faso (Wouterse and Taylor, 2008) and large amount of informal credit is not readily available and may require substantial transaction cost, this assumption may approximate the real-world closely.

The model suggests that on average households will deal with a one-period negative shock by selling assets and maintaining current consumption levels. This is because there are few households at key asset thresholds at any given point in time, since these are dynamically unstable level of assets. Hence, typical households will engage in consumption smoothing when facing negative economic shocks.

Prediction 1: On average, households will deal with a one-period negative economic shock by selling assets to maintain current consumption.

Carter & Lybbert (2012) use a numerical example to show that this model allows for the existence of poverty traps. That is, there is a sudden increase in the derivative of the value function with respect to assets at a level less than $\tilde{L}$. The sharp increase in the marginal value of assets is because beyond that point, called the Micawber threshold in the literature, it becomes dynamically rational for households to accumulate assets to reach the high-level steady state asset level. They also note that “the marginal value of assets will be extraordinarily high in the neighborhood of critical wealth levels; households in these neighborhoods will be reluctant to liquidate assets even in the face of economic shocks.” Under this framework, households just below the Micawber threshold would be willing to make substantial sacrifices of consumption to increase assets, and households just above the threshold to be willing to forego current consumption to protect assets and avoid falling below the critical asset threshold.

Prediction 2: Households at key asset thresholds will be less likely to sell the asset, since these assets are extremely valuable.

An empirical challenge will be identifying such key asset thresholds in which households are likely to asset-smooth rather than consumption-smooth. Such issues are discussed in detail in Section 3.3.

4.2.2 Non-Cooperative Household Model

I now extend this framework to include a male and female member of the household, who own their own assets that are combined for production. The income from joint production is divided among them as a proportion depending on the assets they contribute for production. The male and female can purchase private or public goods for consumption. However, social norms

require the male to spend a fixed proportion of his income on the public good (Kazianga and Wahhaj, 2013).

The male's problem is:

$$\max_{c^m, q, L^m} E_0 \left[\sum_{t=0}^{\infty} \left(\frac{1}{1+\delta} \right)^t u^m(c_t^m + q_t) \right] \quad (2)$$

$$\text{subject to } x_t^m(L_t^m, L_t^f, \theta) = F(L_t^m + L_t^f) * s^m + (1 - \tau)\theta_t L_t^m \quad (2a)$$

$$s^m = \frac{L_t^m}{L_t^m + L_t^f} \quad (2b)$$

$$x_t^m = L_{t+1}^m + c_t^m + q_t \quad (2c)$$

$$F(L_t^m, L_t^f) = \max[F^h(L_t^m + L_t^f), F^l(L_t^m + L_t^f)] \quad (2d)$$

$$L_t^m \geq 0 \quad \forall t \quad (2e)$$

$$\frac{\partial F^h}{\partial L} > \frac{\partial F^l}{\partial L} \quad \forall L \quad (2f)$$

$$F^l(L) > F^h(L) \quad \forall L \leq \tilde{L} \quad (2g)$$

$$q \geq a * (F(L_t^m + L_t^f) * s^m) \quad (2h)$$

while the female's problem:

$$\max_{c^f, q, L^f} E_0 \left[\sum_{t=0}^{\infty} \left(\frac{1}{1+\delta} \right)^t u^f(c_t^f + q) \right] \quad (3)$$

$$\text{subject to } x_t^f(L_t^m, L_t^f, \theta) = F(L_t^m + L_t^f) * s^f + (1 - \tau)\theta_t L_t^f \quad (3a)$$

$$s^f = \frac{L_t^f}{L_t^m + L_t^f} \quad (3b)$$

$$x_t^f = L_{t+1}^f + c_t^f + q \quad (3c)$$

$$F(L_t^m, L_t^f) = \max[F^h(L_t^m + L_t^f), F^l(L_t^m + L_t^f)] \quad (3d)$$

$$L_t^f \geq 0 \quad \forall t \quad (3e)$$

$$\frac{\partial F^h}{\partial L} > \frac{\partial F^l}{\partial L} \quad \forall L \quad (3f)$$

$$F^l(L) > F^h(L) \quad \forall L \leq \tilde{L} \quad (3g)$$

The optimization problems are similar to the standard model; however, the male and female independently and simultaneously make their own decisions. Private and public goods are differentiated, as is typical in intrahousehold resource allocation models (Haddad, Hoddinott and Alderman, 1994).

The cash-in-hand equations for the male (2a) and female (3a) are similar to the one in the standard model (1a). The main difference is that males and females get only a share of output, denoted by s^m and s^f respectively, and they can only use their share of assets (after accounting for the depreciation and stochastic shock). The shares, defined in equations 2b and 3b, are the proportion of assets owned by each gender. For example, if 70 percent of the assets used in production are owned by the male, he receives 70 percent of the income generated from these assets. By definition, $s^m + s^f = 1$.

Equations 2c and 3c indicate that the cash-in-hand not spent on consumption becomes the asset stock of next period for the male and female respectively. Again, these equations are analogous to equation 1b of the standard model.

The production technology is also similar to the standard model. As stated earlier, the assets owned by the male and female are jointly used for production. An alternate specification could allow each of them to engage in separate production using their own labor. However, given the local context, it is realistic to assume that household members pool assets they own as opposed to engaging in independent production (Kondombo et al., 2003). This allows them to enjoy economies of scale of production, and avoid having to own more capital than what is needed.

Equation 2h simply states that the male is required under social norms to spend at least a percent of his income on the commonly consumed good. This is the same assumption as Kazianga and Wahhaj (2013), as is based on local norms that the household head (who is almost always male) is expected to oversee production from the collective plot and use the proceeds to provide for common consumption goods of the household. While this social norm constrains how the male's income is spent, it does not require him to liquidate his assets to ensure a minimum quantity of q is purchased. This allows for interesting dynamics in which the male and/or female liquidate assets at different rates when the total income is not high enough to meet basic common consumption goods needs of the family.

Since the assets owned by male and female are homogenous (at least in the theoretical model) and used for joint production, both follow similar asset accumulation paths as those discussed in the standard model. Thus, predictions 1 and 2 still hold. However, the male and

female may follow different asset management strategies based on their consumption preferences.

Prediction 3: If males and females have similar consumption preferences, they will buy/sell assets at similar levels.

This allows us to better understand gender differences in asset management. For example, if I find males and females have similar patterns of asset management during normal economic conditions but females sell more assets during negative economic shocks, it may indicate that females prioritize the short-term food security of household members more than their male counterparts. Such hypotheses can be tested by analyzing the purposes of livestock sales, how the proceeds were used, and whether that lead to greater household food security.

4.2.3 Existence of Poverty Traps

The empirical strategy will test whether households sell assets to finance current consumption to off-set short-term negative economic shocks. I then test for asset smoothing at potential Micawber thresholds of livestock and other agricultural assets, based on the literature. The model predicts that households just above the Micawber threshold to asset smooth, rather than consumption smooth, when faced by shocks. Household behavior consistent with this prediction would suggest existence of a certain type of poverty trap.

However, there may be reasons to not expect a poverty trap in the real world. The model depends on the credit constraint; if this constraint is take away the poverty traps do not exist. While formal credit is not easily available in rural Burkina Faso, informal sources of credit can make this a less constraining factor. If households have access to multiple income generating

activities, the importance of the Micawber threshold reduces. This is because other source of income can be accessed that do not depend on the asset.

Rental markets and informal ways of accessing the productive asset may also alleviate the need to own the asset. As long as the household has access to the asset, they would not necessarily own it or would be willing to sell it when needed.

The model I present also assumes the asset to be a continuous variable. However, many productive assets such as livestock are discrete. A single unit of larger animals, such as oxen and cows, can be extremely expensive. This would weaken the case for the existence of a Micawber threshold, even if multiple livelihoods exist that require certain thresholds of assets. For example, a pair of oxen is needed for ploughing land and has been noted as an important asset threshold. Yet, the existence of a Micawber threshold is questionable. Given that purchasing a single ox requires incurring significant upfront cost, would households with one oxen consider themselves ‘close enough’ to the switching point that they accumulate resources to buy the second ox in the near future? In such cases, distinguishing between the Micawber threshold (if it exists) and $\tilde{L}$ may be empirically difficult.

Another factor to consider is that if many households try to sell an asset, its price may decrease, reducing the incentive to sell it. However, more of it will need to be sold if households require a minimum amount of money for immediate consumption. In the case of livestock, these effects are further complicated by the fact that it might be harder to maintain a herd because there is less land available for grazing. This would make maintaining a herd more expensive, which may reflect in the price of the asset. Some animals, such as goats, are more resistant to droughts since they can graze on grass and shrubs.

Livestock is the most common asset owned by rural Burkinabe households. While it is an important productive asset and a store of value, but it also plays other important roles.

Kondombo et al. (2003) note that livestock plays an important role in the cultural life of rural people in Burkina Faso, and are linked with prestige. Thus, despite economic reasons for wanting to sell livestock, households may not sell them since its possession increases their utility.

The theoretical model explains asset dynamics and even if poverty traps do not exist in rural Burkina Faso, it suggests that selling productive assets has important long-term impacts on the household's well-being. As explained by Janzen and Carter (2013), "irrespective of whether poverty traps strictly exist in this environment, the evidence does suggest that asset losses in this environment have severe and long-lasting consequences". Hence, in this chapter I explore asset dynamics and questions related intrahousehold resource allocation that are important regardless of whether poverty traps exist in the region being studied.

4.3 Data

The study uses data from the Continuous Farm Household Survey/ Enquête Permanente Agricole (EPA), collected by the Ministry of Agriculture and Food Security of Burkina Faso. The survey gathers detailed plot-level agricultural data on plot characteristics, inputs applied and harvested amount. There is also data on quantity of crops stored by the household. The asset data contains quantity and value of farm machinery, and livestock owned by individual members within the household. The animals include cattle (oxen and cows), sheep, goats, donkeys, pigs and hens. There is data on the consumption, purchase, birth, death, sale and value of sales (and what the proceeds were used for). The data for cattle (oxen and cows) sales are given together, hence it is not possible to know exact sale of each. However, since I know the number of oxen

and cows in each year, I can use the change across years as a proxy for sale (since they could have died or have been consumed).

There are also modules on household composition, self-reported food security, consumption of food groups and their frequency, and other sources of income. Since there is no detailed consumption module, I cannot directly test for the extent of consumption smoothing. Instead, I rely on detailed gender-disaggregated asset data to test for sales in response to weather shocks.

Rainfall estimates comes from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), which uses 0.05° resolution satellite imagery with weather station data to create a gridded time series. The GPS coordinates of villages are then used to extract the precipitation data ranging from 1981-2012.

4.3.1 Assignable Assets

The empirical strategy requires data on sale of productive asset that are assignable to specific household members. While agricultural land is owned by most households (and even by individuals within households) in rural Burkina Faso, the land is not frequently sold or purchased. In our sample, less than one percent of plots were acquired through purchase by households. Customary laws often prohibit sale of land, and the 2009 rural land law requires the approval of customary chiefs for land transactions to be considered legal (Koussoubé, 2015). Such restrictions mean that land is unlikely to be an asset that is sold to meet short-term needs of a household.

Agricultural equipment are also productive assets that could be sold in response to economic shocks. However, most households have small agricultural tools which have little value. For example, the most common equipment that households have are machetes and *dabas*

(a traditional Mossi agricultural tool). The average household owns about 5 machetes and 5 *dabas*; however, each machete and *daba* is worth only about 800 CFA francs (\$1.5) and 460 CFA francs (\$0.9). Larger equipment is rarely owned; for example, less than half a percent of sample households owned a tractor.

Livestock ownership is extremely common in rural Burkina Faso. Households raise oxen, cattle, goats, sheep and poultry for many purposes, ranging from producing labor to providing commodities (such as meat, milk, eggs and skin). Table 4.1 shows that sample households own a number of these animals. While most households do not own all types of livestock, they typically own some livestock.

43 percent of households do not own any oxen. Among households that own oxen, 19 percent own only one ox while 48 percent own exactly two oxen. Similarly, 43 percent of households do not own any other cattle. The average household owns 4.87 of other cattle.

Ownership of medium-sized animals, such as sheep and goats, is more common. Nearly 59 percent of households own at least one sheep, while 78 percent of households own at least one goat. The median number of sheep and goats owned by a household is 3 and 5 respectively. Since these are portable, less lumpy assets compared to oxen and cattle, they may be more useful in coping with small and medium sized shocks (Deere and Doss, 2006). Poultry is also important in rural Burkina Faso. 88 percent of households own some local hens; the median household owns 13 such hens.

4.3.2 Gender-Disaggregated Livestock Ownership

Next, I discuss how livestock ownership differs across men and women. There is a large literature that emphasizes that there is a significant gender asset gap across the world (see Deere

and Doss, 2006 for a review). In most African and Asian countries, men own significantly more livestock than women (Johnson et al., 2016). These differences are greater for larger animals as compared to smaller animals. Quisumbing et al. (2015) report that in the Gourma province of Burkina Faso, men owned about 124,000 and 370,000 CFA francs of small and large livestock respectively, compared to only 26,000 and 6,000 CFA francs of small and large livestock.

Using a more representative sample of Burkina Faso, I find that large animal (oxen and cattle) ownership is almost solely concentrated towards men. While men own more sheep and goats, the gender differential in their ownership is much smaller. The average household has 6 goats owned by males and 2.2 goats owned by females. Poultry ownership is also higher for men; the typical household contains 16 local hens owned by men compared to 4 owned by women.

I want to test whether men and women use their livestock differently to cope with negative economic shocks. Since men own more livestock and are generally responsible for the food security of the family, we may expect them to liquidate more livestock to meet short-term household needs. However, men and women may react differently to economic shocks. Quisumbing (2011) finds that in Bangladesh, different types of negative economic events affect assets owned by men and women differently. For example, while illnesses reduced women's asset holding, wedding and dowry expenses reduced the assets of men. This may partially be due to different perceptions of the shock (Doss, McPeak and Barrett, 2008).

4.4 Identifying Shocks

Low (high) levels of rainfall should not be classified as a drought (flood). Typically, a drought (flood) is defined when precipitation levels are significantly lower (higher) than the

long-term average (Heim, 2002). Hoddinott (2006) uses negative and positive standard deviations away from the long-term mean to measure adverse rainfall shocks. Fafchamps et al. (1998) use deviations away from the long-term mean and its square term to predict income shocks.

In this essay, I use the Standardized Precipitation Index (SPI), developed by McKee et al. (1993) to identify droughts and shocks. The rainfall data is used to fit a gamma distribution. The gamma distribution has been noted to model precipitation data well (Guttman, 1999). The cumulative distribution function is then transformed to a standard normal distribution function, with a Z-score less than -1 indicating a drought. McKee et al. (1993) recommend this cut-off to identify droughts, which is also used by Pauw, Thurlow and van Seventer (2010) to identify droughts in Malawi. A Z-score of greater than 2 is defined as a flood – this is because higher than average rainfall may be good up to a certain point, but extremely high rainfall has negative effects (such as inundating fields). Du et al. (2013) also find that historic floods are detected at SPI values of 2. Since these cut-offs are somewhat arbitrary, sensitivity analysis is conducted for robustness of the results. The 2010 rainfall distribution is based on data from 1981 to 2009, the 2011 distribution uses data from 1982 to 2010 while the 2012 distribution uses data from 1983 to 2011.

The drought indicator is based on the total rainfall at the sowing time and when the plant is in early growth stage. Adequate rainfall at these times are necessary because without planting rains (*sigri saaga*), seed is left in the dry lands and eaten by birds and insects (Roncoli, Ingram and Kirshen, 2001). Farmers may need to replant their fields multiple times, which leads to additional costs and less growing duration for the crop. Hence, villages that receive significantly

less than the historic average July and August rainfall are classified to have suffered from a drought.

Floods are identified using the quantity of rainfall over the crop growing season. This is because too much rain can damage crops and flood lowland fields (Roncoli, Ingram and Kirshen, 2001). Thus, significantly higher than the historic average July, August and September rainfall is used to identify a flood.

During the three survey years, across villages there are 130 instances that are classified as floods and 87 instances that are classified as droughts. Since drought and flood variables are deviations from long-term trends, I interpret them as unexpected events for households. This is partly because there is limited scientific forecasting of rainfall accessible to these farmers. Local knowledge of rainfall, based on winds, bird and insect behavior, and astronomy, is also less effective at predicting total rainfall compared to other weather phenomenon (Roncoli, Ingram and Kirshen, 2002). While households may choose to be located in places with lower weather variability, household fixed effects can control for time-invariant household and geographic level systematic differences. The identification strategy will then assume that controlling for these time-invariant household level heterogeneity, the main explanatory variables (described below) are uncorrelated with the error term of their model.

4.5 Empirical Strategy

4.5.1 Effect of Weather Shocks on Agriculture

I first want to test how weather shocks affected the agricultural income of households. These weather shocks can have effects through two main mechanisms, decreasing crop yields and reducing the area that is cultivated. Households may also change their crop portfolio,

especially in times of droughts. This may also reduce their agricultural income if they switch from high value crops to basic staples.

A household fixed effects model is used to test whether these shocks are correlated with crop yield.

$$Y_{ijht} = \alpha + \beta_1 \text{drought}_{ht} + \beta_2 \text{flood}_{ht} + \beta_3 X_{ijht} + \gamma_h + \theta_j + \mu_t + \varepsilon_{ijht} \quad (1)$$

The dependent variable, Y_{ijht} , is the yield (kg/ha) of crop j on plot i of household h in year t . drought_{ht} and flood_{ht} are dummy variables that equal one if the household was located in a village where a drought or a flood respectively occurred at time. The vector X_{ijht} includes plot and plot manager characteristics, and household characteristics that vary over time. γ_h denote the household fixed effects, θ_j are dummy variables for crop type while μ_t are year dummy variables. The main specification does not control for inputs, since these might be the mechanism through which rainfall affects agricultural output – less fertilizer might be applied to crops because of insufficient rainfall. Additional regressions control for agricultural inputs for additional robustness of the results. The main coefficients of interest are β_1 and β_2 . If the drought and flood reduce crop yields, these coefficients will be negative.

A similar specification will be used to test whether these rainfall shocks lead to less land being cultivated. This may be because households consolidate resources on few plots. While it is unclear early in the season whether a drought will occur, households may still be able to adapt and change the amount of land they cultivate. This is because with a late on-set or insufficient rainfall early in the season, they may need to replant and then reduce the area they cultivate (Roncoli et al., 2001). Secondly, they may grow less of crops that are planted later in the season.

Since extremely high rainfall is less predictable at sowing time, we would not expect area cultivated or crop choice to be affected by floods. This is because farmers cannot anticipate if there is likely to be instances of extreme rainfall that would damage their crop and inundate fields. Droughts develop more gradually, and insufficient early rains will force farmers to replant their fields, giving an opportunity to alter crop choice and area cultivated. Therefore, we may expect greater behavioral response to droughts than floods.

The dependent variable is total cropped area (ha) and the model is estimated using a household level (rather than plot level) dataset. Household level (but not plot or plot manager level) explanatory variables will be included in the vector X_{ijht} .

4.5.2 Asset Sale in Response to Weather Shocks

Next, I test whether households sell their livestock in response to floods and drought. A household fixed effects model is used to test whether households that face droughts and floods sell more livestock.

$$S_{ht} = \alpha + \beta_1 \text{drought}_{ht} + \beta_2 \text{flood}_{ht} + \beta_3 X_{ht} + \gamma_h + \mu_t + \varepsilon_{ht} \quad (2)$$

S_{ht} is the livestock sales of the household at time t , and X_{ht} is a vector of household characteristics that are likely to affect livestock sales. Separate regressions will be estimated to test for sale of different animals. If assets are sold in response to the weather shocks, $\beta_1 > 0$ and $\beta_2 > 0$.

To test for poverty traps, it is not possible use Hansen's threshold method or semi/nonparametric techniques to find important livestock thresholds from within the data. This

is because the panel period is too short - only three years. Instead, similar to Hoddinott (2006), I will use the local production context to suggest an important asset threshold and test the behavior of households above and below it.

There is low mechanization for agriculture in Burkina Faso, and oxen are still the primary way of ploughing and preparing land. Without a pair of oxen, which is needed to prepare the land, households would have much lower efficiency in farming and have much lower incomes. The importance of a pair of oxen is highlighted by the fact that amongst households that own oxen, majority of them own exactly two. Hence, this presents an important asset threshold for poor households in rural Burkina Faso. The specification to test for differential asset sales for households above and below this threshold of two oxen is:

$$S_{ht} = \alpha + \beta_1 drought_{ht} + \beta_2 flood_{ht} + \beta_3 high_{ht} + \beta_4 drought_{ht} * high_{ht} + \beta_5 flood_{ht} * high_{ht} + \beta_6 X_{ht} + \gamma_h + \mu_t + \varepsilon_{ht} \quad (3)$$

This model will be estimated on a sub-sample of households that own at least one oxen. The variables in the model are defined the same as above. Additionally, following Hoddinott (2006), I define $high = 0$ if the household has one or two oxen, and equals $high = 1$ if it has more than two oxen.

Again, $\beta_1 > 0$ and $\beta_2 > 0$ if oxen are sold in response to weather shocks. Additionally, $\beta_4 < 0$ and $\beta_5 < 0$ is consistent with the poverty traps model. That is, households with fewer oxen are less willing to sell them compared to households with more oxen.

I also test some related intrahousehold resource allocation questions on the main asset sales model. In specific, I test whether the presence of infants in the household results in greater asset sales - presumably to sustain consumption levels. We know the first 1000 days from conception till the child's second birthday are crucial for their development and have lifelong

effects (Cusick and Georgieff, 2012). Given the importance of nutrition for children at early ages, households should be more willing to sell assets rather than if the children were older. However, these children are not decision-makers in the household and depend on adults in the household to take into account their long-term well-being and ensure their needs are met. To test whether households sell more assets when children are in the households, I include explanatory variables for number of infants in the household and their interaction with drought and flood.

Another question I explore is whether women's assets are more likely to be sold to deal with a shock than assets owned by men. We know that women are more vulnerable to economic shocks (Bolin and Stanford, 2006), including weather shocks (Miguel, 2005). A small but growing literature tests whether assets owned by men and women are used differently during negative economic shocks. Using a panel survey from Uganda, Quisumbing, Kumar and Behrman (2018) find that husband's assets are better protected against covariate shocks than wife's assets. They also find that weather shocks affect assets of wives but not husbands. In Ghana, Doss et al. (2015) find that while majority of livestock sold was owned by men, a substantial portion (30 percent) of livestock owned by women was also sold. Doss et al. (2015) also make the distinction between the owner of an asset and the person who decided to sell the asset. The one deciding to sell an asset mostly appear to be the owner of the asset.

I also test whether assets owned by men and women are sold at a similar rate during weather shocks. This is an important question, because if women lose a substantial portion of their assets during weather shocks, it damages their ability to generate income in the future. That would lead to persistent effects of these weather shocks for the welfare of women, since they earn less income in the future and potentially have weaker intrahousehold bargaining positions.

In all the regressions that will be estimated, standard errors are clustered at the household level to allow for correlation between observations in the same household within the same year and across the three years.

4.6 Results

4.6.1 Effect of Weather Shocks on Agriculture

Table 4.5 shows that crop yields decrease significantly when droughts and floods, as defined in section 3.4, occur. In the preferred specification with the full set of control variables, I find that a drought reduces the crop yield by 8 percent (at 5 percent significance level) while a flood reduces crop yield by 11 percent (at the 1 percent significance level). The sample households derive a substantial portion of their income from agriculture, and at low levels of income a small reduction in income can adversely affect the household.

However, the weather shocks can influence agricultural income through other mechanisms. Table 4.6 shows that households that were located in a drought-affected village were likely to cultivate 0.26 hectares less land than those in villages not affected by a drought. This represents a 7 percent decrease in cultivated area, statistically significant at the 1 percent level. The reduction in cultivated area mainly comes from non-cereal crop cultivation. The area on which basic cereal crops are cultivated remains unchanged. This may be because millet and sorghum are critical to food security, and are resilient to dry conditions (Yanggen et al., 1998). However, non-cereal crops are cultivated on 0.22 hectares less area. The change in crop portfolio will also affect household income, as moving from higher value crops to lower value staple and cereal crops will mean less revenue can be generated by selling the output.

Floods, however, do not affect the area a household cultivates or the crop portfolio it chooses. The point estimates for area cultivated, cereal and non-cereal cultivated area are quite close to zero and not statistically different from zero at any conventional or reasonable statistical level. As explained earlier, households cannot anticipate extreme rainfall damaging their crops later in the season at sowing time. Droughts develop more gradually, and insufficient early rains will force farmers to replant their fields, giving an opportunity to alter crop choice and area cultivated. Therefore, we may expect greater behavioral response to droughts than floods. Even though floods reduce crop yields more than droughts, households are more affected by droughts since it affects the amount of land they can cultivate and also their crop portfolio.

4.6.2 Asset Sales in Response to Weather Shocks

After establishing that the droughts and floods, as defined in this essay, adversely affect household income, I test whether assets are sold in response to these weather shocks. The magnitude of effects of the weather shocks help us conceptualize what kind of response to expect from households.

Table 4.8 shows that while households sell livestock in response to floods, they typically do not use this coping strategy in times of drought. As this is an average effect over a heterogeneous population, it may mask differences across households. However, the average household does not appear to sell livestock during droughts. While the floods are not large enough to induce the sale of large animals, such as oxen and cows, households sell up to 10 percent of the pigs they own. Broiler sales increase by 0.116 units over the season, which translates to 90 percent of the broiler stock of a household at a given point in time. Households also sell 1.7 more local hens and 0.8 guinea fowl.

Households, of course, have less agricultural output during drought seasons. This translates to less food for consumption and less money to purchase goods. Households consume 0.03 more broilers during droughts, which is about 23 percent of their stock of broilers at a given point in time. Since broilers are extremely sensitive to conditions, they are difficult to maintain and grow effectively during droughts. Therefore, households may be likely to consume them when the cost of maintaining them rises. Households may also consume up to 7 percent of the guinea fowl they own during floods.

It is somewhat surprising to find that while floods lead to significant sale and consumption of livestock, droughts do not induce a similar response. However, this can be explained due to the nature of each shock. Since droughts develop gradually, they allow households to adapt and prepare for economic hardship. This allows households to use fewer expensive inputs, such as fertilizer, and send more family members for off-farm work. They are also able to draw on their stored stock of grains to meet short-term consumption needs. However, floods can destroy crops once agricultural costs have been incurred. Therefore, households require more cash to pay for these costs. Furthermore, floods occurring later in the season do not allow households to use other coping strategies, such as relying on more non-agricultural labor income, till late into the season.

Given that households do not sell oxen during floods or droughts, it is unlikely that we detect any behavior of differential sales for households owning low and high number of oxen. In Table 4.10, I test two specifications of equation 3. In the first three columns, *high* equals zero if the household has one or two oxen, and one if the household owns more than two oxen. In the next three columns, I define *high* as zero if the household has exactly one oxen. Since the Micawber threshold is hypothesized as an asset level less than the livelihood switching point,

households could consider themselves close enough to the switching point with one ox and not want to sell it. In both cases, I do not find evidence that households sell oxen in response to droughts or floods. There is also no evidence that households with high number of oxen are more likely to sell them.

I also test whether poverty traps exist in the least population dense regions of the country. This may be because in these areas, there are fewer livelihood opportunities and productive assets are more crucial for the households. I define all regions with a population density of less than 65 persons/km² as low density. The cut-off was chosen to ensure sufficient observations in the low and high density groups. However, the interaction between *high* and flood/drought remains insignificant in the low population density area (as well as the high population density area). The results remain the same at different cut-offs (30, 40, 50 persons/km²).

Therefore, I do not find evidence of behavior consistent with a poverty trap. This does not, however, mean that these poverty traps do not exist in rural Burkina Faso. It seems that the weather shocks were too small to force households sell oxen. Hence, I am unable to detect a differential in oxen sales between households with high and low number of oxen.

4.6.3 Asset Sales and Intrahousehold Decision-making

Table 4.11 shows how livestock owned by men and women are sold in response to weather shocks. We earlier saw that households sold more pigs during flood times. Despite pig ownership being three time higher for men, these sales seem to come from pigs owned by women. While men sell more broilers and guinea fowl than women (statistically significant at the 5 percent level), in general men and women sell assets at a similar rate during floods.

Moreover, significantly greater number of female owned pigs and guinea fowl are consumed during droughts than those owned by men.

My findings are consistent with Doss et al. (2015)'s Ghana finding that men sell more livestock than women but women also sell a substantial portion of their livestock. Given that men own significantly more livestock than women, droughts actually increase the gender gap in assets despite the fact that men sell more livestock. This can reduce their intrahousehold bargaining positions, since those depend on income of individuals amongst other factors (Browning and Chiappori, 1998).

During droughts, the result is even more stark. More livestock owned by women are consumed than that owned by men. This is surprising since men own significantly more livestock than women. To ensure that the household's dietary needs are met, why aren't more animals owned by men consumed since they own more animals to begin with? While I am unable to completely explain this empirical result, I provide some suggestive evidence that males and females have different preferences over nutritional needs of children in the family. Since females are known to prioritize food expenditures compared to men, the greater priority might induce them to liquidate more animals than men. Overall, the results are concerning that the gender asset gap increases during weather shocks. This suggests that the negative effects of weather shocks persist for women over a longer period of time.

The sales and consumption of livestock during droughts may represent a higher cost of maintaining the animals. With less grazing land available and higher fodder prices, it may be optimal for some households to reduce their ownership of livestock. However, the pattern that female-owned livestock are sold and consumed more than those owned by men suggests that other factors influence the decision.

In table 4.13, I estimate the same model as in table 4.12 but with additional explanatory variables. These include number of baby boys (aged 0-2), number of baby girls (aged 0-2) and their interactions with flood and drought. Therefore, I test whether males and females liquidate (sell or consume) more livestock when the household contains children. For brevity, coefficients for other control variables are omitted.

The results show that households liquidate more livestock if they have a baby boy compared to a baby girl. The presence of a baby boy induces greater liquidation of sheep, local chicken and even cattle. There is also a reduction in liquidation of laying hens, which may be so that the household can consume eggs they produce. Baby girls do not induce the greater sale of any animal.

The consumption of the livestock represents investment in maternal health, which is crucial to the health of children. The greater sale of livestock in households with baby boys is likely to ensure that their nutritional needs are met. However, livestock is not liquidated due to the presence of baby girls. This reflects the patriarchal realities of rural Burkina Faso, where there is greater investment in boys. Interestingly, both men and women seem to conform to such behavior. It does not appear that the preference towards boys is greater among men than women.

4.6.4 Sensitivity to Definition of Drought and Flood

Since the floods and droughts were defined using arbitrary cut-offs of the Standardized Precipitation Index, I test the sensitivity of the main results to using a slightly higher and slightly lower cut-off value. The results are presented in tables 4.13 to 4.15. Robustness 1 defines a flood with SPI greater than 2.1 and drought with SPI less than -1.1. Robustness 2 defines flood with SPI greater than 1.9 and drought with SPI less than -0.9.

For brevity, I only share the coefficients of interest. The regressions are the exact same specification as earlier, with the only difference being that floods and droughts are defined slightly differently. As can be seen, the results remain very similar. For most regressions, the point estimates do not change much and the significance level remains significant. Therefore, the findings of this chapter are not sensitive to the cut-offs chosen to define floods and droughts.

4.7 Conclusion

In this chapter, I study how households cope with weather shocks. Floods reduce crop yields by 11 percent, while droughts reduce yields by 8 percent. Droughts also affect the crop portfolio of households; while they cultivate the same amount of staple crops, they reduce the land used to cultivate cash crops. To overcome these adverse effects, households sell and consume livestock. While households sell pigs, broilers, local chicken and guinea pig during floods, they consume more broilers during droughts. This suggests that they use other coping strategies, such as working off-farm, during droughts. Further research is required to understand what coping strategies households use during droughts, since they do not significantly liquidate their assets during drought years.

Even though more male owned livestock are liquidated during floods, a significant amount of female owned livestock are sold and consumed. This leads to an increase in the gender gap for assets. During droughts, even more female owned livestock are sold and consumed. The asset gender gap worsens significantly more during droughts. This will limit the ability of women to generate income, and worsen their bargaining position within the household. This will lead to ill-effects of the weather shocks persisting for them over time.

Households liquidate more livestock when there are baby boys, presumably to stabilize consumption and ensure their nutritional needs are met. However, they often do not do so in the presence of baby girls in the household. Both men and women seem to engage in this preferential treatment for boys.

This chapter shows how the ill-effects of weather shocks are distributed within households in rural Burkina Faso, and mechanisms through which they can persist over time. The gender asset gap increases during floods, and even more during droughts. Baby girls also seem more vulnerable to the effect of weather shocks than baby boys. Policy-makers need to identify such vulnerable sub-populations so that appropriate interventions can protect them. For example, households with baby girls can be targeted with conditional cash transfers that ensure their nutritional needs are met. Similarly, post-disaster needs assessments should incorporate the loss of assets owned by women, and that their bargaining positions worsen in the aftermath of weather shocks. Asset transfers targeted to women in the recovery period can help undo some of the effects of the weather shocks.

APPENDIX

Table 4.1: Livestock Ownership by Household

Animal	Percentage of HHs that own [animal]	Median	Mean	SD
Oxen	43.00	0	1.14	1.84
Other Cattle	42.62	0	4.87	19.52
Sheep	58.82	3	6.53	11.93
Goats	78.03	5	8.22	10.75
Donkeys	50.73	1	1.79	2.44
Pigs	25.4	0	1.62	4.53
Laying Hens	1.67	0	0.18	2.00
Broilers	1.38	0	0.13	1.51
Local Hens	87.76	13	20.06	26.92
Guinea Fowl	34.78	0	5.81	12.95

Source: Author's calculations

Table 4.2: Livestock Ownership by Males

Animal	Percentage of HHs with [animal] owned by males	Median	Mean	S.D.
Oxen	42.44	0	1.12	1.82
Other Cattle	41.73	0	4.61	18.99
Sheep	54.12	2	5.50	10.55
Goats	67.13	3	5.99	8.72
Donkeys	48.84	0	1.10	1.57
Pigs	11.15	0	0.65	3.02
Local Hens	81.17	10	16.22	24.15
Guinea Fowl	33.45	0	5.57	12.70

Source: Author's calculations

Table 4.3: Livestock Ownership by Females

Animal	Percentage of HHs with [animal] owned by females	Median	Mean	S.D.
Oxen	0.88	0	0.02	0.20
Other Cattle	5.22	0	0.25	1.83
Sheep	19.87	0	1.02	3.16
Goats	35.84	0	2.21	4.74
Donkeys	2.51	0	0.06	0.56
Pigs	17.82	0	0.97	3.11
Local Hens	33.84	0	3.80	9.13
Guinea Fowl	2.2	0	0.22	2.14

Source: Author's calculations

Table 4.4: Floods and Droughts Between 2010 and 2012

Panel A: Number of Floods and Droughts

	2010	2011	2012
Flood	29	1	100
Drought	0	82	5

Panel B: Rainfall Patterns in Villages that Experienced Floods and Droughts

	2010	2011	2012
Average rainfall in flood villages	894		755
Long-term avg. rainfall in those flood villages	685		547
Average rainfall in drought villages		346	331
Long-term avg. rainfall in those drought villages		445	414

Source: Author's calculations

Table 4.5: Effect of Droughts and Floods on Crop Yields

	Yield	Yield	Yield
Drought	-82.36** (34.67)	-84.85** (34.47)	-82.65** (35.49)
Flood	-124.7*** (27.13)	-114.2*** (27.70)	-122.3*** (28.21)
Plot Area		61.03*** (10.49)	66.00*** (12.04)
Collective Plot		22.76 (33.43)	16.03 (35.88)
Plot Far From Home		11.70 (17.53)	8.255 (18.69)
Plot on Lowland		58.11* (32.13)	47.69 (32.83)
Plot Sloped		0.194 (23.80)	-10.11 (24.14)
Plot has Secure Tenure		-24.79 (18.82)	-27.09 (19.08)
Age		0.263 (0.562)	0.304 (0.607)
Literate		3.816 (22.23)	-4.648 (23.04)
Female		-30.50 (27.11)	-36.14 (26.78)
Access to Credit		-17.08 (28.18)	-26.91 (30.02)
Household Head		-8.228 (36.08)	-5.080 (36.44)
Married		65.79*** (24.58)	62.96** (26.00)
Ratio of Children to Women		-7.242 (9.229)	-3.964 (9.722)

Table 4.5 (cont'd)

HH Livestock Owned		1.548 (1.263)	1.428 (1.261)
HH Land Owned		-14.37** (6.216)	-11.48* (6.264)
Non-Farm Income		-0.0274 (0.0178)	-0.0259 (0.0186)
HH Cotton Area Cultivated		-9.425 (8.730)	-15.17* (8.700)
Nitrogen Fertilizer			0.217 (0.229)
Seed			0.000280*** (4.64e-05)
Manure			2.48e-05 (3.84e-05)
Herbicide			-0.00548 (0.0154)
Fungicide			-0.0923 (0.0706)
Pesticide			0.0199 (0.0250)
Raticide			0.0138*** (0.00374)
Labor			-0.00239 (0.00551)
Year 2011	84.61*** (19.49)	80.25*** (19.58)	82.78*** (20.97)
Year 2012	-75.38*** (18.32)	-85.29*** (18.54)	-85.63*** (19.33)
Constant	821.1*** (14.83)	784.9*** (46.55)	772.9*** (47.65)
Observations	58,462	56,593	51,469
No. of Households	2628	2621	2618

Household fixed effects estimation

Standard errors clustered at household level in parentheses

Coefficients of crop indicator variables not shown

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.6: Effect of Droughts and Floods on Land Cultivated

	Area Cultivated	Area Cultivated	Cereal Area Cultivated	Cereal Area Cultivated	Non-Cereal Area Cultivated	Non-Cereal Area Cultivated
Drought	-0.137 (0.123)	-0.262*** (0.0752)	-0.0203 (0.106)	-0.0446 (0.0420)	-0.117 (0.105)	-0.218*** (0.0607)
Flood	-0.0567 (0.0941)	-0.0175 (0.0477)	-0.0970 (0.0699)	-0.0243 (0.0264)	0.0403 (0.0605)	0.00685 (0.0390)
Ratio of Children to Women		-0.00517 (0.0159)		0.00211 (0.00851)		-0.00727 (0.0134)
HH Livestock Owned		-0.00138 (0.00545)		-0.00122 (0.00236)		-0.000160 (0.00353)
HH Land Owned		0.975*** (0.0376)		0.901*** (0.0188)		0.0740*** (0.0239)
Non-Farm Income		0.000166 (0.000111)		7.90e-05 (6.01e-05)		8.66e-05 (5.64e-05)
Year 2011	-0.457*** (0.0584)	-0.0607 (0.0374)	-0.341*** (0.0371)	-0.0154 (0.0202)	-0.116*** (0.0446)	-0.0452 (0.0292)
Year 2012	-0.308*** (0.0651)	-0.0296 (0.0472)	-0.224*** (0.0486)	-0.0142 (0.0234)	-0.0847* (0.0435)	-0.0154 (0.0366)
Constant	4.132*** (0.0313)	0.887*** (0.135)	3.016*** (0.0230)	0.394*** (0.0679)	1.116*** (0.0203)	0.493*** (0.0820)
Observations	7,533	7,352	7,533	7,352	7,533	7,352
No. of Households	2,628	2,622	2,628	2,622	2,628	2,622

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.7: Livestock Sales In Response to Floods and Droughts

	Oxen+Cattle	Sheep	Goats	Donkeys	Pigs	Laying Hens	Broilers	Local Chicken	Guinea Fowl
Flood	-0.00525 (0.0569)	-0.424 (0.367)	0.110 (0.131)	-0.0952 (0.0854)	0.154* (0.0811)	-0.128* (0.0676)	0.116** (0.0567)	1.676** (0.718)	0.757** (0.352)
Drought	-0.0215 (0.0813)	-0.00540 (0.111)	0.0235 (0.122)	0.0593 (0.0472)	0.0593 (0.0982)	0.0809 (0.0623)	0.0201 (0.0296)	0.427 (0.832)	-0.294 (0.373)
No [animal] owned by household (lag)	0.00865 (0.0116)	0.000499 (0.0389)	-0.0252* (0.0131)	0.0318 (0.0262)	-0.0356 (0.0337)	-0.0557** (0.0271)	-0.0600* (0.0309)	0.0619*** (0.0162)	-0.0921** (0.0358)
Household Size	0.0184 (0.0114)	-0.0194 (0.0249)	0.0108 (0.0164)	-0.0964 (0.0966)	0.0173* (0.0104)	-0.00217 (0.00486)	-0.000983 (0.00365)	0.00411 (0.0852)	0.0472 (0.0512)
Ratio of Children to Women	0.00385 (0.0196)	-0.0198 (0.0411)	0.0157 (0.0409)	-0.0380 (0.0374)	-0.00398 (0.0305)	0.0233 (0.0247)	0.00302 (0.0113)	-0.226 (0.252)	-0.0775 (0.108)
HH Land Owned	0.0106 (0.0133)	0.145 (0.105)	0.0124 (0.0281)	-0.0133 (0.0182)	-0.0126 (0.0239)	-0.00521 (0.00980)	-0.000689 (0.00366)	-0.0155 (0.126)	-0.00624 (0.0703)
Non-Farm Income (lag)	-1.51e-05 (4.08e-05)	0.000138* (8.02e-05)	0.000133* (6.98e-05)	-3.30e-05 (2.64e-05)	2.64e-05 (0.000107)	-7.34e-06 (8.72e-06)	-5.11e-06 (7.95e-06)	0.000252 (0.000303)	-0.000138 (0.000107)
HH Cotton Area Cultivated	0.0337 (0.0207)	-0.121 (0.0936)	-0.0183 (0.0357)	0.00942 (0.0150)	-0.0393 (0.0484)	-0.00541 (0.0124)	0.00116 (0.00333)	0.0363 (0.131)	0.0769 (0.0819)
Livestock (lag)	-0.0130 (0.0149)	-0.00298 (0.0230)	0.0173*** (0.00443)	0.00256 (0.00296)	-0.00401 (0.00322)	0.00270 (0.00180)	0.000887 (0.000912)	-0.0360 (0.0322)	0.0130 (0.0111)
Millet Stored (lag)	6.46e-06** (2.67e-06)	-3.51e-05*** (1.30e-05)	-3.78e-05* (2.00e-05)	7.90e-07 (1.09e-06)	-1.94e-06 (2.58e-06)	1.72e-06 (1.40e-06)	-2.37e-07 (1.27e-06)	-8.35e-05 (5.24e-05)	-2.93e-06 (6.84e-06)
Rice Stored (lag)	2.53e-05*** (5.78e-06)	5.70e-06 (4.45e-05)	-2.85e-06 (1.86e-05)	4.60e-06 (3.38e-06)	3.85e-06 (8.31e-06)	-1.01e-06 (2.35e-06)	1.52e-06 (1.52e-06)	6.93e-05 (0.000100)	5.63e-08 (1.47e-05)
Sorghum Stored (lag)	-5.91e-06 (1.60e-05)	-7.06e-06 (1.76e-05)	1.53e-05 (2.72e-05)	1.15e-05 (1.17e-05)	1.76e-05* (1.03e-05)	-2.64e-06 (4.66e-06)	1.67e-06 (2.12e-06)	5.14e-05 (8.30e-05)	2.26e-05 (2.84e-05)
Year 2012	0.0128 (0.0294)	-0.00688 (0.0542)	0.112* (0.0665)	0.163 (0.142)	0.0238 (0.0442)	0.0328 (0.0221)	0.00877 (0.0150)	-0.0458 (0.486)	-0.322 (0.229)
Constant	0.204 (0.128)	0.781** (0.308)	1.003*** (0.223)	1.037 (1.005)	0.354*** (0.121)	0.0164 (0.0884)	0.0164 (0.0531)	8.133*** (1.512)	1.858** (0.783)
Observations	4,534	4,533	4,533	4,533	4,533	4,533	4,533	4,533	4,533

Table 4.7 (cont'd)

Number of households	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451
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Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.8: Consumption of Livestock

	Oxen+Cattle	Sheep	Goats	Pigs	Laying Hens	Broilers	Local Chicken	Guinea Fowl
Flood	0.00376 (0.0130)	0.00305 (0.0671)	0.0529 (0.135)	-0.0416 (0.0271)	-0.0126 (0.0190)	0.0115 (0.0252)	-0.0305 (0.333)	0.405** (0.189)
Drought	-0.00113 (0.0266)	-0.0489 (0.0493)	-0.0326 (0.0544)	0.0469 (0.0494)	0.0360 (0.0341)	0.0294* (0.0176)	-1.915 (1.377)	-0.399** (0.200)
No [animal] owned by household (lag)	-0.0310 (0.0233)	-0.00459 (0.00345)	-0.00669 (0.00670)	0.00710 (0.0120)	-0.0598* (0.0338)	-0.0301 (0.0183)	-0.0103 (0.00848)	-0.0519* (0.0275)
Household Size	0.00340 (0.00360)	0.0199** (0.00862)	0.0123 (0.0100)	0.00553 (0.00397)	-0.00682 (0.00532)	0.00113 (0.00173)	0.0531 (0.0399)	0.0337** (0.0148)
Ratio of Children to Women	-0.00123 (0.00890)	0.00819 (0.0173)	-0.0268 (0.0273)	-0.0102 (0.00729)	-0.0105 (0.0126)	-0.0112 (0.00989)	-0.104 (0.129)	-0.206** (0.101)
HH Land Owned	-0.00131 (0.00573)	0.00460 (0.0111)	0.0144 (0.0139)	-0.00757 (0.00649)	-0.00351 (0.00412)	-0.00383 (0.00291)	0.0660 (0.0835)	-0.0523 (0.0366)
Non-Farm Income (lag)	5.40e-06 (8.10e-06)	7.24e-05* (4.23e-05)	-2.94e-05 (5.86e-05)	-2.62e-05 (1.87e-05)	4.76e-06 (6.64e-06)	2.26e-06 (3.02e-06)	2.82e-05 (0.000254)	-9.73e-05 (9.62e-05)
HH Cotton Area Cultivated	0.00593 (0.00958)	-0.0160 (0.0128)	-0.00880 (0.0131)	0.00339 (0.00968)	-0.0121 (0.0132)	0.00269 (0.00266)	-0.0942 (0.134)	0.0609 (0.0382)

Table 4.8 (cont'd)

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Livestock (lag)	0.0412 (0.0305)	-0.00171 (0.00289)	0.000379 (0.00232)	0.000339 (0.000706)	0.00366* (0.00210)	0.000657 (0.000707)	-0.00161 (0.0156)	-0.00198 (0.00784)
Millet Stored (lag)	-2.54e-06 (2.40e-06)	8.40e-07 (1.43e-06)	-6.66e-06** (2.76e-06)	-2.35e-07 (5.92e-07)	1.22e-06 (1.30e-06)	-2.59e-07 (7.36e-07)	-8.11e-06 (1.14e-05)	-1.53e-06 (3.86e-06)
Rice Stored (lag)	6.71e-06 (4.67e-06)	3.47e-06 (5.04e-06)	2.09e-06 (3.92e-06)	-4.00e-07 (2.01e-06)	1.20e-07 (1.56e-06)	2.64e-07 (8.43e-07)	-1.38e-05 (2.48e-05)	-1.68e-06 (6.15e-06)
Sorghum Stored (lag)	6.86e-07 (1.56e-06)	-3.68e-07 (1.02e-05)	2.48e-05* (1.49e-05)	2.89e-06 (3.49e-06)	-4.61e-07 (4.32e-06)	-1.36e-06 (2.06e-06)	9.69e-05 (6.15e-05)	-5.68e-06 (2.30e-05)
Year 2012	0.00207 (0.00755)	-0.0219 (0.0230)	-0.00862 (0.0268)	0.0394** (0.0184)	-0.00969 (0.0144)	0.0312** (0.0142)	0.0289 (0.182)	-0.223 (0.170)
Constant	-0.128 (0.120)	0.0738 (0.103)	0.308*** (0.106)	0.0426 (0.0390)	0.124* (0.0683)	0.0313 (0.0309)	3.545*** (0.498)	1.515*** (0.529)
Observations	4,534	4,533	4,533	4,533	4,533	4,533	4,533	4,533
Number of households	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.9: Oxen Sales and Asset Smoothing At Key Thresholds

	Threshold=2	High Density	Low Density	Threshold=1	High Density	Low Density
No. Oxen High	-2.333*** (0.218)	-2.094*** (0.224)	-3.159*** (0.545)	-3.638** (1.421)	-2.266*** (0.478)	-4.689** (1.916)
Drought*No. Oxen High	-0.127 (0.440)	-0.106 (0.442)		0.0970 (0.698)	-0.217 (0.656)	
Flood*No. Oxen High	-0.348 (0.580)	-0.385 (0.720)	-0.179 (0.689)	0.155 (0.718)	-0.957 (0.924)	1.355 (0.830)
Flood	-0.148 (0.167)	-0.0259 (0.372)	-0.0678 (0.249)	-0.222 (0.350)		0.573 (0.467)
Drought	-0.298** (0.138)	-0.220 (0.150)		-0.483 (0.480)	-0.00535 (0.415)	
Household Size	0.127*** (0.0463)	0.143** (0.0561)	0.0930** (0.0379)	0.208* (0.120)	0.230 (0.160)	0.204*** (0.0517)
Ratio of Children to Women	0.0311 (0.0668)	0.147* (0.0825)	-0.171 (0.108)	0.180 (0.123)	0.235 (0.229)	0.0195 (0.111)
HH Land Owned	-0.0165 (0.0531)	-0.0139 (0.0583)	-0.0166 (0.0885)	-0.0460 (0.0975)	-0.0535 (0.0994)	0.0526 (0.0896)
Non-Farm Income (lag)	0.000209 (0.000177)	0.000167 (0.000240)	0.000463*** (0.000112)	0.000763 (0.000520)	0.000739 (0.000544)	-0.000428 (0.00174)
HH Cotton Area Cultivated	-0.00911 (0.0687)	-0.0103 (0.0744)	0.612** (0.307)	-0.0622 (0.141)	-0.0485 (0.136)	0.791* (0.441)
Household Livestock (lag)	-0.0829*** (0.0276)	-0.0937*** (0.0319)	-0.0255 (0.0351)	-0.123*** (0.0418)	-0.143*** (0.0446)	0.0438 (0.0718)
Millet Stored (lag)	-2.66e-05 (2.85e-05)	-0.000188*** (3.36e-05)	3.31e-06 (6.25e-06)	3.28e-06 (1.40e-05)	-0.00158** (0.000677)	3.45e-06 (1.03e-05)
Rice Stored (lag)	0.000136***	0.000162***	2.43e-06	0.000156***	0.000154***	-0.000718

Table 4.9 (cont'd)

	(4.54e-05)	(2.67e-05)	(0.00118)	(2.88e-05)	(2.92e-05)	(0.00188)
Sorghum Stored (lag)	3.53e-05**	3.07e-05	4.11e-05**	5.93e-05	0.000134	0.000174*
	(1.72e-05)	(3.74e-05)	(1.67e-05)	(0.000166)	(0.000310)	(9.73e-05)
Year 2012	-0.0630	-0.0583	-0.255	-0.194	-0.108	-0.947**
	(0.0935)	(0.105)	(0.199)	(0.240)	(0.277)	(0.427)
Constant	-0.191	-0.503	0.0522	0.377	0.0327	-1.304
	(0.613)	(0.777)	(0.616)	(1.962)	(2.488)	(0.797)
Observations	1,969	1,413	556	1,000	683	317
Number of households	1,179	830	349	729	494	235

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.10: Sale of Male and Female Owned Livestock

	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	Pigs	Pigs	Laying Hens	Laying Hens	Broilers	Broilers	Local Chicken	Local Chicken	Guinea Fowl	Guinea Fowl
Flood	0.0387 (0.0579)	0.113* (0.0597)	-0.126* (0.0664)	0.00127 (0.0109)	0.112** (0.0545)	0.00361 (0.00914)	1.290** (0.633)	0.438 (0.266)	0.794** (0.351)	-0.00564 (0.0294)
Drought	0.0442 (0.0713)	0.0379 (0.0647)	0.0833 (0.0562)	-0.00572 (0.0335)	0.0252 (0.0251)	-0.00444 (0.00686)	0.213 (0.750)	0.237 (0.286)	-0.370 (0.368)	0.0532 (0.0395)
Male No. of [Animals] (lag)	-0.0748 (0.0474)		-0.0808** (0.0372)		-0.0752* (0.0396)		-0.0506*** (0.0160)		-0.0932** (0.0376)	
Female No. of [Animals] (lag)		-0.0252 (0.0396)		-0.0454 (0.0320)		-0.0330 (0.0303)		-0.102*** (0.0252)		-0.0732** (0.0284)
Household Size	0.0143* (0.00825)	0.00516 (0.00650)	-0.00674 (0.00564)	0.00461 (0.00399)	-0.000523 (0.00338)	-0.000580 (0.000615)	-0.0185 (0.0759)	0.0246 (0.0295)	0.0503 (0.0511)	-0.00139 (0.00312)
Ratio of Children to Women	-0.00872 (0.0209)	0.00669 (0.0195)	0.0344 (0.0232)	-0.00821 (0.00856)	0.000107 (0.0106)	0.00319 (0.00378)	-0.173 (0.231)	-0.0464 (0.0839)	-0.0637 (0.107)	-0.0130 (0.0178)
HH Land Owned	-0.00795	-0.00951	-0.00541	-2.84e-05	0.000885	-0.00127*	0.0115	-0.0272	0.0112	-0.00978

Table 4.10 (cont'd)

	(0.0203)	(0.0140)	(0.00935)	(0.00343)	(0.00355)	(0.000668)	(0.110)	(0.0506)	(0.0699)	(0.00959)
Non-Farm Income (lag)	1.66e-05	2.53e-05	-3.93e-06	-3.80e-06	-6.34e-06	8.22e-07	6.22e-05	0.000189	-0.000150	1.52e-05
	(0.000113)	(2.83e-05)	(9.34e-06)	(5.36e-06)	(8.10e-06)	(1.05e-06)	(0.000219)	(0.000146)	(0.000108)	(2.23e-05)
HH Cotton Area Cultivated	-0.0286	-0.0118	-0.0127	0.00849	4.71e-05	0.00101	0.0609	-0.0371	0.0532	0.00795
	(0.0474)	(0.0110)	(0.0153)	(0.0102)	(0.00310)	(0.000722)	(0.131)	(0.0520)	(0.0803)	(0.00889)
Household Livestock (lag)	-0.00139	-0.00202	0.00313*	0.000354	0.000717	0.000157	-0.0361	-0.00117	0.00909	0.00126
	(0.00167)	(0.00177)	(0.00170)	(0.000835)	(0.000758)	(0.000220)	(0.0310)	(0.00938)	(0.0111)	(0.00184)
Millet Stored (lag)	-2.32e-06	-8.91e-08	2.50e-06	-3.73e-07	1.65e-07	-1.44e-07	-5.44e-05***	-2.88e-05	-5.32e-07	-1.00e-06
	(2.25e-06)	(2.13e-06)	(1.96e-06)	(2.69e-07)	(1.64e-06)	(1.33e-07)	(2.10e-05)	(3.57e-05)	(7.48e-06)	(6.84e-07)
Rice Stored (lag)	6.33e-06	-1.90e-06	-1.05e-06	8.13e-07	1.73e-06	1.28e-07	6.05e-05	8.37e-06	-2.71e-06	8.94e-07
	(8.72e-06)	(1.79e-06)	(2.51e-06)	(1.11e-06)	(1.88e-06)	(9.31e-08)	(6.47e-05)	(4.62e-05)	(1.45e-05)	(9.73e-07)
Sorghum Stored (lag)	2.02e-05	-3.13e-06	-1.43e-06	-1.44e-06	1.88e-06	-4.04e-07	1.80e-05	3.32e-05	2.98e-05	-6.83e-06
	(1.25e-05)	(5.79e-06)	(4.28e-06)	(2.99e-06)	(2.26e-06)	(3.73e-07)	(6.43e-05)	(2.96e-05)	(3.02e-05)	(6.14e-06)
Year 2012	0.00944	0.0106	0.0286	-6.78e-05	0.00793	0.00126	-0.229	0.129	-0.380*	0.0255
	(0.0258)	(0.0369)	(0.0204)	(0.00684)	(0.0145)	(0.00229)	(0.454)	(0.142)	(0.228)	(0.0272)
Constant	0.115	0.234***	0.0265	-0.0188	0.0136	0.00281	6.663***	1.424***	1.714**	0.130**
	(0.0799)	(0.0874)	(0.0921)	(0.0566)	(0.0492)	(0.0138)	(1.376)	(0.469)	(0.781)	(0.0580)
Observations	4,533	4,533	4,533	4,533	4,533	4,533	4,533	4,533	4,533	4,533
Number of households	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.11: Consumption of Male and Female Owned Livestock

	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	Pigs	Pigs	Laying Hens	Laying Hens	Broilers	Broilers	Local Chicken	Local Chicken	Guinea Fowl	Guinea Fowl
Flood	-0.0176 (0.0229)	-0.0269* (0.0150)	-0.00940 (0.0206)	-0.00269 (0.00187)	0.0138 (0.0235)	0.00234 (0.0105)	0.0412 (0.310)	-0.0576 (0.101)	0.423** (0.189)	-0.0128 (0.0127)
Drought	-0.0167 (0.0308)	0.0725* (0.0376)	0.0539 (0.0453)	-0.0187 (0.0170)	0.0267 (0.0168)	0.00281 (0.00575)	-1.854 (1.366)	-0.0730 (0.121)	-0.426** (0.201)	0.0202* (0.0110)
Male No. of [Animals] (lag)	-0.00517 (0.0148)		-0.121* (0.0628)		-0.0286* (0.0160)		-0.00596 (0.0102)		-0.0511* (0.0290)	
Female No. of [Animals] (lag)		-0.00595 (0.00853)		0.000286 (0.000370)		-0.0994 (0.0751)		-0.0259*** (0.00791)		-0.0211*** (0.00742)
Household Size	0.00770** (0.00316)	-0.00160 (0.00333)	-0.00867 (0.00697)	0.00169 (0.00237)	2.49e-05 (0.00131)	0.000863 (0.00116)	0.0505 (0.0358)	0.00716 (0.0165)	0.0369** (0.0147)	0.000154 (0.00131)
Ratio of Children to Women	-0.0156** (0.00638)	0.00643 (0.00494)	-0.00898 (0.0121)	0.00270 (0.00223)	-0.0152* (0.00870)	0.00351 (0.00433)	-0.104 (0.122)	-0.0388 (0.0416)	-0.208** (0.104)	-0.0193* (0.0115)
HH Land Owned	-0.00872 (0.00581)	0.00118 (0.00387)	-0.00673 (0.00569)	0.00215 (0.00164)	-0.00346 (0.00264)	-0.000690 (0.00130)	0.0354 (0.0733)	0.0319 (0.0279)	-0.0488 (0.0367)	-0.00116 (0.00272)
Non-Farm Income (lag)	-3.13e-05** (1.56e-05)	1.06e-05 (1.85e-05)	6.85e-06 (8.48e-06)	-2.78e-06 (3.16e-06)	2.06e-06 (2.95e-06)	5.35e-07 (8.19e-07)	-2.35e-05 (0.000230)	5.11e-05 (5.81e-05)	-0.000114 (9.50e-05)	7.65e-06 (6.34e-06)
HH Cotton Area Cultivated	0.00789 (0.00765)	-0.00606 (0.00596)	-0.0135 (0.0165)	0.00478 (0.00657)	0.00262 (0.00237)	-5.62e-05 (0.00121)	-0.0739 (0.125)	-0.0222 (0.0244)	0.0557 (0.0384)	0.00364 (0.00339)
Household Livestock (lag)	0.000477 (0.000630)	0.000299 (0.000475)	0.00549* (0.00298)	-0.000228 (0.000289)	0.000708 (0.000574)	0.000264 (0.000633)	0.00258 (0.0126)	-0.00365 (0.00447)	-0.00299 (0.00729)	0.000387 (0.000553)
Millet Stored (lag)	-5.08e-08 (6.07e-07)	-1.96e-07 (3.86e-07)	2.17e-06 (2.52e-06)	4.61e-08 (6.01e-08)	-6.71e-08 (7.10e-07)	-2.55e-07 (3.57e-07)	-3.21e-06 (1.69e-05)	-5.15e-06 (8.26e-06)	-8.69e-07 (4.17e-06)	-3.00e-07 (1.92e-07)
Rice Stored (lag)	-2.67e-07 (1.83e-06)	-1.22e-07 (8.40e-07)	1.43e-06 (2.49e-06)	5.10e-07 (7.38e-07)	1.79e-07 (7.71e-07)	4.98e-08 (1.43e-07)	-1.00e-05 (2.41e-05)	-4.39e-06 (9.55e-06)	-2.43e-06 (6.10e-06)	2.03e-07 (3.54e-07)

Table 4.11 (cont'd)

Sorghum Stored (lag)	3.10e-06 (3.50e-06)	-1.59e-08 (7.96e-07)	1.15e-06 (5.06e-06)	-1.65e-06 (1.70e-06)	-7.01e-07 (1.75e-06)	-7.48e-07 (7.40e-07)	8.31e-05 (5.26e-05)	1.24e-05 (1.52e-05)	-3.82e-06 (2.22e-05)	3.03e-07 (2.10e-06)
Year 2012	0.00853 (0.0101)	0.0284** (0.0138)	-0.0115 (0.0132)	0.00107 (0.00195)	0.0299** (0.0126)	-0.000412 (0.00690)	-0.0500 (0.170)	0.0438 (0.0538)	-0.252 (0.171)	0.0190* (0.0106)
Constant	0.0402 (0.0291)	0.0108 (0.0299)	0.140* (0.0842)	-0.0272 (0.0315)	0.0471** (0.0235)	-0.0109 (0.0203)	3.147*** (0.458)	0.445** (0.186)	1.462*** (0.530)	0.0643*** (0.0242)
Observations	4,533	4,533	4,533	4,533	4,533	4,533	4,533	4,533	4,533	4,533
Number of households	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451	2,451

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.12: Livestock Consumption and Sales in Households With Young Children

	Animal	Flood		Drought		Flood*Boy		Drought*Boy		Flood*Girl		Drought*Girl	
		Coeff	S.E.	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
T	Oxen+Cattle	-0.0412	(0.0686)	0.0350	(0.113)	0.0936	(0.0810)	-0.0326	(0.122)	-0.0205	(0.0929)	-0.0688	(0.0810)
M	Oxen+Cattle	-0.0207	(0.0665)	0.0152	(0.110)	0.0759	(0.0794)	-0.0280	(0.111)	-0.0185	(0.0913)	-0.0632	(0.0806)
F	Oxen+Cattle	-0.0180**	(0.00801)	0.0165	(0.0150)	0.0120**	(0.00565)	0.00965	(0.0171)	0.00484	(0.00649)	0.00380	(0.00856)
T	Sheep	0.105	(0.174)	0.195	(0.160)	-1.139	(1.015)	-0.242	(0.208)	0.0740	(0.395)	-0.228	(0.174)
M	Sheep	0.141	(0.164)	0.192	(0.149)	-1.165	(1.014)	-0.323	(0.203)	0.108	(0.396)	-0.241	(0.169)
F	Sheep	-0.0394	(0.0451)	-0.0104	(0.0457)	0.0227	(0.0447)	0.0767*	(0.0461)	-0.0143	(0.0382)	0.0186	(0.0463)
T	Pigs	0.146	(0.121)	0.277	(0.169)	-0.158	(0.105)	-0.106	(0.171)	0.0916	(0.0901)	-0.193	(0.149)
M	Pigs	0.000472	(0.0945)	0.0135	(0.111)	-0.0572	(0.0687)	0.0604	(0.131)	0.105	(0.0682)	-0.0390	(0.112)
F	Pigs	0.134*	(0.0762)	0.266**	(0.123)	-0.0994	(0.0809)	0.154**	(0.0773)	0.00223	(0.0634)	-0.117*	(0.0698)
T	Laying Hens	-0.233	(0.143)	0.154*	(0.0893)	0.101	(0.0783)	-0.143*	(0.0804)	0.0833	(0.0702)	0.0855	(0.0599)
M	Laying Hens	-0.232*	(0.141)	0.199*	(0.121)	0.124	(0.0808)	-0.137*	(0.0758)	0.0687	(0.0739)	0.0367	(0.0628)

Table 4.12 (cont'd)

F	Laying Hens	0.00785	(0.0166)	-0.0618	(0.0819)	-0.00811	(0.0108)	0.00951	(0.0341)	-0.0106	(0.00967)	0.0545	(0.0359)
T	Broilers	0.163*	(0.0878)	0.101*	(0.0516)	-0.0622	(0.0836)	-0.0261	(0.0238)	-0.0117	(0.0697)	-0.0662	(0.0436)
M	Broilers	0.167*	(0.0868)	0.0971**	(0.0490)	-0.0866	(0.0768)	-0.0295	(0.0225)	0.00141	(0.0690)	-0.0528	(0.0336)
F	Broilers	0.00148	(0.0118)	0.00252	(0.00732)	0.0176	(0.0175)	0.00450	(0.00777)	-	(0.00911)	-0.0113	(0.0118)
T	Local Chicken	1.818*	(1.064)	-3.826*	(2.160)	-0.309	(1.073)	3.136*	(1.771)	0.0952	(0.971)	0.867	(1.398)
M	Local Chicken	1.437	(0.950)	-3.271	(2.070)	-0.299	(0.900)	2.366	(1.707)	0.189	(0.879)	0.415	(1.223)
F	Local Chicken	0.425	(0.364)	-0.535	(0.478)	-0.00164	(0.420)	0.716	(0.444)	-0.0508	(0.359)	0.495	(0.445)
T	Guinea Fowl	1.004**	(0.494)	-1.346*	(0.702)	0.0822	(0.466)	0.532	(0.420)	0.261	(0.475)	0.590	(0.454)
M	Guinea Fowl	1.046**	(0.496)	-1.448**	(0.698)	0.0501	(0.465)	0.455	(0.414)	0.323	(0.475)	0.675	(0.451)
F	Guinea Fowl	-0.00360	(0.0418)	0.0721*	(0.0422)	0.00765	(0.0228)	0.0451	(0.0368)	-0.0395	(0.0245)	-0.0470	(0.0392)

T refers to Total, M refers to Male and F refers to Female

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.13: Robustness for Tables 4.6 and 4.7

	Table 6, col 1	Table 6, col 2	Table 6, col 3	Table 7, col 1	Table 7, col 2	Table 7, col 3	Table 7, col 4	Table 7, col 5	Table 7, col 6
Robustness 1									
Flood	-83.48* (44.73)	-81.28* (43.89)	-81.34* (44.88)	-0.0608 (0.132)	-0.289*** (0.0725)	0.143 (0.117)	-0.0388 (0.0485)	-0.204* (0.111)	-0.251*** (0.054)
Drought	-142.9*** (30.02)	-135.9*** (30.85)	-130.3*** (31.27)	-0.000753 (0.104)	0.032 (0.0543)	-0.0353 (0.077)	0.00471 (0.0291)	0.0346 (0.0699)	0.0273 (0.0468)
Robustness 2									
Flood	-103.4*** (32.05)	-107.5*** (31.93)	-107.6*** (32.92)	-0.00695 (0.171)	-0.239*** (0.0655)	-0.0241 (0.0934)	-0.0491 (0.0373)	0.0172 (0.161)	-0.189*** (0.0532)
Drought	-105.0*** (24.83)	-97.40*** (25.3)	-105.2*** (25.91)	0.0363 (0.0931)	0.0219 (0.0469)	0.0041 (0.0728)	-0.0101 (0.0266)	0.0322 (0.059)	0.032 (0.0381)

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.14: Robustness for Table 4.8

	Table 8, col 1	Table 8, col 2	Table 8, col 3	Table 8, col 4	Table 8, col 5	Table 8, col 6	Table 8, col 7	Table 8, col 8	Table 8, col 9
Robustness 1									
Flood	0.0454 (0.0499)	-0.355 (0.386)	0.210* (0.127)	-0.0706 (0.0762)	0.192** (0.0893)	-0.182*** (0.0702)	0.0212 (0.0568)	2.010*** (0.712)	0.758** (0.331)
Drought	-0.0725 (0.0979)	0.0191 (0.120)	0.0203 (0.140)	0.0374 (0.0346)	0.00760 (0.113)	0.109 (0.0805)	0.0374 (0.0348)	0.781 (0.972)	-0.0918 (0.411)
Robustness 2									
Flood	-0.0194 (0.0519)	-0.337 (0.292)	0.0998 (0.120)	-0.0652 (0.0701)	0.127* (0.0749)	-0.124** (0.0551)	0.0376 (0.0464)	1.588** (0.668)	0.619** (0.307)
Drought	0.0559 (0.0918)	0.0129 (0.0979)	0.0394 (0.112)	0.0579 (0.0474)	0.0889 (0.0854)	0.0729 (0.0543)	0.0288 (0.0257)	-0.0413 (0.780)	-0.184 (0.363)

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

Table 4.15: Robustness for Table 4.9

	Table 9, col 1	Table 9, col 2	Table 9, col 3	Table 9, col 4	Table 9, col 5	Table 9, col 6	Table 9, col 7	Table 9, col 8
Robustness 1								
Flood	0.00258 (0.0110)	-0.0170 (0.0639)	-0.0139 (0.134)	-0.00513 (0.0285)	-0.0500*** (0.0191)	-0.00571 (0.0248)	0.00823 (0.436)	0.380** (0.180)
Drought	-0.0316 (0.0211)	-0.0182 (0.0472)	-0.0209 (0.0610)	-0.00565 (0.0468)	0.0512 (0.0425)	0.0446*** (0.0145)	-0.522 (0.477)	-0.274 (0.204)
Robustness 2								
Flood	-0.000810 (0.0103)	-0.0155 (0.0536)	-0.00514 (0.103)	-0.00715 (0.0258)	-0.0405** (0.0165)	-0.0133 (0.0215)	0.157 (0.304)	0.413** (0.186)
Drought	0.00590 (0.0220)	-0.0383 (0.0468)	-0.0300 (0.0503)	0.0498 (0.0441)	0.0697** (0.0355)	0.0323** (0.0164)	-1.708 (1.160)	-0.452** (0.197)

Household fixed effects estimation

Standard errors clustered at household level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations

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CHAPTER 5: CONCLUSION

My dissertation consists of three chapters that study intensification and asset management by households in rural Burkina Faso. In each chapter, I pay special attention to intrahousehold dynamics. Chapters 2 and 3 analyze how allocation of agricultural inputs differs between family members. In the fourth chapter, I assess how men and women are affected differently by negative economic shocks. I find that there is substantial heterogeneity in input allocation and coping strategies between men and women of the same household. On the input allocation side, this suggests that policies that provide agricultural inputs to women and young men can increase efficiency and improve equity between family members. This win-win situation can be achieved by changing the design of current programs, such as the fertilizer subsidy program. This is a cost-effective possibility for policy-makers; it does not require any new programs and just requires marginally more resources for targeting specific individuals to be recipients of the subsidy program. Cash-transfer programs have already made this determination that women are more effective in benefiting the entire family, especially children (Fiszbein and Schady, 2009). Agricultural policies need to make similar changes to be more efficient, at least in countries where women manage substantial agricultural land.

Similarly, targeting women for asset transfers, especially post-disasters, would help reduce the gender asset gap. Programs have already started targeting women for asset transfers, but it is important to note that since their assets are disproportionately liquidated during weather shocks, such targeting is necessary just to maintain the status-quo.

It is important to recognize that as women and young men become more economically empowered, society may resist change. At least in the short-run, this may lead to friction between family members as older men seek to retain their traditional authority. Therefore,

intrahousehold negotiations will slowly allow women and young men to become more influential in the decision-making process.