DISSERTATION

BEHAVIOURAL ECONOMICS AND DECISION-MAKING IN AGRICULTURAL HOUSEHOLDS: EVIDENCE FROM RURAL UGANDA

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Abstract

BEHAVIOURAL ECONOMICS AND DECISION-MAKING IN AGRICULTURAL HOUSEHOLDS: EVIDENCE FROM RURAL UGANDA

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Agriculture is a crucial sector in Africa because the majority of the population lives in rural areas and depends almost entirely on farming. Moreover, the sector forms a significant share of the economies of all African countries. There is a wide consensus that the sector has the potential to contribute towards eradication of hunger, reduction of poverty and sustainable economic development in Africa (IFPRI, 2013).[1] Therefore, it is essential to identify the determinants of agricultural growth and development. We attempt to determine some of the factors that might influence an individual participating in the agriculture sector to make sub-optimal agricultural choices.

[1] International Food Policy Research Institute (IFPRI), 2013. http://www.ifpri.org/blog/agriculture-africa

Using experimental and household survey data, this dissertation examines the impact of entitlements and relative wages on individual productivity and the effect of risk preference on farmers' choice of crops and inputs in rural Uganda. The results generally indicate that a rise in relative wages lowers relative effort and female participants' productivity is more responsive to changes in entitlements compared to male participants. Furthermore, the findings suggest that risk and time preferences play a role in the farmers' decision-making. Risk aversion reduces the probability of adoption of chemical fertilizer; however, it does not influence intensity of use. More loss averse farmers are more likely to use fertilizer and they use more fertilizer per hectare. With respect to crop choices, risk aversion is positively associated with the choice to grow low risk crops. Although risk aversion parameter is not statistically significant, it seems to correlate negatively with the choice to grow and share of land for a high-risk crop beans.

The findings suggest that in the context of household production, inequality caused by exogenous circumstances like gender may have implications for feelings of equity and fairness, which then influences individual effort. Furthermore, the results indicate that policy makers need to take into consideration risk attitude, crop risk, and time preferences when designing agricultural development programs to influence crop and input choices.

Dedication

To my parents, Phenias Masekesa and Cecilia Kungwengwe, my brothers and sister, my friends at Misato Reformed Church.

Summary

The agricultural sector is critical to the economies of all African countries. The growth of the sector is central to not only increasing food security and poverty reduction but as well as to industrialization, economic growth and development (World Economic Forum, 2016)[2]. Empirical findings indicate that suboptimal agricultural choices due to a number of factors that include the absence of full insurance, group-based inequalities, and land tenure insecurity hinder agricultural productivity. However, there is strong evidence of persistence of gender disparities with respect to ownership of property (land) and wages in most African countries and smallholder farmers do not have access to insurance. Inequality caused by exogenous circumstances like gender may have implications for feelings of equity and fairness, thus discouraging individual effort to the detriment of economic growth. Due to the absence of insurance, some rural farmers tend to devote a disproportionate share of farmland to low risk low return crops and avoid modern inputs, thus they remain poor and locked in a poverty trap [Dercon, 1996; Van Campenhout, et al., 2016].

To shed light on the impact of various types of land/ property rights and wage inequality, this study examines the effect of changing entitlements and relative wages on individual productivity. Furthermore, this dissertation investigates whether the household head's risk preference influences the choice to grow low- or high-risk crops and the share of the farmland devoted to each crop. We also examine the effect of risk attitude on adoption and intensity of chemical fertilizer use. We use experimental and survey data to assess the implications of varying entitlements and wages on productivity. We obtained the experimental data from the lab-in-field experiments that we

[2] World Economic Forum on Africa, 2016. https://www.weforum.org/agenda/2016/05/70-of-africans-make-a-living-through-agriculture-and-technology-could-transform-their-world/

conducted simultaneously with the fifth round of the Research on Poverty, Environment, and Agriculture Technologies (RePEAT) survey in 2015. In order to examine the effect of risk and time preferences on crop and input choice, we use experimental and survey data collected during the RePEAT surveys which were conducted in 2003, 2005, 2009, 2012, and 2015 in rural Uganda.

The RePEAT data contains comprehensive community- and household-level data collected in rural Uganda in 2003, 2005, 2009, 2012, and 2015. The community level information includes the distance of the village from the district town and the type of road. Household information includes household composition and demographics, wealth, economic activities, land use, crop production, and crop inputs. The experimental data includes household head's risk and time preferences (risk-aversion, loss aversion, discount rate, and present bias), and output-productivity from the real effort experiments. We use information on crop production to determine the share of farmland devoted to each crop, which is one of the key outcome variables in our analysis. Another key outcome variable is the output-productivity from the real effort experiments. The household and community data is used as control variables in our cross-sectional and panel analysis.

The results generally indicate that there is an inverse relationship between relative wage and relative output: partners paid relatively more work relatively less. This contradicts the most straightforward interpretation of the unitary and collective model predictions of the effect of relative wage on relative output. Our results are though consistent with the predictions of some non-cooperative models. We also find that female participants' productivity is more responsive to changes in entitlements, compared to male participants. Generally, men and women respond differently to changes in entitlements. What is more interesting is that for both male and female participants there is no significant difference in household output when we compare the “Sharing equally” and “Men gets all” categories. Furthermore, we find that risk attitude and time preference influence crop and input choices. More precisely, the results indicate that risk and loss aversion have a significant effect on the adoption of chemical fertilizer. The degree of loss aversion influences the intensity of fertilizer use but other preference parameters do not. The results also suggest that both time and risk preferences influence the choice to grow some crops; however, only loss aversion influences the share of land devoted to growing crops.

Obviously, there is a long distance between the controlled circumstances of our experiment and major policy changes. Yet, our results give support to the idea that equitable policies to promote the advancement of women can be achieved with no detrimental effect on productivity. Moreover, our findings suggest that policies that influence farmer’s risk attitude may be crucial in boosting agricultural choices and, hence, agricultural performance.

Table of Contents

List of Tables

List of Figures

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CHAPTER 1

Introduction

There is a wide consensus that the agricultural sector is critical to the economies of all African countries. The majority of the continent's population lives in rural areas and is employed in the agricultural sector (Davis , et al., 2014). Moreover, 75-80% of Africa's extreme poor resides in rural communities and depends almost entirely on agriculture for their livelihood (Livingston, et al., 2011; Beegle, et al., 2016). Therefore, the enhancement of sustainable agricultural and rural development is fundamental to the attainment of the Millennium Development Goals (AfDB, 2017)[3]. The growth of the agricultural sector is central not only to increasing food security and poverty reduction but as well as to industrialization, economic growth and development (Biteye, 2016). However, the continent's agricultural performance is falling further behind that of other developing regions of the world (Toenniessen, et al., 2008; Benin, 2016).

In development studies there is increasing consensus that rights over assets like land can be critical to increasing productivity and could enable people to move out of poverty (Deere & Doss, 2006; Ali, et al., 2014). More precisely, property rights matter because they determine who controls which resources and set the incentives that property owners face (Carruthers, et al., 2004; Hallowel, 1943). However, there is strong evidence of persistence of gender

[3] African Development Bank (AfDB), 2017. https://www.afdb.org/en/topics-and-sectors/sectors/agriculture-agro-industries/african-agriculture/

disparities with respect to ownership of property (land) and wages in African countries (AfDB, 2015). For instance, titled land remains the de facto preserve of wealthy households and within households, men (Ali, et al., 2014).

It is also recognized that in the absence of perfect insurance markets, crop/production choices may be influenced by the consumption or risk preferences of the farmer (Kurosaki & Fafchamps, 2002). Agriculture involves many forms of risk such as uncertainties in weather and yields, price or market risk, plant diseases and pests. Due to the absence of complete credit and insurance markets in rural areas of developing countries, some smallholder farmers attempt to control farming risk through suboptimal production choices such as devoting a disproportionate part of farmland to low risk low return crops and avoiding modern inputs like fertilizer. Consequently, the farmers remain poor, and locked in a poverty trap [Hazell, et al., 1986; Fafchamps, 1992; Alderman & Paxson, 1992; Dercon, 1996].

Even though empirical studies highlight that group-based inequalities and land tenure insecurity may hinder agricultural productivity, to date the role of relative wages and entitlements on productivity in the context of the household has been largely neglected. Over the years, there has been growing interest in intra-household experiments but none has examined the impact of entitlements on production. Furthermore, previous literature suggests that risk preference would influence farmers' production choices in the absence of complete insurance. However, empirical studies on the effect of risk preference on crop and input choices are very scarce.

This dissertation attempts to address four main research questions: (i) do entitlements influence individuals' productivity within a household? (ii) what is the effect of relative wages on spouses' productivity? (iii) how does risk preference influence the decision to grow low- or high-risk crops and the share of farmland devoted to the crops? (iv) what is the effect of farmer's risk attitude on adoption and intensity of fertilizer-use? In order to answer our four main questions, we use experimental and survey data in our empirical analysis.

The findings suggest that female participants' productivity is more responsive to changes in entitlements, compared to male participants. Moreover, we find that for both male and female participants there is no significant difference in household output when we compare the "Sharing equally" and "Men gets all" categories. We also find that relative wage is inversely related to relative output. This means that individuals paid relatively more work relatively less than their spouses. This contradicts the most straightforward interpretation of the unitary and collective model predictions of the effect of relative wage on relative output. However, these results are though consistent with the predictions of some non-cooperative models. Furthermore, we find that that risk and time preferences influence the farmers' choice of crops and inputs. More risk averse farmers are more likely to grow low risk crops such as sweet potatoes. Higher loss aversion is associated with larger share of land for beans (high-risk crop) but inversely related to the choice to grow sweet potatoes (low-risk crop). The farmer's time preference only influences the choice to grow sweet potatoes; however, it has no significant effect in case of beans and cassava. With respect to fertilizer, risk preference significantly influences its adoption. However, only loss aversion significantly influences the intensity of fertilizer-use.

Even though there is a long distance between major policy changes and the controlled circumstances of our production experiment, our results give support to the idea that equitable policies to promote the advancement of women can be achieved with no detrimental effect on productivity. Furthermore, our findings on the effect of risk and time preferences on crop and input choices may also be somewhat limited, but they provide a basis for future research on impact of experimentally elicited risk preferences on crop and input choices. Our results suggest that policies that influence farmer's risk attitude may be crucial in boosting agricultural choices and, hence, agricultural performance.

The remainder of the dissertation is organized as follows. In chapter 2, we provide a review of the existing literature and we highlight the concerns that have not been addressed adequately which we attempt to address in this dissertation. In chapter 3 we analyze the effect of entitlements and relative wage on spouses' production effort using individual level data from lab-in-field experiments which we carried out with couples in rural Uganda and also household-, and community-level data from the fifth wave of Research on Poverty and Agricultural Technologies (RePEAT) surveys in 2015. Furthermore, we evaluate whether the impact of entitlements and relative wages on productivity varies across gender. In chapter 4, we use survey data from the first through the fifth waves of the RePEAT surveys (2003, 2005, 2009, 2012, and 2015) to compute measures of crop riskiness that we will use in our analysis of the effect of farmer's risk preference on crop choices. We construct a measure of riskiness for the six most grown crops; per our Uganda REPEAT sample, these are cassava, sweet potatoes, beans, coffee, banana, and maize. Chapter 5 uses experimental and survey data from five waves of the RePEAT surveys (2003, 2005, 2009, 2012, and 2015) to examine the effect of risk preference on crop and input choices. Furthermore, this chapter investigates the effect of time preference on the choice of crops and inputs. The last chapter includes the concluding remarks and the policy implications of the empirical findings presented in chapters 3 and 5.

CHAPTER 2

Literature Review

2.1 Introduction

The enhancement of sustainable agricultural and rural development in Africa continues to be heralded as the key driver of poverty reduction, food security, economic growth, and development (Carletto, et al., 2015; Biteye, 2016). Generally, development in African countries' agricultural sector is believed to have a much larger positive impact on the poorest segment of the population (Ligon & Sadoulet, 2008). Empirical studies have highlight that group-based inequalities, land tenure insecurity, and the absence of complete insurance may hinder agricultural productivity.

This chapter reviews literature on intra-household property rights, wage inequality and risk preferences. First, we review the studies that evaluate the impact of intra-household property rights on productivity. Second, we highlight literature that examines the effect of wage inequality on production. Lastly, we review literature that links risk preference and farmers' choice to grow certain crops or to use fertilizer.

2.2 Intra-household Property rights and Productivity

Studies on the effect of intra-household property rights on household outcomes are limited. Most recently, intra-household property rights have been examined mainly in the context of women's bargaining position within the household (Wiig, 2013; Holden & Bezu, 2014). In a study carried out in Peru, Wiig (2013) finds a positive significant impact of land titles on women empowerment. Holden & Bezu (2014) find that land certificates increase wives' awareness of their land rights and contribute to stronger involvement of wives in land related decisions within the households in Ethiopia. A few studies assess the impact of spousal co-ownership of land on agricultural productivity (Ovonji-Odid , et al., 2000; Newman, et al., 2015). Newman, et al. (2015) use plot-fixed-effects approach to analyze the effect of land titling on agricultural productivity in Vietnam. They also consider the productivity effects of single versus joint titling for husband and wife. The authors find that both individual and jointly held titles results in higher yields. Furthermore, they conclude that joint titles will improve women's bargaining power within the household with no associated efficiency losses because there is no tradeoff between joint titling and productivity. Ovonji-Odid , et al. (2000) in their short study in Uganda, find that the majority of women interviewed would change: (1) the way they made their labour available on the farm, (2) their decision-making in terms of crop choice, and (3) the investment they make on the land if they are given co-ownership of family farm. Although this data is suggestive, it lacks firm evidence of causation.

The pre-existing experimental evidence on productivity and control is limited and comes from three sources: first, in a series of intra-household experiments run in Nigeria, India, and Ethiopia, (Munro, et al., 2010; Munro, et al., 2013; Kebede, et al., 2013) the authors have some unreported treatments involving production. In some treatments, in order to earn their endowments the married couples, individually and separately had to assemble and fill matchboxes. The aim of the exercise was to test whether earning the endowment would affect behaviour in subsequent allocation and public good games. As such, the task was designed in the expectation that that all subjects would be able to achieve the maximum output (thereby eliminating variation in actual endowment). In practice, only about 33% of men and 41% of women out of the sample of 871 couples did achieve the maximum (though many others came close to the maximum). The results suggest that the productivity was related to treatment. In particular, women's productivity was lower in all three countries in a treatment where all the income from work was allocated to men compared to the situation where all the income was allocated to the wife. Meanwhile in Nigeria, higher relative wages for men raised their productivity and reduced women's productivity. Munro, et al. (2013) in Uttar Pradesh, India compare the productivity of several hundred mixed sex teams of four in a digging task performed under NREGA - a work-fare programme designed to assist the rural poor in India. In one treatment, spouses are in the same four-person team while in the control spouses work for separate teams. In each case teams dig real water storage tanks for three hours with men doing the digging while women transport the soil to a nearby location. Productivity is nearly 50% higher when spouses work in the same team. This result may be due to the improved monitoring of work effort that can occur when spouses are in the same team. However, it is also compatible with a free-riding interpretation: when spouses work together they represent 50% of the total team, whereas when they work separately each makes up only one quarter of a team. Thus, even with full monitoring of a partner's effort and a unitary household, we would expect lower productivity when partners are separated.

2.3 Wage Inequality and Productivity

People respond to both absolute and relative levels of economic variables (Smith, 1759). According to Nelson, et al. (2012), women continue to face occupational segregation and discrimination in rural labour markets. Outside the experimental literature on households, there are a significant number of papers that investigate the impact of in-game inequality on behaviour.

Perhaps the closest experiment to ours in this respect is a German study (Schröder, et al., 2013), in which the authors run games with partners where the individuals complete pen and paper mazes to earn rewards that are paid and taxed at different rates. The authors find that effort rate is not generally sensitive to tax or wages, except that men's effort is lower when their pre-tax wage is lower and paid less. Since the same effect is not present for changes in tax rates, they conclude that the men's behaviour might best be explained as an issue of identity.

In a real effort experiment under a piece-rate regime, Greiner et al. (2011) observes that with public information lower paid workers shirk more and higher paid workers put more effort. Other examples of recent experiments in which there is wage inequality are Charness & Kuhn (2007), Gachter & Thoni (2010) and Liu-Kiel et al., (2013). In some of these papers, there is no real effort as such - rather subjects choose the 'gift' they would like to make to another player who takes on the role of employer. Charness & Kuhn (2007) in gift-exchange games run with students, the authors finds that the larger the wage "gift" a worker receives from the firm, the larger the wage gift each worker provides in return. They also find that worker's effort is not responsive to co-worker wages. On the other hand, Gachter & Thoni (2010) using three-person gift exchange experiments find that disadvantageous wage discrimination leads to lower efforts, however, participants who are paid more do not increase effort on average. When there are multiple workers who receive different wages for choosing the same 'gift' it seems that the gift given by low wage workers is lower compared to the case with no wage inequality. In Liu-Kiel et al. (2013) and Greiner et al. (2011), on the other hand there is some real-effort by the participants. Greiner et al. (2011) in a real effort experiment finds that wage inequality for the same task has a positive effect on task accuracy for the higher paid students and a negative effect for the lower paid.

Another set of experimental results on the impact of other's income (Fliessbach, et al., 2007; Dohmen, et al., 2011) come from the NeuroEconomics literature. Fliessbach, et al. (2007) uses MRI techniques to monitor brain activities of two individuals who do the same tasks, soon after completing the tasks they are shown their possible monetary rewards and that of the other player and then one of the possible payoffs was randomly picked for payment. The authors find that others' income is significantly correlated with blood oxygenation level-dependent responses in the ventral striatum. Similarly, Dohmen, et al. (2011) finds that the amount earned by the other player has an effect on the ventral; however, the effect is larger for men than women.

2.4 Risk Preferences and Share of Farmland for each Crop

Farming involves risk; however, the level of risk varies with crops choices. Therefore, risk plays a critical role in farmer's production decision making. However, very limited studies have examined the effect of the farmer's risk attitude on crop choices.

There is empirical evidence that risk preferences play a critical role in farmer's decision making both ex ante and post production. Some studies find a significant relationship between risk preferences and farmers' choice of crop mix (Shahabuddin, et al., 1986; Fafchamps, 1992; Kurosaki & Fafchamps, 2002; Bezabih & Sarr, 2012).

Using a model of crop portfolio choice under multivariate risk and preferences, Fafchamps (1992) examines assumptions regarding risk and preferences using simulations. The conclusion of the study is that in absence of full insurance, exposure to risk is likely to influence farmer's choice of crops. The study in Pakistan by Kurosaki et al. (2002) examines how the presence of price and yield risk affects crop choices. The results indicate that farmers' production decisions are affected by the presence of risk. In some papers, the authors derive the estimate of risk attitude. Using survey data from Bangladesh, Shahabuddin, et al. (1986) constructs a quantitative estimate of the risk coefficient based on the safety-first model of farmer behavior. The authors find that some households have positive coefficient for risk and they suggest that these households are expected to "gamble" on riskier but more profitable crops than those with a negative risk coefficient.

Several papers use a measure of risk attitude obtained through experiments (Binswanger, 1980; Bezabih & Sarr, 2012); this is somewhat similar to how we obtain our measure of risk. Bezabih & Sarr (2012) using an experimentally generated measure of risk preference examine the extent to which risk and rainfall variability affect crop decisions in Ethiopia. The results provide evidence that farmers with higher risk aversion have higher level of crop diversity. Binswanger (1980) uses an experimental gambling approach with real payoffs to observe the households' attitude towards risk in rural India. They conclude that rural farmers care about the gain and losses in a choice rather than their final wealth position.

2.5 Risk Preference and Fertilizer-use

The rapid population growth in Africa has put pressure on the limited land resource resulting in land degradation and depletion of soil fertility (Josephson, et al., 2014; Mwangi, 1996).

The low soil fertility largely accounts for the decline in the continent's crop yields per hectare (Mwangi, 1996; Toenniessen, et al., 2008). Use of inorganic fertilizer has been highlighted as one way to replace soil deficits and increase output per hectare (Mwangi, 1996; Toenniessen, et al., 2008; Wallace & Knausenberger, 2016). However, the adoption and intensity of use of fertilizer is very low among smallholder farmers in Africa (Okalebo, et al., 2006; Matsumoto & Yamano, 2011; Oduor, et al., 2016). Risk averting behavior has been highlighted as one of the possible explanations for the limited adoption of fertilizer.

Several studies have examined farmers' risk preferences in relation to adoption of modern inputs such as fertilizer. However, there is no consensus on the effect of risk attitude on adoption and intensity of fertilizer-use. Some authors find a positive relationship (Hagos & Holden, 2011) while others find an inverse relationship (Roosen & Hennessy, 2003; Yusef & Halilemariam , 2011; Verschoor, et al., 2016) between risk aversion and adoption of fertilizer.

Hagos & Holden (2011) examines the role of farmer's risk aversion in fertilizer-use using a measure of risk aversion obtained from hypothetical experiments carried out in Ethiopia. The authors conclude that there is a positive correlation between risk attitude and adoption of fertilizer. On the other hand, in another study carried out in Ethiopia, using a measure of risk derived from real payoff experiments, Yusef & Halilemariam (2011) find a negative relationship between adoption and intensity of fertilizer-use, and risk aversion. Similarly, in a study carried out in eastern Uganda, Verschoor, et al. (2016) elicited risk preferences using both risky choice and hypothetical experiments. The results suggest that an increase in risk aversion reduces fertilizer-use. Roosen & Hennessy (2003) conclude that risk averters use less nitrogen than risk-neutral producers do. However, the authors also highlight that there is weak evidence to support the claim that there is a monotonic decreasing relation between the degree of risk aversion and the optimal inorganic fertilizer application rate.

2.6 Conclusion

The literature review provides evidence of the importance of entitlements, wage inequality and risk preferences in production choices. This dissertation attempts to address the gaps in the existing literature and to test some standard models.

First, this dissertation evaluates the impact of relative wages and entitlements on spouses' production effort. Though the experiments in the reviewed literature provide some interesting points of comparison, the implication for intra-household behaviour is not clear. Recently, there has been a growing interest in intra-household experiments; however, to date the role of rules of entitlements on production has been largely neglected. Our design is framed by the predictions of several standard models of household allocation that we discuss in detail in the next chapter. Since each of these models have predictions for how relative effort should respond to changes in relative wages and property rights, experiments specifically on families are required in order to determine which model best explains the behavior of rural couples in developing countries like Uganda.

Second, we compute measures of risk for the six most grown crops in our REPEAT sample and we rank the crops low to high risk. We use two different standard methods to measure the degree of crop riskiness; one is based on the portfolio theory, and the other on direct measures of variability around a trend. The main objective is to identify the crops to use when we do an analysis of the effect of risk preferences on crop choices.

Lastly, we investigate the effect of the household head's risk preferences on input (chemical fertilizer) and crop (high or low risk crop) choices. Though several studies have acknowledged the likely importance of risk preferences in household decision-making, a few studies examine the impact of farmers' risk attitude on crop choice or adoption of modern inputs. The majority of the studies that consider the effect of risk on farmers' production choices; (i) do not use incentivized measures of risk attitude (ii) have limited geographical variations within the countries of study (iii) omit other aspects of preferences [e.g. loss aversion and time preference parameters] and (iv) assume which crops are riskier and which are safer. We set out to extend existing literature on the determinants of crop and input choices using an incentive-compatible measure of risk attitude, other aspects of preferences and historical data on crop riskiness as key factors. Empirical studies that use a combination of experimentally elicited risk aversion, loss aversion, and time preference parameters to examine the influence of risk preference on crop choices are non-existent to our knowledge.

CHAPTER 3

Do Entitlements and Relative Wages Influence Spouses' Production Effort? Evidence from a Field Experiment in Rural Uganda

3.1 Introduction

Group-based inequalities often have a large impact on the well-being of individuals and these inequalities can be crucial between genders within the same household or other social groups (World Bank, 2006). Inequality caused by exogenous circumstances like gender or other social groups, can discourage individual effort to the detriment of economic growth as well as damage perceptions of fairness in society (Jencks, 2002; World Bank, 2006). In most African countries gender inequality with respect to property rights and wages are very large (African Development Bank, 2012; Mukasa & Salami, 2016). Wage differences based on gender discrimination rather than effort can adversely influence individuals' work effort (Fehr & Schmidt, 1999). Secondly, property rights matter because they determine who controls which resources and set the incentives that property owners face (Hallowel, 1943; Carruthers & Ariovich, 2004). Currently, in Africa titled land remains the de facto preserve of wealthy households and within households, men (Ali, et al., 2014). Women's lack of access to land is highlighted as one of the sources of inequality between women and men (Jones, 1983).

Within this context, there has been growing interest in intra-household experiments (Iversen, et al., 2011; Munro, et al., 2013; Kebede, et al., 2013; Schröder, et al., 2013). However, to date the role of production and the rules of entitlement has been largely neglected. In our design, we investigate how changes in wage rates and entitlements affect behaviour in a lab in the field experiment run with married couples from rural regions in Uganda. We design a game in which the production task itself is straightforward and identical for men and women, but where the rules governing payment vary across subjects and between rounds. In particular, we vary the relative wage rates of husbands and wives and we vary the property rights over the income generated by the couple. In doing this we keep the rules for payment and output transparent, determined by random draws made by the individuals concerned.

Our design is framed by the predictions of several standard models of household allocation, namely the unitary model (Becker, 1991), the collective model (Chiappori, 1992) and non-cooperative models (Woolley, 1993). Each of these models has predictions for how relative effort should respond to changes in relative wages and property rights.

Our main result is that generally higher relative wages lower relative effort. This is contrary to the predictions of unitary and collective models where a rise in one person's wage relative to the other should shift productive effort to the person with the higher wage. On the other hand, this is consistent with some versions of the non-cooperative model. Secondly, we find that the effects of changing wage inequality are larger than the effects of changing property rights. Overall, household productivity is maximized by paying men and women separately for their output, rather than allocating all income to one person or sharing it. Again, this is consistent with a non-cooperative model.

The rest of the chapter is organized as follows. Section 3.2 describes the background and provides an exposition of the theory underlying the experimental design. The experiment design is introduced in section 3.3 and section 3.4 describes the implementation process. The results are presented in section 3.5. Section 3.6 concludes by highlighting our main findings.

3.2 Background

3.2.1 Context

There is strong evidence of persistence of gender disparities with respect to ownership of property (land) and wages in Africa (Appleton, et al., 1999; Lastarria-Cornhiel, 2003; Deere & Doss, 2006; Asiimwe, 2014). Boserup (1970) argues that unless females are granted equal access to productive resources, the poor countries cannot develop. Similarly, Agarwal (1994) suggests that women's ownership of land improves women's productivity, equality, empowerment, and welfare; thus contributing to economic growth and development. However, despite of these claims, gender discrimination in land rights is prevalent in many parts of the world, including Africa (Deere & Doss, 2006).

In various African countries including Uganda (Lastarria-Cornhiel, 2003), the rural development programs continue to grant primary land rights to the husband who is the household head in a bid to stimulate agricultural efficiency and productivity; there is a question whether this kind of policy will yield the desired outcomes.

More than 80% of Uganda's population live in rural areas and depend almost entirely on agriculture (FAO, 2008). In Uganda four main forms of land tenure exist, namely; Customary, Mailo, Leasehold and Freehold (Gombya-Ssembajjwe, et al., 2001). However, the majority of landholding is customary tenure and according to FAO, over 75% of the land is held under this tenure system and is regulated by customary laws. Customary land is allocated to the man when he marries and it is regarded as the husband's property until he dies, at that time the ownership reverts to the clan because customary law dictates that women do not have the right to inherit (Asiimwe, 2014). Therefore, women's access to land is restricted to usufructuary rights only (Gombya-Ssembajjwe, et al., 2001); since ownership and control over land is ultimately with men, approximately only 30% of women have access to and control over proceeds from land in rural Uganda (Ovonji-Odid , et al., 2000). Empirical literature suggests that there are three channels through which property rights can influence land related investment namely; freedom from expropriation, better access to credit and improved land transferability (Demsetz , 1967; Feder, 1988). Since the customary law decrees that women cannot inherit land this imposes high levels of land tenure insecurity on wives, does this insecurity have any impact on the wife's incentives to invest on the land?

Furthermore, the customary land law cripples the ability of women to claim rights to proceeds from the harvest; is there a possibly that this could deter the women's incentives to exert optimal effort when working on the family farms?

The women's land rights are high on the agenda of the women's movement in Uganda (Asiimwe, 2014), because agriculture provides livelihoods for most of the country's poor. The Uganda Land Act only includes a clause that requires spousal consent before land acquired during marriage is sold but the clause requiring co-ownership of land by spouses was not included, even though it had been approved of by members of parliament (Bomuhangi, et al., 2012). According to Lastarria-Cornhiel (2003), other provisions in the Land Act appear to discriminate against women, for instance, it states that family land is represented by the head of the family (in most cases a man) so men have been given the legal power to make all transactions with respect to family land, making this person the owner of the property.

There is continuing evidence of high gender inequality in land ownership in Uganda, women own and control only 7% (FeedtheFuture)[4] of the land even though approximately 70 percent smallholder farmers are women. The rural women provide labour without having a share in the planning or the monetary benefit from it such that there is extreme imbalance in work performance and income distribution between women and men (Wengi, 2011). Gender disparities also exist in the country's labour market; there is evidence of substantial gender

[4] http://feedthefuture.gov/country/uganda

wage gap resulting from discrimination against females in Uganda (Appleton et al., 1999; Kagundu et al., 2007). Similarly, the Gender and Productivity Survey (2009) reports that nearly half of the women in rural Uganda are unpaid workers on family farms, however, only 18% of the men were classified under the unpaid category. This is a cause of worry given that the main occupation of women in Uganda is Agriculture, more precisely, 72 % of all employed women work in agriculture (FOWODE, 2012). Wage differentials based on gender discrimination rather than on effort have detrimental effects on efficiency and growth. The reason is that gender discrimination may have implications for feelings of equity and fairness, such that disadvantaged individuals will tend to exert less work effort and this will in turn deter economic growth. The lack of rights over land coupled with very low or zero wages makes rural women more vulnerable to poverty.

3.2.2 Theory

In order to evaluate the impact of wages and entitlements on output we will consider three well-known classes of models of the household namely the Unitary model (Becker, 1991), the Collective model (Chiappori, 1992) and the Non-cooperative models (Woolley, 1993). The Unitary model treats the household as a single production or consumption unit, whereas the Collective model only assumes that the household reaches Pareto efficient outcomes, but allows the Pareto weights to vary according to some factors of the environment faced by the family members. In the Non-cooperative models, each individual has her own budget and chooses expenditures on private goods and contributions to household public goods independently of the partner. The solution concept is that of Nash equilibrium, which in general is not Pareto efficient.

We outline a simple model to cover the Pareto efficient, unitary models and non-cooperative models in the context of our experiment. In these models, the value of output produced by person i =1,2 is $w_i e_i$ where w_i is the wage rate faced by person i in the task and e_i is the number of straws produced or effort.

Individual preferences of the two agents over income available for consumption, y, are summarized by the increasing, twice differentiable and concave utility functions, u and v respectively. Each person i =1,2 suffers effort costs $c(e_i)$ from production where $c(.)$ is assumed in what follows to be strictly increasing, convex and twice differentiable with $c(0) = 0$.

The household when choosing collectively decides according to the function W, within which a weight of λ is attached to person 1's interests and (1- λ) is attached to the interest of person 2. In the unitary model, λ is a fixed parameter independent of the actions of the players, their fall-back utilities and so on. In the Pareto efficient model (Browning & Chiappori, 1998), λ may depend on a number of factors including outside options and property rights to output.

$$W = \lambda\big(u(y) - c(e_1)\big) + (1-\lambda)\big(v(y) - c(e_2)\big) \tag{3.1}$$

The household income constraint is $y = y_0 + w_1 e_1 + w_2 e_2$ where y_0 is income from outside the experiment. For notational simplicity, we suppress y_0 in what follows. Maximizing W subject to the income constraint produces,

$$\frac{\lambda c'(e_1)}{(1-\lambda)c'(e_2)} = \frac{w_1}{w_2}$$

where c' represents the derivative of the cost function (and c'' will represent the second derivative).

It is clear from this model that:

1. For given λ , e_1/e_2 is <u>increasing</u> in the relative wage w_1/w_2.
2. For given w_1/w_2, relative output, e_1/e_2 is <u>decreasing</u> in λ.

As we shall see, the impact of a rise on w_1/w_2 on actual effort is less clear-cut. In particular, e_i may rise or fall if w_i rises. However, e_{-i} falls if w_i rises. I.e. the partner's effort falls if an individual's wage is higher.

For the unitary model, in the case of changes in property rights, as λ does not change and so effort does not change for either partner.

In the case of the collective model,

$$\begin{bmatrix} e_{1\lambda} \\ e_{2\lambda} \end{bmatrix} = \frac{H^{-1}}{|H|} \begin{bmatrix} v'w_1 / \lambda \\ -u'w_2 / (1-\lambda) \end{bmatrix}$$

Where $e_{1\lambda}$ represents the partial derivative of effort i with respect to λ and H is the Hessian for the maximization problem. That is,

Where

$$H = \begin{bmatrix} w_1^2 \left(\lambda u'' + (1-\lambda)v''\right) - \lambda c_2'' & w_1 w_2 \left(\lambda u'' + (1-\lambda)v''\right) \\ w_1 w_2 \left(\lambda u'' + (1-\lambda)v''\right) & w_2^2 \left(\lambda u'' + (1-\lambda)v''\right) - (1-\lambda)c_2'' \end{bmatrix}.$$

Thus,

$$\begin{bmatrix} e_{1\lambda} \\ e_{2\lambda} \end{bmatrix} = \frac{w_1 w_2}{|H|} \begin{bmatrix} w_2 \left(\left((\lambda u'' + (1-\lambda)v'') - (1-\lambda)c_2'' \right) \left(v'w_1 / \lambda \right) + (\lambda u'' + (1-\lambda)v'') \left(u' / (1-\lambda) \right) \right) \\ -w_1 \left((\lambda u'' + (1-\lambda)v'') \left(v' / \lambda \right) + \left((\lambda u'' + (1-\lambda)v'') - \lambda c_1'' \right) \left(u' / (1-\lambda) \right) \right) \end{bmatrix}$$

This implies that $e_{1\lambda}$ is negative and $e_{2\lambda}$ is positive, so that e_1 / e_2 also falls when λ increases. In other words, a reduction in power makes individuals work harder in the collective household both in an absolute and relative sense. The intuition is that effort is costly and a reduction in power means a transfer of responsibility for effort to that person.

We now turn attention to the non-cooperative model, wherein each person chooses separately and simultaneously a) their level of effort, b) their consumption of a private good, x_i and c) their contribution to a household public good $z = z_1 + z_2$. The utility functions for the spouses are $u = u(z, x_1) - c(e_1);\quad v = v(z, x_2) - c(e_2)$ and we take u, v to be increasing and concave in their arguments. As before, let y be total household income: $y = w_1 e_1 + w_2 e_2$

Case 1. $z_i > 0$.

It is well known (e.g. Warr, 1983; Chen & Woolley, 2001) that in a Nash equilibrium of this game, as long as both $z_i > 0$, then consumption of both z and x_is depend only on the level of y and not the source of the income . In other words, we can continue to write u and v in the indirect form $u(y)$ and $v(y)$.

The first order conditions can therefore be written as:

$$w_1 u'(y) - c_1'(e_1) = 0 \qquad (3.2)$$

$$w_2 v'(y) - c_2'(e_2) = 0$$

For changes in wages, suppose that the Nash equilibrium is stable and interior and let J be the Jacobean matrix associated with equation (2). Then,

$$\begin{bmatrix} e_{1w_1} \\ e_{2w_1} \end{bmatrix} = \frac{1}{|J|} \begin{bmatrix} w_2^2 v'' - c_2'' & -w_1 w_2 u'' \\ -w_1 w_2 v'' & w_1^2 u'' - c_1'' \end{bmatrix} \begin{bmatrix} -u' - w_1 e_1 u'' \\ -w_2 e_1 v'' \end{bmatrix} \qquad (3.3)$$

Where the sign of e_{iw_j} is the derivative of effort made by spouse i with respect to w_j. Stability of the equilibrium implies that the determinant of the Jacobean is positive. Using the concavity of the utility functions and the convexity of the cost functions we get that the sign of e_{iw_i} (the own effect) is ambiguous while the sign of e_{iw_j} is negative. Intuitively the cross-effect is negative because leisure (i.e. less effort) is a normal good. Therefore, as the wage of the partner rises and household income rises, then the other spouse slacks off. The own effect is ambiguous for similar reasons: higher wages increases the opportunity cost of leisure but at the same time, the income effect lowers effort.

Case 2. $z_2 = 0$.

For the case where one partner makes no financial contributions to the household public good, the predictions are somewhat different. In particular, property rights do matter. We cover the case where z_2 is always zero in equilibrium as an example. It is helpful to write $y_1 = \alpha w_1 e_1 + \beta w_2 e_2$ and $y_2 = (1-\alpha) w_1 e_1 + (1-\beta) w_2 e_2$ where α is the share of income generated by person 1 that goes to person 1 and β is the share of person 2's income that goes to person 1. The property right rules can be then be written as combinations of α and β; For instance separate payments amounts to setting α=1 and β=0 and so on. Define $u(y_1, y_2)$ and $v(y_1, y_2)$ as the corresponding indirect utility function for person 1 and 2 respectively. Note that u_2=0 because in this case person 2 makes no contribution to the household public good. Note also that income that passes to person 1 only benefits person 2 through the household public good and income that passes to person 2 only benefits person 2 through private consumption. Since $z_2 = 0$ then this implies that $v_1<v_2$.

First order conditions for the two partners are:

$$w_1 \alpha u_1(y_1, y_2) - c_1'(e_1) = 0 \tag{3.4}$$

$$\beta w_2 v_1(y_1, y_2) + w_2(1-\beta) v_2(y_1, y_2) - c_2'(e_2) = 0$$

It follows that,

$$\begin{bmatrix} e_{1\alpha} \\ e_{2\alpha} \end{bmatrix} = J^{-1} \begin{bmatrix} -w_1 u_1 - w_1 e_1 u_{11} \\ e_1 w_2(\beta(v_{11} - v_{12}) + (1-\beta)(v_{21} - v_{22})) \end{bmatrix} \tag{3.5}$$

Where,

$$J = \begin{bmatrix} w_1^2 \alpha^2 u_{11} - c_1'' & w_1 \alpha w_2 \beta u_{11} \\ w_2 w_1 \left(\beta \left[\alpha v_{11} + (1-\alpha) v_{12} \right] + (1-\beta) \left[\alpha v_{21} + (1-\alpha) v_{22} \right] \right) & w_2^2 \left(\beta \left[\beta v_{11} + (1-\beta) v_{12} \right] + (1-\beta) \left[\beta v_{21} + (1-\beta) v_{22} \right] \right) - c_2'' \end{bmatrix}$$

In general, the effect of changes in α and β on effort levels cannot be signed. However, because there is no incentive for person 1 to make any effort when $\alpha=0$, then any switch to the 'person 2 takes all' rule leads to a predicted drop in e_1. Beyond this, suppose that both z and x are normal goods for both agents, implying that

$$e_{1\alpha} = \frac{w_1}{|J|}(w_2^2(\beta[\beta v_{11} + (1-\beta)v_{12}] + (1-\beta)[\beta v_{21} + (1-\beta)v_{22}] - c_2'')(-u_1 - w_1 e_1 u_{11}) - (-w_1 \alpha\beta w_2 u_{11})(e_1 w_2(\beta(v_{11} - v_{12}) + (1-\beta)(v_{21} - v_{22}))) \quad (3.6)$$

Having set out the basic models we now explain our design and then link the predictions.

3.3 Experiment Design

Each couple performed the same task twice (details are in the next section) under a piece-rate regime. We use four variations of how the money from each task is divided. Firstly, we have the "Paid separately" category and under this class, each individual keeps what she/he earns from completing their task. Secondly, the "Wife gets all." category is when all the money goes to the wife; that is all the money made by the husband and the wife from completing their tasks is owned by the wife. The third category is called the "Husband gets all." In this case, all the money goes to the husband. Lastly, we have the "Shared Equally" category: the money made by the husband and wife is added and divided equally between them. In addition to varying the entitlements, we vary the piece rate for spouses independently such that an individual can either earn 300USh[5] or 600USh for each successfully completed straw. In total, therefore there are 4x4=16 possible combinations of

[5] USh is short for Uganda shillings. US$1 is approximately 3,690USh in October 2015.

entitlements and wage rates for a couple.

To assign the parameters, we presented each couple with three bags to pick cards from before beginning the experiment. One bag contains a mixture of laminated cards showing wage rates for straws assembled by a woman (Wife bag), one contains a mixtures of rates for men (Husband bag) and one contains cards showing who will receive the money made by a couple (Entitlements bag). The wife (husband) is required to pick a paper from the Wife (Husband) bag, this paper determines her (his) wage rate for that particular task. After the draws for the first task have been made and recorded the cards were returned to their bags and the process repeated for the second tasks. The decision to make the payment rules known for both tasks in advance was in order to maximize transparency.

Our hypotheses are based on the household models predictions, which are summarized in Table 3.1 below.

Suppose that λ represents the weight on the wife, and let λ_f represent the weight when the woman ('female') takes all the income; λ_s represents the weight when income is paid separately, λ_h is the weight when all income is split equally ('halved') and λ_m is the weight when income is given to the male partner. It seems reasonable that the weight is higher when all the money goes to the wife and lower when all the money goes to the husband, but it is not clear how to rank λ for the other two cases.

If $\lambda_f > \lambda_s, \lambda_h > \lambda_m$ we expect the following:

1. For any switch away from 'woman takes all the income', a wife's <u>relative</u> output rises
2. For any switch to 'man takes all the income', a wife's <u>relative</u> output rises.
3. For any switch that raises λ, male effort rises while female effort falls.

Firstly, we will discuss the property rights predictions of the three classes of household models that we considered in the previous section. The Unitary model assumes that all income is pooled and the identity of the income recipient or the person controlling an asset does not influence household behavior. This means that irrespective of whom the property rights are given to either the wife or husband, the household output remains the same. Therefore, under the Unitary model assumptions, both male and female participants are expected to be insensitive to variations in entitlements.[6] Similarly, in the case of the non-cooperative model, it follows that as long as $z_i > 0$, i=1,2, then the property rights allocation of the earnings from the experiment do not affect effort levels. Therefore, this implies that the property rights allocation of the earnings from the experiment do not affect effort levels. On the contrary, under the Collective model, entitlements are expected to influence output produced by individuals. The intuition is that a change in property rights causes a shift in power; since effort is costly, a reduction in power will lead to a transfer of responsibility for effort to that person. Therefore, under the collective household, individuals work harder both in an absolute and relative sense when their property rights change in favour of their spouse.

[6] Similarly, the assumption of "law of neutrality" in property rights highlighted in Coase Theorem (1960) suggests that when there are no transaction costs, the initial allocation of property rights makes no difference for outcomes thus rational actors will basically do what is the most efficient.

Secondly, we discuss the predictions on the impact of wages and relative wages on output and relative output, respectively. In the case of the Unitary model, we expected a positive relationship between relative wage and relative output. Furthermore, an inverse relationship between individual wage and spouse work effort is expected. The collective model makes the same predictions as the Unitary model on the impact of individual wage and relative wage on spouse's output and relative output respectively.[7] However, as we saw in the previous section, non-cooperative models suggest that the impact of relative wages on relative output can go either way - that is it can vary in different situations. However, in all three household models, the Unitary, Collective, and Non-cooperative a rise in an individual's wage is associated with a decline in the spouse's output. Furthermore, these three household models predict that own wage has ambiguous effect on own effort. The reason is that higher wages increases the opportunity cost of leisure but at the same time, the income effect lowers effort.

[INSERT TABLE 3.1 ABOUT HERE]

Before moving on to discuss the implementation of the design, it may be useful to consider the limitations of this theoretical framework.

[7] A change in w may also affect the power variable, λ. If that is in the standard direction (i.e. a rise in wages for an individual does not decrease their weight in W), and the elasticity of λ with respect to relative wages is less than 1 then this does not alter the predictions.

First, while the assumptions of the model are standard, we note that c(e) – the relationship between effort and its costs is assumed to be convex. If the relationship is linear or concave then in the models a corner solution would be predicted. For the unitary and collective models, this would mean that generically only 1 partner works, though conceivably the identity of this person might be responsive to the wage rate. The key point though is that output for one person should be zero. For the non-cooperative model a person would either not work at all or work to their maximum and then be unresponsive to changes in wage rates and property rights except, possibly, jumping between maximum possible output and zero effort. Thus in our experiment a lack of convexity in c(e) does not mean that the signs of the predictions are simply reversed it also means that we should see partnerships with zero output by one partner and 'extreme' responses to changes in the parameters.

Stepping outside the models, it is worth considering what other motivations subjects might bring to the experiment and here it is natural to consider issues of fairness and inequity aversion. In the complex relationships of the household changes in individual wage rates also alter, relative wage rates and this may influence the work effort of the partner due to feelings of equity and fairness (Akerlof & Yellen, 1990; Charness & Kuhn, 2007). The well-known inequality-aversion model (Fehr & Schmidt, 1999) postulates that people dislike inequality. How this translates into predictions for the experiment is not clear, because it partly depends on whether individuals are concerned by inequalities in the rules (property rights and wages) or in effort or in income or all three. However, if partners are averse to inequality in incomes, we might expect a non-linear relationship between relative wages and absolute output, with effort for an individual maximized for equal wages but lower when wage rates are both above and below the rate for their partner.

In addition to responding to the terms on which their partner is paid, subjects averse to some kind of inequality may also respond to the terms on which other players in the experiment are paid. For this experiment, although partners are separated for production, in fact for logistical reasons women worked close to women and men close to men. Thus, we might also reasonably anticipate that individuals respond to the terms of payment for people around them.[8] In the next section, we explain the implementation of the experiment.

3.4 Implementation

The game instructions are shown in the Appendix (3.1). In all locations, there is a basic design: couples are assembled and led through a discussion of how to do the work and given opportunities to practice. After questions have been answered, the experimenter explains how subjects are to be paid. They show the participants three bags namely: Entitlements bag, Wife bag and Husband bag. Then the couples come up to the experimenters and one by one draw (with replacement) from opaque bags the cards governing payment for both the first and second round of the work as well as who will receive the money made by the couple. Each

[8] Peers might also affect learning.

person receives a sheet detailing the payment rule (see figure 3.1, which shows a sheet that has been partially completed) and after all couples have gone through this process, men, and women separated and are led to separate production areas. After a further reminder of the rules, they begin 10 minutes of work, at the end of which enumerators tally correct straws and subjects are individually reminded of the rules for the second round. The stock of materials for production is refreshed and then the second round proceeds, again for 10 minutes. At the end, the correct straws are tallied and both husband and wife are informed of the payment they will receive.

After several pilots in Uganda and Japan, we selected a portable, locally sourced task with which we were confident we would be able to obtain variations in output[9] across individuals. Participants were required to select 2 bands of each color from a pile of bands which consisted of four different color bands. After selecting the bands, they were supposed to tie the bands on a straw such that there would be 8 bands in total on each completed straw. Each successfully completed straw was worth either 300USh or 600USh depending on manipulation (see below). If a straw was with more or less than 8 bands or with a wrong mix of colors or with some bands which were on top of one another, it was not counted as a completed straw. The total time for completing each task was 10 minutes. In the introduction to the experiment, a demonstrator shows that 8 rubber bands (2 of each of four different colours) must be tied around a drinking straw and then all participants have a go at assembling a straw. If any of the participants makes a mistake, the demonstrator highlights the mistake

[9] Output refers to the number of correctly completed straws.

and shows them the correct way again.

[INSERT FIGURE 3.1 ABOUT HERE]

The rates of payment were chosen after two field pilots in Uganda and laboratory tests with the enumerators. The amounts paid per straw mean someone who produces 10 straws over the two rounds at 300 shillings per straw would generate the equivalent of 1 day's wages in most rural areas. Since the experiment, including instructions took at most 1.5 hours to complete, these payment rates are generous compared to other forms of work available to most of the subjects.

To implement the experiment consistently we used a script written in English (Appendix 3.1) which contained guidance on setting up the rooms as well as sections on how to inform the subjects. Since English is understood only imperfectly by many participants the script was translated into the dominant local language by the experimenters and this was the language used for all oral explanations. Uganda has many local languages so in some locations the instructions were given twice in two local languages.[10] In addition to the script, we used a flipchart to remind subjects of the basic idea and each subject carried with her or him a copy of the personal payment rule for their spouse. The sites used for the experiments varied considerably: in sites with more than one room, it would be impossible for spouses to monitor

[10] We knew from the prior survey whether there was a mixture of language speakers present in the experiment and adjusted accordingly.

each other during the work, but in many cases, we were using a single room school or church for the games. In this case, we had to push men and women as far apart as possible, but it was possible that subjects could theoretically monitor their spouses. In practice, this was quite difficult even in single-room locations. Men and women worked with their backs to one another often 10 meters apart in rooms that were dim and where it would be difficult to watch a spouses' effort without moving from the production site. Perhaps a more serious issue with small locations was the possibility that peer effects would be important in behaviour: men and women could see the work of the others in their group. Again, without scrutiny, it would be impossible to see how many straws others were making, but we cannot rule out that in the smaller facilities, subjects could get some sense of how hard others were working. The worry in such a situation is that peer effects might dominate effects of variation in payment rates and property rights. However, what is worth emphasizing is that the separation of men and women meant that spouses could not directly observe the efforts of their partner.

Prior to the main fieldwork, we carried out a further pilot in 5 villages across the four regions of Uganda. In each location, the experiment was undertaken after households had taken part in an extensive household survey. As far as possible, we kept to the plan for the actual implementation. After this pilot, we made some small changes, notably increasing the rates of pay, since productivity in the field was lower than amongst the enumerators. We also added points of extra clarification and emphasis to the script.

3.5 Data and Descriptive Statistics

3.5.1 Data

The main study was carried out in 46 villages in four different regions of Uganda namely Central, Eastern, Northern and Western regions. Villages used in our experiments are part of the Research on Poverty, Environment, and Agriculture Technologies (RePEAT) 2015 survey. The villages were selected from a stratified random sample across the four regions mentioned above. Therefore, our sample is a fair geographical representation of rural Uganda. The 2015 RePeat survey is the fifth wave of the survey rounds carried out jointly by the National Graduate Institute for Policy Studies (GRIPs), the Foundation for Studies on International Development (FASID) and Makerere University (Yamano et al, 2003; Msweyige and Matsumoto, 2015). RePEAT data contains household level panel data starting from the year 2003.

Within the selected villages, we invited all households who were selected into the RePEAT survey where the partners were more than 18 years of age and under 50.[11] The actual recruitment of the eligible couples was done by our survey team with the help of local community chairs. The experiments were carried out in rural Uganda from September (2015) to January (2016), we had four survey teams that is one team in each region. Each survey

[11] The low cut-off age is due to the fact that these households were also interviewed subsequently about their most recent fertility decisions for a separate study, conducted by other members of the REPEAT team.

team comprises of 7 to 9 people and they speak several languages which were relevant for communicating with participants in the different regions. The experiments were all carried out after the survey part of the study. In addition to the games described here subjects also took part in some other, individual experiments organized by other researchers in the team. The order of the experiments was the same in each location, but varied across locations and we include dummies for order effects in the regression analysis of the next section.

The total number of participants in the experiments is 394. Table 3.2 shows the summary statistics of the background demographic and socio-economic characteristics of the participants. The household characteristics include household size, number of children, hours spent on earning activities, farm labour, education, and age. The community-level information captured includes average land size per household, proportion of households who can afford more than two meals a day, number of tribes and distance to the nearest district town. The average age of the participants is 34 years and average highest grade of education completed is primary 6. Average number of people in a household is 10 and the number of children is about 4. Per capita consumption of the household is on average US$48. The mean share of farm labour is slightly lower for females compared to men and the number of hours in work related to earning is about 5 hours a day.

When we consider community level data the average of the proportion of households who can afford at least two meals a day is 72 and the mean land size is 2.5 acres per household. The average distance of the communities to the district town is 17 miles. The average number of tribes in each community is 3.

[INSERT TABLE 3.2 ABOUT HERE]

3.5.2 Descriptive Statistics

The descriptive statistics for output and relative output in various categories are shown in Table 3.3 (see also figures 3.2 and 3.3). There is a large and significant (at p<0.001, sign test) difference in output between the first and second rounds. Participants complete on average 2.17 more items in the second round compared to the first. However, the mean relative output is not significantly different between the two rounds. Similarly, we find that on average male participants complete 6.76 straws and females 6.68 straws. There is no significant gender differences in average number of straws completed (p-value=0.68, two-tailed t-test).

[INSERT TABLE 3.3 ABOUT HERE]

In Table 3.4, we present the results of tests of differences in sample means. In the final column of table 3.4, we note whether the direction of change is consistent with the collective theory of the household. As can be seen there are broadly two patterns in the data. First, when we consider the mean of relative output for different levels of relative wage. The average relative output declines as the relative wage rises from 0.5, to 1 and 2, respectively. We find significant differences in the relative output across the three relative wage categories (only at the 10% level in the first comparison). The lowest relative wage is associated with the highest relative output; this is opposite of the predictions of the unitary and collective models. However, the results are consistent with the non-cooperative model.

The second broad pattern in the data is the absence of a clear relationship between rule categories and outcomes predicted by the collective and unitary models. Most of the relevant test results are not significant. The exception is the difference in relative output moving to "Wife receives all" income. Under the collective model, this should increase male output relative to female and this is what occurs. However, it is only the "Separate" to "Wife receives all" comparison that is statistically significant at the 5% level.

We also consider the mean output across sharing rule categories. The "Paid separately" category has the highest average output (7.0) and "Sharing equally" category has the lowest average output (6.47). The difference between these two means is significant at the 5% level (p-value=0.043, two-tailed t-test). We do not find significant difference in the average number of straws completed across other sharing rule categories.

The results show that on average the output produced is 6.6 straws when the spouse's wage rate is Ush300 and is 6.9 straws when the spouse's wage rate is Ush600. The average number of straws completed when the individual's wage is Ush300 is not significantly different from when it is Ush600 for either men or women. The three household models, the Unitary, Collective, and Non-cooperative predict that a rise in an individual's wage is associated with a decline in the spouse's output; however, our results do not in general support the prediction. In fact, the results go in the opposite direction and are significant at the 10% level for the effect of women's wages on men's effort.

[INSERT TABLE 3.4 ABOUT HERE]

All these results are of course for unconditional comparisons of means. In the next section, we conduct a regression analysis to allow controls for changes in the other parameters of the experiment as well as features of the household and community.

[INSERT FIGURE 3.2 ABOUT HERE]

[INSERT FIGURE 3.3 ABOUT HERE]

3.7 Estimation Methodology

In this section, we use both experimental and survey data to explore the relationship between productivity and entitlements as well as the wage rate. We estimate two major equations; (i) the effect of relative wage and property rights on relative output and (ii) the impact of wages and rules of allocation on the absolute level of output.

3.7.1 Relative Output

Firstly, we test the predictions on relative output using the following equation:

$$O_{it} = \beta_0 + \beta_1 T + \beta_2 R_{it} + \beta_3 X_{it} + \beta_4 (X_{it} * R_{it}) + \beta_z Z_i + \varepsilon_i \quad (3.7)$$

where O_{it} is the dependent variable and it is treated as a continuous variable. O_{it} is relative output (=husband output/wife output) of couple i for round t, where t=1,2. The explanatory variables T, R_i, X_i are round ID, Relative wage (=husband wage rate/wife wage rate) and the sharing rule, respectively. We include T in the equation in order to isolate the influence of the learning effect[12]. T is a dummy variable equal to 1 for first round and 0 for second round. To capture the impact of property rights, we include (X_i) which is a categorical variable for property rights (entitlements)[13]. We have four entitlements categories namely; "Man gets all", "Sharing equally", "Paid separately" and "Woman gets all". The base group is "Man gets all". Z_i is a vector of individual and household characteristics as well as game-related variables . Errors are clustered at the community level.

The variables contained in Z_i are as follows. "Age" and "Spouse's Age" refer to the age of the participant and that of the participant's spouse, respectively. The variables "Education" and "Spouse's education" mean the number of years of schooling for the participant and the

[12] In a repeated game setting, the subjects might learn and develop strategies (Andreoni, 1988).
[13] We use entitlements and property rights interchangeably.

spouse, respectively. Regional dummy variables for region 1, 2, 3 and 5 are included and region 1 is the base group[14]. They are five game-related variables. We include game-related variables because we carried out several different experiments during the RePEAT 2015 survey. The order in which these games were played in each community was randomly determined and we include dummies for this order. The "Trust game dummy" is a binary variable for the order of the trust game while, the variable "Risk dummy" is a dummy which is equal to "1" when the Risk game[15] is played before the Production game and "0" if not.

We noted earlier the possibility of behavioral effects in an experiment of this kind. To allow for peer effects we include three variables, namely; Average Peer output, Peer rule 1 and Peer rule 2. The "Average Peer output" is the mean output of other participants for each gender group in each community in that round. Individuals might also react to the perceived fairness of their entitlements compared to others in the group. Entitlement categories assigned values 1, 2, 3 and 4 representing "Man gets all", "Sharing equally", "Paid separately" and "Woman gets all", respectively. In other words, as the value of the variable increases female entitlement becomes stronger. The variable "Peer rule 1" refers to the lowest property rights category realized in each location and round. "Peer rule 2" represents the highest valued property rights category for each community in that round.

[14] Names of regions: 1 – East, 2 – Central, 3 – West, and 5 – Northern.
[15] This was a Holt-Laury measure of attitudes to risk and time discounting at the individual level. The trust game was actually a sequence of trust games played out with a variety of anonymous partners around the country.

3.7.2 Absolute Output

In order to test the theoretical predictions on absolute output, we consider the following equation:

$$S_{it} = \beta_0 + \beta_1 T + \beta_2 W_{it} + \beta_3 P_{it} + \beta_4 X_{it} + \beta_5 (P_{it} * X_{it}) + \beta_z Z_i + \mu_i \qquad (3.8)$$

In equation (3.8), S_{it} is a dependent variable. S_{it} is how many straws an individual i successfully produced in round t, where t=1,2. The explanatory variables T, X_i, Z_i are the same as in equation (3.7). However, in this case, the vector Z_i contains two more variables (household size and Gender), than equation (3.7). "Household size" refers to the number of individuals within the household. Gender is a binary variable, which takes a value 1 if the participant is male and 2 if female. The variables W_i, P_i are defined as own wage rate and spouse's wage rate, respectively[16]. We run equation (3.8) separately for male and female participants in order for us to evaluate whether they respond differently to variations in spouse wages and property rights.

[16] Own wage rate is the Payment per straw for each participant. Spouse wage rate is the spouse's payment per straw.

3.8 Results

3.8.1 Relative Output

The OLS regression results for equation (3.7) are shown in Table 3.5. The results confirm the conclusion of the previous section that there is an inverse relationship between relative wage and relative output. The unitary and cooperative models predict that the coefficient on relative wage is positive; thus, our results challenge this notion. However, our results are consistent with some versions of the non-cooperative model. When we allow for interactions between entitlement rules and wages, we find that the effect of relative wage on relative output is significantly different across sharing rule categories (p-value=0.013, two-tailed t-test).

Secondly, we find evidence that entitlements influence relative output. The relative output is significantly lower when subjects participate in "Paid Separately" sharing rule category compared to "Man gets all" category (p-value=0.007). Moreover, the interaction between relative wage and "Paid Separately" is significant and positive (p-value=0.004). This implies that when relative wage increases, the difference in relative output declines when we compare "Paid Separately" and "Man gets all" categories. However, there is no significant difference in relative output when we compare the "Sharing Equally" and "Man gets all" categories. In other words, some variations in property rights lead to a change in relative productivity within the household but there is no pattern that coheres with the predictions of any specific household model.

Male education has a positive effect on relative output but the spouse's education has no significant impact. As expected age has a negative effect on relative output, however, the age of the spouse has no significant effect. There is evidence that peer effects influenced relative output, this is not very surprising because some participants could observe the output produced by others in the same room.

[INSERT TABLE 3.5 ABOUT HERE]

3.8.2 Absolute Output

Equation (3.8) allows us to examine the effects of entitlements and wage rate on absolute output. In order to determine the gender specific treatment differences in productivity, we estimate the equation (3.8) separately for females and males[17], the results are shown in columns 1 and 2, respectively in Table 3.6.

When we consider only female participants (column 1, Table 3.6), we find that the spouse's wage rate does not significantly influence output. We also observe that female participant's

[17] We also carried out Seemingly Unrelated Regression (SUR), the results indicate that the errors for equation (2) for males only and equation (2) for females only are uncorrelated (p-value=0.35).

behavior is influenced by variations in entitlements. The output produced by women is significantly different when we compare “Sharing Equally” and “Women gets all” categories (p-value=0.077, two-tailed t-test) and when we compare “Women gets all” and “Paid separately” categories (p-value=0.085, two-tailed t-test). However, female participants’ output is not significantly different when we compare “Sharing Equally” and “Men gets all” categories. Furthermore, women’s output in “Women gets all” is not significantly different from that in “Men gets all” category (p-value=0.46).

In column 2, Table 3.6 we show the regression results we obtain when we consider men only. We find that for male participants the spouse’s wage rate has no significant effect on output. Furthermore, we find no significant evidence that entitlements influence male participants output (p-value=0.69, two-tailed t-test). In other words, the changes in wages on individual output are not significant but when combined they add up to a significant change in relative output.

Given that the participants carried out a manual task, as expected we find that younger participants significantly, produce more output than the older ones. Peer effects do influence output for both male and female participants and especially productivity is positively correlated with the productivity of workers in the same group.

[INSERT TABLE 3.6 ABOUT HERE]

In table 3.7, we show the household models predictions and our empirical results.

[INSERT TABLE 3.7 ABOUT HERE]

3.9 Conclusions

We evaluate how changes in relative wage rates and entitlements affect behaviour in a series of experiments run with married couples. The wage rates and entitlements are randomly assigned to each individual and couple, respectively. Men and women work in separate production areas, making it impractical for the spouses to monitor each other's effort while they are performing their tasks. Nevertheless, each spouse knows the rules that apply to their work and to their partners when working.

Our findings suggest that there is an inverse relationship between relative wage and relative output: partners paid relatively more work relatively less. This contradicts the most straightforward interpretation of the unitary and collective model predictions of the effect of relative wage on relative output. Our results are though consistent with the predictions of some non-cooperative models.[18] We also find that the impact of relative wage on relative

[18] It is in keeping with some of the evidence on individual labour supply such as Camerer, et al, 1997, Crawford et al, 2012 wherein a behavioural interpretation (reference point effects in income) is offered as an explanation.

output can differ across sharing rule categories. In other words, the magnitude of the impact will vary for different property rights categories.

Looking at the manipulation of property rights over the output from the experiment, our results show that entitlements do influence relative output in a manner that is not clearly supportive of any particular model. What is notable is that separate payment leads to the highest level of output.

We also observe that men and women respond differently to changes in entitlements and spouse's wage rate. Female participants' productivity is more responsive to changes in entitlements, compared to male participants. Furthermore, what is more interesting is that for both male and female participants there is no significant difference in household output when we compare the "Sharing equally" and "Men gets all" categories. Obviously, there is a long distance between the controlled circumstances of our experiment and major policy changes. Yet, our results give support to the idea that equitable policies to promote the advancement of women can be achieved with no detrimental effect on productivity. In other words, the adjustment of property rights for married people can be used as a tool to reduce gender inequality and this would have no inverse effect on economic growth.

CHAPTER 4

An Estimation of the Riskiness of Crops Grown in Rural Uganda

4.1 Introduction

Farming involves risk and the level of risk faced by the farmer varies with crop choices. Therefore, the riskiness of each crop influences the farmer's production decision (Bezabih & Di Falco, 2012). A limited number of studies examine the degree of crop riskiness in Uganda and the majority of the studies rely on subjective measures of crop riskiness (Kapoor, 1993; Veljanoska, 2014; Mubiru, et al., 2015; Van Campenhout, et al., 2016). A quantitative and objective approach to measuring the riskiness of each crop allows for a more comprehensive understanding of the relationship between crop riskiness and farmers' crop choices.

In this chapter, we derive the measures of crop riskiness that we will use in our analysis of the effect of farmer's risk preference on crop choices. We construct a measure of riskiness for the six most grown crops; per our Uganda REPEAT sample, these are cassava, sweet potatoes, beans, coffee, banana, and maize. The data we use do derive the measure of crop risk includes area of farmland for each crop, yield per hectare and district price for each crop. We define crop yield as the amount of harvested product (kg) divided by the crop area (hectares). It is important to note that, there is possibility of measurement error for some of the data.

It is difficult to estimate crop yields accurately, especially in the context of African farming systems characterized by smallholder farmers that produce a wide range of diverse crops (Fermont & Benson, 2011; Murphy, et al., 1991). In Uganda the challenges in estimating crop yield also include: (i) not all planted area is harvested, (ii) intercropping, (iii) in regions with an even rainfall distribution some farmers have a habit of continuously planting crops throughout the season or year, (iv) some crops like cassava, sweet potatoes, banana and coffee have extended harvest period and (v) no cadastral information on land use (Fermont & Benson, 2011).

In our REPEAT sample, some farmers practice intercropping: therefore, what they report to be the area of land for each crop could be a very rough estimation. The quality of the yield data may also suffer from measurement errors because some farmers measure their harvest in traditional ways (bags, bunches, gorogoro, debe and others) and when they are asked to report their harvest in kilograms it might not be very accurate. Moreover, since most smallholder farmers do not keep records of harvest and crop area, the accuracy of the information they provide during interviews depends heavily on their ability to recall.

Figure 4.1 presents the distribution of household yield (kg/hectare) for each of the six crops for all the years (2003, 2005, 2009, 2012, and 2015). Outliers may dramatically skew the results; therefore, household yield data is winsorized in order to improve statistical efficiency. The distribution of the yield per hectare for each of the crops shows that data is lumpy; this could be a result of farmers rounding off the estimates of their harvest or the share of land devoted to each crop.

[INSERT FIGURE 4.1 ABOUT HERE]

In Table 4.1, we present the mean yield values generated from REPEAT data and those obtained from FAOSTAT (2017)[19] for six crops. We find that mean yields from REPEAT data and FAOSTAT are not too different for most of the crops. However, we do find some huge discrepancies between our mean yields and those of FAOSTAT for some crops, for example, the FAOSTAT mean yield for cassava for year 2005 is more than five times that of the mean we obtain using REPEAT data, but the estimates converge more or less by 2012. Since the FAOSTAT cassava yield values change so much, it is possible there is measurement error in their data for years 2003, 2005, and 2009.

The yield distribution (Figure 4.1) and the large variance of the yield (Table 4.1) obtained using REPEAT data for five survey rounds show that the difference between the minimum and the maximum yield for each of the six crops is very huge. Such a huge difference is hard to account for, even if we assume that some of the households have better soil fertility, experience, or superior inputs. For this reason, we suspect that there could be some

[19] Food and Agriculture Organization of the United Nations (FAOSTAT) - http://www.fao.org/faostat/en/#data/QC

measurement errors in yield data. If the quality of our data suffers from measurement error then this may be problematic in our attempt to measure crop risk. Since we are not certain about the quality of some of our data, we consider two approaches in our estimation of crop riskiness namely the single-index model (Collins & Barry, 1986; Turvey, 1991; Bezabih & Di Falco, 2012) and variability in crop yields (Cernay, et al., 2015).

[INSERT TABLE 4.1 ABOUT HERE]

4.2 Single Index Model

The Single-index model (Collins & Barry, 1986) is derived from the portfolio theory. The model is a risk-return generating process that enables us to derive coefficients corresponding to the riskiness of each crop. The principal assumption is that revenues associated with various farm enterprises are related only through their covariance with some basic underlying index. The model decomposes crop risk into two, namely: nonsystematic risk and systematic/ non-diversifiable risk. Nonsystematic risk can be reduced through diversification since it is the crop's specific risk. On the other hand, systematic risk cannot be mitigated through diversification because it inherent in the portfolio. In other words, systematic risk measures the proportionate contribution of a crop's risk to the variance of the underlying index.   With respect to a portfolio, the systematic risk can be determined by defining an index comprised of the stochastic revenues of a reference portfolio (R_{pt}). The reference portfolio is the total return from the farmer's crop portfolio:

$$R_{pt} = \sum_{i=1}^{n} w_i R_{it} \tag{4.1}$$

where p stands for portfolio and R_{it} is the stochastic crop revenue for crop i at time t and w_i (weight for each crop) is the share of farm land allocated to growing crop i . The expected return of a portfolio is calculated as:

$$E(R_p) = \sum_{i=1}^{n} w_i E(R_i) \tag{4.2}$$

The portfolio variance (σ_p^2) defined as:

$$\sigma_p^2 = \sum \sum w_i w_j \, Q_{ij} \sigma_i \sigma_j \tag{4.3}$$

where Q_{ij} is the correlation between crop i and j. The standard deviation of crop i is σ_i. By definition, the variance of the portfolio is a function of the standard deviation of each crop and the correlation among the crops. The single-index model (SIM) is motivated by the stock market portfolio choice models (Turvey, 1991; Gempesaw, et al., 1988) . The model assumes a linear relationship between each crop's return and the portfolio return[20]:

[20] Refer to Collins & Barry (1986) for detailed derivations of systematic risk (beta coefficient).

$$R_{it} = \alpha_i + \beta_i R_{pt} + e_{it} \tag{4.4}$$

where R_{it} is the revenue from crop *i* at time t, α_i is the intercept and e_{it} is the error term. β_i captures the response of crop *i* to changes in the crop portfolio return (R_{pt}). The individual crop's systematic risk is computed as $\beta_i \sigma_p$. However, only beta is used as measure of a crop's systematic risk relative to the index because the market risk σ_p is common to all crops (Gempesaw, et al., 1988; Turvey, 1991).

The single-index model (SIM) is a computationally simple technique relative to other portfolio choice models; therefore, it is widely used in analyzing risk-return tradeoff in agriculture (Gempesaw, et al., 1988; Blank, 1991; Turvey, 1991). They are several assumptions used in SIM which include the following: (1) the return for each crop is influenced by only R_{pt} which is a macroeconomic factor (2) e_{it} the crop's residual variability, has no influence on the crop's ranking among alternative crops and (3) each crop is a small part of the overall crop portfolio. The first assumption suggests that microeconomics factors unique to each crop have no significant effect on the riskiness β_i of that crop. The second assumption is based on the SIM argument that a crop's residual variability can be reduced through diversification therefore it will have no effect on its ranking relative to other crops (Blank, 1991). Assumption (3) means that a single crop should not dominate the reference portfolio. Some of the assumptions of the SIM have been criticized by various authors (Blank, 1991; Bos & Newbold, 1984)

In this section, we use REPEAT household level panel data collected over 5 years (2003, 2005, 2009, 2012, and 2015). The panel data includes yield per hectare, share of farmland allocated to each crop and district price for each crop. Using fixed effects regression, we estimate equation (4.4) in order to derive the beta coefficient for each of the six major crops. Following Collins & Barry, we use the beta parameter as our measure of the crop's riskiness. We compute the beta coefficient using two different units of analysis, namely: (i) household and (ii) village. More precisely, we estimate beta for each crop within the household as well as within each village. Furthermore, we will consider two different methods: (1) we calculate the revenue of a reference portfolio using equal weight ($w_i = 1$) for all crops and (2) we compute the return of a reference portfolio using the share of farm land devoted to each crop as the ($w_i = share\ of\ land\ for\ crop\ i$) weight (Collins & Barry, 1986; Turvey, 1991; Bezabih & Di Falco, 2012).

Method (1)

First we use the revenue of a reference portfolio generated using equal weight (w_i) for all crops to estimate equation (4.4) in order for us to obtain the beta coefficient for each crop at (i) household level and (ii) village level. The beta coefficients obtained from the fixed effects regression of equation (4.4) are presented in Table 4.2.

[INSERT TABLE 4.2 ABOUT HERE]

Cassava has the lowest beta coefficient followed by sweet potatoes then banana for both household and village levels analysis. Maize has the highest beta coefficient at household level followed by beans. However, beans have the largest beta for village level. Crops with higher beta coefficient are riskier. In other words, among the six major crops cassava has the lowest risk followed by sweet potatoes and then banana.

Method (2)

We now use proportion of household farmland for each crop as weights in generating the revenue of a reference portfolio (R_{pt}). Similar to method (1), we use the calculated (R_{pt}) in the estimation of equation (4.4) at the household and village levels to determine the beta coefficient for each crop. In Table 4.3, we present the beta coefficients.

[INSERT TABLE 4.3 ABOUT HERE]

The results in Table 4.3 are very similar to the ranking of crop riskiness in Table 4.2. Cassava has the lowest beta coefficient, indicating that it is the least risky crop among the six major crops. Similarly, we find that maize has the highest beta coefficient when our unit of analysis is the household. However, the beta coefficient for maize is relatively larger compared to that of the other five crops when we use the weighted model. This could be because the share of land allocated to maize is very large such that there is a mechanical link between the left and right hand side of equation 4.4.

The results in Tables 4.2 & 4.3 indicate that bananas, maize, beans, and coffee consistently have higher beta coefficients than cassava and sweet potatoes. However, considering the results in table 4.2 & 4.3, it is not clear which of the four higher risk crops (bananas, maize, beans, or coffee) is the riskiest.

4.3 Variability in Crop Yields

Cernay et al. (2015) quantitatively analyze yield variability and risk of yield loss for major legume and non-legume crops. They use historical time series data to compute yield anomalies, which are used to estimate three different crop riskiness measures for four European and two American regions. The authors define yield anomalies as yield residuals. Following Cernay et al. (2015), we compute yield anomalies for each of the six major crops using panel data from five REPEAT surveys for the years 2003, 2005, 2009, 2012 and 2015.

The unit of analysis we use to calculate crop risk is village level data. In order to obtain the yield anomalies, we start by estimating the following specification:

$$Y_t = a + bT_t + e_t \tag{4.5}$$

where Y_t and T_t denotes the yield per hectare (at village level) and time t , respectively. e_t is the error term, a is the intercept and b is the parameter of the yield trend. The expected yield $\hat{Y}_t$ obtained from OLS regression of equation (4.5) is used to calculate the yield residual, $(Y_t - \hat{Y}_t)$ and the yield anomaly $\bar{Y}_t$, which is defined as,

$$\bar{Y}_t = \frac{Y_t - \hat{Y}_t}{\hat{Y}_t} \tag{4.6}$$

The yield residual is normalized to enable us to compare different crops with no dimension dependency. Using the yield anomalies, we estimate three different measures of crop riskiness: (i) 10^{th} percentile of yield anomalies, (ii) variance of yield anomalies and (iii) expected yield loss.

The 10^{th} percentile is defined as follows:

$$\Pr[\bar{Y}_t \leq q] = 0.10 \tag{4.7}$$

where q is the 10th percentile of the yield anomalies distribution and is the value beyond which the yield is considered to be a substantial loss.

The second measure of risk is Yield Variance, which is the squared value of the standard deviation. The following is the expression for standard deviation (SD):

$$SD = \sqrt{\frac{1}{T-1}\Sigma_{i=1}^{t}(\bar{\text{Y}}_t - \frac{1}{T}\Sigma_{i=1}^{t}\bar{\text{Y}}_t)^2} \quad (4.8)$$

Expected Yield Loss, which is the third measure of risk, is expressed as:

$$EYL = E[\bar{\text{Y}}_t|\bar{\text{Y}}_t < q] \quad (4.9)$$

The expected yield loss is the mean of yield anomalies that are less than the 10th percentile of the yield anomalies distribution.

In Table (4.4), we present the derived standard deviations, 10th percentile of yield anomalies and expected yield loss for each of the six major crops. The crops with the highest standard deviation have higher yield variance, thus they are riskier. Similarly, crops with higher absolute value for the 10th percentile of yield anomalies and expected yield loss have higher risk. Sweet potatoes have the lowest risk and beans have the highest risk for all three measures of risk. Cassava has the second lowest risk when we use the 10^{th} percentile of yield anomalies as well as the expected yield loss as our measure of risk. However, a classification of standard deviation shows that cassava has the third lowest risk. In case of maize, coffee and banana the risk measures give different rankings for the crops. For instance, the second risk measure (10^{th} percentile of yield anomalies) indicate that maize has the third lowest risk but the expected yield loss parameters show that maize has the second highest risk. Our results are somewhat similar to those of Cernay et al. (2015), in that the authors also find different crop rankings when they use the three different measures of risk.

[INSERT TABLE 4.4 ABOUT HERE]

4.4 Comparing Results from the two Approaches

Table 4.5 presents the ranking of the six main crops based on all the measures of crop risk. Below we will compare the results obtained using SIM to those from the variability in crop yields approach.

[INSERT TABLE 4.5 ABOUT HERE]

Case 1: Single-Index Model (Village level) vs Variance of yield anomalies

The order of crop riskiness that we observe when we use the single-index model for village yield per hectare is relatively similar to that of the variance of yield anomalies approach. Cassava, banana, and sweet potatoes are ranked lower risk compared to beans, coffee, and maize. Furthermore, the ranking of coffee derived from the single-index model is identical to that derived from the variance of yield anomalies. We also observe that maize and beans have higher risk compared to the other four major crops for both measures of risk.

Case 2: Single-Index Model (Village level) vs 10th percentile of yield anomalies

The two methods rank beans as the riskiest crop. Furthermore, for both risk measures, cassava and sweet potatoes are ranked as the top two lowest risk crops. However, it is important to note that cassava has the lowest beta coefficient and the second lowest 10th percentile of yield anomalies. Even though the two measures of risk give the same ranking in terms of riskiness for coffee and beans, the other four crops are ranked slightly differently.

Case 3: Single-Index Model (Village level) vs Expected yield loss

The ranking derived from the single-index model is almost identical to that of expected yield loss approach. Four crops namely coffee, maize, beans and banana are ranked the same by the two approaches. However, these two approaches rank the riskiness of cassava vs sweet potatoes differently. When we consider the single-index model, cassava has the lowest beta coefficient thus it is less risky than sweet potatoes and the other four crops. On the other hand, sweet potatoes have the lowest expected yield loss indicating that it has lower risk than cassava and the other four major crops.

Discussion

We think that the difference in the underlying assumptions could be the main reason why single-index model and variability in crop yields approaches give somewhat different results in our analysis. First, the variability in crop yields approach does not take into consideration the crop prices, while the single-index model does. Including crop price in measuring crop riskiness is essential if the farmers take their crops to market because the prices may vary greatly across seasons, districts, or regions. However, in case of our rural Uganda sample very few households participate in the market, so there is a chance that crop prices might not play a pivotal role in farmers' perception of crop risk. Second, the single-index model is based on the assumption that no crop dominates the portfolio. If one crop dominates then the order of bias will be larger for that crop's beta estimates thus overstating the riskiness of the crop. This issue is not a cause of worry when using the variability in crop yields approach because the share of farmland for each crop is not considered when estimating risk. Third, measurement errors in our data could also be the cause of the difference in crop rankings across these two approaches. In the single-index model, the beta coefficient (risk measure) is estimated using OLS, so measurement error in the independent variable will tend to bias the beta coefficients towards zero. However, since the single-index model takes into account the yields and crop prices of all crops grown by the farmers when calculating riskiness of each crop, the overall bias of measurement errors might diminish as the number of crops increases. In case of the variability in crop yields approach, it is hard to predict the direction of the bias for the risk measures. Since the variability in crop yields approach is centered on yield anomaly, which is a ratio of yields, for small farms the yield variability might be subject to large errors. Each one of the approaches that we use to estimate crop riskiness [single-index model and variability in crop yields] has limitations; which measure to use would depend on the policy issues that you will be trying to address.

4.5 Conclusion

Irrespective of which method we use, sweet potatoes and cassava are ranked as the lower risk crops compared to maize, beans, banana, and coffee. However, there are two exceptional cases in columns (1) and (6) of Table (4.5), in which banana is less risky than cassava or sweet potatoes, respectively. In general, cassava and sweet potatoes dominate the other four crops in terms of being less risky. Furthermore, the ranking of beans is either the riskiest or the second riskiest crop. However, our results are unclear with respect to the exact order of crop ranking for the crops because this varies with the method used to calculate the crop risk. Our results highlight the possibility that earlier work on riskiness of crops may not be entirely accurate.

A limited number of studies investigate the riskiness of crops grown in Uganda and most of the studies use qualitative approaches like farmers' interviews and survey. In a study carried out in Uganda, Veljanoska (2014) uses the single-index model to determine crop riskiness. The author's results indicate that cassava, sweet potatoes and maize have the same risk (beta coefficient=0) and these three crops have lower risk compared to coffee, beans and bananas. Furthermore, the results also suggest that among our 6 main crops, banana has the highest risk (beta coefficient). The discrepancies in the author's findings and ours could be due to a number of reasons: (i) we do not include Northern region in our analysis because due to security issues (Kony rebel war) we could not conduct surveys in the region for the years 2003, 2005, 2009 and 2012, (ii) Veljanoska (2014) uses the household's weighted income as the reference portfolio; however, in our study following Turvey (1991) and Bezabih & Di Falco (2012) we use the sum of weighted individual crop value as the reference portfolio, (iii) the author does not explicitly state whether he uses gross or net income, in our case we use gross returns; if the author uses net income then that can also account for some of the differences in our results (Gempesaw, et al., 1988). Some studies highlight that in Uganda, cassava and sweet potatoes are low risk crops (Kapoor, 1993; Mubiru, et al., 2015; Van Campenhout, et al., 2016), this is somewhat similar to our results.

In the next chapter, we examine the effect of risk preference on the choice to grow and share of farmland devoted to growing low- and high-risk crops. The results we obtain on crop riskiness indicate that in Uganda, cassava and sweet potatoes are the low-risk crops and beans are high-risk crops. Therefore, the crops that we consider in chapter 5 are sweet potatoes, cassava, and beans.

CHAPTER 5

The Effect of Farmer's Risk Preference on Household Crop and Input Choices in Rural Uganda

5.1 Introduction

Agriculture involves many forms of risk such as uncertainties in weather and yields, price or market risk, plant diseases and pests. Furthermore, perceived risk linked with fertilizer use and other crop intensification strategies adds to the inherent risks of farming [Dercon, 1996; Van Campenhout, et al., 2016]. Therefore, risk influences the welfare of rural households who heavily depend on agriculture for their livelihoods [Kurosaki & Fafchamps, 2002]. Due to the absence of complete credit and insurance markets in rural areas of developing countries, the farmers attempt to control farming risk through risk management strategies [Hazell, et al., 1986; Fafchamps, 1992; Alderman & Paxson, 1992]. Risk management strategies used by farmers include devoting part of farmland to low risk crops which are usually low return crops [Dercon, 1996] and avoiding modern inputs. However, if farmers devote disproportionate farm area to famine reserve crops (low return crops) they are most likely to remain poor and locked in a poverty trap [Dercon, 1996; Van Campenhout, et al., 2016].

A number of studies have acknowledged the likely importance of risk preferences in household decision-making [Kapteyn & Teppa, 2002; Tanaka & Yamano, 2015]. Despite the critical role played by risk in household production choices, only a few studies examine the impact of farmers' risk attitude on crop and input choices [Fafchamps, 1992; Yusef & Halilemariam , 2011; Bezabih & Sarr, 2012; Verschoor, et al., 2016]. The majority of the studies that consider the effect of risk on farmers' production choices; (i) do not use incentivized measures of risk attitude (ii) have limited geographical variations within the countries of study (iii) omit other aspects of preferences [e.g. loss aversion and time preference parameters] and (iv) assume which crops are riskier and which are safer. These studies have generally concluded that risk-aversion is associated with farmer's production choices. Though hypothetical experiments are less costly and easier to perform with a larger sample than real payoff experiments, economists are skeptical about whether the observed personal attitudes and traits are behaviorally meaningful (Dohmen, et al., 2011). Including other preference parameters is necessary because some studies find that behavioural biases such as loss aversion influence agricultural choices (Liu, 2013; Bougherara, et al., 2012; Ward & Singh, 2015). This chapter sets out to extend existing literature on the determinants of crop and input choices using an incentive-compatible measure of risk attitude, other aspects of preferences and historical data on crop riskiness as key factors.

The main aim of our study is to evaluate the effect of the household head's risk preference on crop choices and fertilizer-use. More precisely, the principal questions that this study addresses are: (a) does risk preference influence the probability of a farmer to grow low or high risk crops?, (b) what is the effect of risk attitude on the share of farmland devoted to low or high risk crops?, and (c) what is the effect of farmer's risk attitude on adoption and intensity of chemical fertilizer-use?. We use data from field experiments and panel data from the Research on Poverty, Environment, and Agricultural Technology (RePEAT) survey covering 94 villages and 1289 randomly selected households in eastern, central, and western Uganda for the years 2003, 2005, 2009, 2012, and 2015. The measures of risk aversion and loss aversion that we use in our analysis are elicited from real payoff field experiments.

Generally, the findings indicate that risk and time preferences do play a role in the farmers' decision-making. More risk averse farmers are more likely to grow low risk crops such as sweet potatoes. Higher loss aversion is associated with larger share of land for beans (high-risk crop) but inversely related to the choice to grow sweet potatoes (low-risk crop). The farmer's time preference only influences the choice to grow sweet potatoes; however, it has no significant effect in case of beans and cassava. With respect to fertilizer, risk preference significantly influences its adoption. However, only loss aversion significantly influences the intensity of fertilizer-use.

In the next section, we present the background, theoretical and conceptual framework. Section 3 describes data used and descriptive statistics. Section 4 presents the experimental design and implementation. Section 5 explains the estimation strategy. In section 6, we present and discuss the main results, then in section 7 we conclude.

5.2 Background

5.2.1 Agriculture in Uganda

In Uganda poverty remains firmly embedded in the rural areas where 80 percent of the country's population live [FAO, 2008; IFAD, 2012]. Rural households depend heavily on agriculture for their livelihoods since it is the major source of food and income. IFAD (2012) highlights that in Uganda, helping rural farmers to move from subsistence farming to market-oriented production would increase their incomes and improve their living standards and levels of food security.

Agriculture plays a vital role not only in the livelihoods of rural households but also in Uganda's economy as a whole. The sector is the backbone of the economy because it employs 73% of the working population, contributes 24% to GDP, accounts for 48% of exports, and provides the bulk of the raw materials for most of the industries that are predominantly agro-based [MAAIF, 2011]. The Government of Uganda looks to the agricultural sector to drive growth and contribute to further reduction of rural poverty [MAAIF, 2011; IFAD, 2012].

Small-scale farmers dominate the sector and they account for 90% of the farming community; however, their yields remain low due to various reasons that include low adoption of modern inputs and technology [PARM, 2015]. Agriculture in Uganda faces various challenges and these include low productivity due to declining soil fertility [Okoboi & Barungi, 2012;

Pender, et al., 2004]. Although fertilizer use is recognized as one of the key strategies to increase agricultural productivity, there is extremely low level of inorganic fertilizers use in rural Uganda [Okoboi & Barungi, 2012; Deininger & Okidi, 2001; Pender, et al., 2004; Bayite-Kasule, et al., 2011]. According to Van Campenhout, et al., 2016, risk is an important barrier to sustainable crop intensification methods like fertilizer use in Uganda. Smallholder farmers view the use of fertilizer as a risky choice because even though on average it may increase profitability, it may also increase variance in crop yield especially with rain-fed agriculture [Seligman, et al., 1992].

Crop production in Uganda is mostly rain-fed making it vulnerable to weather hazards and climate change [PARM, 2015]. Since agriculture is almost entirely rain-fed, weather shocks increase the riskiness of growing crops that are highly sensitive to drought [UoG, 2007; Komutunga & Musiitwa, 2001]. Consequently, some of the risk management strategies used by farmers in rural Uganda include income skewing and crop diversification. More precisely, the farmers select a crop mix that varies along attributes such as resilience to drought and time to maturity in order to reduce covariance in output [Mubiru, et al., 2015; Van Campenhout, et al., 2016].

The most commonly grown famine reserve crops in Uganda are cassava and sweet potatoes [Kapoor, 1993; Mubiru, et al., 2015; Van Campenhout, et al., 2016]. The production of these two crops is widely and evenly distributed across regions. Cassava and sweet potatoes have very comparable characteristics. Both crops have high yield ability and a low yield risk because of minimum labour requirements, drought resistance: they can be stored in-ground and the farmers can stagger their harvest taking advantage of market price swings [Hall, et al., 1998; Jameson, 1970; Mugisa, 2010; Mukasa, 2003]. It is important to note that cassava and sweet potatoes are perceived as food for the poor or as a famine food in Uganda [Hall, et al., 1998]. However, over the years both crops are increasingly been grown by subsistence farmers as a cash crop for sale as cheap food to the Uganda urban poor [Hall, et al., 1998; Mugisa, 2010]. In the previous chapter, we computed the degree of crop riskiness for six of the most commonly grown crops as per our Uganda RePEAT sample. The results in Table (4.4) indicate that sweet potatoes and cassava are lower risk crops compared to maize, beans, banana, and coffee. In general, cassava and sweet potatoes dominate the other four crops in terms of being less risky and beans are ranked as either the riskiest or the second riskiest crop.

In Table (5.1), we show the average prices for the years 2003, 2005, 2009, 2012 and 2015 of the three crops (cassava, sweet potatoes, and beans) that we will consider in this chapter. The price of beans is more than double that of cassava and of sweet potatoes. Therefore, in case of our Uganda sample, beans is high-risk high return while cassava, and sweet potatoes are both low risk, low return crops.

[INSERT TABLE 5.1 ABOUT HERE]

Due to the absence of complete credit and insurance markets in rural Uganda, crop diversification is one of the limited risk management strategies that the farmers can use. However, if the farmers allocate disproportionate share of the farm to low-risk low-return crops such as sweet potatoes and cassava, they may find themselves locked in a poverty trap. Furthermore, the decline in agricultural productivity due to declining soil fertility is contributing to poverty and food insecurity [Pender, et al., 2004]. Therefore, it is important to understand the factors that influence crop choice and those that hinder chemical fertilizer use.

5.2.2 Literature Review

Farming involves risk and the level of risk faced by farmers varies with crops and input choices. Therefore, risk plays a critical role in farmer's production decision making. However, very limited studies have examined the effect of the farmer's risk attitude on crop and input choices.

There is empirical evidence that risk preferences play a critical role in farmer's decision-making both ex ante and post production. When yields are variable and uncertain there is a postulated link between risk attitude and the planting of riskier and safer crops. Some studies find a significant relationship between risk preferences and farmers' choice of crop mix

[Shahabuddin, et al., 1986; Fafchamps, 1992; Kurosaki & Fafchamps, 2002; Bezabih & Sarr, 2012].

Using a model of crop portfolio choice under multivariate risk and preferences, Fafchamps (1992) examines assumptions regarding risk and preferences using simulations. The conclusion of the study is that in absence of full insurance, exposure to risk is likely to influence farmer's choice of crops. The study in Pakistan by Kurosaki & Fafchamps (2002) examines how the presence of price and yield risk affects crop choices. The results indicate that farmers' production decisions are affected by the presence of risk. In some papers, the authors derive the estimate of risk attitude. Using survey data from Bangladesh, Shahabuddin et al. (1986) constructs a quantitative estimate of the risk coefficient based on the safety-first model of farmer behavior. The authors find that some households have positive coefficient for risk and they suggest that these households are expected to "gamble" on riskier but more profitable crops than those with a negative risk coefficient.

Several papers use a measure of risk attitude obtained through experiments [Binswanger, 1980; Bezabih & Sarr, 2012]; this is somewhat similar to how we obtain our measure of risk. Bezabih et al. (2012) using an experimentally generated measure of risk preference examines the extent to which risk and rainfall variability affect crop decisions in Ethiopia. The results provide evidence that farmers with higher risk aversion have higher level of crop diversity. Binswanger (1980) uses an experimental gambling approach with real payoffs to observe the households' attitude towards risk in rural India. They conclude that rural farmers care about the gain and losses in a choice rather than their final wealth position.

Secondly, some works find that farmers' risk preferences influence their input choices such as fertilizer-use. However, some authors find a positive relationship [Hagos & Holden, 2011] while others find an inverse relationship [Roosen & Hennessy, 2003; Yusef & Halilemariam , 2011; Verschoor, et al., 2016] between risk aversion and adoption of fertilizer.

Roosen and Hennessy (2003) conclude that risk-averse producers use less nitrogen than risk-neutral ones. However, the authors also highlight that there is weak evidence to support that an increase in risk aversion leads to lower input use. Hagos and Holden (2011) examine the role of farmer's risk aversion in fertilizer-use using a measure of risk aversion obtained from hypothetical experiments carried out in Ethiopia. The authors conclude that there is a positive correlation between risk attitude and adoption of fertilizer. On the other hand, in another study carried out in Ethiopia, using a measure of risk derived from real payoff experiments, Yusef and Halilemariam (2011) find a negative relationship between adoption and intensity of fertilizer-use, and risk aversion. Similarly, in a study carried out in eastern Uganda, Verschoor et al. (2016) elicited risk preferences using both risky choice and hypothetical experiments. The results suggest that an increase in risk aversion reduces fertilizer-use.

Understanding the determinants of low-income farmers' production behavior is critical for developing effective agriculture related policies like crop insurance, land reform, subsidies and price supports that can be implemented to facilitate agricultural sector development and poverty reduction. Various studies have highlighted that crop choices are related to the farmer's risk attitude: however, few studies used measured risk in their analysis. We use measured risk to access the impact of the household head's risk attitude on crop and input choice. Furthermore, we also control for loss aversion and time preference. Our two main variables of interest are the share of farmland devoted to growing each crop and quantity of fertilizer used by each household. In our Uganda RePEAT sample, the widely grown crops are cassava, sweet potatoes, beans, banana, maize, and coffee. However, in this chapter we focus on the share of farmland devoted low risk crops (cassava and sweet potatoes) and to beans, which has higher return and ranked higher risk than cassava and sweet potatoes[21].

5.2.3 Conceptual Framework

Harry Markowitz Model (1952) posits that the optimal portfolio for a risk-averse investor will not be as risky as the portfolio of an investor who is willing to accept more risk and the model emphasizes that risk is an inherent part of higher reward. In the context of agriculture, the more risk-averse farmers' crop and input portfolio will be less risky than that of less risk-averse farmers. More precisely, the more risk-averse farmers would devote greater share of their farmland to low risk crops or are less likely to adopt modern inputs that are perceived to be risky compared to risk neutral farmers.

[21] Refer to Tables 4.4 & 5.1

5.2.3.1 Risk and Time Preferences and Share of Farmland for Low Risk Crops

We use a portfolio choice model to analyze how risk attitude influences the share of land devoted to growing food security crops. Dercon (1992) models a portfolio choice model in which the household has to decide how much land to allocate to two crops. One of the crops is low risk with a certain income and the second crop is risky but has higher expected income. The primary goal of this model is to examine the impact of the availability of liquid assets (livestock) on the share of land devoted to growing low risk low return crops. The model highlights the importance of time preference and risk-aversion in farmer's utility maximization problem. The first-order conditions derived from the utility maximization problem using the portfolio choice model indicate that risk preferences influence share of land for low risk crops. Dercon (1992) mentions that factors other than liquid assets also affect share of land, however, in the final model the impact of risk preference is rather unclear. On the other hand, although the rate of time preference appears in the utility function, it does not influence the share of land devoted to less risky crop. We provide more details about the model and the mathematical illustration in Annex (5.1).

In case of loss aversion and present bias there are no standard theoretical production models. However, since the rate of time preference does not influence the share of land for low risk crop in the Dercon (1992) model, we would not expect the degree of present bias to do so.

Furthermore, based on the standard model for the investment decision we expect loss aversion to influence share of farmland used for growing low risk crops. The portfolio choice and trading volume model suggests that loss aversion influences the optimal portfolio choice of loss-averse investors. More precisely, the trading volume and the stocks portfolio for investors with high degree of loss aversion are different from that of lower loss aversion investors [Gomes, 2005]. In agriculture production, a farmer chooses a crop portfolio taking into consideration the probabilities of success and failure of each crop as well as profit/loss associated with each possible outcome. For instance, modern crops that require a lot of purchased modern inputs (i.e. fertilizer, improved seeds), could yield a farmer negative profit if they fail, however, if the crop is a success the farmer receives large profits compared to traditional crops. The farmer's decision-making process is loosely similar to that of an investor in the stock market. Intuitively, we would expect loss-averse farmers to grow less of modern crop because of the possible negative outcome and grow more of the traditional crop, which in worst-case scenario would yield zero profit if we consider the wealth at the beginning of the production season as the reference point.

5.2.3.2 Risk and Time Preference and Adoption of Chemical Fertilizer

Fertilizer use is considered risky because even though it increases the mean output, the degree of yield variability increases with the level of fertilizer. Furthermore, the issue of farmers' subjective risk plays a role in the farmer's decision to adopt fertilizer-use. Feder (1980) models an optimization problem that incorporates fertilizer use under uncertainty. The author's main goal is to determine variables that influence adoption of new farming technology. The first-order conditions derived from the maximization problem highlights that the optimal level of fertilizer per acre is independent of the degree of risk aversion. In Annex (5.2), we provide more details about the model. We expect that if farmers use the current wealth as a reference point then loss-averse farmers will be reluctant to pay for fertilizer.

Duflo et al. (2011) develop a simple model of biases in farmer decision making. The authors argue that behavioral biases such as farmer's impatience and present-bias limit profitable investments in fertilizer in developing countries.

[INSERT TABLE 5.2 ABOUT HERE]

Our study aims to address three main questions: (1) does risk preference influence the probability of a farmer to grow low or high-risk crops (2) what is the effect of risk attitude on share of farmland devoted to low or high-risk crops, and (3) how does the farmer's risk attitude influence the adoption and intensity of fertilizer-use. Furthermore, we also examine whether time preference influences crop choice or fertilizer use? The starting point of our analysis is the theoretical predictions shown in Table (5.2).

5.2.4 Measuring Risk and Time preferences

We elicit risk and time preference measures using experiments. In this section, we highlight how we derive the parameters from the results obtained in the experiments.

Risk aversion

Assuming a Constant Relative Risk Aversion (CRRA) utility function over experimental earnings Y, which is defined as $(Y) = \frac{Y^{1-\delta}}{1-\delta}$, the curvature of the utility function δ is the coefficient of CRRA. The sign of δ indicates the individual's risk preference. That is when δ<0 the individual is risk-loving, δ>0 the person is risk-averse and δ=0 indicates risk neutral. Following Holt & Laury (2002), the subjects in our experiments were faced with pair-wise choices which had varying probabilities, p_i and payoffs, Y_i. We compute δ by equating two choices that give the same level of expected utility to the participant. In order to find the CRRA coefficient range for each participant, we calculate δ at the switching points (i.e. participant's choice switches from lottery A to B). For example, referring to figure (5.1), say the participant chooses Column A for rows 1-1 through 1-4 and then switches to column B, the CRRA coefficient range lower bound will be derived from solving for δ for this equation[$4000^{(1-\delta)} = 0.5(7000)^{(1-\delta)} + 0.5(2000)^{(1-\delta)}$]. The risk aversion parameter for each participant is calculated as the mean of the lower and upper bound parameters of the CRRA coefficient range.

We expect risk-loving participants to switch to lottery B before row 1-3 ($\delta < 0$), while risk averse individuals switch to B after row 1-4 ($\delta > 0$). The risk neutral participants are expected to switch to lottery B when δ is around zero.

Loss aversion

In order for us to elicit the degree of loss aversion, we use lottery games that include losses and gains. Kahnemen & Tversky (1979) developed the Prospect theory, which highlights the importance of loss aversion when individuals make decisions. According to the Prospect theory, loss aversion is the notion that people value wealth relative to a given reference point and they are much more sensitive to losses than gains of the same amount. We estimate loss aversion (λ) using the mean value of each individual's CRRA coefficient (δ) and the following value functions $u(Y) = Y^{1-\delta}$ and $u(Y) = -\lambda(-Y)^{1-\delta}$. The first value function is for gains and the second one is for losses, $Y > 0$ and $Y < 0$ respectively. The interval of the loss aversion coefficient will depend on each individual's switching point for risk 4.

Time Preference

We compute the subjective discount rate and present bias parameters using data from games 5 through 8. Similar to the risk games the participants are given pair-wise choice of money, however, this is a hypothetical game. Games 6 and 8 are used to derive the subjective discount rate. In order to derive the subjective discount rate we equate the switching points between two choices using the following value function $v(Y) = Y_0 + \beta \sum_{t>0} \frac{1}{(1+r)^t} .(Y_t)$; where r

is the discount rate, Y_0 is the present value for the participant for payoff Y_t that is to be received at time t.

To elicit the degree of present bias we use games 5 and 7. Present bias refers to the tendency of people to give stronger weight to a smaller immediate payoff over a larger delayed payoff, yet when the same option is presented with both payoffs delayed, people are more inclined to wait the extra year to get the larger payoff [O'Donoghue & Rabin, 1999]. The pair-wise choices in game 5 and 6 are identical but the only difference is in the timing of payment. If there is no present bias the switching points for games 5 and 6 would be identical, similarly we would expect the same for games 7 and 8. We estimate present bias (β) using the mean value of each individual's discount rate (r) and the following value function, $v(Y_0) = \frac{1}{(1+r)^t} \cdot v(Y_t)$. In deriving the present bias, we assume that $v(Y_t) = Y_t$ and we equate the switching points between two choices.

We exclude participants with irrational answers for risk and time games from our analysis because we cannot estimate such parameters; irrational answers include multiple switching points and reversed choices.

5.3 Data and Descriptive Statistics

5.3.1 Data

We use survey and experimental data collected in rural Uganda in 2003, 2005, 2009, 2012, and 2015, as part of the Research on Poverty, Environment, and Agricultural Technology (RePEAT). The households were sampled from the respondents to a previous household survey on policies for improved land management in Uganda, conducted by the International Food Policy Research Institute (IFPRI) and Makerere University from 1999 to 2001 [Pender, et al., 2004]. The coverage of the IFPRI survey was 107 local councils 1s (LC1s) and these were selected through stratified random sampling. The selected LC1s were selected from two-thirds of the regions in Uganda and they represent seven of the nine major farming systems of the country. The LC1s from the north and northeastern part of the country were not included in the sample due to security issue (Kony rebel war).

The RePEAT surveys were jointly conducted by Makerere University, the Foundation for Advanced Studies on International Development (FASID), and the National Graduate Institute for Policy Studies (GRIPS). The first RePEAT survey in 2003 was carried out in 94 of 107 LC1s studied by IFPRI. The total number of households interviewed was 940; from each IFPRI's LC1, the RePEAT survey randomly selected additional households, such that each LC1 has 10 households to make a total of 940 sample households.

The survey data collected contain basic household composition and demographics, wealth, and economic activities as well as community level variables. The data also includes parcel-level information on land tenure systems, land conflicts, land use, and crop inputs just to mention a few. The experiment data includes risk-aversion, loss aversion, discount rate, and present bias variables for the year 2009 [Tanaka & Yamano, 2015].

In our main analysis, we use RePEAT survey data for the years 2009, 2012, and 2015[22] and we only consider households that participated in the Risk and Time games. Attrition rate over the years 2009, 2012, and 2015 is about 4.9 percent. We report the summary statistics for the household and village level in Table (5.3). There is no notable difference in the age of the household head between the game and non-game households for all the years. On average, the years of education of the household head is 6 for both the game and non-game households in all three-survey rounds. The average household size is large and it is relatively constant over the survey rounds. Man typically heads households, less than 15% of the sampled households have a female head. The average size of land holdings is around 7 acres; however, for the year 2012 there is large difference for game households. With respect to the household characteristics, the game and non-game households were on average similar within the years with the exception of livestock value and farm size. On average, the village level characteristics are similar for the game and non-game households.

[22] The risk and time preference data was collected in 2009, since the standard economic models suggest that risk and time preferences are relatively stable over time, we use the same preference parameters for the years 2012 and 2015. We use these years in our main analysis because preference parameters elicited in 2009 are not causally affected by planting decisions in 2009 and the years after.

[INSERT TABLE 5.3 ABOUT HERE]

The household head's average risk and time parameters are presented in Table (5.4). The average household head is moderately risk averse because mean risk aversion is 2.15. The mean loss aversion parameter is 8.07, indicating that the average farmer's disutility from a loss of a dollar will be equivalent to utility derived from gaining 8 dollars. The loss aversion mean is relatively high but the median is 2.5; this could be because many subjects that showed risk-loving behavior in the gains only game might have chosen the safest options in the gains and losses game. On average, the household heads have a discount rate of 29% and the degree of present bias is 0.76.

[INSERT TABLE 5.4 ABOUT HERE]

5.3.2 Descriptive Statistics

In Table (5.5), we show the general trend in share of land for the six mostly grown crops and fertilizer use for the years 2003, 2005, 2009, 2012, and 2015 for the panel. The share of land for all the crops is relatively constant over time. The quantity of fertilizer-used seems to be increasing over time but it is still very low, in 2003 the average quantity of fertilizer-used was 1.06kg/ha and in2015 it was 2.68kg/ha in 2015. It is important to note that fertilizer use was highest in 2009; this was largely due to the experimental interventions on maize production carried out on RePEAT households in January 2009. The experimental interventions included distributing free inputs (maize hybrid seeds, base and top-dressing fertilizer) and providing training on how to use the modern inputs to households within randomly selected RePEAT villages (20 in Central and 26 in Eastern regions) in Uganda [Matsumoto, 2014]. Moreover, in August and September 2009 the team visited some villages three times to sell the same modern inputs while offering discount rates (0%, 10%, or 20%) from the market price.

[INSERT TABLE 5.5 ABOUT HERE]

We present the descriptive statistics regarding share of land devoted to cassava, sweet potatoes, beans, and fertilizer quantity across risk aversion quartiles for the years 2009, 2012, and 2015 in Table (5.6.). Households in the fourth quartile have the higher degree of risk aversion compared to those in lower quartiles. There is a significant difference in the mean share of land devoted to cassava between the first and fourth quartile (1% significance level). In general, there is a positive relationship between risk aversion and share of land devote to growing cassava. With respect to share of land devoted to growing sweet potatoes there is no significant difference in means of the forth and first quartiles. Share of farmland allocated to growing beans declines when risk aversion increases. The mean share of land for beans for the first quartile is higher than that of the forth quartile and the difference is statistically significant (1% level). There is no significant difference in the average quantity of fertilizer per hectare when we compare the two extreme risk aversion quartiles.

[INSERT TABLE 5.6 ABOUT HERE]

5.4 Experimental Design and Implementation

5.4.1 Experimental Design

We use the Holt and Larry (2002) pair-wise choice framework to design our experiment. In order to derive true preferences we use real payoffs for risk games however, time preference games were played hypothetically because in the case of time preferences making future payments would involve cumbersome arrangements since a negligible percentage of the sample households have a bank account. Each participant played eight games in total: that is four risk and four time preference games. The subjects before starting the games are informed that one of the risk games will realize and they will be given money based on theirs answers. Figure (5.1) and (5.2) replicates the answer sheets used in risk game 1 and time game 6, respectively.

[INSERT FIGURE 5.1 ABOUT HERE]

[INSERT FIGURE 5.2 ABOUT HERE]

Participants were required to choose between column A and B in all the games. This choice was repeated eight times with different pairs of lotteries for both risk and time games. Column A for risk games 1 through 3 offers a definite payoff of 4000USh. On the other hand, Column B contains two possible payoffs with given probabilities. Column A and B for risk games have circled numbers which represent the number of each ball; we use four balls to make the issue of probability clearer to our participants. For instance, if a participant chooses Column A if risk game 1, 2 or 3 is played for real; then whatever ball is drawn he/she will be given 4000USh. However, if risk game 1 row 1-2 is played for real and the subject chooses Column B, then if ball 1 or 2 is drawn he/she receives 5500USh. If ball 3 or 4 is drawn, the payoff will be 2000USh.

The payoffs, probabilities of each payoff for the risk games and the risk-aversion parameters are shown in Appendix Table (5.1). For time games the payoffs, times of payment and discount rates are shown in Appendix Table (5.2). For risk games 1, 2 and 3 the participants would always get a positive payoff. These three games are used to measure the participants' risk aversion. In order for us to elicit loss aversion, we include losses and gains in risk game 4. In case of time, games 6 and 8 are used to derive discount rate and games 5 and 7 to elicit the degree of present bias.

5.4.2 Implementation

The participants are led through a discussion on how the games are to be played. Then the experimenter illustrates chances of possible outcomes using 4 balls while engaging the subjects. Furthermore, the experimenter demonstrates how the bingo machine is used to pick a row. After the questions raised by participants with regard to the games instructions have been answered, they start to play the real risk games. Once all subjects choose their answers, the experimenter picks one game by asking two of the participants to draw a random ball from 1 through 4 (sheet) and 1 through 8 (row). Then each participant picks a random ball 1, 2, 3 or 4 from the bingo machine, the ball determines the payoff he/she receives. Since a loss was possible if risk game 3 realized, we gave all subjects 5000USh for participating in the game. Therefore, since the highest possible loss is 4000USh, the lowest net payoff would be 1000USh. The time preference game was played after the risk game following the same procedure; however, this was a hypothetical game.

5.5 Estimation strategy

In this section, we highlight empirical specifications that we employ to examine the effect of risk and time preference on crop and input choices. Firstly, we estimate the determinants of the choice to grow each one of the three crops (cassava, sweet potatoes, and beans). Secondly, we test whether the household head's risk attitude and time preference influence the share of farmland allocated to each crop. Thirdly, we consider the determinants of adoption of fertilizer. Then lastly, we examine the effect of farmer's risk and time preferences on intensity of fertilizer-use. Table (5.7) presents all the control variables used in our analysis[23].

[INSERT TABLE 5.7 ABOUT HERE]

5.5.1 Risk Attitude and Choice to grow each crop

The choice to grow a crop depends on household, crop and community level characteristics. In order to test whether risk and time preferences affect the probability of a farmer to grow each of the three crops, we consider the following form:

$$GROW_{hdit} = 1\{\beta X_{hit} + \phi_{dt} + \mu_{hdit} > 0\} \quad (5.1)$$

Our dependent variable $GROW_{hdit}$ is a binary variable equal to 1 if the household h in district d grows crop i at time t and zero otherwise. X_{hit} is a set of household, farm, crop and community characteristics. Household characteristics include age, years of education, gender, degree of present bias, discount rate, risk aversion, and loss aversion of the household head, dependency ratio, number of males and females above 10 years, livestock value per adult,

[23] Some variables (remittance, non-farm income, and credit-receiver dummy variables) are potentially endogenous.

and land holdings (hectares). Also included are dummies for non-farm income (=1 if household has nonfarm income and 0 otherwise), remittance (=1 if household received remittance and 0 otherwise), credit access (=1 if household received credit and 0 otherwise), wealth and participation in ROSCA (=1 if household participate and 0 otherwise). Wealth is a categorical variable; we have four wealth categories namely: poorest_wealth, poor_wealth, nonpoor_wealth and rich_wealth. We generate the wealth categories using the quartiles of household wealth. We define household wealth as the total value of assets and livestock. We use attitude as a proxy for farm characteristics and climate. Crop characteristic include crop yield variability and 10th percentile of yield residuals[24] for each district, which we computed in the previous chapter; we include both because they reflect different aspects of risk. Crop yield variability highlights the spread of the yield data while the 10th percentile reflects crop yield loss. Furthermore, the 10th percentile of yield residuals to some extent reflects the skewness of the distribution; we suspect that the skewness of the distribution (right-skewed) of yield anomalies might matter. Community level characteristics included are distance to nearest district town and type of road (=1 if tarmac and 0 otherwise). ϕ_{dt} captures the district-year unobservable characteristic that influence crop choice. μ_{hdit} is the error term and β represent the vector of parameter estimates. We use the Probit model to estimate the probability of growing each crop.

[24] In our regression analysis, we consider the absolute value of the 10th percentile of yield residuals (we drop the negative sign to make interpretation easier). A higher absolute value means higher risk.

5.5.2 Risk Preference and Crop's share of farmland

To examine whether risk and time preferences affect the proportion of land allocated to crops that have different risk ranking, we estimate the following equation:

$$SHARE_{hdit} = \beta X_{hit} + \Phi_{dt} + \mu_{hdit} \quad (5.2)$$

where $SHARE_{hdit}$ is the share of farmland allocated to crop i at time t by household h in district d. X_{hit} is a set of household, farm and community characteristics which are exactly the same as the ones we use above in the Probit model. Also the parameters, Φ_{dt}, μ_{hdit} and β are defined exactly the same as above (section 5.1).

The data on share of land devoted to crop i is only available for households that grow that particular crop; therefore, our dependent variable has a skewed distribution. Given the nature of our dependent variable of interest [have many of zero observations] we use a Tobit model to estimate equation (5.2).

In case of many zeros for the dependent variable, the Tobit model assumes a corner solution. However, this assumption is restrictive because there is a possibility that zero observation could be due to non-participation or participation rather than just allocating zero share of farmland to a crop. In other words, Tobit model is inappropriate if the choice to grow a crop is decoupled from the amount of land allocated to that crop. Therefore, we also use Cragg's double hurdle model to estimate the effect of risk preference on the share of farmland for a crop. The model postulates that individuals pass two separate hurdles before they are observed with a positive level of output. In the context of farmers, the decision to grow a crop has two components. The first hurdle corresponds to the choice to grow a crop and the second to the share of farmland to allocate to that crop. In this study, we use a double hurdle model that has two equations [equations (5.1) & (5.2)]. Equation (5.1) explains the determinants of growing a crop and equation (5.2) explains factors that influence the share of land devoted to a crop.

5.5.3 Determinants of Adoption of Fertilizer

The farmer's choice to use fertilizer is influenced by household, farm and community characteristics in the form:

$$FERT\_AD_{hdt} = 1\{\beta Z_{ht} + \phi_{dt} + e_{hdt} > 0\} \tag{5.3}$$

$FERT\_AD_{hdit}$ is a dummy variable equal to 1 if household h in district d uses fertilizer at time t and zero otherwise, where h = 1, …,N and t = 1, …, T. Z_{ht} is a set of household, farm and community characteristics. The household characteristics include dependency ratio, household size, livestock value per adult, land holdings, and dummies for non-farm income, remittance, wealth, credit receiver, and participation in ROSCA: age, education, gender, ethnicity, risk attitude, loss aversion, impatience, and degree of present bias of the household head. We also include the number of crops grown by the household and crop dummy variables (=1, if the household grows the crop) for each of the six mostly grown crops (cassava, sweet potatoes, beans, banana, maize and coffee). We use altitude as a proxy of farm level characteristics. Community level characteristics include distance to nearest district town, type of road (=1 if tarmac and 0 otherwise) and district average price of fertilizer. ϕ_{dt} captures the district-year unobservable characteristic which affect fertilizer adoption. e_{hdt} is the error term and β represent the vector of parameter estimates. In order to examine the effect of risk preference on adoption of fertilizer, we use the Probit model to estimate equation (5.3).

5.5.4 Risk Preference and Intensity of Fertilizer-use

In order to examine the impact of risk preference on intensity of fertilizer-use, we consider the following equation:

$$FERT\_QT_{hdt} = \beta Z_{hit} + \phi_{dt} + e_{hdit} \tag{5.4}$$

$FERT\_QT_{hdt}$ refers to the quantity of fertilizer used (kg/ hectare) by household h in district d at time t. The parameters ϕ_{dt} , e_{hdt} and β are defined as above. Z_{ht} is a set of household, farm and community characteristics. The household, farm, and community level characteristics are identical to those in equation (5.3). We estimate equation (5.4) using a Tobit model.

5.6 Results

5.6.1 Risk Preference and Choice to grow & share of farmland for each crop

Cassava

In Table (5.8), we present the estimation results on the determinants of growing cassava and the share of land devoted to growing the crop. The Probit results in Columns (2) show that risk and time preference parameters do not have significant effect on the probability to grow cassava. However, some household, crop, and village characteristics have significant effect on the choice to grow cassava. Households in regions where cassava has higher yield variance and 10^{th} percentile of yield residuals are more likely to grow cassava. This is a puzzling result because it suggests that households in districts where the riskiness of cassava is higher are more likely to grow cassava. The possible explanation is that for a significant number of districts the majority of crops have high yield variance and 10^{th} percentile of yield residuals due to harsh weather or soil conditions. Therefore, even though cassava riskiness will be higher than other districts, it will still be less risky compared to other crops within that district. The choice to grow cassava is positively related to the dependency ratio and number of males in the household. Cassava is considered a food security crop, and is one of the most important staple foods in Uganda, accounting for a large proportion of caloric intake (Haggblade & Dewina, 2010). Therefore, it is not surprising that larger households are more likely to grow cassava. Altitude has negative impact on the decision to grow cassava. This result is consistent with studies, which suggest that cassava is mostly grown in drought prone areas because it is drought resistant [Hall, et al., 1998; Jameson, 1970; Mugisa, 2010; Mukasa, 2003].

Results in Column (1) suggest risk and time preferences do not influence the share of land devoted to growing cassava. The results in Column (3) are consistent with those in Column (1) with respect to both risk and time preferences. Although the risk aversion parameter is not statistically significant in all specifications, it seems to correlate positively with both the choice to grow cassava and share of land devoted to growing it. Furthermore, we find that yield variance and the 10th percentile of yield residuals are negatively related to share of land for cassava. This indicates that households in regions where cassava has higher riskiness devote less share of land to cassava.

[INSERT TABLE 5.8 ABOUT HERE]

Sweet Potatoes

The estimation results for the determinants of growing and allocating a share of farmland to sweet potatoes are shown in Table (5.9). Column (2) suggests that both risk and time preferences influence the decision to grow sweet potatoes but the discount rate has no significant effect. More risk averse farmers are more likely to grow sweet potatoes; this is probably due to the low riskiness of the crop. There is positive relationship between the choice to grow sweet potatoes and present bias. Sweet potatoes have short growing period, can easily be intercropped with maize and other crops, can be stored in-ground and farmers can stagger their harvest taking advantage of market price swings. Therefore, myopic farmers might choose to grow sweet potatoes because they can get immediate financial reward from harvesting the crop at their desired points in time (sequential harvesting). Furthermore, loss aversion has a negative impact on the likelihood of growing sweet potatoes. The crop is susceptible to destruction by microorganisms and pests (Okonya, et al., 2014); therefore, loss averse farmers might be less willing to incur the cost of pesticides because if the crop fails after using pesticides they will have negative returns. Other determinants of the decision to grow sweet potatoes include the 10^{th} percentile of yield residuals, ROSCAs participation, and altitude. There is an inverse relationship between altitude and the choice to grow sweet potatoes, this result is not surprising. Higher altitude is generally associated with moderate to high rainfall; since, sweet potatoes are drought resistant, we expect that sweet potatoes are mostly likely to be grown in drought prone areas [Hall, et al., 1998; Jameson, 1970; Mugisa, 2010; Mukasa, 2003]. ROSCAs participation reduces the chance to grow sweet potatoes. Households that are members of the Rotating Savings and Credit Associations (Roscas) are less likely to grow sweet potatoes; this is not surprising because savings are also risk coping strategy. Farmers tend to grow low risk crops as consumption security mechanisms; however, if they have savings they will have an alternative safety net for 'bad' years. Households in districts with a higher 10^{th} percentile yield residual (sweet potatoes) are less likely to grow and devote less share of farmland to the crop.

Columns (1) and (3) report the Tobit model estimation results on the share of land allocated to growing sweet potatoes. The results in Column (1) indicate that farmers with higher degree of present bias devote larger share of land to sweet potatoes; however, other preference parameters are not significant. In Column (3), risk and time preferences are not significantly associated with the share of land for sweet potatoes. In both specifications the 10th percentile of yield residuals, and altitude are negatively related to share of land for sweet potatoes. Farmers in the poorest wealth category tend to devote larger share of farmland to sweet potatoes compared to those in the rich wealth category. The results indicate that households that receive remittance allocate a lower share of land to sweet potato; the results are as we expected. Farmers in Uganda consider sweet potatoes as a food security crop so they grow it as a consumption security mechanism; however, if they have liquid assets (wealth) or receive remittance, they will have an alternative safety net for 'bad' years.

[INSERT TABLE 5.9 ABOUT HERE]

Beans

Table (5.10) reports the estimation results for the determinants of growing and allocating a portion of the farmland to beans. The Probit results in Column (1) reveal that risk attitude and time preference do not influence the choice to grow beans. Gender, education, wealth, landholdings, yield variance, 10th percentile of yield residuals, and credit access are inversely related to the probability of growing beans. On the other hand, number of crops grown and number of males and females above 10 years are positively associated with the choice to grow beans.

The estimation results on share of farmland allocated to growing beans are in Columns (1) and (3). Results in column (1) suggest that more risk averse farmers devote less share of farmland to beans. Higher degree of impatience is associated with larger share of land for beans. In both Columns (1) and (3), present bias does not influence the share of farmland allocated to beans. Loss aversion is only significant when we use Craggit estimation. More loss averse farmers devote a larger share of land to beans. Although risk aversion parameter is not statistically significant, it seems to correlate negatively with the choice to grow and share of land for a high-risk crop beans. Other determinants of share of land for beans in Column (3) are yield variance, 10th percentile of yield residuals, dependency ratio, wealth, landholdings, altitude, number of crops grown, and distance to town. Households in districts with higher beans yield variance and/ or 10th percentile of yield residuals devote less share of land to beans. Higher altitude is positively associated with share of land for growing beans; this is expected because beans require fertile soils and water.

[INSERT TABLE 5.10 ABOUT HERE]

5.6.2 Determinants of Adoption and Intensity of Fertilizer-use

Table (5.11) presents the determinants of adoption and intensity of chemical fertilizer-use[25]. The results in column (1) suggest that farmers with higher risk aversion are less likely to use fertilizer. There is a positive association between loss aversion and fertilizer-adoption. This result is opposite of what we expected. The possible explanation is that the farmers are less concerned with the possible loss associated with one input (fertilizer) but more concerned about the total loss because farming involves other purchased inputs such as seeds and pesticides. For instance, farmers who purchases seeds might consider the use of fertilizer as a way to reduce the probability of crop failure that would yield them negative returns. Time preference has no significant effect on the decision to use fertilizer. Other statistically significant determinants of fertilizer-use are household head education and age, wealth, ROSCAs participation, non-farm income, altitude, free input intervention and crops grown. Households with more educated heads are more likely to use fertilizer. This is consistent with previous studies that suggest that education creates a favorable mental attitude for researching and accepting new practices (Caswell, et al., 2001).

Columns (2) and (3) report the estimated results of the Tobit model. Results in Column (2) suggest that risk and time preferences do not significantly influence intensity of fertilizer use. However, Column (3) indicates that more loss averse farmers use more fertilizer per hectare.

[25] In Appendix Table (5.4), we present results obtained from estimating equation (5.3) without the risk aversion/loss aversion variable.

The coefficients of head education, non-farm income, credit access, free input intervention, and altitude are positive and significant. The effect of non-farm income is as we expected, with higher income the household can afford to purchase more fertilizer (Green & Ng'ong‘ola, 1993). The age of the household head is negatively associated with intensity of use; this is consistent with the findings in prior studies (Kebede, et al., 1990). These results may indicate that older people are unaware of modern technologies or they are used to traditional ways such that the idea of doing things differently seems far-fetched.

[INSERT TABLE 5.11 ABOUT HERE]

In Table (5.12), we highlight the effect of a change in risk preference from high degree of risk aversion (risk aversion parameter = 6.07) to low aversion/ risk loving (risk aversion parameter= -0.62). The results indicate that when an individual shifts from high aversion to risk loving the share of land that they devote to cassava and sweet potatoes (low risk crops) decline by 0.00629 and 0.00399, respectively. On the other hand, the change in preference results in larger share of land devoted to high-risk high return crop (beans). The results also indicate that the change in risk attitude will increase the quantity of fertilizer per hectare by 0.08kgs.

[INSERT TABLE 5.12 ABOUT HERE]

Appendix Table (5.3) presents the robustness checks where we investigate whether there is attrition bias or not. First, we generate inverse weights for each household by probit estimation of attrition on pre-determined covariates. Then we regress cassava share of land on both the weighted and non-weighted household and community level characteristics, the results from the two models are similar. Furthermore, we carry out a Hausman test, we fail to reject Ho (p-value=0.994); therefore, the difference in coefficients of the two models is not systematic. The results in Appendix Table (5.3) indicate that attrition bias does not confound the main results.

5.7 Conclusion

Farming involves risk therefore, risk plays a critical role in farmer's production decision making. We examine the effect of the household head's risk and time preferences on the share of land allocated to cassava, sweet potatoes and beans, the adoption and intensity of chemical fertilizer-use.

The findings suggest that risk and time preferences do not influence the farmer's decision to grow cassava as well as the share of farmland devoted to growing it. This result contradicts Dercon and the standard investment models predictions of the effect of risk preferences on share of land devoted to low risk crops in our case cassava. Time preference does not influence the share of land for cassava; this result is consistent with Dercon's prediction but it contradicts the standard investment model prediction.

Secondly, the results suggest that risk preference is associated with the choice to grow sweet potatoes. More risk averse farmers are more likely to grow sweet potatoes but the reverse is true for farmers with high loss aversion. Higher degree of present bias is associated with higher probability of growing sweet potatoes. Both risk and loss aversion do not influence the share of land devoted to growing sweet potatoes, this result contradicts both Dercon and the standard investment models predictions. Furthermore, time preference has no significant effect on the share of land allocated to sweet potatoes. This contradicts the standard investment model prediction that there is a significant relationship. However, the results support Dercon's prediction that the degree of present bias and the discount rate do not influence the share of land devoted to low risk crops.

Thirdly, we find that risk attitude and time preference do not significantly influence the decision to grow beans. With respect to the share of land for beans, loss aversion has a significant effect but risk aversion and time preference do not. Loss aversion is positively related to the share of land allocated to beans (a high-risk crop), this somewhat contradicts the standard investment model predictions.

Fourthly, our findings indicate that the household head's risk preference influence the adoption of chemical fertilizer. Farmers with higher loss aversion are more likely to use fertilizer. On the other hand, more risk averse farmers are less likely to adopt fertilizer. However, time preference parameters do not influence the choice to use fertilizer. We also find that higher degree of loss aversion is associated with larger quantities of fertilizer per hectare. Risk aversion does not have a significant effect on intensity of fertilizer-use. This contradicts the standard investment model that predicts an inverse relationship between risk aversion and intensity of fertilizer-use. However, this is consistent with Feder's proposition that risk aversion has no effect on quantity of fertilizer used per hectare. Furthermore, time preference does not influence the intensity of fertilizer use. This contradicts Duflo's predictions that both present bias and the discount rate are negatively associated with fertilizer use.

Moreover, we find that both crop yield variance and 10th percentile of yield residuals have a strong effect on the share of land allocated to growing beans, sweet potatoes, and cassava. Thus, they contribute to the variations in cultivated areas for each crop. The households in districts where the yield variance or 10th percentile of yield residuals of a crop is higher tend to devote less share of farmland to that particular crop with the exception of cassava. We also find that the crop yield variance and 10th percentile of yield residuals of other crops grown in a district affect both the choice to grow a crop and share of farmland devoted to it.

Our study has several limitations. First, there is possibility of measurement error for some of the data [share of land for each crop, yield per hectare and prices for each crop and fertilizer] that we use in deriving crop riskiness. Due to the concerns of measurement error, we use two different standard methods to calculate crop riskiness [single-index model and variability in crop yields] and we find somewhat similar results. In the single-index model, the beta coefficient (risk measure) is estimated using OLS, so measurement error in the independent variable will tend to bias the beta coefficients towards zero. However, since the model takes into account the yields and crop prices of all crops grown by the farmers, the overall bias of measurement errors might diminish as the number of crops increases. On the other hand, it is hard to predict the direction of the bias for the risk measures when we use the variability in crop yields approach. Second, the experimental preference data is only available for the household head; maybe if we had preferences data for all spouses the results would be different. Although our assessment has some limitations, our evidence is the first of its kind thus partially filling a gap in the literature.

Generally, the findings indicate that risk and time preferences do play a role in the farmers' decision-making. More risk averse farmers are more likely to grow low risk crops such as sweet potatoes. Although the risk aversion parameter is not statistically significant, it seems to correlate negatively with the choice to grow and share of land for a high-risk crop beans. Loss aversion is positively associated with the share of land for beans (high-risk crop) but inversely related to the choice to grow sweet potatoes (low-risk crop). The farmer's time preference only influences the choice to grow sweet potatoes; however, it has no significant effect in case of beans and cassava. We also find that the choice to grow and share of farmland devoted to a crop is influenced by the crop's riskiness (crop yield variance and 10^{th} percentile of yield residuals) as well as by the riskiness of other crops grown in that district. Since there is an inverse relationship between crop risk and the choice to grow the crop, policy makers could design some form of crop insurance to encourage the growing of that crop. However, a holistic approach to risk has to be taken when designing policies to promote growing of a crop because reducing the riskiness of one crop may have counter-intuitive impacts on the planting of other crops. Therefore, we recommend decision makers to take into consideration not just the risk and time preferences of the farmers but also the riskiness of the crops. With respect to fertilizer, risk preference significantly influences its adoption. However, only loss aversion significantly influences the intensity of fertilizer-use. The negative relationship between risk aversion and the probability to use fertilizer indicates that farmers perceive fertilizer as risky. Therefore, there is need to educate farmers about the benefits of intensification in order to change their perception and encourage them to practice intensified cropping.

CHAPTER 6

Conclusions and Policy Implications

6.1 Introduction

A wide range of studies have highlighted that African countries need to increase their efforts to improve agriculture productivity in order to achieve economic development and reduce poverty. However, the continent's agricultural performance is falling further behind that of other developing regions of the world (Toenniessen, et al., 2008; Benin, 2016). Among the factors identified to have an effect on agriculture productivity are group-based inequalities (land ownership and wages), agricultural risk, and farmer's risk preference.

In Africa, the majority of rural households are subsistence farmers who rely on family labour. Therefore, understanding the factors that influence effort and other production choices in the context of the household is essential. However, experimental and empirical studies on the factors that influence intra-household production choices are limited; this dissertation attempts to fill in the gap in literature. First, we evaluate the impact of entitlements and relative wages on spouses' production effort. Second, we calculate measures of crop riskiness for each of the most commonly grown crops and rank the crops as low- or high-risk. Third, we examine the effect of the head's risk preference on household crop and input choices.

The following section summarizes the study's main findings. In the third section, we highlight the policy implications of our finding. We discuss the limitations of the study and conclude in the fourth section.

6.2 Summary of Findings

6.2.1 Do entitlements and relative wages influence spouses' production effort?

In Chapter 3, we evaluate the impact of entitlements and relative wages on spouses' productivity. The results generally indicate that both relative wages and entitlements influence individuals' productivity. We find an inverse relationship between relative wage and relative output: partners paid relatively more work relatively less. This result contradicts the unitary and collective model predictions of the effect of relative wage on relative output but it is consistent with the predictions of some non-cooperative models. We also find that the impact of relative wage on relative output can differ across sharing rule categories.

Regarding the manipulation of property rights over the output from the experiment, our results show that entitlements do influence relative output in a manner that is not clearly supportive of any particular model. However, what is notable is that separate payment leads to the highest level of output. This suggests that when individual have full ownership of the reward they exert more effort. We also find that women and men respond differently to changes in entitlements and spouse's wage rate. Furthermore, for both male and female participants there is no significant difference in household output when we compare the "Sharing equally" and "Men gets all" categories.

6.2.2 An estimation of the riskiness of crops grown in rural Uganda

We use two different standard methods to measure the degree of crop riskiness, one based on portfolio theory (Single Index model) and one based on direct measures of variability around a trend (Variability in crop yields approach). First, we calculate crop riskiness using the Single Index model. We find that cassava has the lowest risk and beans are either the riskiest or the second riskiest crop. When we use the variability in crop yields approach, we find that sweet potatoes are the lowest risk crop while beans are the riskiest or second riskiest.

Irrespective of which method we use, sweet potatoes and cassava are ranked as the lower risk crops compared to maize, beans, banana, and coffee. We also find that the ranking of beans is either the riskiest or the second riskiest crop. However, our results are unclear with respect to the exact order of crop ranking for the crops; for instance in some cases, cassava is ranked less risky than sweet potatoes and sometimes the reverse is true. Although the ranking is unclear, cassava and sweet potatoes dominate the other four crops in terms of being less risky. Our results are consistent with other studies in Uganda, which highlight that cassava and sweet potatoes are low risk crops.

6.2.3 The effect of farmer's risk preference on household crop and input choices

In chapter 5, we examine the effect of risk preference on crop and input choices. The chapter addresses four main questions: First, what is the impact of risk preference on the probability of a farmer to grow low- or high-risk crops? Second, how does risk attitude influence the share of farmland devoted to low- or high-risk crops? Third, what is the effect of farmer's risk attitude on adoption and intensity of chemical fertilizer-use? Forth, does time preference influence crop and input choices? Based on the results we obtained in chapter 4, we use sweet potatoes and cassava as the low risk crops and beans as the high-risk crop.

Generally, the findings indicate that risk and time preferences influence farmers' decision-making. More risk averse farmers are more likely to grow low risk crops such as sweet potatoes. Higher loss aversion is associated with larger share of land for beans (high-risk crop) but inversely related to the choice to grow sweet potatoes (low-risk crop). The farmer's time preference only influences the choice to grow sweet potatoes; however, it has no significant effect in case of beans and cassava. We also find that the riskiness of the crops influence the probability of growing a crop and share of land devoted it. With respect to fertilizer, risk preference significantly influences its adoption. However, only loss aversion significantly influences the intensity of fertilizer-use.

6.3 Policy Implications

Improved agricultural productivity leads to increased food security, poverty reduction, economic growth, and development; therefore, understanding the determinants of agricultural productivity is essential. Our findings in chapters 3 and 5 suggest that relative wages, entitlements, and risk preferences influence the production choices within households.

In most African countries gender inequality with respect to property rights and wages are very large (African Development Bank, 2012; Mukasa & Salami, 2016). Currently, in Africa titled land remains the de facto preserve of wealthy households and within households, men (Ali, et al., 2014). A number of studies have highlighted women's lack of access to land as one of the sources of inequality between women and men (Jones, 1983). However, there is a strong evidence of persistence of gender disparities with respect to ownership of property in Africa countries including Uganda (Deere & Doss, 2006; Asiimwe, 2014). In chapter 3, we find that for both male and female participants there is no significant difference in household output when we compare the "Sharing equally" and "Men gets all categories". This result gives support to the idea that equitable policies to promote the advancement of women can be achieved with no detrimental effect on productivity. In other words, the adjustment of property rights for married people can be used as a tool to reduce gender inequality and this would have no inverse effect on economic growth.

The findings in chapter 5 suggest that risk preference play a role in farmers' decision-making.

Risk aversion positively influences the probability to grow low risk crops. Furthermore, although risk aversion parameter is not statistically significant, it seems to correlate negatively with the choice to grow and share of land for a high-risk crop beans. We also find that both the crop yield variance and the 10th percentile of yield residuals significantly influence planting decisions. More precisely, the choice to grow a crop and share of farmland devoted to it is influenced by the crop's riskiness as well as by the riskiness of other crops grown in that district. The farmers in districts where the yield variance or 10th percentile of yield residuals of a crop is higher tend to devote less share of farmland to that crop. Since there is an inverse relationship between crop risk and the choice to grow the crop, policy makers could design some kind of crop insurance to encourage the growing of that crop. However, policy makers need to take a holistic approach to risk when designing policies to promote growing of a crop because reducing the riskiness of one crop may have counter-intuitive impacts on the planting of other crops. We recommend decision makers to take into consideration not just the riskiness of the crops but also risk and time preferences of the farmers. Our results also indicate that there is a negative relationship between risk aversion and the probability to use fertilizer. This suggests that farmers perceive fertilizer as risky; therefore, there is need to educate farmers about the benefits of intensification in order to change their perception and encourage them to practice intensified cropping. Since risk influences both planting decisions and input choices, agricultural insurance can contribute to improving agricultural productivity.

6.4 Limitations of the study

Our study has several limitations. In chapter 3, we attempt to examine the impact of entitlements on productivity. Our results indicate that for both male and female participants there is no significant difference in household output when we compare the "Sharing equally" and "Men gets all categories". Various studies have highlighted that women's lack of access to land is one of the sources of inequality between women and men in developing countries. Our result suggests that adjusting ownership rights from just husband to couple can reduce gender inequality with no inverse effect on household productivity. However, we acknowledge that there is a long distance between the controlled circumstances of our experiment and major policy changes. More precisely, the effect on productivity of adjusting property rights for spouses might be more complex than that of varying entitlements over a day's earnings.

In chapter 4, we estimate crop riskiness using two different standard methods, one based on portfolio theory (Single-Index model), and the other on direct measures of variability around a trend (variability in crop yields approach). There are two major concerns in this chapter. The first issue is with regard to some of the assumptions of the models. The single-index model is based on the assumption that no crop dominates the portfolio. If one crop dominates then the order of bias will be larger for that crop's beta estimates thus overstating the riskiness of the crop. This issue is not a cause of worry when using the variability in crop yields approach because the share of farmland for each crop is not considered when estimating risk.

The second issue is the possibility of measurement error for some of the data. First, some farmers practice intercropping: therefore, what they report to be the area of land for each crop could be a very rough estimation. Second, some farmers measure their harvest in traditional ways (bags, bunches, gorogoro, debe and others) and when they are asked to report their harvest in kilograms it might not be very accurate. Third, since most smallholder farmers do not keep records of harvest and crop area, the accuracy of the information they provide during interviews depends heavily on their ability to recall. Therefore, there is a possibility that the quality of the yield data may suffer from measurement error; we define crop yield as the amount of harvested product (kg) divided by the crop area (hectares). We use crop yield data to estimate the measures of crop riskiness. If there is measurement error in our data, the implications on the results on crop riskiness depends on the method used in calculating risk. In the single-index model, the beta coefficient (risk measure) is estimated using OLS, so measurement error in the independent variable will tend to bias the beta coefficients towards zero. However, since the single-index model takes into account the yields and crop prices of all crops grown by the farmers when calculating riskiness of each crop, the overall bias of measurement errors might diminish as the number of crops increases. In case of the variability in crop yields approach, it is hard to predict the direction of the bias for the risk measures. Since the variability in crop yields approach is centered on yield anomaly, which is a ratio of yields, for small farms the yield variability might be subject to large errors.

In chapter 5, we have constraints imposed by the dataset. The experimental preference data is only available for the household head; maybe if we had preferences data for all spouses the results would be different. Furthermore, the results in this chapter heavily depend on the accuracy of the results obtained in chapter 4; the crops we analyze in chapter 5 are chosen based on their riskiness.

In conclusion, although our assessment has some limitations, our evidence is the first of its kind thus partially filling a gap in the literature. We hope that our study provides some guidance for future research. Furthermore, we hope this dissertation will stimulate further research on the effect of property rights, relative wages, and risk and time preferences on intra-household production decisions.

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Table 3.1: Summary of Household Models Predictions

Increase or change in variable	Effect on	Model: Unitary	Collective	Non-cooperative
w_1 / w_2	e_1 / e_2	+	+	?
w_1	e_1	?	?	?
w_1	e_2	-	-	-
1 takes all →Other case	e_1 / e_2	0	+	0
Other case → 2 takes all	e_1 / e_2	0	+	0
1 takes all →Half	e_1	0	+	0
1 takes all → Separate	e_1	0	+	0
1 takes all → 2 takes all	e_1	0	+	0
1 takes all →Half	e_2	0	-	0
1 takes all → Separate	e_2	0	-	0
1 takes all → 2 takes all	e_2	0	-	0

Note: In these models, the value of output produced by person i=1,2 is $w_i e_i$ where w_i is the wage rate faced by person i in the task and e_i is the number of straws produced or effort.

Table 3.2: Summary statistics for demographic and socio-economic characteristics

Variable	Mean	(Std. Dev.)	Min	Max	N
Household-level characteristics					
Age	34.656	7.709	20	50	784
Years of education	6.005	3.418	0	16	784
Number of children	4.628	1.893	1	11	784
Household size	10.469	3.589	5	27	784
Per Capita Consumption (US$)	48.007	39.984	4.506	236.985	656
Hours engaged in earning activities (per day)	5.385	2.597	0	13	780
Days in the past week this person slept under a bed net	5.813	2.594	0	7	780
Female share of farm labour	0.404	0.211	0	1	492
Male share of farm labour	0.429	0.231	0	1	492
Community-level characteristics					
Proportion of households who can (currently) afford at least two meals a day	72.390	30.039	0	100	748
Average land size in acres per household	2.529	1.936	0.25	10	748
Total number of tribes	3.187	5.715	1	45	748
Distance to the nearest district town (miles)	16.984	14.733	1	66	748

Notes: 1. Standard deviations are in parentheses. 2. Per capita consumption is valued at October 2015 rate of 1US$=3690 Uganda Shillings. 3. N refers to the total observations. Since the subjects did the task twice, this is twice the number of individuals.

Table 3.3: Descriptive Statistics

variables		Mean (Output)	Std. Dev	Min	Max	N
Game Round	Round 1	5.635	(2.422)	0	12	392
	Round 2	7.809	(2.641)	0	13	392
Gender	Male	6.763	(2.658)	0	13	392
	Female	6.681	(2.852)	0	13	392
Sharing rule	Man gets all.	6.768	(2.738)	0	13	207
	Sharing	6.468	(2.797)	0	13	267
	Paid separately	7.006	(2.608)	0	13	174
	Woman gets all.	6.763	(2.866)	0	13	135
Spouse wage	USh300	6.620	(2.900)	0	13	363
	USh600	6.907	(2.542)	0	13	367

variables		Mean (Relative Output)	Std. Dev	Min	Max	N
Game order	Round 1	1.177	(1.010)	0	10	380
	Round 2	1.156	(0.898)	0	11	388
Sharing rule	Man gets all.	1.122	(0.790)	0	7	202
	Sharing	1.163	(1.023)	0	10	259
	Paid separately	1.132	(0.646)	0	4	173
	Woman gets all.	1.286	(1.318)	0	11	133
Relative wage	0.5	1.368	(1.437)	0	11	177
	1	1.146	(0.820)	0	10	409
	2	1.022	(0.519)	0	3.333	181

Table 3.4: Summary of Household Model Tests (unconditional)

Variable	Effect on	Model t-stat	p-value	Comment on sign
w_1 / w_2 (0.5 →1)	e_1 / e_2	-1.49	0.069	Opposite to prediction
w_1 / w_2(0.5 →2)	e_1 / e_2	-3.022	0.001	Opposite to prediction
w_1 / w_2(1 →2)	e_1 / e_2	-2.42	0.009	Opposite to prediction
w_1	e_1 (male)	-0.721	0.471	-
w_1	e_2 (female)	0.596	0.276	Opposite to prediction
w_2	e_1	1.592	0.056	Opposite to prediction
w_2	e_2	0.824	0.411	-
1 takes all →2 takes all	e_1 / e_2	1.290	0.100	Matches prediction
1 takes all→Half	e_1 / e_2	0.534	0.297	Matches prediction
Separate → 2 takes all	e_1 / e_2	1.900	0.031	Matches prediction
1 takes all →Half	e_1	-1.284	0.100	Opposite to prediction
1 takes all → Separate	e_1	-0.918	0.180	Opposite to prediction
1 takes all → 2 takes all	e_1	-0.468	0.320	Opposite to prediction
1 takes all →Half	e_2	0.702	0.242	Opposite to prediction
1 takes all → Separate	e_2	-1.734	0.043	Matches prediction
1 takes all → 2 takes all	e_2	-0.252	0.401	Matches prediction

Notes: tests are 1-tailed when Unitary/ collective models make clear directional prediction, 2-tailed otherwise.

Table 3.5: Regression results - Relative output

VARIABLES	Relative output
Round	-0.118*
	(0.0693)
Relative_wage	-0.326**
	(0.135)
Sharing	0.164
	(0.327)
Paid separately	-0.579***
	(0.209)
Woman gets all.	0.811
	(0.824)
Relative_wage* Sharing	-0.0932
	(0.281)
Relative_wage * Paid separately	0.500***
	(0.169)
Relative_wage* Woman gets all.	-0.510
	(0.600)
Region 2	-0.162
	(0.193)
Region 3	-0.424**
	(0.200)
Region 5	0.102
	(0.222)
Trust game dummy(=1, if spouse comes first on the game script)	0.166
	(0.141)
Risk dummy(=1, if Production is before risk game)	0.118
	(0.159)
Age	-0.0163**
	(0.00752)
Spouse's Age	0.00478
	(0.00903)

Education	0.0579***
	(0.0146)
Spouse's education	-0.0430
	(0.0286)
Average Peer output	-0.106**
	(0.0421)
Peer rule 1	0.0604
	(0.0885)
Peer rule 2	-0.0415
	(0.0769)
Constant	2.674***
	(0.631)
Observations	384
R-squared	0.116

Notes: Standard errors in parentheses clustered at the village level.*** p<0.01, ** p<0.05, * p<0.1. p-values are from a two-tailed test.

Table 3.6: Regression results - Absolute Output

VARIABLES	(1) Output	(2) Output
Round	2.346***	2.159***
	(0.150)	(0.142)
Own_wage_rate	-0.0220	-0.127
	(0.0854)	(0.0821)
Spouse_wage_rate	0.111	0.0891
	(0.168)	(0.150)
Sharing	1.192	-0.396
	(0.974)	(1.090)
Paid separately	1.427	0.788
	(0.967)	(1.103)
Woman gets all.	-1.144	-0.220
	(1.418)	(1.189)
Spouse_wage_rate * Sharing	-0.281	0.0548
	(0.227)	(0.206)
Spouse_wage_rate * Paid separately	-0.208	-0.288
	(0.219)	(0.202)
Spouse_wage_rate * Woman gets all.	0.292	0.0126
	(0.297)	(0.239)
Region 2	-0.101	0.118
	(0.441)	(0.395)
Region 3	-0.388	-0.533
	(0.546)	(0.387)
Region 5	0.175	0.749**
	(0.483)	(0.359)
Trust game dummy(=1, if spouse comes first on the game script)	0.129	0.489*
	(0.318)	(0.289)
Risk dummy(=1, if Production is before risk game)	-0.260	-0.349
	(0.353)	(0.268)
Age	-0.0520*	-0.0725***
	(0.0279)	(0.0268)
Spouse’s Age	0.0287	0.0164

	(0.0261)	(0.0277)
Education	0.171**	0.176***
	(0.0638)	(0.0477)
Spouse’s education	-0.0266	0.0916*
	(0.0543)	(0.0518)
Average Peer output	0.450***	0.392***
	(0.152)	(0.109)
Peer rule 1	0.220	0.412*
	(0.287)	(0.220)
Peer rule 2	-0.364**	-0.321*
	(0.164)	(0.168)
Constant	-0.0499	1.831
	(1.597)	(1.803)
Observations	391	391
R-squared	0.332	0.418

Notes: Standard errors in parentheses clustered at the village level.*** p<0.01, ** p<0.05, * p<0.1. p-values are from a two-tailed test

Table 3.7: Household Models Predictions and Empirical Results

Increase or change in variable	Effect on	Model			
		Unitary	Collective	Non-cooperative	Empirical result
w_1 / w_2	e_1 / e_2	+	+	?	-
w_1	e_1	?	?	?	0
w_1	e_2	-	-	-	0
Entitlements	e_1 / e_2	0	+/-	0	+/-
Entitlements	e_1	0	+/-	0	+/-

Table 4. 1: Household Yield (kg/hectare) for 6 crops

	MEAN YIELD (kg/hectare)								
	2003		**2005**		**2009**		**2012**		**2015**
CROP	REPEAT	*FAO*	REPEAT	*FAO*	REPEAT	*FAO*	REPEAT	*FAO*	REPEAT
Cassava	2672.0	*13456.8*	2230.3	*14408.3*	2123.4	*7182.9*	2624.5	*3297.3*	2264.1
	(3131.9)		(2409.0)		(2343.7)		(2563.4)		(2482.9)
Sweet Potato	4125.3	*4386.6*	4039.9	*4413.6*	3679.2	*4541.9*	4441.4	*4097.3*	4740.8
	(4000.4)		(3744.7)		(3739.0)		(3978.9)		(4711.4)
Coffee	1237.6	*571.5*	552.5	*601.1*	573.1	*612.1*	974.2	*573.5*	544.3
	(na)		(711.7)		(743.7)		(2088.7)		(677.6)
Maize	1022.3	*1831.0*	1387.6	*1585.9*	1370.5	*2499.6*	1352.5	*2499.1*	1380.7
	(1020.9)		(1363.2)		(1325.8)		(1226.5)		(1179.0)
Banana	2885.3	*4480.2*	2722.4	*4430.1*	2455.0	*4304.1*	2485.1	*4304.1*	2165.2
	(3850.2)		(3745.2)		(3125.9)		(3792.0)		(2643.9)
Beans	547.9	*673.1*	614.3	*577.3*	582.5	*488.6*	627.6	*1299.9*	649.0
	(589.9)		(606.9)		(598.8)		(563.9)		(624.2)

Note: 1. Standard deviations are in parentheses. 2. FAO refers to Food and Agriculture Organization of the United Nations (FAOSTAT). 3. The Standard deviation for the yield for FAOSTAT is not provided on the website. 3. For the year 2003 we only had 1 household in our sample with coffee yield data

Table 4. 2: Beta Coefficients when ($w_i = 1$)

Crop Name	**Beta Coefficient**	
	Household level	Village level
Cassava	0.000562	0.000949
Sweet Potato	0.00478	0.00379
Coffee	0.123	0.0450
Maize	0.247	0.0571
Banana	0.00630	0.0285
Beans	0.215	0.175

Table 4. 3: Beta Coefficients ($w_i = share\ of\ land\ for\ crop\ i$)

Crop Name	**Beta Coefficient**	
	Household level	Village level
Cassava	0.000547	0.0125
Sweet Potato	0.0327	0.0327
Coffee	0.635	0.361
Maize	0.855	0.21
Banana	0.0126	0.261
Beans	0.747	0.583

Table 4. 4: Three Measures of Risk (Village level)

	RISK MEASURE		
	Standard Deviation	10th Percentile	Expected Yield loss
CROP	(1)	(2)	(3)
Cassava	1.017	-0.668	-0.804
Sweet Potato	0.756	-0.601	-0.727
Beans	5.637	-2.529	-6.313
Maize	6.293	-0.669	-4.789
Banana	0.888	-0.796	-0.959
Coffee	1.850	-0.773	-1.080

Table 4. 5: Crop Ranking

RANKING (6 is riskiest)	RISK MEASURES						
	Crop Yield Variability			*Single-Index Model*			
	Standard Deviation	10th Percentile	Expected Yield loss	Household level	Village level	Household level(W)	Village level(W)
1	S Potato	S Potato	S Potato	Cassava	Cassava	Cassava	Cassava
2	Banana	Cassava	Cassava	S Potato	S Potato	Banana	S Potato
3	Cassava	Maize	Banana	Banana	Banana	S Potato	Maize
4	Coffee	Coffee	Coffee	Coffee	Coffee	Coffee	Banana
5	Beans	Banana	Maize	Beans	Maize	Beans	Coffee
6	Maize	Beans	Beans	Maize	Beans	Maize	Beans

Notes: 1. S Potato refers to sweet potatoes. 2. (W) refers to weighted model. 3. The village is the unit of measure for all three-risk measures under the Crop Yield Variability Approach.

Table 5. 1: Prices of Three Crops

Variable	**Year**				
	2003	**2005**	**2009**	**2012**	**2015**
District level					
Cassava price/kg	203.38	422.76	719.35	830.36	812.31
	(51.18)	(160.11)	(236.47)	(248.07)	(267.30)
Sweet potatoes price/kg	194.32	199.06	469.99	621.60	745.67
	(43.47)	(42.85)	(67.98)	(101.99)	(115.80)
Beans price/kg	562.52	1,273.46	1,946.02	2,333.49	2,980.20
	(224.74)	(469.15)	(680.88)	(838.54)	(866.38)

Notes: 1. Standard deviations are in parenthesis. 2. The price is in Uganda Shillings. 3. Source: (RePEAT survey data)

Table 5. 2: Summary of Theoretical Predictions

Increase	Impact on	MODEL: Dercon	Standard Investment	Feder	Duflo
Risk aversion	p	?	+		
Loss Aversion	p	?	+		
Impatience	p	0	?		
Present Bias	p	0	?		
Risk aversion	x		-	0	
Loss Aversion	x		-		
Impatience	x				-
Present Bias	x				-

Notes: 1. p is share of land devoted to low risk crop. 2. x is fertilizer per hectare. 3. The signs +, - and ? mean "increase", "decrease" and "the model allows any sign", respectively. Lastly, 0 refers to "no effect".

Table 5. 3: Summary Statistics by Year and Household Participation in Experiment

VARIABLES	2009		2012		2015	
	Game HHs	Non-Game HHs	Game HHs	Non-Game HHs	Game HHs	Non-Game HHs
Household head characteristics						
Age	50.65	48.06	53.56	49.20	55.49	53.35
	(14.50)	(15.39)	(13.89)	(15.14)	(13.36)	(105.18)
Education	6.12	6.35	6.11	6.02	6.19	6.73
	(3.78)	(3.67)	(3.75)	(3.46)	(4.08)	(3.85)
Gender (=1 If Male)	0.87	0.84	0.84	0.82	0.81	0.82
	(0.34)	(0.37)	(0.37)	(0.38)	(0.39)	(0.38)
Household characteristics						
Household Size	8.03	7.34	7.98	7.33	7.71	6.67
	(4.12)	(3.29)	(3.86)	(3.22)	(3.84)	(3.04)
Per Capita Food Expenditure (USh)	172.25	220.10	348.14	373.64	259.54	310.64
	(164.97)	(237.61)	(398.57)	(425.61)	(301.05)	(410.90)
Males Above 10 Years	3.09	2.29	3.64	2.70	4.55	1.94
	(2.17)	(1.71)	(2.37)	(2.13)	(3.01)	(1.79)
Non-Farm Income (USh)	307.74	552.44	617.68	724.28	607.66	459.50
	(559.42)	(1601.17)	(1322.97)	(1926.41)	(1957.37)	(1479.77)
Assets Value (no livestock, USh)	829.21	1004.22	1065.15	1199.48	1447.95	1171.00
	(4031.33)	(3880.34)	(1925.39)	(2591.90)	(3780.93)	(3984.13)
Value Of Livestock (USh)	1164.85	1456.53	1955.87	2829.20	2236.48	2269.11
	(2743.74)	(4673.73)	(4905.82)	(8651.97)	(8734.60)	(9754.26)
Farmland Size (Acres)	7.77	6.99	7.22	10.51	6.42	6.69
	(23.21)	(12.23)	(16.49)	(47.79)	(10.50)	(30.21)
Village characteristics						
Number Of People	1202.50	1099.90	1290.27	1254.00	1618.93	1956.82
	(1703.50)	(1324.82)	(1416.27)	(1336.41)	(3228.16)	(4015.04)
Size Of Lc1 (Square Miles)	2.94	3.57	2.43	2.47	4.16	4.49
	(5.25)	(6.26)	(1.90)	(1.97)	(6.90)	(7.28)
Distance to Market (Miles)	3.22	3.67	3.63	3.34	4.15	4.04
	(2.11)	(2.63)	(3.15)	(3.18)	(2.98)	(3.02)
Distance to District Town (Miles)	12.89	14.21	9.81	9.96	10.45	10.65

	(10.43)	(11.66)	(7.98)	(9.47)	(10.05)	(10.18)

Notes: 1. Standard deviations are in parenthesis. 2. Monetary values are in 1000UShs. 3. Game HHs means households that participated in the experiment. Non-Game households refer to households that did not participate in the experiment.

Table 5. 4: Household head Risk and Time Preferences

Variables	**Game Households**	
	Mean	**SD**
Risk Aversion Parameter (Risk1)	2.15	2.59
Loss Aversion Parameter (Risk1 & 4)	8.07	11.59
Discount Rate (Time6)	0.29	0.38
Present Bias (Time5 & 6)	0.76	0.52

Notes: The statistics are derived from data from Risk games 1 & 4 and Time games 5 & 6, see the game lotteries in Appendix Tables 5.1 & 5.2.

Table 5. 5: Share of land for 6 main crops and fertilizer use over time

Variables	Year					All
	2003	**2005**	**2009**	**2012**	**2015**	**Sample**
Cassava Share of land	0.10	0.11	0.10	0.08	0.09	0.10
	(0.15)	(0.14)	(0.12)	0.11	0.13	0.13
Sweet Potato Share of land	0.07	0.07	0.06	0.08	0.06	0.07
	(0.11)	(0.09)	(0.08)	0.10	0.10	0.10
Beans Share of land	0.15	0.15	0.14	0.17	0.18	0.16
	(0.14)	(0.13)	(0.14)	0.14	0.16	0.14
Banana Share of land	0.22	0.20	0.15	0.18	0.19	0.19
	(0.22)	(0.20)	(0.18)	0.20	0.22	0.21
Maize Share of land	0.17	0.17	0.17	0.18	0.19	0.18
	(0.18)	(0.16)	(0.17)	0.15	0.19	0.17
Coffee Share of land		0.07	0.08	0.10	0.11	0.07
		(0.11)	(0.12)	0.14	0.16	0.13
Fertlizer (kg/Hectare)	1.06	2.48	5.25	2.50	2.68	2.78
	(10.88)	(17.53)	(13.54)	12.11	12.91	13.56

Notes: 1. Standard deviations are in parenthesis. 2. This is at household level. 3. In 2003, in our sample very few households grew coffee.

Table 5. 6: Share of land for each crop, Fertilizer-use and Risk Quartiles

Variables	**Quartiles Of Risk Aversion**				**Mean Difference**
	1	2	3	4	1-4
Cassava share	0.09	0.08	0.10	0.11	-0.023***
	(0.11)	(0.11)	(0.12)	(0.13)	
Sweet Potatoes share	0.07	0.07	0.07	0.06	0.007
	(0.09)	(0.09)	(0.10)	(0.09)	
Beans share	0.17	0.17	0.14	0.15	0.027***
	(0.16)	(0.17)	(0.13)	(0.13)	
Fertilizer (kg/ha)	3.97	2.31	4.12	3.51	0.461
	(14.98)	(9.49)	(13.65)	(9.71)	

Notes: 1. Standard deviations are in parenthesis. 2. Share refers to the share of land devoted to a crop. 3. ***, ** and * are 1%, 5% and 10% significance level, respectively.

Table 5. 7: Control Variables

Control Variables	Dependent Variables			
	Cassava	Sweet Potatoes	Beans	fertilizer-use
Household Head Characteristics				
risk aversion	√	√	√	√
loss aversion	√	√	√	√
Discount rate	√	√	√	√
Degree of Present bias	√	√	√	√
Age	√	√	√	√
Years of education	√	√	√	√
Age	√	√	√	√
Gender	√	√	√	√
Household Characteristics				
Dependency Ratio	√	√	√	√
Number of males above 10 Years	√	√	√	
Number of females above 10 Years	√	√	√	
household size				√
Wealth*	√	√	√	√
land holdings (hectares)	√	√	√	√
ROSCA participation*	√	√	√	√
Non-farm income*	√	√	√	√
Remittance*	√	√	√	√
Credit receiver*	√	√	√	√
Free input intervention*				√
livestock value per adult	√	√	√	√
Farm Characteristics				
Altitude	√	√	√	√
Crop Characteristics				
Yield Variance (YV) for each of the 6 crops	√	√	√	
10^{th} Percentile of Yields distribution for each of the 6 crops	√	√	√	
Number of crops grown	√	√	√	√

Grows (=1 if household grows crop *i*)				√
Community Characteristics				
Distance to district town (km)	√	√	√	√
Type of road (tarmac==1)	√	√	√	√
Inorganic fertilizer Price/kg				√

Notes: 1. * means it is a dummy or categorical variable. 2. √ means it is included as a control variable. 3. Crop *i* refers to cassava, sweet potatoes, beans, banana, maize and coffee, the 6 most commonly grown crops in our sample.

Table 5. 8: Determinants of the Choice to Grow and Allocate Share of Land to Cassava

		CRAGGIT	
VARIABLES	**Tobit**	**Probit**	**Tobit**
	(1)	**(2)**	**(3)**
Risk aversion	0.00237	0.000907	0.00433
	(0.00281)	(0.0277)	(0.00338)
Loss aversion	-0.000393	-0.00105	-0.000426
	(0.000460)	(0.00155)	(0.000689)
Discount rate	0.00329	-0.0428	0.0251
	(0.00979)	(0.0524)	(0.0178)
Present bias	-0.00533	-0.0208	-0.0212
	(0.00499)	(0.0976)	(0.0137)
10^{th} percentile yield residual _Cassava	0.0691**	2.210***	-0.417***
	(0.0286)	(0.377)	(0.0285)
10^{th} percentile yield residual _SPotato	-0.239***	-3.089***	0.0221
	(0.0449)	(0.158)	(0.0660)
10^{th} percentile yield residual _Beans	0.00262	0.995*	-0.410***
	(0.0230)	(0.576)	(0.0481)
10^{th} percentile yield residual _Maize	-0.0427	-0.195	0.0990**
	(0.0591)	(0.175)	(0.0399)
10^{th} percentile yield residual _Banana	0.126***	0.928***	0.374***
	(0.0320)	(0.0868)	(0.0271)
10^{th} percentile yield residual _Coffee	-0.0693***	-0.558	-0.158***
	(0.00419)	(0.370)	(0.0310)
Cassava Yield variance	0.0309***	0.349***	-0.0665***
	(0.00503)	(0.100)	(0.00771)
Sweet Potato Yield variance	0.00211	-0.00507	0.150***
	(0.00431)	(0.171)	(0.00173)
Beans Yield variance	0.0493***	0.456**	0.00521
	(0.00739)	(0.231)	(0.0126)
Maize Yield variance	-0.231***	-1.468**	-0.345***
	(0.0220)	(0.576)	(0.0265)

Banana Yield variance	-0.0551***	-0.404***	-0.0174***
	(0.00227)	(0.0332)	(0.00389)
Coffee Yield variance	-0.0251***	0.0323	-0.103***
	(0.00924)	(0.157)	(0.00983)
AGE	-0.000340	-0.00600*	0.000574***
	(0.000233)	(0.00317)	(0.000219)
Years of Education	-0.00134	-0.00801	-0.000468
	(0.00185)	(0.0120)	(0.00114)
GENDER	0.00235	-0.0717	0.0136
	(0.0183)	(0.181)	(0.0156)
Dependency Ratio	0.00192	0.0615***	-0.000527
	(0.00342)	(0.0140)	(0.00404)
Number of males (age>10)	0.000174	0.0357**	-0.00731***
	(0.000475)	(0.0172)	(0.00169)
Number of females (age>10)	-0.00244**	-0.0335***	0.000424
	(0.00113)	(0.00611)	(0.00273)
poorest_wealth	0.00386	0.00545	0.0143
	(0.0243)	(0.284)	(0.0209)
poor_wealth	0.00491	0.0469	-0.00420
	(0.0322)	(0.300)	(0.0378)
nonpoor_wealth	-0.0109	-0.0298	-0.0237
	(0.0240)	(0.242)	(0.0253)
land holdings (ha)	6.18e-05	0.00182	-0.000275
	(8.84e-05)	(0.00181)	(0.000237)
ROSCA dummy	-0.00515	-0.0591	0.00340
	(0.00597)	(0.156)	(0.0139)
Non-farm income dummy	0.00154	0.0699	-0.00219
	(0.00201)	(0.0491)	(0.00564)
Distance town	0.000390	0.00616**	0.000273
	(0.000622)	(0.00242)	(0.000987)
Road to town (tarmac=1)	0.00756	0.127	-0.00440
	(0.0167)	(0.174)	(0.0251)
altitude	-3.06e-05	-0.000501***	1.70e-05
	(2.10e-05)	(0.000124)	(2.51e-05)
Livestock value per adult	2.03e-09	8.31e-08	-9.90e-09***

	(5.13e-09)	(7.38e-08)	(3.62e-09)
Remittance dummy	0.00924	0.0657	0.0101
	(0.0149)	(0.168)	(0.00666)
Credit receiver dummy	-0.00247	-0.182*	0.0258
	(0.00849)	(0.104)	(0.0199)
Number of crops grown	0.00716**	0.290***	-0.0341***
	(0.00329)	(0.0409)	(0.00369)
Constant	0.418***	0.168	1.079***
	(0.0188)	(0.554)	(0.0822)
Observations	1,415	1,415	1,415
District by time	YES	YES	YES

Notes: 1. Robust standard errors in parentheses 2. *** p<0.01, ** p<0.05, * p<0.1. 3. Livestock value Adult is the value of livestock per number of adults in the household. 4. We include district-by-time dummies among our covariates 5. SPotato is sweet potatoes.

Table 5. 9: Determinants of the Choice to Grow and Allocate Share of Land to Sweet Potatoes

		CRAGGIT	
VARIABLES	**Tobit**	**Probit**	**Tobit**
	(1)	**(2)**	**(3)**
Risk aversion	0.00150	0.0123*	0.00493
	(0.00224)	(0.00675)	(0.00520)
Loss aversion	-0.000716	-0.0103***	0.000499
	(0.000560)	(0.00388)	(0.00130)
Discount rate	-0.0118	-0.0114	-0.00955
	(0.00961)	(0.115)	(0.0252)
Present bias	0.0106***	0.116***	0.00584
	(0.00235)	(0.0229)	(0.00900)
10^{th} percentile yield residual _Cassava	-0.550***	-3.224***	-1.114***
	(0.0576)	(0.640)	(0.100)
10^{th} percentile yield residual _SPotato	-0.228***	-1.977***	-0.595***
	(0.0294)	(0.383)	(0.159)
10^{th} percentile yield residual _Beans	0.307***	3.668***	0.549***
	(0.0374)	(0.566)	(0.108)
10^{th} percentile yield residual _Maize	0.0381	-2.377***	0.650***
	(0.0465)	(0.406)	(0.180)
10^{th} percentile yield residual _Banana	-0.0363***	-0.567***	-0.0112***
	(0.00427)	(0.0302)	(0.00374)
10^{th} percentile yield residual _Coffee	0.0591***	-0.417	0.115
	(0.0186)	(0.625)	(0.141)
Cassava Yield variance	-0.0864***	-0.657***	-0.153***
	(0.0232)	(0.204)	(0.0532)
Sweet Potato Yield variance	0.00973	0.219	0.00722
	(0.00881)	(0.253)	(0.0200)
Beans Yield variance	0.0511*	0.541	0.0691
	(0.0269)	(0.350)	(0.0512)
Maize Yield variance	0.0225	0.108	0.0703
	(0.0401)	(0.703)	(0.0627)

Banana Yield variance	0.0399***	0.475***	0.0170**
	(0.00659)	(0.0933)	(0.00740)
Coffee Yield variance	-0.0346*	-0.119	-0.0854**
	(0.0201)	(0.307)	(0.0390)
AGE	-0.000394***	-0.00182	-0.00104***
	(9.58e-05)	(0.00186)	(0.000325)
Years of Education	-0.00296***	-0.0329***	-0.00419**
	(0.000418)	(0.00159)	(0.00181)
GENDER	-0.0102*	-0.155	0.00129
	(0.00584)	(0.160)	(0.0247)
Dependency Ratio	-0.00463	0.00421	-0.0142*
	(0.00491)	(0.0528)	(0.00779)
Number of males (age>10)	-0.000502	-0.00567	-0.00360***
	(0.000567)	(0.0111)	(0.00130)
Number of females (age>10)	0.000578	0.0113	0.00299**
	(0.00167)	(0.0125)	(0.00136)
poorest_wealth	0.0288***	0.132	0.0853**
	(0.00952)	(0.158)	(0.0375)
poor_wealth	0.0165	0.0722	0.0322
	(0.0122)	(0.118)	(0.0258)
nonpoor_wealth	0.00400	0.0163	0.00591
	(0.0130)	(0.159)	(0.0405)
land holdings (ha)	0.000136***	0.000491	0.000294
	(1.56e-05)	(0.00244)	(0.000259)
ROSCA dummy	-0.00840	-0.275***	0.0344*
	(0.00872)	(0.0766)	(0.0195)
Non-farm income dummy	0.00247	-0.0592	0.00849
	(0.00631)	(0.0488)	(0.0328)
Distance town	-0.000370	0.000666	-0.00340*
	(0.000633)	(0.00596)	(0.00180)
Road to town (tarmac=1)	0.00276	-0.0459	0.0221
	(0.00866)	(0.0703)	(0.0374)
altitude	-6.17e-05***	-0.000561***	-8.53e-05***
	(1.74e-05)	(0.000187)	(2.28e-05)
Livestock value per adult	2.33e-09	5.66e-08	1.07e-09

	(4.59e-09)	(5.15e-08)	(9.69e-09)
Remittance dummy	-0.0176**	-0.127	-0.0429***
	(0.00749)	(0.108)	(0.0147)
Credit receiver dummy	0.00386	0.0943	-0.00276
	(0.00638)	(0.102)	(0.00363)
Number of crops grown	0.00197	0.250***	-0.0536***
	(0.00165)	(0.0448)	(0.00829)
Constant	0.507***	3.523***	0.941***
	(0.0576)	(1.219)	(0.119)
Observations	1,417	1,417	1,417
District by time	YES	YES	YES

Notes: 1. Robust standard errors in parentheses 2. *** p<0.01, ** p<0.05, * p<0.1. 3. Livestock value Adult is the value of livestock per number of adults in the household. 4. We include district-by-time dummies among our covariates 5. SPotato is sweet potatoes.

Table 5. 10: Determinants of the Choice to Grow and Allocate Share of Land to Beans

VARIABLES	Tobit	CRAGGIT	
		Probit	**Tobit**
	(1)	**(2)**	**(3)**
Risk aversion	-0.00166**	-0.0137	-0.00253
	(0.000667)	(0.0226)	(0.00253)
Loss aversion	0.000926	0.00483	0.00136***
	(0.000583)	(0.00296)	(0.000525)
Discount rate	0.00548***	-0.0851	0.0105
	(0.00169)	(0.102)	(0.0106)
Present bias	0.00439	0.105	0.00634
	(0.00359)	(0.111)	(0.00400)
10^{th} percentile yield residual _Cassava	0.273***	2.952***	0.563***
	(0.00753)	(0.390)	(0.0217)
10^{th} percentile yield residual _SPotato	0.330***	1.591**	0.476***
	(0.0240)	(0.810)	(0.0343)
10^{th} percentile yield residual _Beans	-0.362***	-4.222***	-0.161***
	(0.0233)	(0.203)	(0.0219)
10^{th} percentile yield residual _Maize	-0.0753***	-0.647*	-0.263***
	(0.0135)	(0.334)	(0.0429)
10^{th} percentile yield residual _Banana	-0.00257	-1.948***	0.00221**
	(0.00410)	(0.210)	(0.00101)
10^{th} percentile yield residual _Coffee	-0.109***	0.614	-0.258***
	(0.0275)	(0.545)	(0.0251)
Cassava Yield variance	0.0661***	0.687***	0.138***
	(0.00317)	(0.161)	(0.00233)
Sweet Potato Yield variance	0.0331***	-0.327***	0.0287
	(0.0109)	(0.0395)	(0.0177)
Beans Yield variance	-0.129***	-0.789**	-0.191***
	(0.0115)	(0.360)	(0.00946)
Maize Yield variance	-0.0149***	-0.0139	0.0504***
	(0.00531)	(0.341)	(0.00122)

Banana Yield variance	-0.0175***	-0.587***	-0.0135***
	(0.00159)	(0.0669)	(0.00219)
Coffee Yield variance	0.0237***	0.276*	0.0497***
	(0.00358)	(0.150)	(0.00434)
AGE	-0.000543	-0.00673	-0.000301
	(0.000380)	(0.00615)	(0.000947)
Years of Education	-0.00122	-0.0277***	-2.34e-05
	(0.000981)	(0.00549)	(0.00190)
GENDER	-0.0112	-0.220***	-0.00504
	(0.0157)	(0.0444)	(0.0220)
Dependency Ratio	0.0127***	0.0737	0.0159***
	(0.00182)	(0.0746)	(0.00454)
Number of males (age>10)	0.00128	0.0349***	0.000677
	(0.00130)	(0.00804)	(0.00324)
Number of females (age>10)	-8.60e-07	0.0198*	-0.000745
	(0.000877)	(0.0102)	(0.00156)
poorest_wealth	0.0349***	0.297**	0.0428***
	(0.00412)	(0.144)	(0.0150)
poor_wealth	0.0121	0.259*	0.00522
	(0.00919)	(0.154)	(0.0139)
nonpoor_wealth	0.00479	0.0886	-0.000737
	(0.00936)	(0.120)	(0.00795)
land holdings (ha)	-0.000252***	-0.00290**	-0.000103***
	(5.72e-05)	(0.00114)	(2.23e-05)
ROSCA dummy	0.00697	0.338	-0.00963
	(0.00591)	(0.227)	(0.00795)
Non-farm income dummy	-0.00877**	-0.0442	-0.00556
	(0.00399)	(0.0798)	(0.00819)
Distance town	-0.000393	-0.00249	-0.000794***
	(0.000248)	(0.00334)	(0.000231)
Road to town (tarmac=1)	0.0198	0.0423	0.0324
	(0.0170)	(0.0616)	(0.0250)
altitude	3.94e-05**	0.000223	3.58e-05*
	(1.59e-05)	(0.000371)	(1.86e-05)
Livestock value per adult	1.97e-10	1.68e-07	-6.34e-09

	(3.22e-09)	(1.24e-07)	(4.60e-09)
Remittance dummy	-0.00935*	0.0431	-0.0222***
	(0.00508)	(0.0737)	(0.00557)
Credit receiver dummy	-0.00355	-0.0968*	0.00427
	(0.00485)	(0.0541)	(0.0112)
Number of crops grown	-0.00705***	0.240***	-0.0316***
	(0.00232)	(0.0621)	(0.00357)
Constant	0.106***	1.416***	-0.128
	(0.0183)	(0.471)	(0.109)
Observations	1,417	1,417	1,417
District by time	YES	YES	YES

Notes: 1. Robust standard errors in parentheses 2. *** p<0.01, ** p<0.05, * p<0.1. 3. Livestock value Adult is the value of livestock per number of adults in the household. 4. We include district-by-time dummies among our covariates 5. SPotato is sweet potatoes.

Table 5. 11: Determinants of Adoption and Intensity of Fertilizer-use

VARIABLES	(1) Probit	(2) OLS	(3) Tobit
Risk aversion	-0.0523*	-0.0783	-0.551
	(0.0301)	(0.176)	(0.445)
Loss aversion	0.0272***	0.0255	0.240**
	(0.00702)	(0.0316)	(0.102)
Discount rate	0.0880	1.440	1.866
	(0.160)	(1.265)	(2.661)
Present_biasT5	0.172	0.407	2.550
	(0.113)	(0.913)	(2.005)
AGE	-0.0125**	-0.0489*	-0.178**
	(0.00490)	(0.0269)	(0.0753)
Years of education	0.0731***	0.231*	0.825***
	(0.0187)	(0.132)	(0.247)
GENDER	0.189	0.561	2.726
	(0.165)	(1.119)	(2.815)
Dependency ratio	-0.0606	-0.267	-0.941
	(0.0687)	(0.375)	(1.004)
Household size	0.0147	-0.0195	0.0868
	(0.0165)	(0.0663)	(0.217)
poorest_wealth	-0.485**	1.189	-2.075
	(0.203)	(1.179)	(2.899)
poor_wealth	-0.124	1.055	0.357
	(0.182)	(0.915)	(2.528)
nonpoor_wealth	-0.189	0.123	-1.150
	(0.160)	(0.764)	(2.278)
land holdings (ha)	0.000229	-0.00864	-0.000447
	(0.00175)	(0.00799)	(0.0344)
ROSCA dummy	0.302*	0.345	2.649
	(0.161)	(0.784)	(2.145)

Non-farm income dummy	0.256**	1.245*	4.699***
	(0.112)	(0.661)	(1.649)
Distance town	-0.000558	-0.0471	-0.0474
	(0.00683)	(0.0405)	(0.0963)
Road to town (tarmac=1)	0.0807	1.588	1.398
	(0.168)	(1.027)	(2.263)
altitude	9.73e-05	0.00388*	0.00683**
	(0.000212)	(0.00207)	(0.00287)
Livestock value per Adult	5.87e-08	-2.96e-09	3.50e-07
	(6.65e-08)	(2.18e-07)	(1.16e-06)
Remittance dummy	0.172	0.328	2.554
	(0.138)	(0.582)	(1.920)
Credit receiver dummy	0.0926	1.189	3.431*
	(0.132)	(0.880)	(1.847)
FreeInput intervention dummy	1.451***	2.829***	14.48***
	(0.180)	(1.037)	(2.102)
Inorganic fertilizer (price/kg)	-1.40e-05	-3.57e-07***	-0.000563
	(3.00e-05)	(9.06e-08)	(0.000449)
Grows cassava (=1)	0.189	0.252	0.476
	(0.147)	(0.710)	(1.906)
Grows sweet potatoes (=1)	-0.0511	-1.379*	-3.428*
	(0.143)	(0.733)	(1.954)
Grows beans (=1)	-0.184	-1.617	-3.678
	(0.165)	(1.241)	(2.275)
Grows maize (=1)	1.738***	3.944***	27.90***
	(0.340)	(0.758)	(5.043)
Grows banana (=1)	0.0429	-1.267**	-1.996
	(0.103)	(0.606)	(1.516)
Grows coffee (=1)	0.279**	1.168	3.387*
	(0.139)	(0.756)	(1.931)
Number of crops grown	-0.0631*	-0.499***	-1.288***
	(0.0374)	(0.152)	(0.468)
Constant	-2.528***	0.200	-38.35***

	(0.669)	(3.381)	(9.826)
Observations	1,264	1,356	1,356
Number of hhdid	622	646	646
District by time	YES	YES	YES

Notes: 1. Robust standard errors in parentheses 2. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. 12: Comparing the Means for Risk Aversion Extremes

Variable	**Risk aversion parameter=-0.62 (Mean 1)**	**Risk aversion parameter=6.07 (Mean 2)**	**(Mean 1) - (Mean 2)**
Share of land for cassava	0.516	0.523	-0.00629
Share of land for sweet potatoes	0.508	0.512	-0.00399
Share of land for beans	0.557	0.553	0.00437
Fertilizer kg/hectare	0.269	0.192	0.0767

Notes: 1. Mean (1) refers to the average of the variable when individuals are risk loving/neutral. 2. Mean (2) is the average of the variable when individuals have high degree of risk aversion.

Figure 3.1: Payment Card

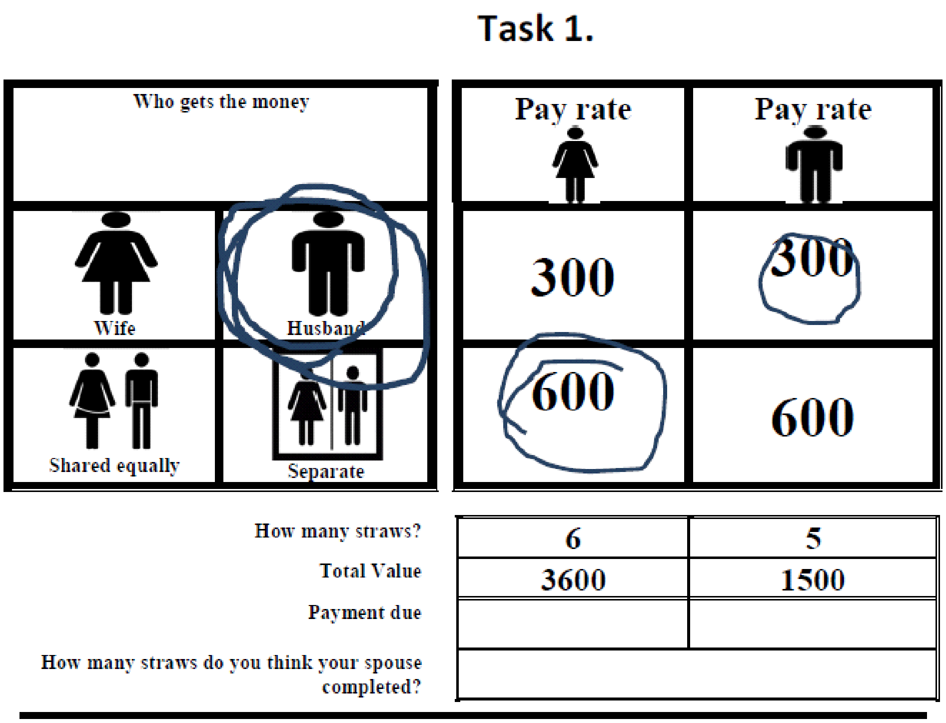


Figure 3.2: Average Output by Sharing rule categories

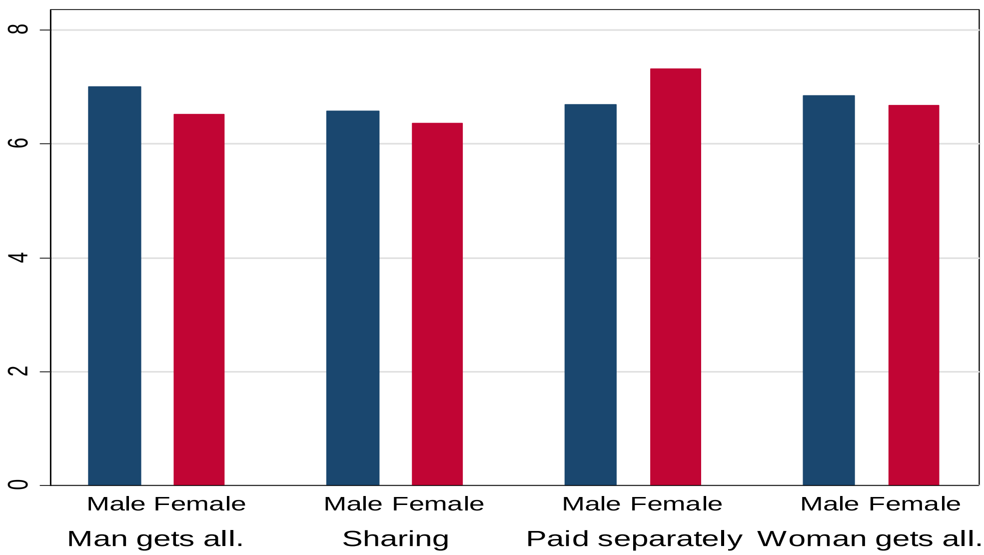


Figure 3.3: Average Relative Output by Relative wage categories

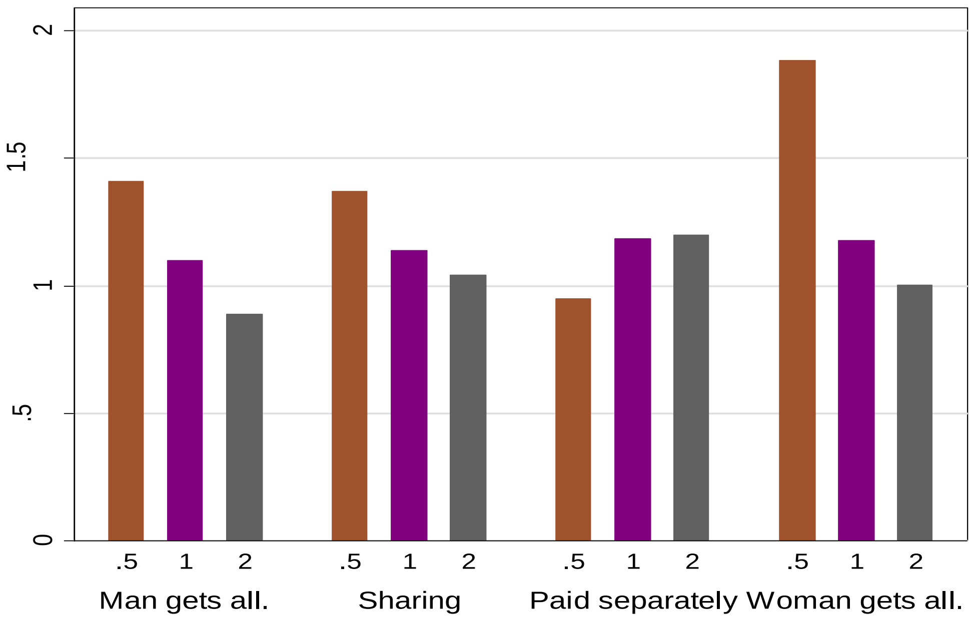
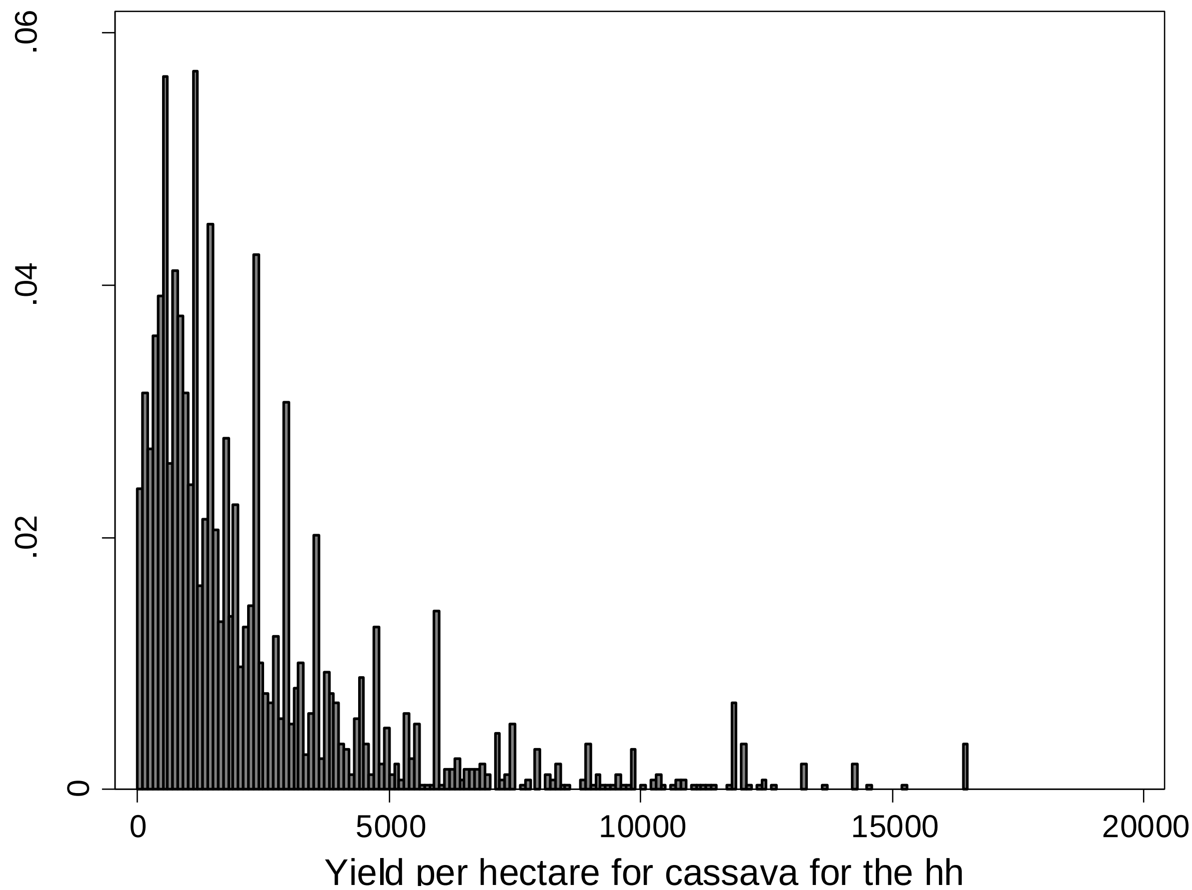
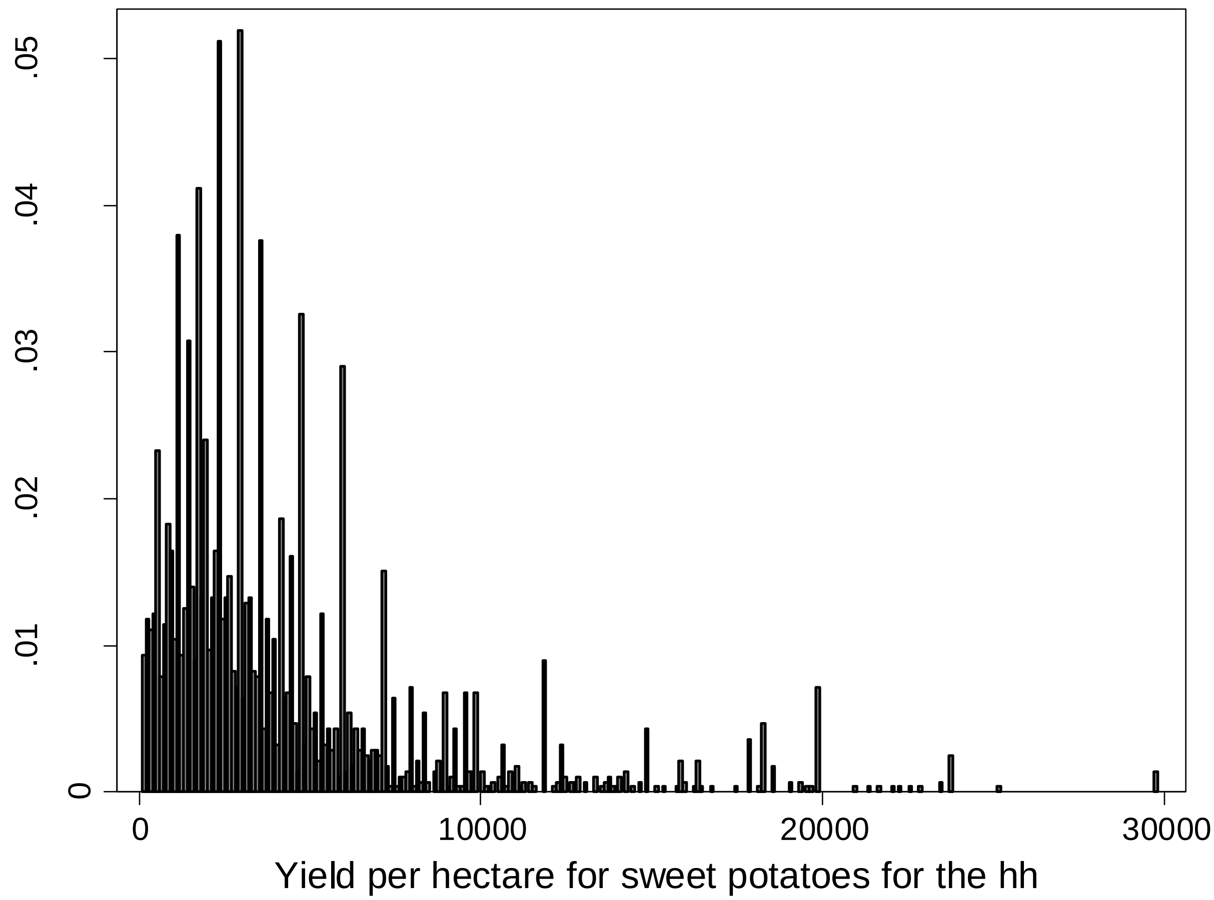


Figure 4. 1: Household Yield (kg/hectare) for each of the 6 crops

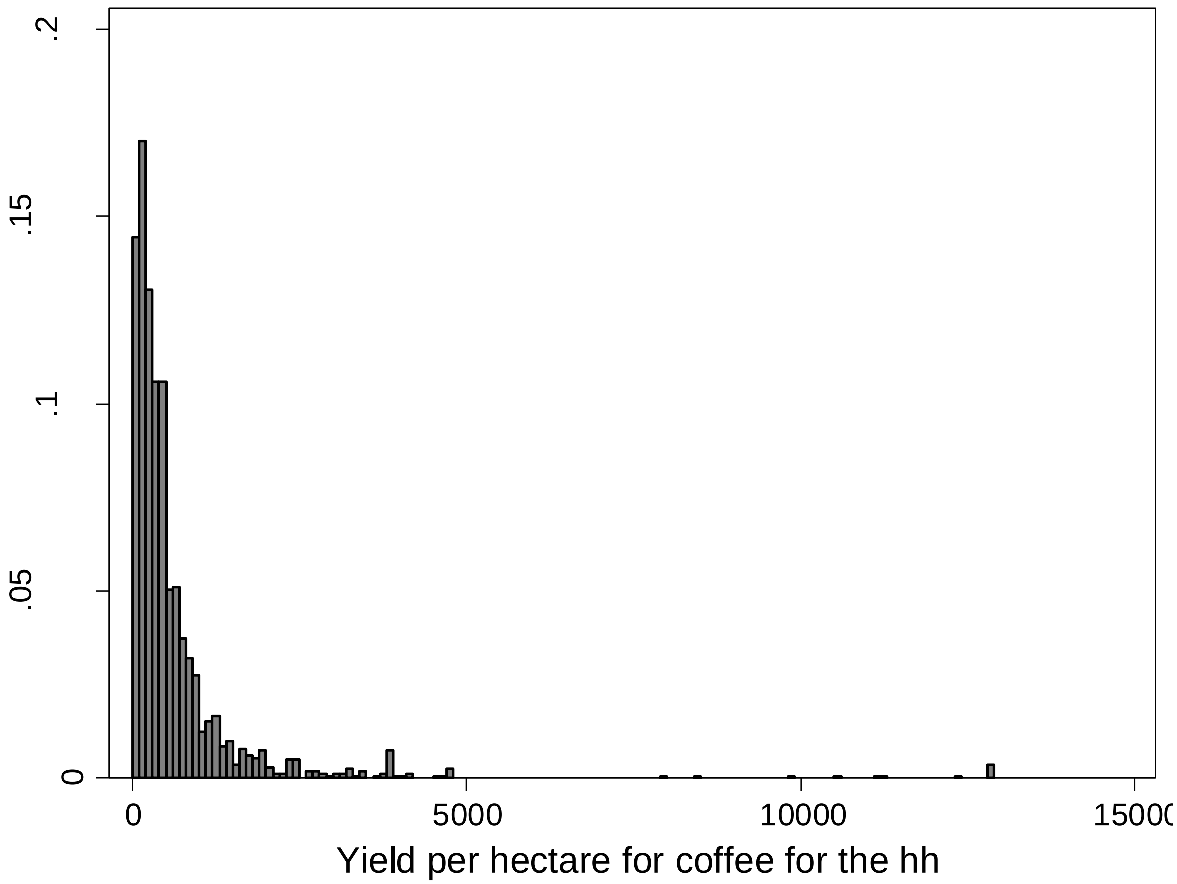
Cassava Yield (kg/hectare)



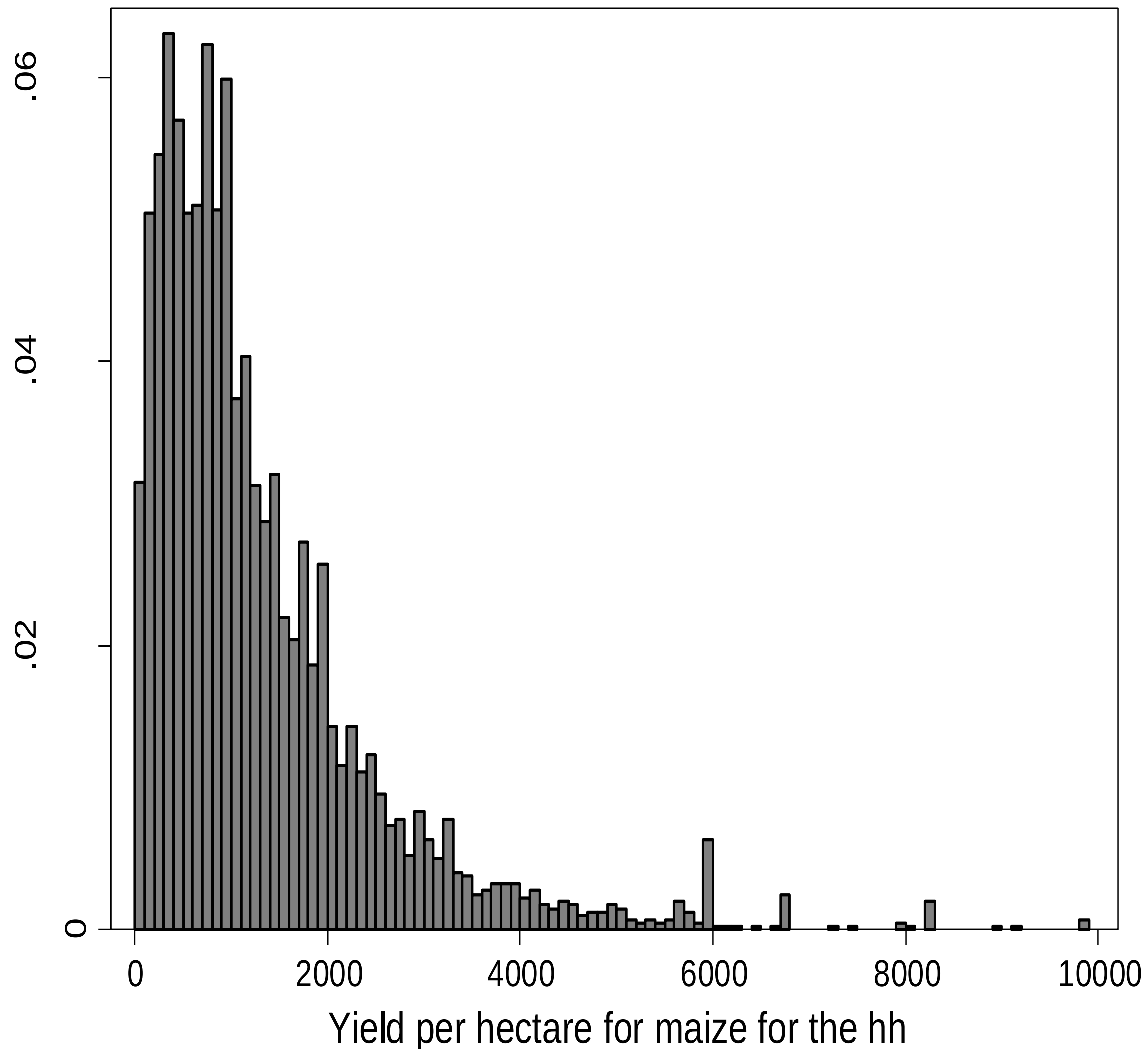
Sweet Potatoes Yield (kg/hectare)



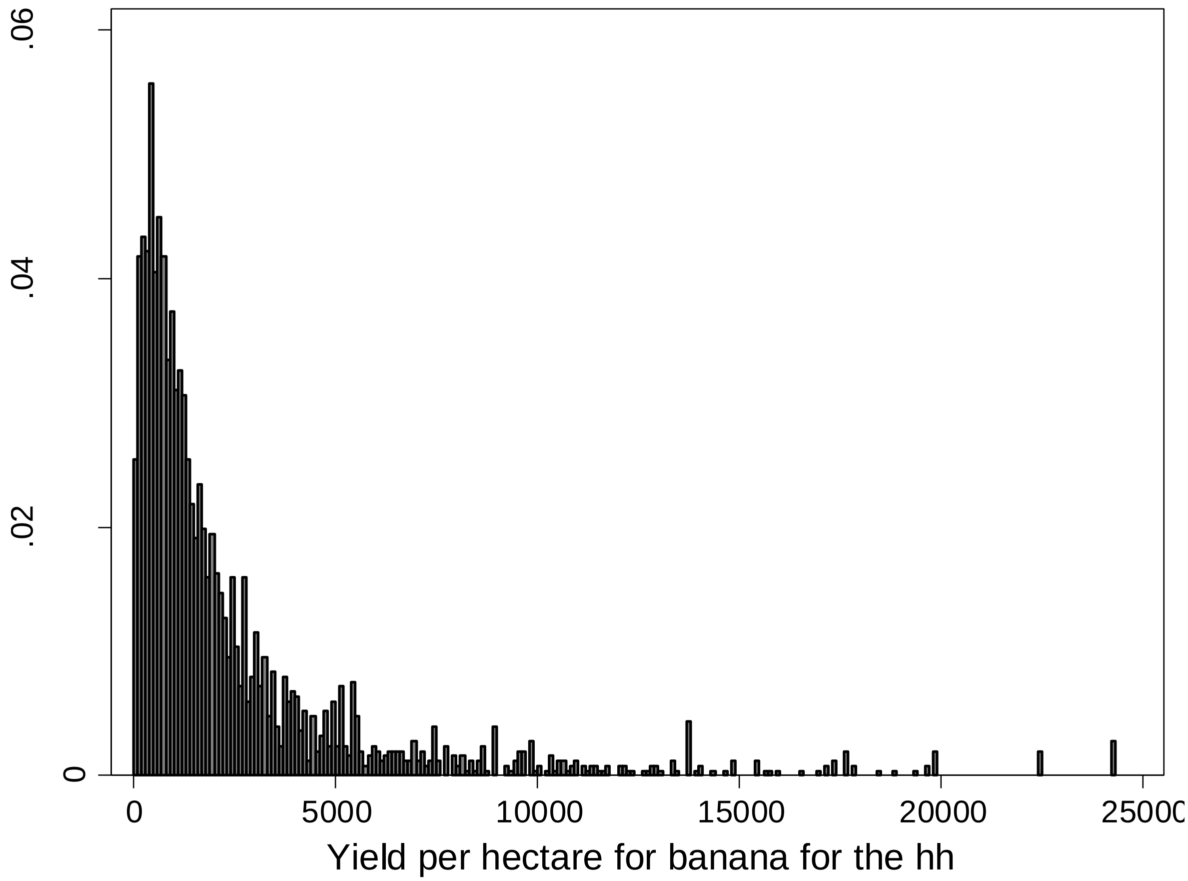
Coffee Yield (kg/hectare)



Maize Yield (kg/hectare)



Banana Yield (kg/hectare)



Beans Yield (kg/hectare)

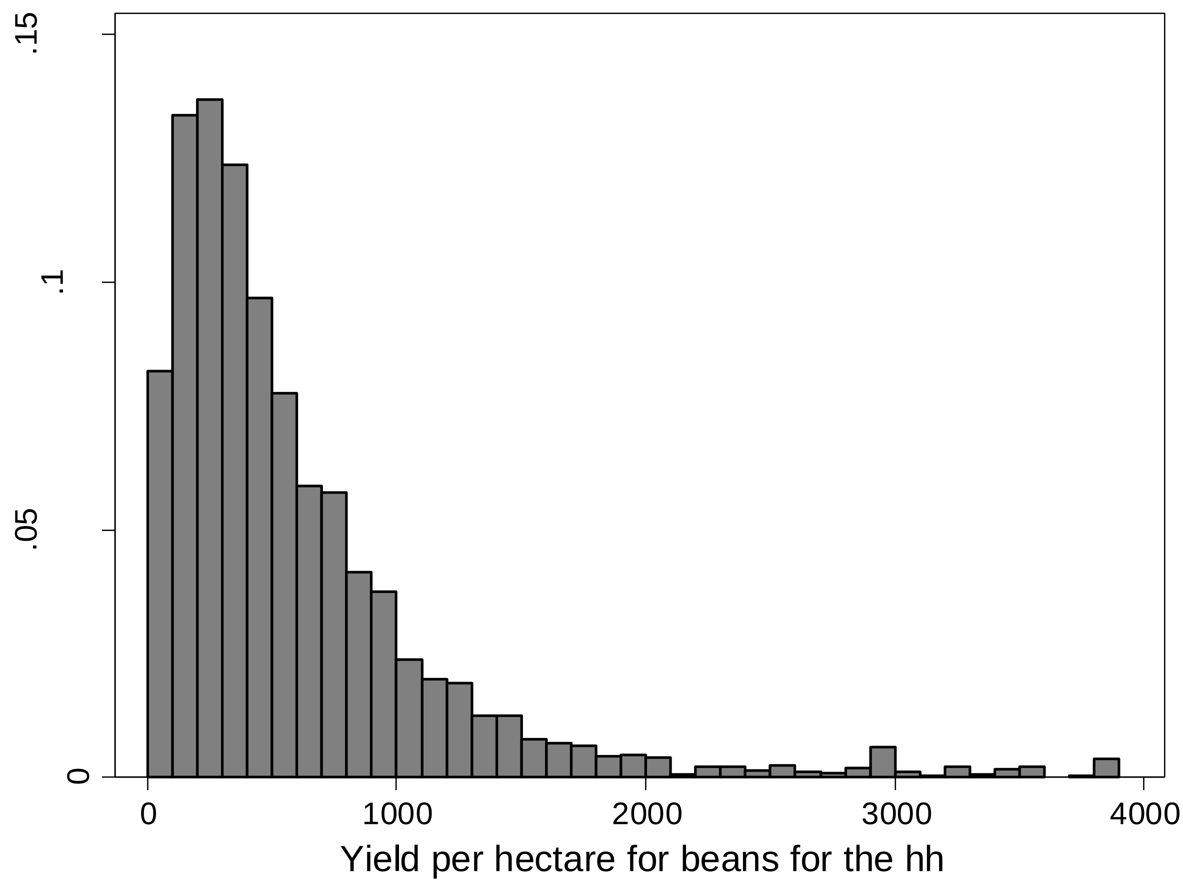


Figure 5. 1: Answer sheet for Risk 1

	A	B		Do you prefer A or B?
	①②③④	①②	③④	
1–1	4,000	4,000	2,000	
1–2	4,000	5,500	2,000	
1–3	4,000	6,000	2,000	
1–4	4,000	7,000	2,000	
1–5	4,000	8,000	2,000	
1–6	4,000	8,000	3,000	
1–7	4,000	8,000	3,500	
1–8	4,000	8,000	4,000	

Figure 5. 2: Answer sheet for Time 6

	A	B	Do you prefer A or B?
6–1	12,000 in 6 months	10,000 in 4 months	
6–2	14,000 in 6 months	10,000 in 4 months	
6–3	16,000 in 6 months	10,000 in 4 months	
6–4	18,000 in 6 months	10,000 in 4 months	
6–5	18,000 in 6 months	8,000 in 4 months	
6–6	18,000 in 6 months	6,000 in 4 months	
6–7	18,000 in 6 months	4,000 in 4 months	
6–8	18,000 in 6 months	2,000 in 4 months	

Appendices

Appendix 3.1 : Game Instructions (not for publication)

["Straws Task script"]

[Instructions for Participants]

[STEP 1: All husbands AND wives together. General Introduction: If this is not the first session of the day, you don't have to say points 6 and 8]

1. Welcome. Thank you for taking the time to come today. [Introduce EXPERIMENTERS and the assistants.] You can ask any of us questions during today's programme.
2. We have invited you here because we want to learn about how people work and make decisions.
3. There are several parts to this session, but here you are going to be asked to do a task TWO times for money. Each time everyone will work for 10 minutes
4. Whatever money you win today will be yours to keep.
5. All payments will be made at the end of all the experiments.

What you need to do will be explained fully in a few minutes. But first we want to make a few things clear.

6. First, this is not our money. We belong to a university, and this money has been given to us for research.
7. Second, this is a study about how *you* work. Therefore you should not talk with others.

This is very important. Please be sure to obey this rule because it is possible for one person to spoil the activity for everyone. I'm afraid that if we find you talking with others, we will have to send you home, and you will not be able to earn any money here today. Of course, if you have questions, you can ask one of us.

8. Third, the study has several parts. We will tell you about the other parts later on, after we have finished this part.
9. Finally, make sure that you listen carefully to us. You will be able to make a good amount of money here today, and it is important that the instructions are clear for you so that you can follow them.

First we are going to explain about the work and then we will explain about the payment for the work.

<u>[Step 2. Explaining the work – one person speaks, another person does the showing]</u>

I'm going to tell you about the work. Men will work in one place and women will work in a separate place, but you will all be doing the same job.

Here are some rubber bands [Hold up an example to everyone in the room] and some drinking straws [Hold up an example].You will be asked to collect rubber bands and straws from a table and take them back to where you are working. There you will need to tie 8 bands onto a straw. On each straw there must be 2 of each of these 4 colours. YELLOW [show] RED [show] BLUE [show] and GREEN [show]. When you have put the 8 bands on like this [show] and then put it on your table. There will be payment for each completed straw that is done correctly. [you can pass around a few bands so that people can

This straw [hold up correct example] is done correctly

This straw [hold up straw] does not have enough bands in it

This straw [hold up straw] has the wrong mix of colours

This straw [hold up straw] has all the straws on top of each other.

Now, XX [name of the other experimenter in the room] will show you how to do this. After she has shown you how to do it we will do a little practice.

[First, she takes some bands. Then she sorts out some coloured bands. She ties the bands on the straw.]

So, in a moment we will do a practice. Everyone will go to the table once and bring back a few bands and make a straw correctly [if it's easier, you can pass out the straws and bands].
Let's check you understand so far:
How many green bands must be on the straw [ans: 2]. How many red bands must be on the straw [ans:2]. How many blue bands must be on the straw [ans:2]. How many yellow bands [ans:2]

Okay, let's do a practice.
[allow one go for each participant and check <u>everyone</u> to see that their straw is correct. If it's

not, point it out to the person. Collect a few examples and show whether they are right or wrong. Don’t time this bit: the aim is to teach the participants how to make a good straw]

Everybody did a good practice.

[answer questions]

[Step 3. Explaining the payment]

Let me tell about the payment. Remember that you going to do this task for 10 minutes twice so there are going to be two rules for payment. One for the first time and one for the second. All payments will be made at the end of all the experiments.

In a moment I am going to ask each person in turn to pull a card from a cloth bag.

This is the bag for the women [hold up a bag to be used for the women with a label ‘woman’ in English on one side and in the local language on the other side] What does this say? [wait for someone to shout out]

And this is the bag for the men [hold up a bag to be used for the men, with the same kind of labelling. Ask again]

[pull 2 cards from the men’s bag, one 300 and one 600].

These cards show how much will be paid for each correctly done straw. You can see it’s either 300 or 600 shillings that will be earned for every correctly done straw. After you have pulled a card from the bag, we will record that amount and then replace it for the next person. So every woman will have the same chance of getting 600 or 300 and every man will have the same chance of getting 600 or 300.

[put the cards back in the bag]

Let's do an example

[Do a practice. take one card: one from the woman's bag and one from the men's bag. Show the numbers around the room and say what they mean. For example 300 is pulled from the men's' bag and 600 from the women's bag. Then you would say, 'each straw completed properly by the man will pay 300 shillings and each straw completed properly by the woman will be paid 600 shillings'. So if the man makes one straw the payment is 300 and he makes 2 straws the payment is 600 and so on.].

So they are the amounts we will pay for every item that's correct.

Now, who gets the money? We have another bag. We call this the "Who gets the money bag" [hold up the bag and also point to the chart;]

Each couple will pull ONE card from this bag. Just one card per couple. There are four kinds of cards.

[Hold up each in turn].

Can you see this card [you can also point to the chart]? If you pull this card [show ] all the money goes to the wife. That's all the money made by the husband and all the money made by the wife.

If you pull this card [show ] all the money goes to the husband. That's all the money made by the husband and all the money made by the wife.

If you pull this card [show ] all the money made by the husband will go the husband and all the money made by the wife, will be handed over to the wife. You will be paid separately.

And If you pull this card [show ] all the money made by the husband and all the money made by the wife, will be added up and you will both get half of it. It will be shared equally.

Remember, after each couple has pulled a card we will put it back in the bag for the next draw.

Because you are doing the work twice, we will ask you to make all the draws from the bag twice.

First, each couple will pull one card from the women's bag and one card from the men's bag and one from the 'Who gets the money' bag. We will record your answers and replace the cards. Those cards will determine the payment rules for the first time you do the work.

Then you will do the same thing for the second time. This time you will be determining the rules of payment for the second time you do the work. The rules of payment might be the same, but they might not be.

For the ‘who gets the money bag’ the man will pull out the card for one of the tasks and the women will pull out the card for the other task.

We will record your answers and replace the cards and then circle your answer sheets as a reminder

[point to chart and make everyone look at it then at their answer sheets]

to show you the rules.

[point to sheet]

At the top of the sheet will be rules for the first time you do the work.

And at the bottom will be the rules for the second time.

You will take your copy to remind you of the rules.

Both times you will work for 10 minutes.

Let me tell you one more thing that’s important. At the very end of the session today we will tell your husband or wife how much money you made and we will tell you how much money he made but we won’t tell your spouse whether you worked hard or not. It’s your choice how hard you work. Men and women work in different places so your spouse won’t know how difficult the work is for you. And, there are lots more yellow bands than green or red and blue. They might get in your way and that’s why your spouse won’t know how hard the job was for you, just how many straws you made.

Right, we are nearly ready to start.

[Bring forward each couple one at a time. Give each person an answer sheet.

1. Do rules of payment for task 1 first.
2. Each woman takes a card. Record its value and replace the card
3. Do the same for the man and the 'who gets the money card'. Either spouse can be responsible for taking the card from this bag. Record the answers and then <u>do the same procedure again for the second task. Remind them why you are doing it twice.</u>
4. Make sure the cards are replaced in the bags and both husband and wife have a fully completed reminder sheet. Then ask them to wait a little while the other couples are done.
5. When all couples are done]

Would wives now please go with [Thea] and husbands with [Theo]? [women and men go to separate rooms or separate places. Each person takes their answer sheets with them.

[Instructions for Wives]

[allocate each wife to a place in the room. Point to the rules for payment for the first round]

We are nearly ready to start the first task. But first I want to check you understand

[STEP 4: To be read– "Control Questions"]

Let me ask two questions to check whether you understood the instructions.

1. If you have a card that says [300] and you make 2 items correctly, how many shillings will be paid? [correct people if necessary]

2. If you have a card that shows  [point to card or hold an example] how will the paid? [all to your husband, all to you, shared equally or paid separately?] [correct participant if necessary]

[Opportunity to ask questions of clarification]

You have [**10**] minutes to work on your straws. We will start after 5. 5.4.3.2.1. Start!.

[STEP 4: Task is carried out SIMULTANEOUSLY by all wives. At the end, announce the end of 10 minutes. Count and check straws & put the appropriate amount in the answer sheet on the 'how many straws' row. Also ask them how many straws they think their husbands made and fill this in]

[STEP 5: To be read to all the women jointly]

Thank you for completing that task. Now we will do a second task

(omitted: instruction for husbands and the remaining parts of the instructions for task 2)

Appendix Table 5.1: Risk Preference Experiment

	Column A				Column B				CRRA interval
Row	**prob (p)**	**prize (Y1)**	**prob (1-p)**	**prize (Y2)**	**prob (p)**	**prize (Y3)**	**prob (1-p)**	**prize (Y4)**	**under EUT**
1-1	1	4000			0.5	4000	0.5	2000	n/a
1-2	1	4000			0.5	5500	0.5	2000	$-\infty < \delta \leq -0.62$
1-3	1	4000			0.5	6000	0.5	2000	$-0.62 < \delta \leq 0.00$
1-4	1	4000			0.5	7000	0.5	2000	$0.00 < \delta \leq 0.66$
1-5	1	4000			0.5	8000	0.5	2000	$0.66 < \delta \leq 1.00$
1-6	1	4000			0.5	8000	0.5	3000	$1.00 < \delta \leq 2.92$
1-7	1	4000			0.5	8000	0.5	3500	$2.92 < \delta \leq 6.07$
1-8	1	4000			0.5	8000	0.5	4000	$6.07 < \delta \leq \infty$
2-1	1	4000			0.75	4000	0.25	2000	n/a
2-2	1	4000			0.75	4500	0.25	2000	$-\infty < \delta \leq -0.82$
2-3	1	4000			0.75	5000	0.25	2000	$-0.82 < \delta \leq 0.92$
2-4	1	4000			0.75	5500	0.25	2000	$0.92 < \delta \leq 1.62$
2-5	1	4000			0.75	6000	0.25	2000	$1.62 < \delta \leq 2.00$
2-6	1	4000			0.75	7000	0.25	2000	$2.00 < \delta \leq 2.39$
2-7	1	4000			0.75	7000	0.25	3000	$2.39 < \delta \leq 5.62$
2-8	1	4000			0.75	7000	0.25	4000	$5.62 < \delta \leq \infty$
3-1	1	4000			0.25	4000	0.75	2000	n/a
3-2	1	4000			0.25	7000	0.75	2000	$-\infty < \delta \leq -1.15$
3-3	1	4000			0.25	10000	0.75	2000	$-1.15 < \delta \leq 0.00$
3-4	1	4000			0.25	13000	0.75	2000	$0.00 < \delta \leq 0.41$
3-5	1	4000			0.25	16000	0.75	2000	$0.41 < \delta \leq 0.62$
3-6	1	4000			0.25	16000	0.75	3000	$0.62 < \delta \leq 1.60$
3-7	1	4000			0.25	16000	0.75	3500	$1.60 < \delta \leq 3.04$
3-8	1	4000			0.25	16000	0.75	4000	$3.04 < \delta \leq \infty$
4-1	0.5	6000	0.5	-500	0.5	6000	0.5	-4000	
4-2	0.5	4000	0.5	-500	0.5	6000	0.5	-4000	
4-3	0.5	1000	0.5	-500	0.5	6000	0.5	-4000	
4-4	0.5	500	0.5	-500	0.5	6000	0.5	-4000	
4-5	0.5	500	0.5	-500	0.5	6000	0.5	-4000	
4-6	0.5	500	0.5	-500	0.5	6000	0.5	-4000	
4-7	0.5	500	0.5	-500	0.5	6000	0.5	-4000	
4-8	0.5	500	0.5	-500	0.5	6000	0.5	-4000	

Note: The CRRA interval shows the range within which the participant switches from A to B for risk game 1 to risk game 3. The table shows the possible payoffs (Y) and the probability (p) of realizing the payoff.

Appendix Table 5.2: Time Preference Experiment

	Column A		Column B		Discount rate
Row	Month (t)	prize (Y1)	Month (t)	prize (Y2)	interval
5-1	0	10000	2	12000	0.00 < r ≤ 9.54
5-2	0	10000	2	14000	9.54 < r ≤ 18.32
5-3	0	10000	2	16000	18.32 < r ≤ 26.49
5-4	0	10000	2	18000	26.49 < r ≤ 34.16
5-5	0	8000	2	18000	34.16 < r ≤ 50.00
5-6	0	6000	2	18000	50.00 < r ≤ 73.21
5-7	0	4000	2	18000	73.21 < r ≤ 112.13
5-8	0	2000	2	18000	112.13 < r ≤ 200.00
6-1	6	12000	4	10000	0.00 < r ≤ 9.54
6-2	6	14000	4	10000	9.54 < r ≤ 18.32
6-3	6	16000	4	10000	18.32 < r ≤ 26.49
6-4	6	18000	4	10000	26.49 < r ≤ 34.16
6-5	6	18000	4	8000	34.16 < r ≤ 50.00
6-6	6	18000	4	6000	50.00 < r ≤ 73.21
6-7	6	18000	4	4000	73.21 < r ≤ 112.13
6-8	6	18000	4	2000	112.13 < r ≤ 200.00
7-1	0	10000	1	11000	0.00 < r ≤ 10.00
7-2	0	10000	1	12000	10.00 < r ≤ 20.00
7-3	0	10000	1	13000	20.00 < r ≤ 30.00
7-4	0	10000	1	14000	30.00 < r ≤ 40.00
7-5	0	9000	1	14000	40.00 < r ≤ 55.56
7-6	0	8000	1	14000	55.56 < r ≤ 75.00
7-7	0	7000	1	14000	75.00 < r ≤ 100.00
7-8	0	5000	1	14000	100.00 < r ≤ 180.00
8-1	6	11000	5	10000	0.00 < r ≤ 10.00
8-2	6	12000	5	10000	10.00 < r ≤ 20.00
8-3	6	13000	5	10000	20.00 < r ≤ 30.00
8-4	6	14000	5	10000	30.00 < r ≤ 40.00
8-5	6	14000	5	9000	40.00 < r ≤ 55.56
8-6	6	14000	5	8000	55.56 < r ≤ 75.00
8-7	6	14000	5	7000	75.00 < r ≤ 100.00
8-8	6	14000	5	5000	100.00 < r ≤ 180.00

Note: Columns A and B show the pair-wise choices faced by the participants. The discount rate interval shows range where the participant switches from B to A for games 6 &8.

Appendix Table 5.3: Robustness check - Attrition

VARIABLES	(1) **Weighted**	(2) **Un-weighted**
Risk aversion	0.00184	0.00226
	(0.00189)	(0.00185)
Loss aversion	-0.000134	-0.000390
	(0.000454)	(0.000435)
Discount rate	0.00519	0.00111
	(0.0117)	(0.0109)
Present bias	-0.0251**	-0.00540
	(0.0111)	(0.00851)
10^{th} percentile yield residual _Cassava	0.0463	0.0243
	(0.0361)	(0.0364)
10^{th} percentile yield residual _SPotato	-0.0133	-0.00341
	(0.0281)	(0.0363)
10^{th} percentile yield residual _Beans	0.0280	0.0567*
	(0.0378)	(0.0337)
10^{th} percentile yield residual _Maize	-0.143**	-0.230***
	(0.0581)	(0.0535)
10^{th} percentile yield residual _Banana	-0.0634***	-0.0457**
	(0.0201)	(0.0212)
10^{th} percentile yield residual _Coffee	0.00391	-0.0261
	(0.0200)	(0.0205)
Cassava Yield variance	0.198	0.0469
	(0.134)	(0.127)
Sweet Potato Yield variance	-0.257*	-0.262**
	(0.135)	(0.125)
Beans Yield variance	0.0584	-0.0212
	(0.0954)	(0.106)
Maize Yield variance	-0.0174	-0.00404
	(0.107)	(0.108)
Banana Yield variance	0.104***	0.182**
	(0.0273)	(0.0803)
Coffee Yield variance	0.0904	-0.0610
	(0.135)	(0.121)
AGE	-0.000507	-0.000276
	(0.000348)	(0.000327)
Years of Education	0.00197*	-0.000997
	(0.00116)	(0.00109)
GENDER	0.0170	0.00603
	(0.0110)	(0.0109)
Dependency Ratio	0.00376	0.00265
	(0.00475)	(0.00461)
Number of males (age>10)	0.000473	0.000120
	(0.00200)	(0.00191)
Number of females (age>10)	-0.000135	-0.00226
	(0.00139)	(0.00166)
poorest_wealth	0.0315**	0.00199
	(0.0126)	(0.0128)
poor_wealth	0.0137	0.00503
	(0.0116)	(0.0117)

nonpoor_wealth	0.00484	-0.00898
	(0.0105)	(0.0108)
land holdings (ha)	5.51e-05	8.82e-05
	(0.000153)	(0.000188)
ROSCA dummy	0.000938	-0.00164
	(0.00948)	(0.00981)
Non-farm income dummy	-0.00766	-0.00132
	(0.00772)	(0.00761)
Distance town	0.000596	0.000350
	(0.000470)	(0.000452)
Road to town (tarmac=1)	0.0132	0.00358
	(0.0102)	(0.0107)
altitude	-2.56e-05	-3.62e-05**
	(2.31e-05)	(1.72e-05)
Livestock value per adult	4.77e-09	2.11e-09
	(3.92e-09)	(4.27e-09)
Remittance dummy	0.0108	0.0141
	(0.00900)	(0.00881)
Credit receiver dummy	-0.00513	-0.00154
	(0.00999)	(0.00895)
Constant	0.0617	0.432**
	(0.235)	(0.210)
Observations	1,415	1,415
District by time	YES	YES

Notes: 1. Standard errors in parentheses, 2. *** p<0.01, ** p<0.05, * p<0.1, 3. Dependent variable is "cassava share of land".

Appendix Table 5.4: Robustness check 2 - Determinants of Fertilizer Adoption

VARIABLES	(1) Probit	(2) Probit
Risk aversion		0.0207
		(0.0227)
Loss aversion	0.0195***	
	(0.00519)	
Discount rate	0.0963	0.205
	(0.159)	(0.158)
Present_biasT5	0.157	0.125
	(0.111)	(0.109)
AGE	-0.0115**	-0.0111**
	(0.00487)	(0.00489)
Years of education	0.0735***	0.0720***
	(0.0186)	(0.0187)
GENDER	0.193	0.206
	(0.164)	(0.167)
Dependency ratio	-0.0671	-0.0686
	(0.0682)	(0.0685)
Household size	0.0163	0.0205
	(0.0166)	(0.0162)
poorest_wealth	-0.472**	-0.454**
	(0.204)	(0.204)
poor_wealth	-0.122	-0.110
	(0.182)	(0.181)
nonpoor_wealth	-0.191	-0.186
	(0.159)	(0.160)
land holdings (ha)	1.90e-05	-1.73e-05
	(0.00174)	(0.00177)
ROSCA dummy	0.313*	0.317**
	(0.160)	(0.161)
Non-farm income dummy	0.256**	0.250**
	(0.112)	(0.112)
Distance town	0.000175	0.00199
	(0.00678)	(0.00674)
Road to town (tarmac=1)	0.0504	0.00929
	(0.165)	(0.166)
altitude	0.000102	9.55e-05
	(0.000213)	(0.000225)
Livestock value per Adult	5.18e-08	5.78e-08
	(6.71e-08)	(6.53e-08)
Remittance dummy	0.164	0.175
	(0.137)	(0.138)
Credit receiver dummy	0.0970	0.103
	(0.132)	(0.130)

FreeInput intervention dummy	1.449***	1.482***
	(0.179)	(0.182)
Inorganic fertilizer (price/kg)	-1.05e-05	-8.64e-07**
	(2.99e-05)	(4.03e-07)
Grows cassava (=1)	0.200	0.240
	(0.147)	(0.148)
Grows sweet potatoes (=1)	-0.0494	-0.0813
	(0.143)	(0.142)
Grows beans (=1)	-0.182	-0.222
	(0.164)	(0.162)
Grows maize (=1)	1.731***	1.806***
	(0.336)	(0.340)
Grows banana (=1)	0.0309	0.0218
	(0.103)	(0.104)
Grows coffee (=1)	0.268*	0.268*
	(0.139)	(0.137)
Number of crops grown	-0.0634*	-0.0658*
	(0.0373)	(0.0376)
Constant	-2.636***	-2.659***
	(0.672)	(0.677)
Observations	1,264	1,274
Number of hhdid	622	628

Notes: 1. Standard errors in parentheses, 2. *** p<0.01, ** p<0.05, * p<0.1, 3. Dependent variable is "fertilizer adoption".

Annex 5.1: Portfolio Choice model

We present a simplified version of the Portfolio choice model in Dercon (1996). This model is one of the models that motivates the hypotheses in Table (5.2).

The household is assumed to have access to two crop incomes with different means and riskiness in each period *t* and it can allocate proportions of its total available land L to each activity according to its objectives. In this multi-period model, the household has to make decisions on how much land to allocate to two crops, at the beginning of each period .Thus, the maximization problem can be written as follows:

$$\text{max: } u = E_t \sum_{t=0}^{T} (1+\delta)^{-t} C_t^{\rho}$$

$$\text{s.t} \quad A_{t+1} = (1+i).(A_t + y_t - C_t) \quad \geq 0$$

$$y_t = y_{t1} + y_{t2} = p_t.L.r_1 + (1-p_t).L.r_2$$

$$0 \leq p_t \leq 1 \qquad (2.1)$$

With ρ the constant relative risk aversion, δ the discount rate, C_t consumption and y_t income at time *t*. The variables A_t and i are total liquid assets at time *t* and rate of return on savings. p_t is the proportion of land allocated to growing crop 1 which is the safe crop. The returns from growing the safe crop and risky crop are r_1 and r_2 in each period per unit of land, respectively. The income from growing crop 1 is y_{t1}. Since crop 2 is risky, the income from growing crop 2 is y_{t2}, equal to $(1-p_t).L.r_2^1$ with a probability of q, and equal to $(1-p_t).L.r_2^2$ with probability (1-q).The assumption is that $r_2^1 < r_1 < r_2^2$ such that the expected return per unit of land for growing the risky crop, $E(r_2) = qr_2^1 + (1 -$

$q)r_2^2$ is larger than r_1. When the household devotes some of its land to growing crop 2, then y_t is uncertain. Based on its current income y_t and asset stocks A_t the household decides on how much of its land to devote to the low risk crop in the following year. The first order conditions derived from solving the maximization problem:

$$\frac{\partial Ł}{\partial C_t} = u'(C_t) - \frac{1+i}{1+\delta} Eu'(C_{t+1}) - \lambda \leq 0: \ \frac{\partial L}{\partial C_t} C_t = 0 \tag{2.2}$$

$$\frac{\partial Ł}{\partial p_{t+1}} = \frac{1}{1+\delta} Eu'(C_{t+1}).(Lr_1 - Lr_2) - \gamma \leq 0: \ \frac{\partial Ł}{\partial p_{t+1}} p_{t+1} = 0 \tag{2.3}$$

$$\frac{\partial Ł}{\partial \lambda} = A_t + y_t - C_t \geq 0: \quad \lambda \frac{\partial Ł}{\partial \lambda} = 0 \tag{2.4}$$

$$\frac{\partial Ł}{\partial \gamma} = 1 - p_{t+1} \geq 0: \ \gamma \frac{\partial Ł}{\partial \gamma} = 0 \tag{2.5}$$

where Ł is the Lagrangean function for the dynamic programming problem and λ , γ the Lagrangean multipliers related to A_{t+1} and p_{t+1}, respectively. With constant relative risk aversion and if equation (2.3) holds with equality while equation (2.4) holds with inequality, then condition (2.3) can be expressed as follows;

$$\frac{\partial Ł}{\partial p_{t+1}} = \frac{1}{1+\delta} [(q\rho(Lr_1 - Lr_{21}).((A^*_{t+1} + p_{t+1}Lr_1 + (1-p_{t+1})Lr_{21})^{\rho-1} + (1 - q)\rho(Lr_1 - Lr_{22}).((A^*_{t+1} + p_{t+1}Lr_1 + (1-p_{t+1})Lr_{22})^{\rho-1}] = 0 \tag{2.6}$$

The expression for the proportion of land devoted to growing the less risky crop derived from reworking (2.6) is as follows:

$$p_i = \alpha_0 + \alpha_1 . \frac{A_i^*}{L_i} \tag{2.7}$$

However, Dercon mentions that equation (2.7) is not an optimal solution in terms of the exogenous variables, other factors also influence α_0 and α_1 . The other factors could include risk and time preferences.

Annex 5.2: Adoption of new technology under uncertainty model

This is the simplified version of the Adoption of new technology under uncertainty model in Feder (1980) and it also motivates the hypotheses in Table (5.2). Suppose a farmer with a fixed farm size $\bar{L}$ (acres), can allocate the farm between only two crops. The first crop is low yield, does not require chemical inputs and the yield is certain. The second one is a modern crop, which is high yield variety, requires modern inputs such as fertilizers and improved seeds, and has high degree of yield variability because it is vulnerable to weather variations. Since the farmer is less familiar with the modern crop, additional and subjective uncertainty follows compared to the traditional crop.

In the model the assumption is that, the farmer's objective is to maximize the expected utility of income, π and the utility function is strictly concave reflecting risk aversion.

$$U = U(\pi)$$

$$U' > 0\ ;\ U'' < 0$$

The objective function is as follows;

$$\text{Max } EU\{P.L.[y(x) + \varepsilon.h(x)] + R.(\bar{L} - L) - c.x.L\} \tag{3.1}$$

s.t

$$L \leq \bar{L}$$

where L represents land input allocated to the modern crop, P the price per unit of the modern crop, c the cost per unit of fertilizer , R the fixed net return per acre allocated to the traditional crop and ε is a random variable with zero mean. The variables x and h are mean output, fertilizer input and a term related to output variability, respectively (they are all in per acre terms).

The maximization of the objective function with respect to x and L , results in the following first order conditions;

$$\frac{\partial EU}{\partial L} = E\{U'[P(y + \varepsilon.h) - R - c.x]\} = 0 \tag{3.2}$$

$$\frac{\partial EU}{\partial x} = E\{U'[P(y' + \varepsilon.h') - c]\}L = 0 \tag{3.3}$$

By Feder (1977, Lemma 4)

$$P(y' + \varepsilon.h') - c = [P(y + \varepsilon.h) - R - c.x](\frac{h'}{h}) \tag{3.4}$$

Re-arranging (3.4);

$$P.y'.h + (R + c.x - P.y).h' - c.h = 0 \tag{3.5}$$

Feder concludes that since the utility function parameters do not appear in equation (3.5), it is evidence that the optimal level of fertilizer-use, x^* is independent of the degree of risk aversion.