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Stefanija Veljanoska

To cite this version:

Stefanija Veljanoska. Agricultural risk, remittances and climate change in rural Africa. Economics and Finance. Université Panthéon-Sorbonne - Paris I, 2016. English. NNT : 2016PA01E057 . tel-01724418

HAL Id: tel-01724418

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Université Paris 1 Panthéon-Sorbonne

et

Paris School of Economics

Agricultural risk, remittances and climate change in rural Africa

Stefanija Veljanoska

Thèse présentée et soutenue publiquement
à l'Université Paris 1 Panthéon-Sorbonne le 9 décembre 2016
en vue de l'obtention du grade de
Docteur en sciences économiques
de l'Université Paris 1 Panthéon-Sorbonne et Paris School of Economics

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L'université Paris I Panthéon-Sorbonne n'entend donner aucune approbation ni improbation aux opinions émises dans cette thèse. Ces opinions doivent être considérées comme propres à leur auteur.

To my mother.

Acknowledgments

First and foremost, I am greatly thankful to Katrin Millock for accepting to be my Ph.D. advisor. I learnt a lot form her during the last four years. I thank her for the precious and continuous advices regarding my research, but also for guiding me in the academic environment. Her careful approach to every stage of my work during this period is of great importance for me. I thank her for being always available, despite her charged schedule, for her kindness, for her support and for all inspiring discussions.

I deeply acknowledge Pascale Combes Motel, Margherita Comola, Salvatore Di Falco and Alberto Zezza for serving on my Ph.D. committee. I thank them for their time and effort in reading and in providing valuable and constructive comments during the pre-defense for the improvement of my work.

I thank Marie-Anne Valfort for her insightful suggestions during my "bilan 12-18". I thank Viviane Makougni, Elda André, Joel and Loïc Sorel for their numerous advices and help, and for making the MSE a very pleasant place to work. I thank all the members of the Environmental axis, Katheline Schubert, Mireille Chiroleu Assouline, Mouez Fodha, Antoine d'Autume, Hélène Ollivier and Fanny Henriet, for the rewarding seminars and talks. It is a real pleasure to work in and be surrounded by such an environment.

The whole adventure called "writing a Ph.D dissertation" is special because of the opportunity we have to meet extraordinary people. The list is long. Antoine, Vincent, Bertrand, Anastasia, Ezgy, Sebastian, Sandra, Yvan, Mehdi, Elliot, Anna, Francesco, Diana, Victoire, Zaneta, Pierre, Rudy, Margarita, Esther, Djamel, Elsa, Farshad, Nelly, Emanuelle, Math-

ieu, Anna, Moutaz, Federica, Mabe, Fatma, Nicos, Paolo and Lorenzo thank you for all the discussions and nice moments that we shared during all these years. I thank all the office mates and friends: Lorenzo, Baris, Hamzeh, Mathias, Diane, Yassine, Dmitri, Can, Emna, Pauline, Catharina, Ilya and Masha for their continuous encouragement and for providing means of relaxation all the time. I had the chance to share the apartment with Alessandra, but not only the apartment. We shared friends, Giulia, Joanna, Lenka, Fulvio, Carolina, Emanuelle, Vittorio, Mehmet; we shared recipes, dinners and most of all we shared incredible moments. I thank Julian, Marco and Alexia for contributing to my "flatmate" experience. Thomas had the chance to have three roles, a friend, a colleague and a flatmate. I thank him for all advises and encouragements, especially during these last months. I thank: Hamzeh and Razieh for their kindness, support and all Sunday dinners; Baris for all passionate discussions and advices; Diane for her unconditional help (in all senses) and friendship; Thais and Juliette for the memorable time and talks we had during these four years; Ingrid for interpreting very well her role of "Ph.D. sister"; Anca for being the best conference friend; Anil, Alice, Hélène, Steven, Sanela, Jadran, Chaghaf, Rémi, Lucie, Bojana, Jill, Alice, Igor, Fanny, Sarah, Maria, Nico, Aurélie, Paul-Joseph, Amélie, Jules and Isaure for being so good at saying the right things at the right moment. For ten years we walked side by side with Anil, and then, at some point, Hélène joined us. I am very lucky to be accompanied by them on the journey. I thank Geoffrey for his adaptability, his (in)appropriate jokes and for being such a good listener of complains. I thank the Macedonian team: Elena, Ana, Sofi, Ljupka, Solza, Bisera, Marija, Goce and Jelena, for always being "virtually" there. Your continuous friendship and support has always been a motivation for me.

Even though, I have left my family and friends since a while, I never felt alone in Paris.

A part from the friends that I have already mentioned above, I want to thank Claude, Pascale, Louisette, Quentin and their family for making me discover the French culture, for all the Christmas Eves spent together, for all the warmth and all the support. I thank them for making me feel that I am part of the family. And last, but not the least, I thank my whole family for believing in me. I thank my grandmother for respecting all my decisions and for teaching me to think rationally. I thank my parents for the lifelong support and unconditional love. And, I thank my mother for carefully watching over every single step I made and providing me with advises that helped to build my path.

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Chapter 1

Introduction

Risk has a paramount impact on livelihoods in the developing countries. It comes from various sources: climatic, economic, political or individual-specific sources. There are two undisputed facts about Sub-Saharan Africa. The first one is that households' income is highly volatile and uncertain. The second one is that poverty is commonly present in this part of the world. Uninsured risk can cause shortfalls in income and consumption that can lead households into persistent poverty. Its consequences can be severe for people's living conditions; it can bring them to a certain minimal acceptable level of income and, without any protection, it can result in hardship.

However, people can take actions to protect themselves against risk. These actions can be diverse as the type of risk/shock faced by households are different. In particular, income variability and losses can be caused by common (aggregate) risk, or individual-specific (idiosyncratic) risk. Common or aggregate risk is a covariate risk that is faced by all members of a given community or a region. The idiosyncratic risk is specific to a particular individual.

Households encounter shocks[1] that include both characteristics, covariate and idiosyncratic. When describing the strategies that households use to cope with risk, the frequency, intensity and the persistence of their impact are features to be considered as they can question the efficiency of these strategies [Dercon, 2005].

Formal protection through credit and insurance markets is incomplete or even absent in these countries [Bell, 1988, Besley, 1995]. Therefore, households have developed sophisticated strategies in order to manage risk. Individual-specific shocks can be smoothed within a community through risk-sharing strategies. Risk-sharing can be considered as an individual consumption smoothing as a result of a membership in a given network or community. If all members of a community are affected by a common shock, then risk cannot be shared. In that case, transfers from outside the community or inter-temporal transfers can be the only possibility that households might have to buffer the shock and smooth consumption. The literature mentions also another classification of the strategies that attempt to reduce exposure to risk: risk-management (*ex ante*) and risk-coping (*ex post*) strategies [Alderman and Paxson, 1994]. The first group of strategies aims at reducing the degree of riskiness of income such as income diversification and income skewing. The second group includes self-insurance in the face of a shock through, for example, precautionary savings or informal risk-sharing strategies within a group.

Income diversification consists in combining different income sources that have a correlation coefficient that is less than one. Households can work on farm and also have other off-farm activities. They can fragment parcels into plots and cultivate different crops. Instead of just being specialized in crop production, agricultural households can raise livestock

[1]The term 'shock' refers to a realization of a risky process/event.

or engage in agricultural wage activities. But, income diversification is not without a cost. There can be considerable constraints that do not allow poor farmers to diversify the sources of their income. Non-agricultural activities or businesses are not easily accessible and have up-front investment requirements. Even though poor households have higher need for income diversification as their insurance possibilities are more limited, capital and other constraints can exclude them from income diversification. In order to reduce their exposure to risk they might opt for income skewing strategies which consists in allocating resources to low-risk, low-return activities. The implications of such strategies are that households might forgo some profitable opportunities because of uninsured risk.

Credit can be a substitute to insurance and can initiate households to engage in high-risk activities. But credit is highly collateralized in these societies and asset-poor households cannot participate in the credit market which prevents them from engaging in high-risk activities as the downside risks are high. Households that own higher amount of assets can borrow in bad times, when agricultural yields are low for example, or even sell their assets in order to smooth income and consumption. Households with few assets, on the contrary, do not have the same opportunities for consumption smoothing. As a consequence, they are obliged to enter in low-risk/low-return strategies in order to reduce the riskiness of their income. This leads to a more profound poverty [Dercon, 2005].

In the framework of my dissertation, I focus on the micro-level study of covariate risk caused by weather fluctuations to which agricultural households are exposed and the consequences on their agricultural decisions. The aim of this research is to contribute to the existent literature at the intersection of environmental, development and agricultural economics, by providing new evidence on what influences households' decision-making in terms

of insurance and diversification. In the second chapter of this dissertation, I explore the impact of migrants' transfers as substitutes for formal credit and insurance on the degree of crop diversification or specialization and on the degree of riskiness of a crop portfolio that households decide to cultivate. In addition to these output choices, in a third chapter, I also study the impact of remittances on the decisions of households to use riskier inputs such as fertilizer. In the fourth chapter, I analyze the insurance feature of land fragmentation, whether it can provide benefits for agricultural households that are exposed to higher rainfall variability. Finally, the aim of the fifth chapter is to examine the impact of higher inequality in water consumption, that can be due to climate variability, on social unrest which can be perceived as another source of risk.

1.1 Crop diversification and remittances

In the second chapter of the dissertation, I study to what extent remittances can push farmers to cultivate riskier crops and engage in more specialized crop production. The New Economics of Labor Migration (NELM) assumes that migration and remittances have the role to replace missing credit and insurance markets by generating informal risk-sharing strategies between the migrants and their family. According to this literature, migration is a decision made on the household level [Stark, 1991]. A household sends a migrant away from his home such that the covariance of facing a negative shock of the remaining household and the migrant simultaneously is lower than 1. In this sense, migration is considered to be an insurance strategy, as migrants' remittances will serve to absorb any negative shock of the remaining household and to smooth consumption. Therefore, it is natural to expect

that households that receive higher amounts of remittances will engage in riskier agricultural activities.

The objective of this second chapter is to complete the existing literature testing whether remittances by relaxing credit and insurance constraints encourage households to undertake riskier decisions in terms of crop production. A first objective is to provide an answer to the question whether farmers engage in crop diversification or specialization when they receive remittances. The novelty of the chapter is to use more exact measures of diversification such as the Shannon index, the Simpson index and the Berger-Parker index in addition to the number of crops. The advantage of using these measures is that they not only take into account the number of different crops, but also the share of land dedicated to each crop. In order to complete this analysis, a second objective is to test whether remittances increase the degree of riskiness of a farmer's crop portfolio. A novelty is the construction of a measure of riskiness of each crop cultivated by a given household and to evaluate how different crops contribute to the riskiness of the total crop portfolio and afterwards to study its relation to remittances, by using the Single Index Model (SIM) developed by Turvey [1991].

Remittances are not a random process and remittances-receiving households might systematically differ from those households that do not receive remittances. I adress endogeneity by using an instrumental variable (IV) approach where I use the mean district level of remittances interacted with the maximal educational level within the household as instrument. Average remittances at district level represent a proxy for migrational network and financial facilities on district level that can increase household remittances. Maximal education within a household is a strong determinant of migration decisions. These two variables impact household crop diversification decisions only through the amount of remittances re-

ceived by the household. In order to account for censored nature of the endogenous variable - remittances - I estimate remittances as a function of the average district level of remittances interacted with the maximal education (the instrument) and the other covariates by using a Tobit model; then I obtain the fitted values of household remittances, and finally, I use an IV approach where the fitted values of household remittances estimated previously are used as an instrument in a standard two stage least squares approach (2SLS) [Angrist, 2001, Wooldridge, 2010]. The advantages of using this alternative estimation strategy compared to 2SLS are at the same time to keep the nonlinear nature of remittances, to include fixed effects in the first stage and obtain consistent and efficient estimates in the second stage of the IV estimation.

A first finding is that remittances do not have a significant direct impact neither on crop diversification nor risk choices. There is stronger and novel evidence that the negative marginal effect of remittances on crop diversification for credit constrained households is greater than for non-credit constrained households. This implies that remittances enable farmers to undertake more risk through crop specialization by removing (at least partially) insurance and credit constraints for those farmers that are facing them.

1.2 Fertilizer use and remittances

In order to complete the above analysis, in a third chapter of the dissertation, I further study whether remittances promote fertilizer use. It has been shown by the agronomic literature that there are low levels of adoption rates of fertilizer among African farmers. One of the main reasons that prevents farmers from buying this costly input are liquidity and credit

constraints which are mostly due to the credit market imperfections in developing countries [Mwangi, 1996, Croppenstedt et al., 2003, Morris, 2007]. Another factor that prevents fertilizer adoption is the limited ability of farmers to cope with risks. Fertilizer is considered as a risky input as it generates a higher mean and higher variance of agricultural yields [Dercon and Christiaensen, 2011]. Knowing that agriculture in the developing world is mostly rain-fed, fertilizer can be unprofitable investment in periods of poor rainfall intensity [Alem et al., 2010]. Dercon and Christiaensen [2011] show that not only credit constraints but also negative shocks to consumption discourage farmers to adopt fertilizer. Given that all these constraints limit fertilizer use, the objective of this chapter is to test whether remittances received from migrants can potentially relax credit constraints and provide insurance, and enhance fertilizer use.

Previous research show that remittances improve agricultural productivity and investment by improving household liquidities [Taylor et al., 2003, Atamanov and Van den Berg, 2012]. But the insurance feature of remittances still remains empirically unexplored. The only work that studies a similar question is Mendola [2008]. It studies migration as substitute for insurance and its impact on the adoption of high yield varieties (HYV) in Bangladesh. Using a cross-section analysis, she finds that wealthier households engage in costly international migration and therefore use HYV compared to poorer households. One of the contributions of this chapter is to take into account the amount of past remittances as a risk insuring strategy in the case of fertilizer use in a panel data analysis on rural Uganda. Migration might not be a sufficient condition for insurance, as remittances are uncertain, but it is at the origin of the potential insurance strategy of a given household. Another contribution is that I separate organic and inorganic fertilizers as inorganic fertilizer is a

more expensive, commercialized input and the organic fertilizer is mainly produced on farm. After instrumenting for remittances, I find that they have a strong and significant impact on the probability and on the intensity of using both organic and inorganic fertilizer. As credit constraints are insignificant in the estimations, the main channel through which remittances increase fertilizer use seems to be through its insurance feature.

1.3 Implications of land fragmentation for agricultural production and rainfall variability

Land fragmentation, defined as a farm that has spatially separated parcels of land, is a phenomenon observed in many countries especially in developing countries. Empirical evidence shows that land fragmentation is detrimental for agricultural productivity and output [Wan and Cheng, 2001, Rahman and Rahman, 2009, Van Hung et al., 2007, Tan et al., 2010]. It does not allow for scale economies; it generates time costs due to distance (households not only have to travel from their homes to the parcels, but also between the different parcels); it prevents farmers from using machinery as it can be difficult for them to displace the machines from one parcel to another. However, there is not a consensus on whether land fragmentation has only a negative impact on agricultural outcomes. According to the study of Blarel et al. [1992] on Ghana and Rwanda, land fragmentation has no significant impact on agricultural yield. In addition, the authors show that land fragmentation actually reduces the variability of agricultural income. Land fragmentation can facilitate the adjustment of labor across seasons, dealing with risk through crop diversification and it improves

agro-biodiversity [Fenoaltea, 1976, Di Falco et al., 2010, Blarel et al., 1992, Bentley, 1987, Van Hung et al., 2007].

The objective of this chapter is to test whether a higher degree of land fragmentation reduces the exposure of agricultural households to weather variability. In particular, the chapter aims at verifying whether households with more fragmented land holdings incur lower reductions in their agricultural yield when they face rainfall variability compared to households with more consolidated land. The impact of land fragmentation on agricultural yield when there is rainfall variability has not been quantitatively addressed earlier by the literature.

In order to empirically verify the ability of land fragmentation to neutralize the negative effect of rainfall deviations, I estimate the impact of the degree of land fragmentation on households' agricultural yield in value. There are two empirical issues to deal with. The first one is how to measure land fragmentation. Following the literature, I use two measures: the number of parcels that the household owns and operates and a Simpson Index calculated for these parcels. The advantage of the Simpson index is that it not only considers the number of parcels but also how evenly land is distributed among the different parcels when calculating the degree of land fragmentation. I expect that both measures have similar incidence on crop production per acre in value if the results are robust. In the analysis, I include a variable that represents the annual deviation in rainfall in the district where the household lives and I add also an interaction term between the rainfall deviation and the degree of land fragmentation. This interaction variable accounts for a possible difference that might exist between households that have different levels of land fragmentation when studying the impact of rainfall deviations on agricultural yield. The second empirical issue is that land

fragmentation is not completely exogenous, and farmers can choose, to some extent, the level of fragmentation that they want to operate. In Uganda, almost half of the parcels are inherited or received as a gift and the other half are purchased or rented. To deal with this issue, I instrument the actual degree of operated land fragmentation with the number of parcels that are inherited by the household as this land fragmentation is exogenously received by the household through the inheritance process [Foster and Rosenzweig, 2011].

In both cases, with and without instrumentation, results show that higher land fragmentation decreases the loss of agricultural yield when households experience rain deviations. But, higher degree of land fragmentation leads to losses in yields for households for which rain deviation is close to zero. The results also show that the benefits of having fragmented land are higher when farmers are exposed to higher annual rainfall deviations. These results are validated when using both types of measures for land fragmentation, the number of parcels and the Simpson index. If we assume a rain deviation equal to 0.5 and to 1 standard deviation respectively, the agricultural yield in value decreases by 3 percent in the former case and increases by 19 percent in the later case when the number of parcels increases by one. These results illustrate that developing countries the completeness of insurance and credit markets should be a pre-condition for promoting land consolidation programs. If these markets are incomplete or missing, then land fragmentation can be an alternative for farmers operating in rain-fed environments.

1.4 Water inequality and conflict

Climate change will increase temperature and rainfall variability. In particular, higher variability of rainfalls may limit water availability which increase in turn the inequality in access to water for consumption. Inequality in water consumption and how it might provoke low-level conflict is the topic of the last chapter of the dissertation. The possibility of inter-state conflict is greater when there is scarcity of water [Soubeyran and Tomini, 2012]. Delbourg and Strobl [2014] find that a decrease in current water streamflow increases the likelihood of bilateral water events that are dominated by conflict rather than cooperation. There is a growing literature on absolute water scarcity and civil wars, as well. These studies use rainfall measures, for example, the Palmer drought index in Couttenier and Soubeyran [2013], precipitation levels in Berman and Couttenier [2015] or precipitation and temperature [Burke et al., 2009, O'Loughlin et al., 2012] to evaluate water scarcity and test its impact on internal conflicts.

The objective of this chapter is to test the impact of relative water scarcity instead of absolute water scarcity on low-level conflict. The first contribution of the chapter is the use of disaggregated household data to measure water scarcity compared to the existing studies that use aggregate country measures or, in the most disaggregated studies, water scarcity at a geographical grid level. A second contribution is that we test the impact of relative water scarcity on internal conflict since previous studies rely on absolute measures of water scarcity. The data we use to construct the conflict variables are on district level which is matched to household data that enable us to construct water consumption inequality at district level. By doing so, our aim is to contribute to the general literature on inequality

and civil conflicts, that has relied on cross-country data, to a large extent. The drawback of these studies is the quality of the data used on income distribution and civil conflict that may suggest a causal relationship between the two phenomena [Cramer, 2003].

The main hypothesis that we want to test is whether inequality in access to water consumption brings grievances that can lead to internal low-level conflict. We use three different sources to examine this hypothesis: household data on water consumption and land ownership from the Living Standard Measurement Studies-Integrated Survey on Agriculture (LSMS-ISA) on Uganda, established by the World Bank, data on riots and protests from the Uppsala Armed Conflict Location and Event Dataset (ACLED) and weather data from the TS3.21 dataset from the Climatic Research Unit of the University of East Anglia. Two types of dependent variables are used, a binary variable that indicates if a district faced an event of rioting or protesting in a given year, and a count variable measuring the number of events of riots and protests. The methods that we use accordingly are a linear probability model to test for the incidence of riots and protests and a negative binomial model to test the frequency of events.

The results show that inequality in water consumption does not affect significantly neither the incidence nor the frequency of social unrest in Ugandan districts, which is also the case when using inequality in land distribution and income inequality. We find strong evidence that deviations in temperature increase the incidence and the frequency riots and protests in the same year of occurrence. The significant effect of only temperature found here on disaggregated data goes in the same direction as a result from the literature using international data, i.e., that changes in temperature caused by climate change may increase the incidence of civil war in Africa [Burke et al., 2009]. This particular effect of deviations

Figure 1.1 – Time line of rainy and cropping seasons for year t

in temperature has not been found earlier on low-level conflict data.

1.5 Ugandan context and data

Uganda is a landlocked country situated in East Africa with about 34 million inhabitants. In the period between 2011 and 2015, the agricultural sector contributed to the Ugandan GDP by 27.2 percent as reported by the World Bank Indicators. Still, the agricultural sector employs about 71 percent of the active population and covers about 70 percent (around 17 million ha) of the total area that is available for cultivation [FAOSTAT, 2011]. According to the World Bank indicators, about 84 percent of the population of Uganda lives in rural areas in 2014. Ugandan agriculture is mostly rain-fed. However, there are some parts of Uganda that benefit from the number of lakes and rivers present in the country. According to the World Bank Indicators, the percentage of agricultural irrigated land of total arable land was only 0.1 percent in 2013.

Uganda lies across the equator. Its climate is humid with very hot periods during the year. It has two rainfall seasons, one from March to May and another from September to November as showed in Figure 1.1. The first cropping season is related to the growing cycle

of temporary crops that are cultivated and harvested in the first half of the year, up till the end of June. The second cropping season covers the period from July to December. It should be highlighted that the cropping seasons are related mostly to the rainy seasons and less related to the growing cycle of crops. Some places in the Northern region in Uganda are exposed however to only one extended cropping season.

In the dissertation I use data from the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) established by the Bill and Melinda Gates Foundation and implemented by the Living Standards Measurement Study (LSMS) within the Development Research Group at the World Bank. The Uganda National Panel Survey (UNPS) sample includes economic and social information on about 3 200 households (with about 2 000 households that are engaged in cultivation of crops). These households were previously interviewed in the 2005/2006 Uganda National Household Survey (UNHS). The sample also includes households that were randomly selected after 2005/2006. This sample is representative at the national, urban/rural and main regional levels (North, East, West and Central regions). Afterwards, the initial sample was visited for three consecutive years (2009/10, 2010/11 and 2011/2012).

The surveys on the agricultural activities in the LSMS-ISA include detailed information on the two separate cropping seasons. In chapters 1 and 2, the agricultural data is aggregated to an annual level as the other data, such as remittances and other income are given yearly. For example, when I use households' crop revenues in order to calculate the risk measure, I use the annual revenue of a given crop for a given household. When measuring the degree of crop diversification, I use an annual average of the household season diversity. Concerning fertilizer use, I include a binary variable that indicates if a farmer used fertilizer at least in one

of the seasons and another variable that accounts for the total quantity per acre of organic or inorganic fertilizer used on annual level. In 2013, the use of inorganic fertilizer in Uganda was only 2.2 kilograms per hectare, compared to 18 kilograms per hectare within Sub-Saharan Africa, or Kenya with 52.5 kilograms per hectare as average level. The purchase of fertilizer is made at the beginning of each rainy season and it is applied just after the purchase, at the beginning of March and September. In the analysis, I assume that remittances are received before the agricultural choices that are made in the year t described in Figure 1.1. In this dataset, the average level of remittances in the year 2005/2006 is 86 200 Ugandan Shillings and 125 700 in the year 2009/2010 on the entire sample. If we take into account only the households that receive remittances, the average remittances for 2005/2006 and 2009/2010 are respectively 252 300 and 416 100 Ugandan Shillings. There is an increase over the period and the within variation has to be considered in the estimation strategies when considering their impact on crop diversification and fertilizer use decisions.

Table 1.1 – Average remittances in $t-1$

	2005/2006	2009/2010	between variation	within variation
remittances	86.2	125.7	4.107	2.197
remittances>0	252.3	416.1	6.745	2.680

The data used to construct the rainfall and temperature variables that are used in the dissertation come from the TS3.21 dataset from the Climatic Research Unit of the University of East Anglia. It is monthly average data on precipitation and temperature from high-resolution grids, 0.5 x 0.5 degrees, that cover more than one century (1901-2012). Uganda has experienced extreme weather episodes in the last years, especially in the North. As

reported by the Ugandan Ministry of Water and Environment, between 1991 and 2000, Uganda experienced seven droughts. Nevertheless, the climate is suitable for crop production and the rainfall intensities are expected to grow. The rainfall distribution across seasons will become more and more irregular. As the agricultural production is of the subsistence-type and rain-fed, Ugandan farmers are significantly exposed to weather variability. According to Figures 1.2 and 1.3, rainfall and temperature vary considerably in Uganda. As a consequence of climate change, temperature continuously increases since 2000 in the 4 regions. The Northern and the Eastern regions are slightly warmer compared to the other regions. The Northern region faced high negative rainfall deviation from the long run mean (divided by the long run standard deviation) in 2010 as shown in Figure 1.4. The size of the intervals of the absolute value of rainfall deviations are shown in the right corner of each map in Figure 1.4, and the size of the deviations increases over time. In 2011, all the of country faced only positive rainfall deviations with a maximal value of 2.6, that resulted in floods in the South-East Region. Because of its geographical position, Uganda is affected by both positive and negative rainfall deviations.

The socio-economic module of the LSMS-ISA includes a questionnaire to describe major distress events that households have experienced in the past 12 months. There are questions on the occurrence and the length of the shock, as well as the impact on households' income, assets, food production and food purchases. Among the different type of events are drought, floods, pest attacks, livestock epidemics and others that are related to climate change. Table 1.2 presents the percentage of households that experienced the different shocks. Most households have been subject to drought or irregular rain. The common point of the different chapters in this dissertation is to analyze the implication of rainfall variability on different

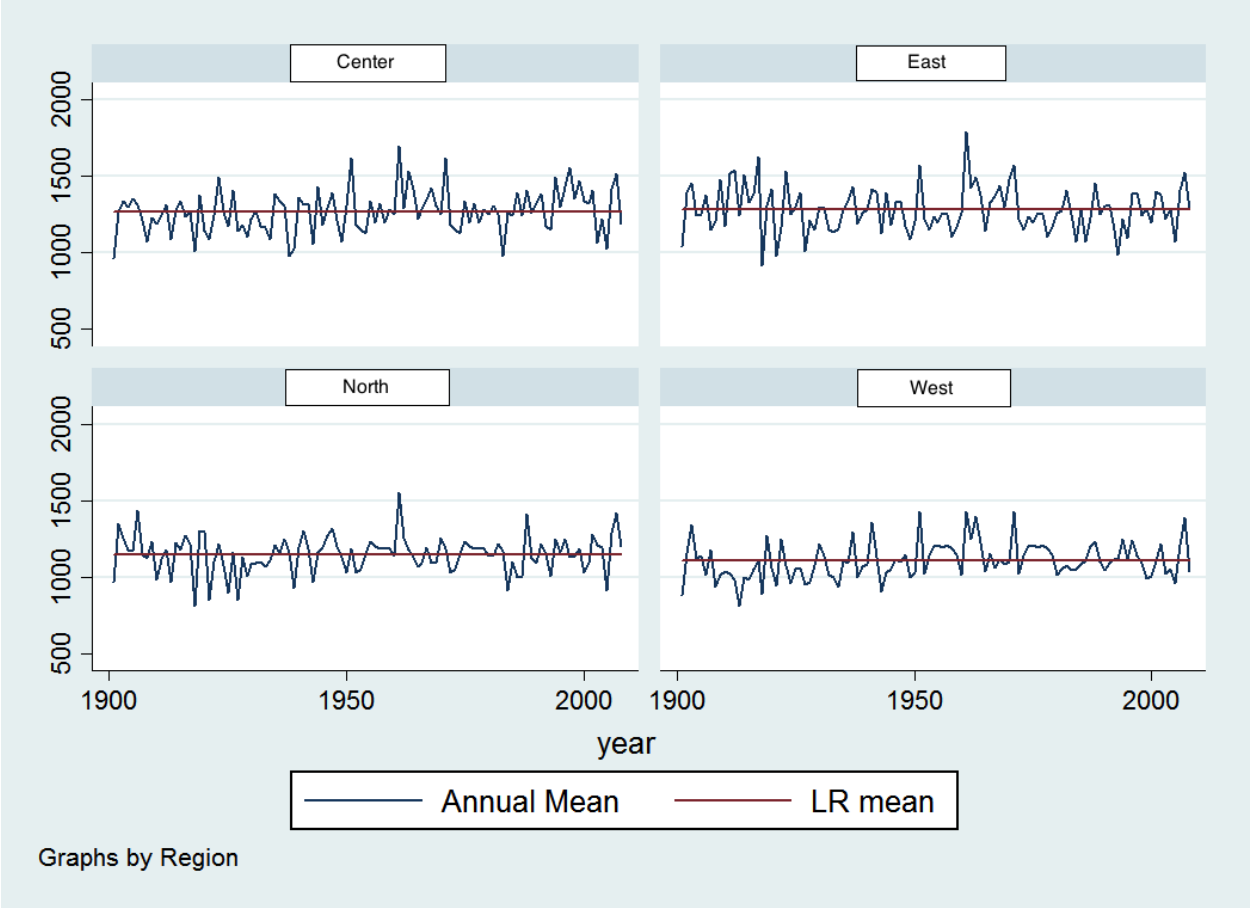


Figure 1.2 – Rainfall variability in Uganda for the 4 Regions: annual mean and long run mean
Source: Author's calculation on the CRU TS3.21 dataset

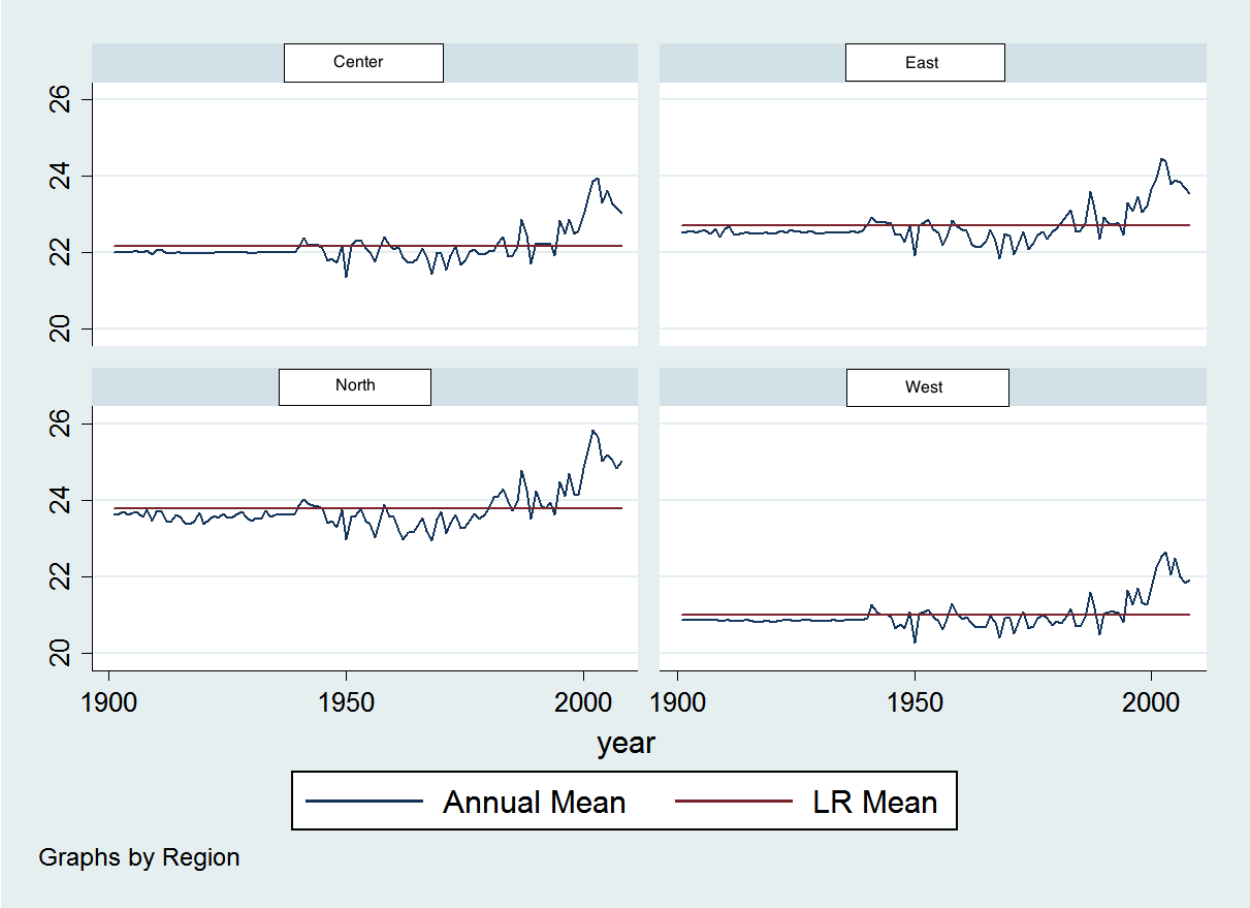


Figure 1.3 – Temperature variability in Uganda for the 4 Regions: annual mean and long run mean
Source: Author's calculation on the CRU TS3.21 dataset

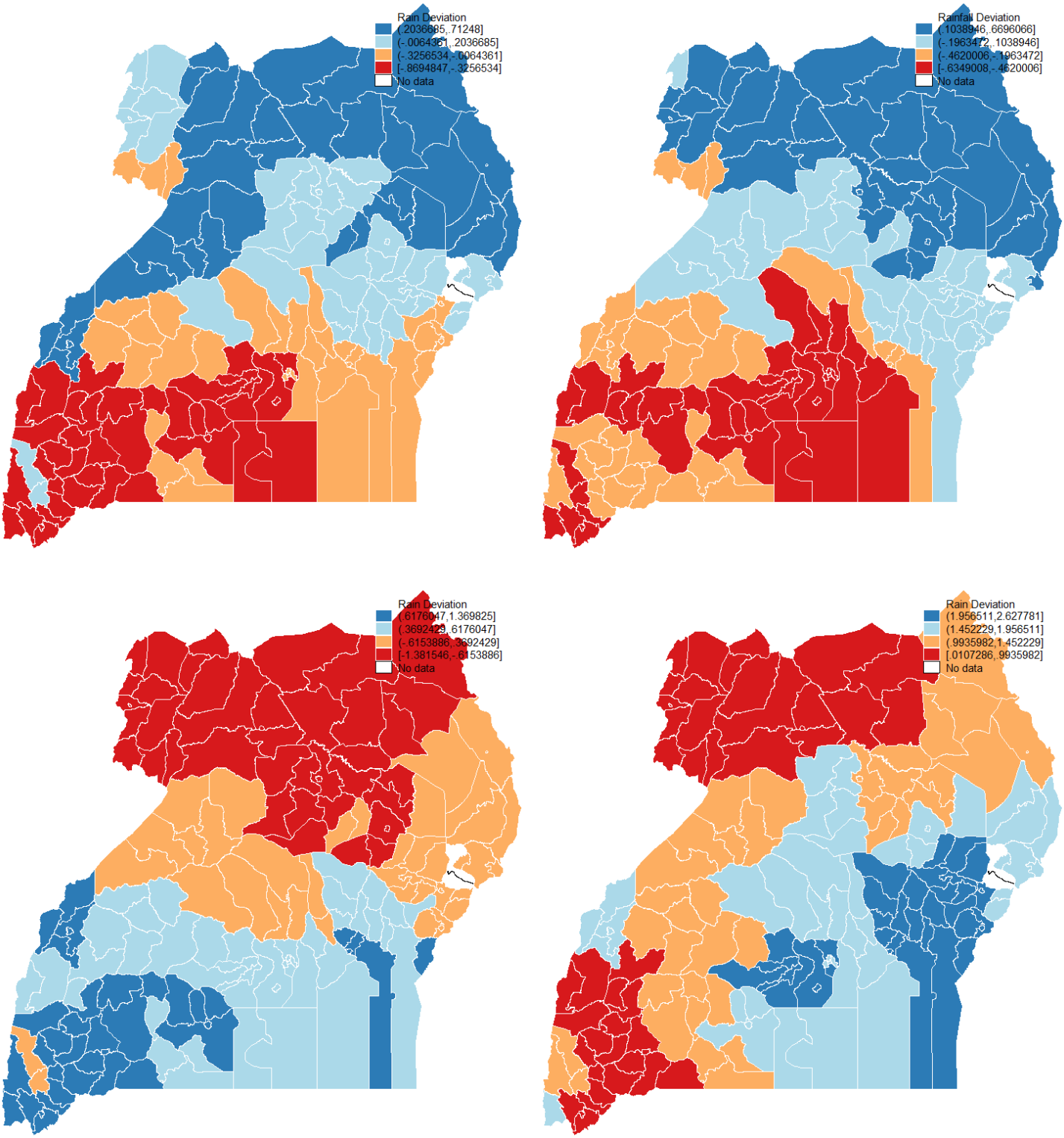


Figure 1.4 – Rainfall deviation by district in the years of the survey from left to right: 2005/2006, 2009/2010, 2010/2011 and 2011/2012
Source: Author's calculation on the CRU TS3.21 dataset

agricultural decisions. It is therefore relevant to analyze the behavior of Ugandan households to deal with covariate shocks and the consequences on their agricultural decisions.

Table 1.2 – Shocks experienced in the last 12 months

Year	2009/2010	2010/2011
Drought/Irregular Rains	45.83	26.92
Floods	2.11	3.84
Landslides/Erosion	0.75	0.26
Unusually High Level of Crop Pests and Disease	4.66	1.51
Unusually High Level of Livestock Disease	2.79	1.43
Unusually High Costs of Agricultural Inputs	2.04	0.72
Unusually Low Prices for Agricultural Output	1.80	1.36
Reduction in the Earnings of Currently (Off-Farm) Employed Household Member(s)	0.95	0.19
Loss of Employment of Previously Employed Household Member(s)	0.31	0.42
Serious Illness or Accident of Income Earner(s)	6.47	5.77
Serious Illness or Accident of Other Household Member(s)	6.40	5.70
Death of Income Earner(s)	0.92	0.64
Death of Other Household Member(s)	2.52	2.23
Theft of Money/Valuables/Non-Agricultural Assets	3.64	1.77
Theft of Agricultural Assets/Output (Crop or Livestock)	4.32	1.81
Conflict/Violence	1.16	1.02
Fire	0.89	0.83
Other	3.60	3.26

As the climate changes, the need to ascertain suitable adaptation strategies for farmers is crucial. Ugandan households use different adaptation practices that are documented in the survey. These strategies include: selling assets, using savings, migration, formal borrowing, informal borrowing, reducing consumption, and reliance on help from relatives, friends and local governments, off-farm work, crop diversification and agricultural wage labor. Therefore, the consequences of climate change on the decisions of Ugandan farmers and how farmers adapt to it needs more profound attention.

Chapter 2

Agricultural Risk and Remittances

2.1 Introduction

Remittances are an important element of households' livelihood strategies. They are sent for different motives: altruism, exchange, inheritance, investment and insurance [for a survey see Rapoport and Docquier, 2006]. The early theoretical work modeled the decision to migrate as an individual decision driven by wage differences between the origin place of the migrant and the destination. In this line of research, migrants' transfers were not taken into account. The New Economics of Labor Migration (NELM), mainly established by Stark [1991], modified the manner of explaining migration motives and consequences. According to NELM, a decision for a household member to migrate is made collectively and migrants keep interacting with households at the origin place. However, in the framework of an agricultural household model where markets are complete, migration and remittances do not affect production outcomes or decisions. If we assume that labor markets are perfect, then a household can hire on the labor market to compensate for the family member that migrated.

If migrants send remittances, these remittances serve to increase the household income that will in turn increase consumption, but will not affect production because consumption and production decisions are separable. A finding that implies that remittances have an impact on production choices indicates that there is non-separability between consumption and production decisions due to market imperfections. In particular, according to the considerations of Stark [1991], migrants and remittances serve to replace credit and insurance constraints and have an impact on production decisions. They enable households to engage in riskier activities. This result is validated in a household model where non-separability holds.

There is a growing literature that examines the impact of remittances and migration on the different welfare aspects of remaining households. The evidence on the impact of remittances and migration on agricultural outcomes is, however, under-explored. Studies examining the impact of migration and remittances on agricultural income and agricultural productivity include Lucas [1987], Taylor and Wyatt [1996], Rozelle et al. [1999], Taylor et al. [2003], De Brauw [2010] and Atamanov and Van den Berg [2012]. An important result of the papers that study the impact of migration and remittances on agricultural output and productivity is that migration generates labor loss and has negative impact on agricultural outcomes, but that remittances partially compensate for this loss. This chapter focuses on the impact of remittances on households' decisions in terms of agricultural risk management.

Rural households in African countries operate in highly volatile environments. In this framework, access to credit and insurance markets is indispensable, but these markets are imperfect or even inexistent in most developing economies [Bell, 1988, Besley, 1995]. Migration and remittances can provide insurance by generating informal risk-sharing strategies between the migrants and their remaining family. The mechanism behind this is the follow-

ing: a household sends a migrant away such that the covariance of facing a negative shock of the remaining household and the migrant simultaneously is negative; thus migration diversifies the sources of income for both parties [Stark and Levhari, 1982]. In this sense, migration is considered to be an insurance strategy as migrants' remittances serve to absorb any negative shock of the remaining household and allow to smooth consumption. Yang and Choi [2007] and Gubert [2002] showed that households facing a negative income shock received higher amounts of remittances, but the received amount did not allow them to fully buffer the shock. Besides, remittances can be considered as any other kind of income, even if households do not face shocks. Remittances, as an altruistic transfer, increase the wealth of households. Therefore, households might change their behavior towards risk. It is intuitive to expect that better insured and wealthier households, households with higher remittances, are those that undertake riskier agricultural activities and have less need to diversify their production.

In a farm household model with missing or incomplete markets, remittances can generate heterogeneous impacts on farm income and decisions. For a household that is asset-poor and is constrained from participating in the credit market, the liquidity and insurance feature of remittances might overcome those barriers and encourage the household to undertake riskier decisions, i.e., specialize more its production or cultivate riskier crops, and by that increase income. By contrast, remittances might have a smaller effect on the decisions of a wealthy household that do not face these constraints. This chapter aims at verifying empirically these assumptions, testing for a heterogeneous effect on household crop riskiness decisions depending on the credit constraint status of the household. A novelty of this chapter is that I account for a non-homogenous impact of remittances on households. It might depend on

the initial constraints that households face. When studying the impact of remittances on the different crop riskiness decisions, remittances are interacted with the credit constraints faced by households in order to account for a possible heterogeneous effect. As the existing evidence on the insurance role of remittances is scarce, this chapter aims at providing new evidence by using more exact measures of riskiness and considering the heterogeneous effects that remittances might have.

The first objective of the chapter is to provide an answer to the following question: do households with higher amounts of remittances engage in crop specialization or crop diversification? On the one hand, farmers that receive higher remittances might choose more specialized crop production as specialization is seen as a risk increasing strategy. Migration and remittances allow for spatial income diversification, thus there is less need to use crop diversification as an *ex ante* insurance strategy. There are only two papers that explore the potential of migration and remittances to encourage households to make riskier agricultural production decisions, Damon [2010] and Gonzalez-Velosa [2011]. Gonzalez-Velosa [2011] shows that remittances increase the fraction of farmers in a given community in the Philippines that cultivate only one high-risk crop or low-risk crop. On the other hand, several studies show that farmers in developing countries under-diversify their portfolio due to knowledge and financial barriers [Di Falco et al., 2007, Di Falco and Chavas, 2009]. Remittances are also considered as substitutes or complements to rural loans [Richter, 2008]. They can relax credit constraints either directly, by substituting for them, or indirectly, by inducing a risk averse household to take a loan that previously was not taken because of fear of losing the collateral. Thus, it is possible that farmers can diversify more their crop production with the assistance of remittances. A contribution of the chapter is the use of

household panel data and of different and more exact measures of diversification such as the Shannon index, the Simpson index and the Berger-Parker index [Baumgärtner, 2006, Smale et al., 2003]. The advantage of using these indices is that they not only take into account the number of different crops cultivated by a farmer, but also the distribution of land shares to each crop planted.

Considering only the different diversity indices will not yield an exhaustive picture of the degree of riskiness of a farmer's output. The second objective of this chapter is to complete the previous analysis by constructing a measure of riskiness of each crop cultivated by a given household and to evaluate how different crops contribute to the riskiness of the total crop portfolio. The second question that arises is: do households that receive higher amounts of remittances increase the riskiness of their crop production by cultivating more crops with higher but more uncertain returns? In order to construct the measure of the individual crop and portfolio riskiness, I use the Single Index Model (SIM) developed by Turvey [1991] and applied by Bezabih and Di Falco [2012]. Damon [2010] studies how basic grains acreage, coffee acreage and other cash crop acreage respond to remittances. Using data from El Salvador, she finds that the land area dedicated to basic grains increases and the area dedicated to commercial cash crops decreases with remittances and migration. In an analysis on community-level data from the Philippines, Gonzalez-Velosa [2011] finds that remittances reduce the proportion of farmers cultivating low income crops (corn, coconut) and increase the proportion of farmers cultivating high income crops (mango).

In order to analyze the impact of remittances on the agricultural outcomes, I use panel data from the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) established by the World Bank. A direct estimation of the impact of remit-

tances on the agricultural choices will yield biased results. I address the endogeneity issues by using an instrumental variable (IV) approach and using an interaction term between the average district level of remittances and the maximal educational level of the household as instrument. The results show that remittances have no significant direct impact on farmers' risk decisions in terms of crop portfolio and crop diversification. However, there is novel evidence that the negative marginal impact of remittances is stronger for credit-constrained households than for non-credit constrained households. Credit-constrained households diversify less their crop production, which confirms, to some extent, the role of remittances as an insurance tool.

The answers to these questions have important policy implications. On the one hand, the economic literature states that African farmers choose low yield/low risk portfolios because of their negative past experience. This is mostly due to missing insurance and credit markets, and also absence of irrigation systems. It was shown that low yield portfolios are sub-optimal, and taking more risk in the decision making can increase the efficiency of the household agricultural portfolio as farmers forgo more profitable opportunities for the sake of certainty [Dercon, 2006]. Therefore, the existence of uninsured risk makes households stuck in poverty traps, especially when households are obliged to avoid risk linked to their subsistence needs. The consequences are amplified in the case of African farms when considering climate change, since the African continent is the most vulnerable to climate change. Adaptation to climate change by cropping drought or flood resistant crops will put pressure on farmers to engage in risk avoidance, thus pushing them into poverty. As we find that remittances can deal with this uninsured risk at least partially and thus promote riskier strategies, then reducing costs of sending remittances might help in reducing the negative consequences of missing credit

and insurance markets.

The chapter is organized as follows. Section 2.2 describes the data, the measures of crop diversity and riskiness, and gives the descriptive statistics. Section 2.3 introduces the econometric specification and discusses the endogeneity problems and solutions. Section 2.4 presents the results of the different diversification and riskiness estimations. Finally, Section 2.5 includes a summary of the results, limitations and further research ideas.

2.2 Data and descriptive statistics

In order to better understand the crop choice patterns of Ugandan farmers, Table A.1 shows the share of households cultivating a given crop and Table A.2 shows the average contribution of each crop to the total value of each household's production on the raw data (in Appendix). According to Table A.1, the major cereal crops are maize, cassava, millet and sorghum; important vegetables and fruits are beans, groundnuts, sweet potatoes and food banana; the traditional cash crops are coffee and to some extent cotton and sugarcane. What we observe is that, on average, other crops than cash crops are mostly included in the households' portfolio even if their contribution to the average production value is lower than that of cash crops.

Given these descriptive statistics on the crop choices in the sample, I proceed with construction of the different types of dependent variables based on what households cultivate and how they allocate their land. Two different sets of dependent variables will be used in the analysis. The first set includes different diversification indices. The second dependent variable is the weighted portfolio beta which is an average of each beta from a Single Index

Model estimation for the crops cultivated by a given household. The construction of this variable is explained in detail in Section 1.2.2 and Appendix A.1.

2.2.1 Definition and descriptive statistics on the diversity indices

The first set of dependent variables is constituted of different diversity indices that are adapted from the ecological literature [Baumgärtner, 2006, Smale et al., 2003]. I limit the analysis to the inter-specific aspect of diversity, including the diversity measures of the different crops, but not the different varieties/seeds of a given crop. The diversity indices can be classified into three categories. The first category refers to the simplest measure of diversity, i.e., a richness/count index, and it represents the total number of crops cultivated by a household. The richness index assumes an equal contribution of each crop to the household's crop diversity. One might argue that different crops should count differently for the degree of diversity. The second category of diversity index, the Berger-Parker index, takes into account the dominance of certain crops over other. According to the definition given in Table 2.1, the lower the share of the land dedicated to the most abundant crop, the higher the value of the Berger-Parker index. The third category of diversity indices, the Simpson index and the Shannon index, include in their definition the richness and the evenness of crops. The evenness refers to the level of equality of the abundance of different crops. A higher value of these indices is due to a higher number of crops but also to a higher equality of the abundance of the different crops. In the present analysis, the latter can be interpreted as equal land shares among different crops. A summary of the definitions is given in Table 2.1.

Table 2.1 – Definition of the diversity indices

Index	**Mathematical calculation**	**Explanation**	**In this chapter**
Count	$D = S$ $D \geq 1$	S- the number of species in the ecosystem	S-number of crops cultivated by the farmer
Berger-Parker	$D = 1/p_{max}$ $D \geq 1$	p_{max} - the most abundant species The higher the abundance of the most abundant species, the lower the index value.	p_{max} -the highest land share dedicated to a crop
Shannon	$D = -\sum p_i ln p_i$ $D \geq 0$	p_i - proportion or relative abundance of species	p_i -the land share occupied by crop i
(inverse) Simpson	$D = 1/\sum p_i^2$ $D \geq 1$	p_i - proportion or relative abundance of species	p_i -the land share occupied by crop i

Source: Table and calculations adapted from Smale et al. [2003] and Baumgärtner [2006]

In order to construct the different dependent variables, it is necessary to have detailed information on the share of land that farmers dedicate to different crops. The LSMS-ISA data contain this information, but for some households the shares do not sum up to 100 percent.[1] Thus I restrict the sample to households for which the crop shares, net of fallow land, sum up correctly. This implies that we might not have the information for both seasons for all households. I control for this issue by introducing a dummy for whether the agricultural data used are from both seasons, from the first season or from the second season. The attrition rate among the agricultural households between the first (2005/2006) and the second wave (2009/2010) is 11 percent, and between the second (2009/2010) and the third wave (2010/2011) is 9 percent. The number of households that are present in the three waves is 1742. I restrict the sample to those households for which land shares sum to 100 percent, and the final sample comprises 1538 households.

Table 2.2 describes the summary statistics of the dependent variables. The statistics on the count index show that on average, households planted 5 crops in the period from 2009 to 2011. The average number of cultivated crops increased between the two periods from 4.98 to 5.17. 80 percent of the households cultivated two to six crops and only three percent of the households cultivated only one crop with the median being five crops during the whole period. The other diversity variables are lower than the count index which indicates that land is not equally distributed to different crops. All the three diversity indices are left-censored to zero or one for households that cultivate one crop and their mean value increases from one year to the other. This increase can be due to an increase in the number of cultivated

[1] This is most likely due to interviewer mistakes and therefore I can infer that the error is not correlated with household characteristics.

crops, but also from a more equal allocation among different crops.

2.2.2 Construction of the measure of riskiness

One of the purposes of the chapter is to construct a riskiness measure of each crop cultivated by a farmer and to compute the overall riskiness of the farmer's crop production. To do so, I will use the Single Index Model (SIM) used, among others, by Turvey [1991] and by Bezabih and Di Falco [2012]. Unlike the Capital Asset Pricing Model (CAPM), SIM is not an equilibrium model and can be applied to any portfolio. This is an argument for the application of the SIM on African agriculture where markets are incomplete.

The Single Index Model assumes that the revenues associated with various farm enterprises are related through their covariance with some basic underlying factor or index. The risk correlated with this index is called non-diversifiable or systematic risk and the second risk component is the part of farm returns that is not correlated with the index, called specific risk that can be completely diversified. The systematic risk can be determined by a reference portfolio defined as:

$$I_{pht} = \sum_{i=1}^{n} w_{iht} I_{iht} \tag{2.1}$$

where w_{iht} refers to the land weights of crop i for household h in the time t and I_{iht} are the stochastic crop revenues. A parameter that measures the anticipated response of a particular crop to the changes in portfolio returns needs to be estimated. This coefficient, β_i, is given by a panel regression of I_{iht} on the reference portfolio I_{pht}:

$$I_{iht} = \alpha_i + \beta_i I_{pht} + e_{iht} \tag{2.2}$$

Table 2.2 – Summary statistics of the dependent variables

	Total				2009/2010				2010/2011			
Variable	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Risk variable												
weighted portfolio beta	0.28	0.50	0	7.60	0.29	0.55	0	7.60	0.28	0.45	0	6.08
Inter-specific diversity variables												
count index n	5.07	2.05	1	16	4.98	2.06	1	13	5.17	2.04	1	16
inverse Simpson	3.36	1.35	1	9.40	3.27	1.31	1	8.08	3.48	1.39	1	9.40
Shannon	1.28	0 .42	0	2.30	1.25	0.43	0	2.27	1.32	0.42	0	2.30
Berger-Parker	2.40	0.87	1	6.79	2.34	0.83	1	5.69	2.46	0.90	1	6.92

By definition $\beta_i = \frac{\sigma_{ipht}}{\sigma^2_{pht}}$ which means that β_i is a sufficient measure of marginal risk. Beta coefficients are estimated with the Equation (2.2) by using a panel fixed effects model in order to account for the unobserved household characteristics. The portfolio beta coefficient is calculated as a weighted average of the beta coefficients estimated for each crop that the household cultivates. A more detailed explanation of the SIM is given in Appendix A.1.

Table 2.3 gives the estimates of different crop beta coefficients. We can interpret these coefficients in the following way: if we consider, for example, cotton and maize, we observe that an increase in the reference portfolio of 1 Ugandan Shilling (UGX) will induce a more than proportional increase of the cotton revenue of 1.22 UGX and no increase in the maize revenue. These estimates indicate that cotton is riskier than the average crop portfolio, whereas maize has a more stabilizing effect. The estimates of the beta coefficients are consistent with the agricultural and economic literature on riskiness of crops.

Table 2.3 – Estimation results: Beta Coefficients

Crop	**Coefficient**	**Crop**	**Coefficient**
sweet potatoes	0	sorghum	0.22
cassava	0	beans	0.25
maize	0	avocado	0.36
millet	0	mango	0.43
pumpkins	0	simsim	0.50
dodo	0	tomatoes	0.50
vanilla	0	pineapples	0.52
paw paw	0.02	oranges	0.63
rice	0.03	banana	0.70
eggplants	0.04	tea	0.78
pigeon peas	0.08	irish potatoes	1.05
banana beer	0.10	cotton	1.22
soy beans	0.11	field peas	2.00
ground nuts	0.12	sunflower	2.00
yam	0.13	cabbage	2.31
onions	-0.13	cocoa	3.23
banana sweet	0.14	passion fruit	3.69
coffee	0.15	tobacco	5.25
Jack fruit	0.20	sugarcane	7.96

According to Table 2.2 the mean portfolio beta is relatively low (0.28). The minimum is 0, which means that the crop portfolio does not react to the variation of the reference portfolio. The maximum is 7.60 which means that an increase of 1 UGX in the reference portfolio provokes an increase of 7.60 UGX in the given portfolio.

2.2.3 Definition and descriptive statistics of the explanatory variables

Table 2.4 presents definitions and the summary statistics of the explanatory variables that are used in the estimations. Summary statistics are given for the whole sample, column (All HHs), for the share of households that do not receive remittances, column (Non-Rem HHs) and for the share of households that receive remittances, column (Rem HHs). A difference in means between these two groups is reported, to test for any differences of the characteristics between the two groups of households. The main variable of interest is the lagged level of remittances that a household receives from its migrants. About 35 percent of the households in the data-set reported that they received remittances locally or from abroad. The mean value of remittances is 101 000 UGX per household. Among the households receiving remittances, the average is 315 000 UGX. Intuitively, the district average of remittances is lower for households that do not receive remittances compared to those that receive remittances.

Based on the descriptive statistics of the whole sample, household heads have on average 48 years, are mostly male (about 70 percent) and have on average attended only primary school. The average number of male and female adult members of the households is around 3 and the average dependency ratio is 1.70, which indicates that for every adult worker there is 1.70 household members of non-working age. The average assets are around 5 780 000 UGX and the average non-agricultural income is higher than the average level of remittances which may question the strength of the role of remittances as insurance . About half of the households are credit-constrained. This variable takes value 1 if a household was refused to

Table 2.4 – Definition and descriptive statistics of the explanatory variables on the whole sample and by group of HHs

Variable	Definition	All HHs	Non-Rem HHs	Rem HHs	Dif in Means
Remittances					
remittances	received by the hh from migrants locally or abroad in *t-1* (UGX)	101	0	315	-315***
ditlevelremit	mean district level of remittances *t-1* (UGX)	101	94	126	-32***
Household characteristics					
sex	the gender of the hh head equals 1 if the hh head is male	0.71	0.79	0.52	0.273***
age	the age of the hh head	47.8	45.6	52.4	-6.86***
education	the highest school level achieved by the hh head 0-no education, 1-primary, 2-secondary	1.01	1.03	0.97	0.06
edumax	the number of years of schooling of the most educated hh member in $t-1$	8.5	8.4	8.7	-0.3**
averageduc	average number of years of schooling of all hh members in $t-1$	4.75	4.67	4.89	-0.22***
madults	male hh members between 16 and 65 years	2.89	3.02	2.61	0.42***
fadults	female hh members between 16 and 65 years	3.04	3.13	2.85	0.28***
dep. ratio	the dependency ratio of the hh	1.70	1.60	1.76	-0.16
Wealth characteristics					
non-agricultural income	income from non agricultural activities (UGX)	588	678	397	281***
assets	total assets in monetary value (UGX)	5 780	4 050	9 430	-5 380***
credit constraint	credit constraint dummy equals 1 if the household is constrained, 0 otherwise	0.50	0.50	0.50	0
Land characteristics					
land	land ownings in acres	3.21	3.41	2.80	0.61
quality index	weighted index of soil quality with: level 1 being good quality and level 3 being poor quality	1.43	1.43	1.44	-0.01
Weather characteristics					
rain	rain deviation in $t-1$ in district d from the long run mean divided by the long run standard deviation in absolute terms	0.28	0.29	0.27	0.02**
temperature	temperature deviation in $t-1$ in district d from the long run mean divided by the long run standard deviation in absolute terms	2.39	2.36	2.44	-0.08***
Observations		3 076	2 087	989	

Note: All categories of revenues are in thousands of Ugandan Shillings (UGX). For example the average level of remittances for all households are 101 000 UGX. The exchange rates of Ugandan Shillings per US dollar for January 2009, 2010 and 2011 are respectively 1 976, 1 936 and 2 332. The average land ownings correspond to 1.3, 1.4 and 1.13 hectares.

obtain credit by an informal or formal financial institution, but also if a household did not apply for a loan because of the fear to lose a collateral or to feel indebted, and 0 otherwise [Boucher et al., 2008]. There are significant differences between households that receive remittances and those that do not in terms of socio-economic characteristics. Households that do not receive remittances are more likely to have a male head, and they are younger than the heads of the households that receive remittances. There are also differences in terms of education; households that receive remittances have higher average and maximal education compared to households that do not receive remittances. Concerning the alternative means of income diversification, households that receive remittances have lower non-agricultural income but higher value of assets. The former is probably due to the fact that households with remittances have less need for income diversification through non-agricultural activities compared to households that do not receive remittances. Interestingly, no statistically significant difference concerning the credit constraint position is found between the two groups, and the same holds for land ownings and land quality.

Table 2.5 – Descriptive statistics of the count index in 2010/2011 by group of HHs

	Credit constrained HHs	**Non-Credit constrained HHs**	**Dif in Means**
Non-Remittances	5.1	5.3	-0.2
Remittances	4.6	5.1	-0.5*
Dif in Means	0.8**	0.2*	
Observations	230/173	349/286	

Before introducing the econometric specification, I discuss the descriptive analysis of the number of crops cultivated by a given household depending on the credit constraint status of the same household. Table 2.5 presents the different averages of the number of crops in the last year of the data used in this chapter, 2010/2011. The first line indicates

the average number of crops cultivated by households that did not receive any remittances during the entire period. The second line gives the average number of crops cultivated by households that either received remittances in 2005/2006 or in 2009/2010 or in both waves. The last line indicates the number of observations by group of households in each column. Columns differ by the credit constraint position of households. The calculations are made for households that do not change their credit constraint position over time. They are either credit constrained over the entire period, either non-credit constrained.

On average, credit constrained households that do not receive any remittances cultivate 5.1 crops. Households that receive remittances and face credit constraints specialize more their crop production, the average level of cultivated crop is 4.6. The difference of these two averages is significant at the level of 5 percent which indicates that remittances encourage such households to specialize more their production. Households that do not face credit constraints cultivate 5.3 crops on average when they receive remittances and 5.1 when they do not receive remittances. This represents a small change in the level of diversification that is significant at the level of 10 percent. As expected, receiving remittances generates a more significant difference for households that face credit constraints than those that do not. For non-credit constrained households, remittances do not significantly change the decision of how many crops such households cultivate. Remittances might not influence their production choices, but should probably matter for their overall consumption. It is less intuitive that the level of crop diversification is lower for credit constrained households than non-credit constrained households, even though the difference between receiving or not receiving remittances is higher for the former group.

2.3 Identification strategy

In this section, the econometric specification and the different estimation methods used to study the impact of remittances on the agricultural outcome variables are discussed. First, I proceed by defining the general equation to estimate, which is the same for the two sets of dependent variables. Second, I discuss the endogeneity problems related to the econometric specification and propose an instrumental variable approach, as well as a justification of the instruments that will be used in order to solve these problems.

2.3.1 Econometric specification

In order to study the impact of remittances on the farmer's crop diversity and crop riskiness, I use the following equation:

$$\begin{aligned} Q_{ht} = \alpha_0 + \alpha_1 X_{ht} + \alpha_2 R_{ht-1} + \alpha_3 C_{ht} + \alpha_4 C_{ht} * R_{ht-1} + \alpha_5 RAINDEV_{dt-1} \\ + \alpha_6 TEMPDEV_{dt-1} + \mu_h + \eta_t + \varepsilon_{ht} \end{aligned} \tag{2.3}$$

where Q_{ht} stands for the agricultural outcome variables of household h in time t, described before. X_{ht} represents household characteristics such as the gender, the age and the level of education of the household head and the number of female and male members net of migration. Controlling for socio-economic factors such as sex, age and education of the household head is important as several studies showed that household heads with different gender, age and education level make different risk choices. It has been shown that older and female household heads choose lower risk activities [Bezabih and Di Falco, 2012]. Household heads with higher education may choose low risk activities as they might have more information

on the negative consequences of taking risk. Also, the number of female and male remaining adults of the household and the land ownings are included as they are the principle production factors and thus can impact the crop production decision making. The dependency ratio can also be a factor that influences the risk behavior of households as the number of non-working members can be a barrier to risk. X_{ht} also includes land ownings as higher land ownings might also increase the possibility of diversification.[2] A weighted index of land quality is included too in order to capture the fact that cultivating riskier crops might demand a higher quality of land.

Concerning the variable of interest, I use a lagged value of the level of remittances R_{ht-1} received by the household h following the assumption that households would make a decision on agricultural risk taking and crop diversification in the period t once it received the remittances in the previous period $t-1$. In this chapter, I focus only on the transfer of remittances as an insurance strategy and not on migration, as having a migrant is a necessary but not a sufficient condition to receive remittances and thus to be insured. Also, in the LSMS-ISA data, only the annual flow of migrants is recorded and not the stock of migrants. This past stock is probably behind the remittances transfers as there are more households in the sample that report to receive remittances than those that have at least one migrant.

C_{ht} is a dummy that indicates whether a household is credit-constrained or not. Such a constraint can be overcome by remittances, but also by other forms of income diversification such as off-farm activities that are represented by non-agricultural income. However, the covariance between the agricultural and non-agricultural income in the same location should

[2] I do not include assets and non-agricultural income as they are highly endogenous and linked to remittances received by households.

be higher than the covariance of agricultural income and remittances from different places, thus remittances should offer higher insurance than non-agricultural income earned in the same location. I include an interaction term between C_{ht} and R_{ht-1} in order to account for any heterogeneous effects of remittances depending on whether a household is credit cosntrained or not. Household (μ_h) and time (η_t) fixed effects are also taken into account in Equation (2.3).

Finally, weather conditions have an important impact on the diversification decisions of farmers. The temperature, $TEMPDEV_{dt-1}$, and precipitation anomalies, $RAINDEV_{dt-1}$, are constructed as deviation in time $t-1$ in the district d from the long run annual mean divided by the long run annual standard deviation of the given district.

2.3.2 Estimation method(s)

Direct panel fixed effect estimation of Equation (2.3) will yield biased results. First, remittances are not random and depend on household characteristics. Thus, households that have migrants and receive remittances may differ systematically from households that neither have migrants nor remittances. Second, there might be some unobserved characteristics of the household that have a simultaneous impact on migration, remittances and agricultural decisions such as entrepreneurial spirit. The third endogeneity problem is reverse causality which may also exist if households that are prone to risk taking send a migrant once they have made their agricultural decision and expect remittances in return. The latter case of endogeneity is avoided, to some extent, as the lagged value of remittances is used.

Another technical issue arises as the dependent variables - diversity indices and the

portfolio beta - are left-censored which requires a Tobit estimation. Also, the count index n is a categorical variable that takes limited number of values and for which a Poisson estimation should be used. These non-linear models do not allow the use of fixed effects. However, the number of censored observations in the sample is around three percent. Therefore, I use a panel fixed effects model that can also be appropriate as it allows to purge the unobserved time invariant household characteristics.

Other studies have addressed these endogeneity problems by using an instrumental variable (IV) approach. Several authors use the distance to the borders or the consulate to instrument the outcomes of migrants in the destination country [McKenzie et al., 2010]. Some authors use also natural shocks such as rainfall intensity to instrument migration when studying outcomes abroad [Munshi, 2003, Yang and Choi, 2007] and others use economic shocks such as depreciation of different currencies to instrument migration [Yang and Martínez Alvear, 2006, Yang, 2008], or unemployment rates and GDP shocks in the receiving countries [Damon, 2010, Gonzalez-Velosa, 2011]. Also cultural, historical, community and political factors can be used as instrumental variables, such as the historical migration rate in a given village or migration networks in the receiving countries [McKenzie, 2006, Acosta, 2011].

As migration is mostly internal,[3] a local instrumental variable that is correlated with remittances received by the household and uncorrelated with agricultural risk borne by the household should be used. Therefore, I use a district based instrumental variable, i.e., the average level of remittances on district level. This instrument is also adopted in the literature

[3]During the year 2009-2010 less than one percent of the migrants migrated abroad; and during the year 2010-2011 less than two percent of the migrants went abroad.

when studying the impact of remittances on agricultural outcome [for example Rozelle et al., 1999, Atamanov and Van den Berg, 2012]. It represents a proxy for a local remittances norm. I hypothesize that the average district level of remittances in $t-1$ affects the remittances received by households in $t-1$, but does not have a direct impact on crop choices and is not correlated with unobservable household characteristics. In order to introduce more variability at household level, I interact the district average remittances with the years of schooling of the most educated person in the household in $t-1$.[4] Acosta [2011] finds that better educated households receive higher amounts of remittances. In the case of Uganda, Appleton and Balihuta [1996] find that primary schooling has an impact on agricultural productivity, but there are diminishing returns to secondary schooling. The results on secondary schooling are insignificant. The impact of primary schooling on switching from sorghum to riskier crops is small and hardly significant, and insignificant for secondary schooling. The average maximal education in the LSMS-ISA sample is 8.5 years, which exceeds the 7 years of primary schooling. Therefore, maximal education within a household should drive the migration decision, without having an impact on agricultural risk decisions. As long as I control for the household's average education in $t-1$ and primary and secondary schooling of the household head in t, the incidence of maximal education on agricultural risk decisions should be through remittances and migration only [Mendola, 2008]. The first stage estimation of remittances can be written as:

$$\begin{aligned} R_{ht-1} = \beta_0 + \beta_1 X_{ht} + \beta_2 C_{ht} + \beta_3 R_{dht-1} + \beta_4 edumax_{ht-1} + \beta_5 R_{dht-1} * edumax_{ht-1} \\ + \alpha_6 RAINDEV_{dt-1} + \alpha_7 TEMPDEV_{dt-1} + \mu_h + \eta_t + \upsilon_{ht-1} \end{aligned} \tag{2.4}$$

[4]Similarly, Amuedo-Dorantes and Pozo [2006] construct an instrument based on the per capita count of Western Union offices in the state during the previous year interacted with household members' education.

where R_{ht-1} stands for the level of remittances received by the household h in the period $t-1$. X_{ht} represents the household characteristics such as the household head's gender, age and level of education, as in the Equation (2.3) and as before there are household and time effects. The average district level of remittances is represented by the variable R_{dht-1} where d refers to the district where the household h lived at time $t-1$. It is calculated as the total amount of remittances received in the district d divided by the total number of households in the district. $edumax_{ht-1}$ is the number of years of schooling of the most educated member of the household h in time $t-1$. It is expected that household remittances increase with the district level of remittances interacted with the highest education level in the household. Some districts might have better education opportunities than others that can influence the level of remittances and migration. In order to account for these differences, I use the quintile at district level to which the maximal education level of a given household belongs. This helps to reinforce the exclusion restriction.

Equation (2.4) is supposed to be estimated with a Tobit model, as remittances are observed only for about a third of the sample. There is a trade-off whether this first stage equation should be estimated by using a Tobit model or panel fixed effects estimation in a context of a two stage least squares estimation strategy (2SLS). If a non-linear first stage such as Tobit is used, then the results from the second stage will be inconsistent [Angrist, 2001]. Therefore, a panel first stage model seems more appropriate even though the endogenous variable is censored. An alternative strategy in order to preserve the non-linear nature of the censored endogenous variable is to i) estimate Equation (2.4) by using a Tobit model, ii) obtain the fitted values of R_{ht-1} and iii) estimate Equation (2.3) by an IV approach using as instrument the fitted values of R_{ht-1} [Angrist, 2001, Wooldridge, 2010]. This strategy

bypasses the problem of non-efficient estimates in the second stage regression when we use a simple non-linear model in a first stage. Thus the advantages of using this alternative estimation is to keep the nonlinear nature of remittances, include fixed effects in the first stage and obtain consistent and efficient estimates in the second stage of the IV estimation. In Equation (2.3) there is an interaction term between the credit constraint dummy and the endogenous regressor R_{ht-1} which in return generates another endogenous regressor. In order to deal with the latter, I instrument the interaction term $C_{ht} * R_{ht-1}$ by another interaction term $C_{ht} * R_{dt-1} * edumax_{ht-1}$ in the case of a linear 2SLS and $C_{ht} * predicted\ value\ of\ remittances$ in the alternative method of IV estimation. I will rely on the results obtained through this alternative strategy when commenting the different results.

2.4 Results

The first stage regression presented in Table 2.6 confirms that the district average level of remittances interacted with the maximal educational level of the household has a positive and significant impact on the level of remittances received by households. An increase of the predicted instrumented value of remittances by 100 000 (column (2)) induces an increase of 58 200 UGX of household remittances in time $t-1$.[5] The F-statistic is higher than 10 in both estimations and higher than the Stock and Yogo 10 percent IV size which indicate that the instruments are valid. Finally, the Anderson-Rubin test is in favor of the second instrument (column (2)) since it rejects the null hypothesis of valid exclusion restrictions. Therefore, I choose this second instrument for the interpretation of second stage results (column (3) in

[5]The level of remittances is scaled in order to have a better interpretation of the results; each variable is divided by 10 000 UGX.

each of the following tables).[6]

Table 2.6 – First Stage estimation

Remittances	IV Panel FE (1)	IV Panel FE (2)
Instruments		
mean district level of remittances in $t-1$*edumax	0.121***	
	(0.030)	
predicted value of remittances in $t-1$ from a Tobit estimation		0.582***
		(0.113)
HH Control Variables		
	YES	YES
Validity Tests		
F-statistic	12.5	20.62
Stock and Yogo 10% IV size	7.03	7.03
Anderson and Rubin Wald Test (p-value)	0.91	0.00
Observations	3,076	3,076
R-squared	0.082	0.082
Number of hhid	1,538	1,538

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The two columns report the results of a panel fixed effects estimation. In the second column the predicted value of remittances in $t-1$ is obtained as a result of a panel Tobit random effect estimation. Standard errors in parentheses are clustered at district level. Individual and time effects, and dummies for whether the agricultural data include both seasons or only the first season or the second one, are included in each regression, as well as the other control variables that are included in the second stage of the estimation procedure.

2.4.1 Impact of remittances on inter-specific crop diversification

The regression results for Equation (2.3) are in Tables 2.7, 2.8, 2.9 and 2.10. The IV estimation results, column (3) in each Table, indicate that remittances have no significant di-

[6] I tested other variables to introduce more variability at household level. I tested male/female ratio of adults at working age in order to explain the migration decisions of a household. The results of the second stage estimation do not change. But, this variable is not significantly correlated with household remittances as in Uganda half of the migrants are female and half are male; there is not one type of migration that dominates the other. The second variable that I tested is the probability of having a mobile phone to capture the use of mobile money. Again, second stage results do not change. However, one might argue that owning a mobile phone depends on wealth and therefore remittances. Mobile money was introduced in Uganda in 2009, thus after the first wave of the sample. Finally owning a mobile phone can improve access to information: output and input prices, weather conditions. Therefore, I decide to keep maximal education quintiles as it seems to be the most relevant.

rect effect on households' crop diversity choices. However, there is a negative and significant effect at the five percent significance level of remittances when they are interacted with the credit constraint dummy. When discussing the results on the magnitude of the interaction term, I use the results for the Shannon index, Table 2.9, as it is qualitatively similar to the other indices. The results can be interpreted as follows: if we have two households that receive 300 000 UGX[7] and one is credit-constrained and the other not, the credit-constrained household has a relative crop abundance index that is lower by 0.081[8] compared to a non-credit-constrained household. This is rather a large effect since the mean of the index is 1.28 (varying form 0 to 2.3). A credit-constrained household that receives remittances distributes its land more unequally among different crops (Table 2.9 and Table 2.10) and cultivates a smaller number of crops (Table 2.7) compared to a non-credit-constrained household. The overall conclusion from these different indices of diversity indicates that remittances push credit-constrained farmers into higher crop specialization compared to non-credit-constrained households. This result is new compared to the existing literature. Since remittances play a role of insurance for households that are credit-constrained and the change in crop diversification of households that do not face financial constraints is less significant, these results illustrate that remittances indeed relax credit constraints for those households for which they exist.[9] These novel results go in line with the study of Gonzalez-Velosa [2011] where remittances decrease the fraction of farmers on a community level that engage in the production of three or more crops and increases the fraction of farmers that produce one

[7]The mean value of remittances among households that receive remittances.

[8]As the coefficient of remittances (and credit constraint) is insignificant, the calculation of the effect is the following: -0.027*3.

[9]It is not possible to ascertain that they remove completely credit constraints as the magnitude of the coefficients is rather small. But we can claim that remittances relax partially these constraints.

crop. By comparison, the novelty of the present study is that the analysis of the impact of remittances on diversity decisions is done at the household level and includes a larger set of diversity indices in addition to a count index.

The results show further that the size of land is important for the degree of crop diversification of farmers. An increase of the land size of one acre decreases the relative abundance of crops by 0.004 points at a significance level of one percent (Table 2.9). Households with higher land ownings distribute land more unequally among different crops. This indicates that there are some crops that dominate others which is confirmed by the Berger Parker index (Table 2.8). When using the standard measure of crop diversity, the count index, land ownings are not significant (Table 2.7). For all other diversity measures, the higher the land holding of a farmer, the lower the equality of the shares of land that are dedicated to different crops. The interpretation of this result might be linked to the existence of economies of scale in crop cultivation for the farmers in the sample. Land as production factor thus seems to have an important influence on crop diversification decisions. This result is opposite to the one found by Cavatassi et al. [2012] on Ethiopia that higher land ownings lead to diversity as there is higher feasibility of crop diversification. The difference between the farmers studied in this chapter and in Cavatassi et al. [2012] is that the mean size of land ownings are 1.21 hectares in Uganda compared to 0.5 hectares in Ethiopia. This allows us to make an argument that supports the existence of economies of scale as Ugandan farmers cultivate larger land surfaces than Ethiopian farmers.

There are few socio-economic factors that influence the household's decision in terms of crop diversification. In the case of the count index (Table 2.7) and the Shannon index (Table 2.9) the number of female adults has a positive and significant effect on the number of crops

Table 2.7 – Second stage estimation of number of crops

Count Index	Poisson FE	IV Panel FE	IV Panel FE	IV Panel FE
			(predicted remittances in 1st stage)	
	(1)	(2)	(3)	(4)
remittances	0.001	0.006	0.052	0.004
	(0.005)	(0.044)	(0.053)	(0.030)
credit constraint	0.010	0.037	0.140	0.052
	(0.026)	(0.109)	(0.109)	(0.113)
remittances*credit constraint	-0.002	0.000	-0.103*	-0.088*
	(0.006)	(0.073)	(0.058)	(0.056)
land	-0.001	-0.005	-0.005	-0.002
	(0.001)	(0.004)	(0.004)	(0.005)
land quality index	-0.023	-0.106	-0.108	-0.110*
	(0.022)	(0.068)	(0.068)	(0.065)
male adults	-0.005	-0.039	-0.019	-0.011
	(0.018)	(0.069)	(0.067)	(0.064)
female adults	0.028	0.131***	0.139***	0.105**
	(0.017)	(0.046)	(0.047)	(0.046)
dep.ratio	-0.007	-0.035	-0.041	-0.021
	(0.017)	(0.046)	(0.047)	(0.044)
sex	-0.035	-0.123	-0.178	-0.049
	(0.089)	(0.291)	(0.309)	(0.297)
age	0.003	0.017	0.016	0.016
	(0.003)	(0.011)	(0.011)	(0.010)
primary education	0.083	0.429**	0.471***	0.513***
	(0.064)	(0.178)	(0.178)	(0.176)
secondary education	0.087	0.415	0.500	0.567*
	(0.094)	(0.293)	(0.306)	(0.291)
average education		0.001	0.008	0.021
		(0.028)	(0.028)	(0.026)
rainfall deviation				0.821**
				(0.385)
temperature deviation				-1.273***
				(0.196)
Observations	3,076	3,074	3,074	3,074
R-squared		0.131	0.118	0.125
Number of hhid	1,538	1,537	1,537	1,537

Robust Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Column (1) shows the results of a Poisson fixed effect estimation and the two other columns report the results of a panel fixed effects estimation. The instrumental variable used in column (2) corresponds to the mean district level of remittances interacted with maximal education in the HH; in column (3) and colum (4) it corresponds to the predicted value of remittances after a panel Tobit estimation. Standard errors in parentheses are clustered at district level. Individual and time effects, and dummies for whether the agricultural data include both seasons or only the first season or the second one, are included in each regression.

Table 2.8 – Second stage estimation of the effect on absolute abundance

Berger-Parker Index	Panel FE	IV Panel FE	IV Panel FE	IV Panel FE
			(predicted remittances in 1st stage)	
	(1)	(2)	(3)	(4)
remittances	-0.006	0.006	0.043	0.027
	(0.008)	(0.023)	(0.042)	(0.031)
credit constraint	0.019	0.013	0.095**	0.074
	(0.049)	(0.053)	(0.047)	(0.051)
remittances*credit constraint	-0.005	-0.001	-0.083**	-0.080**
	(0.011)	(0.040)	(0.036)	(0.036)
land	-0.007**	-0.007**	-0.008***	-0.007**
	(0.003)	(0.003)	(0.003)	(0.003)
land quality index	0.006	0.008	0.006	0.005
	(0.036)	(0.036)	(0.037)	(0.037)
male adults	-0.007	-0.007	0.009	0.011
	(0.029)	(0.031)	(0.030)	(0.030)
female adults	0.009	0.009	0.015	0.004
	(0.029)	(0.028)	(0.029)	(0.029)
dep.ratio	0.029	0.028	0.023	0.029
	(0.030)	(0.030)	(0.029)	(0.029)
sex	0.013	0.012	-0.032	0.011
	(0.145)	(0.144)	(0.152)	(0.153)
age	-0.001	-0.000	-0.001	-0.001
	(0.008)	(0.008)	(0.009)	(0.009)
primary education	0.157	0.152	0.184	0.202
	(0.125)	(0.125)	(0.133)	(0.136)
secondary education	0.210	0.204	0.271	0.299*
	(0.154)	(0.155)	(0.169)	(0.167)
average education		-0.006	-0.000	0.004
		(0.013)	(0.012)	(0.012)
rainfall deviation				0.390**
				(0.188)
temperature deviation				-0.383***
				(0.099)
Constant	2.297***			
	(0.396)			
Observations	3,076	3,074	3,074	3,074
R-squared		0.121	0.101	0.111
Number of hhid	1,538	1,537	1,537	1,537

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The three columns report the results of a panel fixed effects estimation. The instrumental variable used in column (2) corresponds to the mean district level of remittances interacted with maximal education in the HH; in column (3) and (4) it corresponds to the predicted value of remittances after a panel Tobit estimation. Standard errors in parentheses are clustered at district level. Individual and time effects, and dummies for whether the agricultural data include both seasons or only the first season or the second one, are included in each regression.

Table 2.9 – Second stage estimation of the effect on relative abundance

Shannon Index	Panel FE	IV Panel FE	IV Panel FE	IV Panel FE
			(predicted remittances in 1st stage)	
	(1)	(2)	(3)	(4)
remittances	-0.000	-0.003	0.014	0.004
	(0.003)	(0.008)	(0.014)	(0.008)
credit constraint	0.003	-0.007	0.026	0.012
	(0.024)	(0.027)	(0.026)	(0.027)
remittances*credit constraint	-0.006	0.004	-0.030**	-0.028**
	(0.004)	(0.020)	(0.015)	(0.015)
land	-0.004***	-0.004***	-0.004***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
land quality index	-0.026*	-0.026*	-0.027*	-0.027*
	(0.015)	(0.015)	(0.015)	(0.015)
male adults	0.002	0.001	0.007	0.009
	(0.013)	(0.013)	(0.012)	(0.012)
female adults	0.027**	0.026**	0.029**	0.022*
	(0.012)	(0.012)	(0.012)	(0.012)
dep.ratio	-0.005	-0.004	-0.006	-0.003
	(0.011)	(0.011)	(0.011)	(0.011)
sex	-0.029	-0.025	-0.043	-0.016
	(0.065)	(0.062)	(0.065)	(0.065)
age	0.001	0.002	0.001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)
primary education	0.094*	0.090*	0.103**	0.113**
	(0.048)	(0.047)	(0.049)	(0.049)
secondary education	0.125*	0.117*	0.144**	0.160**
	(0.065)	(0.062)	(0.067)	(0.066)
average education		-0.002	0.001	0.003
		(0.006)	(0.006)	(0.006)
rainfall deviation				0.222***
				(0.074)
temperature deviation				-0.244***
				(0.039)
Constant	1.174***			
	(0.148)			
Observations	3,076	3,074	3,074	3,074
R-squared	0.137	0.134	0.125	0.128
Number of hhid	1,538	1,537	1,537	1,537

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The three columns report the results of a panel fixed effects estimation. The instrumental variable used in column (2) corresponds to the mean district level of remittances interacted with maximal education in the HH; in column (3) and (4) it corresponds to the predicted value of remittances after a panel Tobit estimation. Standard errors in parentheses are clustered at district level. Individual and time effects, and dummies for whether the agricultural data include both seasons or only the first season or the second one, are included in each regression.

Table 2.10 – Second stage estimation of the effect on relative abundance

Inverse-Simpson Index	Panel FE	IV Panel FE	IV Panel FE	IV Panel FE
			(predicted remittances in 1st stage)	
	(1)	(2)	(3)	(4)
remittances	-0.010	0.001	0.047	0.016
	(0.011)	(0.030)	(0.051)	(0.032)
credit constraint	0.037	0.025	0.127*	0.078
	(0.070)	(0.077)	(0.068)	(0.074)
remittances*credit constraint	-0.011	-0.000	-0.102**	-0.095**
	(0.015)	(0.059)	(0.046)	(0.047)
land	-0.012***	-0.012***	-0.012***	-0.010***
	(0.004)	(0.004)	(0.004)	(0.004)
land quality index	-0.020	-0.018	-0.020	-0.022
	(0.047)	(0.047)	(0.048)	(0.048)
male adults	0.012	0.010	0.030	0.035
	(0.039)	(0.040)	(0.039)	(0.039)
female adults	0.026	0.025	0.032	0.011
	(0.038)	(0.037)	(0.038)	(0.038)
dep.ratio	0.024	0.024	0.018	0.029
	(0.039)	(0.039)	(0.038)	(0.038)
sex	-0.049	-0.048	-0.102	-0.021
	(0.205)	(0.199)	(0.211)	(0.210)
age	0.000	0.001	-0.000	-0.000
	(0.011)	(0.011)	(0.012)	(0.011)
primary education	0.258	0.249	0.290*	0.320*
	(0.168)	(0.168)	(0.173)	(0.177)
secondary education	0.400*	0.389*	0.472**	0.519**
	(0.221)	(0.217)	(0.232)	(0.225)
average education		-0.007	0.000	0.008
		(0.019)	(0.019)	(0.017)
rainfall deviation				0.610**
				(0.257)
temperature deviation				-0.764***
				(0.136)
Constant	3.177***			
	(0.519)			
Observations	3,745	3,078	3,078	3,078
R-squared	0.086	0.084	0.064	0.096
Observations	3,076	3,074	3,074	3,074
R-squared	0.088	0.086	0.071	0.082
Number of hhid	1,538	1,537	1,537	1,537

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The three columns report the results of a panel fixed effects estimation. The instrumental variable used in column (2) corresponds to the mean district level of remittances interacted with maximal education in the HH; in column (3) and (4) it corresponds to the predicted value of remittances after a panel Tobit estimation. Standard errors in parentheses are clustered at district level. Individual and time effects, and dummies for whether the agricultural data include both seasons or only the first season or the second one, are included in each regression.

cultivated by the household and the level of relative abundance of crops. One additional female member of a household increases the number of crops by 0.14 crops and the Shannon index by 0.03 units. This indicates that households with more female members include a higher number of crops in their production portfolios and allocate more equally their land, which indicates that households with a higher number of female members might be more risk-averse. Education also has a positive and significant impact on crop diversity (Table 2.7, 2.10 and 2.9). Primary educated household heads and secondary educated household heads have higher values of the Shannon index by respectively 0.10 and 0.14 compared to household heads with no education (Table 2.9). Similarly, a household head with primary education cultivates 0.5 crops more than household heads with no education, all else equal (Table 2.7). More educated household heads engage in higher crop diversity as they might have more knowledge about the benefits of diversification and consequences of crop specialization. Contrary to Cavatassi et al. [2012], I do not find any significant impact of the household structure given by the dependency ratio on crop diversity decisions.

Rainfall and temperature deviations are included in the second stage regression presented in column (4) of each Table. For example, one standard deviation of rain increases the number of crops by 0.821, and it also increases the other diversity indices. This suggests that farmers that live in districts with higher rainfall variability increase their crop diversity in terms of number and evenness of land distribution among the different crops they cultivate. The effect of temperature is the opposite. For temperature, one standard deviation leads to a decrease of the number of crops by 1.3. The incidence of temperature deviation on the other indices is similar.

2.4.2 Impact of remittances on the riskiness of the crop portfolio

The results of the estimation on the relationship between the riskiness of a crop portfolio and remittances are less significant than the diversity decisions. Remittances have a positive but statistically insignificant effect on the level of the portfolio beta (Table 2.11). In the estimation where we consider remittances as a continuous variable, column (2) in Table 2.11, we can see that a non-credit-constrained household receiving 300 000 UGX (close to the average level of remittances) has a higher portfolio beta index of 0.05 units, but this effect is significant only at a ten percent level. On the one hand, Damon [2010] finds that households in El Salvador that receive remittances increase the share of land that they dedicate to subsistence crops and decrease the share of land dedicated to cash crops. On the other hand, Gonzalez-Velosa [2011] shows that remittances reduce the fraction of farmers that produce corn, coco and banana and increase the fraction of farmers that produce high-value crops in the Philippines. To some extent, this chapter favors the latter result as there is some evidence that remittances increase the riskiness of farmers' crop portfolio. However, the statistical significance of the result in this chapter is not sufficient to draw any final conclusion.

According to column (3) in Table 2.11, having a household head that is male increases the risk index by 0.17 points compared to a female household head, all else being constant. This result confirms the finding of Bezabih and Di Falco [2012]. In the same manner, having an additional adult member that is female decreases the portfolio beta of the given household by 0.01 units. Surprisingly no other household characteristics, land ownings or household dependency ratio have a significant impact on farmers' decisions on the degree of riskiness

Table 2.11 – Second stage estimation of the effect on riskiness

Weighted Portfolio Beta	Panel FE	IV Panel FE	IV Panel FE	IV Panel FE
			(predicted remittances in 1st stage)	
	(1)	(2)	(3)	(4)
remittances	0.001	0.016	0.018	0.017
	(0.003)	(0.013)	(0.013)	(0.011)
credit constraint	0.004	0.013	0.014	0.005
	(0.015)	(0.014)	(0.017)	(0.019)
remittances*credit constraint	-0.002	-0.012	-0.013	-0.011
	(0.003)	(0.012)	(0.010)	(0.010)
land	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
land quality index	0.003	0.003	0.003	0.004
	(0.015)	(0.015)	(0.015)	(0.015)
male adults	0.003	0.005	0.006	0.006
	(0.010)	(0.010)	(0.010)	(0.010)
female adults	-0.013*	-0.013*	-0.013*	-0.014*
	(0.007)	(0.008)	(0.007)	(0.007)
dep.ratio	0.003	0.001	0.001	0.003
	(0.010)	(0.010)	(0.010)	(0.010)
sex	0.179*	0.170*	0.169*	0.173*
	(0.099)	(0.100)	(0.100)	(0.101)
age	0.001	0.002	0.002	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
primary education	-0.086	-0.085	-0.084	-0.086
	(0.067)	(0.066)	(0.066)	(0.065)
secondary education	-0.044	-0.037	-0.037	-0.039
	(0.070)	(0.069)	(0.072)	(0.071)
average education		-0.001	-0.001	-0.000
		(0.005)	(0.004)	(0.005)
rainfall deviation				-0.054
				(0.072)
temperature deviation				-0.073
				(0.053)
Constant	0.193*			
	(0.100)			
Observations	3,076	3,074	3,074	3,074
R-squared	0.016	-0.004	-0.003	-0.003
Number of hhid	1,538	1,537	1,537	1,537

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The three columns report the results of a panel fixed effects estimation. The instrumental variable used in column (2) corresponds to the mean district level of remittances interacted with maximal education in the HH; in column (3) and (4) it corresponds to the predicted value of remittances after a panel Tobit estimation. Standard errors in parentheses are clustered at district level. Individual and time effects, and dummies for whether the agricultural data include both seasons or only the first season or the second one, are included in each regression.

of their crop portfolio.

One possible explanation why the results on the crop riskiness choice of Ugandan farmers are statistically insignificant may be that the individual crop riskiness β_i does not vary over time. Thus, if a household cultivates the same crops in the two periods and if the weights of these crops do not change significantly, then the portfolio beta will not differ between the periods. In addition, the two waves used in this analysis are consecutive. Since making different crop decisions may take time, the invariability of the dependent variable may be due to the consecutiveness of the waves and the invariability of the crop risk measure.

2.4.3 Robustness check

I assume that migration is a necessary but not a sufficient condition to receive remittances and therefore obtain insurance for households. Remittances are not as formalized and predefined as insurance contracts or other transfers [Vargas-Silva, 2012]. They are determined by different factors: the degree of altruism of the migrant, his living situation and employment status. These factors can all influence the predictability and frequency of remittances.

In order to disentangle the effect of remittances from the effect of migration, I do the same estimations of crop diversity choices as before, but with the number of migrants of the household instead of remittances.[10] In Table 2.12, the variable *migrants* represents the number of adult household members that are absent more than six months from the household's place of origin. As previously, I have to deal with endogeneity problems related to migration. I instrument migration by using the average number of migrants on a district

[10]The results presented in the section are only focused on the Shannon index as the other indices confirm the same impact of migration on crop diversity. The impact of migration on the portfolio beta is non-significant as in the case when studying the impact of remittances and therefore is not included in this section.

level (proxy for a community migration norm) and the distance to the closest road that is a household specific variable (proxy for the cost of migration). The results are presented in Table 2.12 and show that migration does not have any statistically significant impact on the level of relative abundance of crops.[11] In the case of Ugandan farmers, it is more the insurance feature of remittances that is driving their crop diversity choices than migration.

Table 2.12 – Second stage estimation of the effect of migration on relative abundance

Shannon Index	Panel FE	IV Panel FE	IV Panel FE (predicted migrants in 1st stage)
	(1)	(2)	(3)
migrants	-0.004	0.027	0.030
	(0.004)	(0.018)	(0.019)
credit constraint	-0.003	-0.012	-0.001
	(0.029)	(0.032)	(0.029)
migrants*credit constraint	0.005	0.007	0.004
	(0.004)	(0.005)	(0.005)
land	-0.004***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)
land quality index	-0.019	-0.020	-0.021
	(0.013)	(0.013)	(0.013)
male adults	-0.002	0.003	0.003
	(0.012)	(0.012)	(0.013)
female adults	0.028**	0.030**	0.031**
	(0.011)	(0.012)	(0.012)
dep.ratio	-0.004	-0.009	-0.009
	(0.012)	(0.013)	(0.013)
sex	0.004	0.022	0.025
	(0.064)	(0.062)	(0.064)
age	0.001	0.000	0.000
	(0.003)	(0.003)	(0.003)
primary education	0.056	0.064	0.066
	(0.046)	(0.043)	(0.043)
secondary education	0.079	0.100	0.101
	(0.062)	(0.064)	(0.064)
Constant	1.215***		
	(0.147)		
Observations	3,074	3,074	3,074
R-squared	0.133	0.091	0.089
Number of hhid	1,537	1,537	1,537

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The three columns report the results of a panel fixed effects estimation. The instrumental variable used in column (2) corresponds to the average number of migrants on district level and the distance to the closest road and in column (3) it corresponds to the predicted value of remittances after a panel Tobit estimation. Standard errors in parentheses are clustered at district level. Individual and time effects, and dummies for whether the agricultural data include both seasons or only the first season or the second one, are included in each regression.

[11] The results in Table 2.12 can be compared to the results in Table 2.9. The impact of weather conditions on the Shannon index are similar as before, when using remittances.

2.5 Conclusion

I investigate the impact of remittances on agricultural outcomes, notably crop specialization or diversification and riskiness in crop choice of Ugandan farmers by using an IV panel fixed effects approach. The first result of the chapter is that the direct impact of remittances is not significant neither on crop diversification nor on risk choices. The second novel result shows that remittances induce credit-constrained households to specialize their crop production more compared to non-credit-constrained households. It implies that remittances enable farmers to undertake more risk through crop specialization. Remittances may thus remove (at least partially) credit constraints for those farmers that are facing them. The results show also that land ownings, education and gender are important drivers of farmers' crop cultivation decisions and land distribution among different crops. An important result is that higher land possession increases crop specialization. Regarding other household characteristics, I find significant differences in crop choices in terms of risk between male and female heads of households.

Following these results, an open question that arises is to investigate whether households engage in low-risk crop specialization or high-risk crop specialization. One may argue that specializing in a low risk/low return crop is a risk decreasing strategy. Another point that needs to be addressed too is that migration and remittances are risky strategies on their own, as the outcomes from these kinds of income diversification are not certain. Studying whether households receive remittances on a regular basis or only when they face shocks will give a better argument as to whether remittances play the role of insurance. Unfortunately, such an analysis necessitates a longer time dimension of panel data and therefore cannot be

done in the present chapter. Finally, as it is shown in the analysis that larger land ownings are a significant factor of crop specialization, further research is needed in order to determine whether this is due to economies of scale and whether this setup is more efficient compared to small-scale diversified farms. This does not seem to be the case in Ethiopia where higher crop diversity goes together with larger land possessions [Cavatassi et al., 2012]. The average land ownings for the Ugandan farmers and Ethiopian farmers are 1.21 hectares and 0.5 hectares, respectively. It thus seems that economies of scale explanations dominate here as Ugandan farmers have a larger area of cultivated land than Ethiopian farmers.

Considering the insignificance of factors in explaining the risk related to crop choices, limited variability of the portfolio beta variable may be an explanation for two reasons. The first reason is that the individual crop riskiness does not vary over time. If a household cultivates the same crops in the two periods and if the weights of these crops do not change significantly, then the portfolio beta will not differ between the periods. The second reason is that the two waves in this analysis are consecutive, thus we cannot expect that farmers easily make different cropping decisions. Since making different crop decisions may take time, the invariability of the dependent variable may be due to the consecutiveness of the waves and the invariability of the crop risk measure. A data-set that includes more survey rounds or a longer gap between the rounds will be more suitable to analyze effects of remittances on the portfolio beta.

The results are important in a context of poverty trap avoidance. Opting for more specialized production can yield higher income for farmers, allowing for capital accumulation and enabling them to avoid or escape poverty traps. On the one hand, Ugandan agriculture is mostly rain-fed and relying only on one low-risk crop can lead farmers into a poverty

trap. Instead, higher diversity in crops that have different resistance to weather shocks should be a better solution when adapting to irregular weather conditions. This strategy seems more appropriate when dealing with the consequences of climate change. On the other hand, crop specialization can yield economies of scale. A cost/benefit analysis on whether crop diversification or crop specialization in riskier crops is the most beneficial can be done by agro-ecological zone in future research in order to evaluate if remittances contribute to undertaking the most efficient strategy. Economies of scope are favored by crop diversification, but economies of scale are favored by crop specialization. A further analysis of economies of scale or economies of scope in the Ugandan agricultural sector is needed, together with a study on the crop production efficiency and not only crop choice. The analysis can also be extended to infra-specific diversity, by including different crop varieties that can have different impact on risk behavior.

A.1. Construction of the portfolio beta: Estimation of the Single Index Model (SIM)

According to the SIM, the revenues that come from different farming activities are related through their covariance with some index. There are two types of risks: a systematic risk that is related to the index and a specific risk that is not correlated with the index and that can be purged with diversification. The systematic risk can be determined by a reference portfolio defined as:

$$I_{pht} = \sum_{i=1}^{n} w_{iht} I_{iht} \tag{A.1}$$

where w_{iht} refers to the land weights of crop i for household h in the time t and I_{iht} are the stochastic crop revenues. The choice of the reference portfolio depends on what is the most important single influence on returns. In the present case, there are two major groups of shocks that can influence agricultural returns: quantity shocks and price shocks. Thus, we can consider a household's weighted income as a reference portfolio as it is subject to all these shocks. A household's income indeed depends on the household's growing conditions (weather, crop diseases, land characteristics) and prices for input factors and products. The variance of the portfolio is given by the following expression:

$$\sigma^2_{pht} = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{iht} w_{jht} \sigma_{ijht} \tag{A.2}$$

where σ_{ijht} represents the crop variance and covariance relationships between crop i and crop j for the household h. According to the model, riskiness is based on the relationship

between portfolio risk, the relative proportions of the crops held in the portfolio and the contribution of each crop to the portfolio variance. A change in the portfolio variance due to a change in the weight of the crop depends on the covariance between the crop and the portfolio returns:

$$\frac{\partial \sigma^2_{pht}}{\partial w_{iht}} = 2\sum_{j=1}^{n} w_{jht}\sigma_{ijht} = 2\sigma_{ipht} \tag{A.3}$$

A parameter that measures the anticipated response of a particular crop to the changes in portfolio returns needs to be estimated. This coefficient, β_i, is given by a panel regression of I_{iht} on the reference portfolio I_{pht}:

$$I_{iht} = \alpha_i + \beta_i I_{pht} + e_{iht} \tag{A.4}$$

By definition, $\beta_i = \frac{\sigma_{ipht}}{\sigma^2_{pht}}$ which means that β_i is a sufficient measure of marginal risk. The variance of the portfolio can be rewritten in terms of single index parameters as follows:

$$\sigma^2_{pht} = \left[\sum_{i=1}^{n} w_{iht}\beta_i\right]^2 \sigma^2_{pht} + \sum_{i=1}^{n} w^2_{it}\sigma^2_{eiht} \tag{A.5}$$

where the first term in the equation (A.5) is the systematic risk and the second term is the specific risk (σ_{eiht} corresponds to the variance and covariance relationships between the error term from equation (A.4) and crop i). The term $\sum_{i=1}^{n} w_{iht}\beta_i$ is called portfolio beta, and if we assume that the specific risk is completely diversified (is equal to 0) then $\sum_{i=1}^{n} w_{iht}\beta_i = 1$, which means that the portfolio beta for the reference portfolio equals 1. Once an appropriate reference portfolio has been identified, the systematic risk of any other

portfolio can be measured relative to 1. For example, if $\sum_{i=1}^{n} w_{iht}\beta_i$ is greater than 1, it has more systematic risk than the reference portfolio.

Table A1 – Share of households cultivating:

Crop:	**2005-2006**	**2009-2010**	**2010-2011**
Maize	75.2	73.4	71.3
Cassava	62.4	68.8	71
Beans	67	71.9	70
Sweet potatoes	54.1	58.4	58
Banana food	47.5	46.7	50
Ground nuts	30.5	33	32
Coffee	27.6	25.3	27.5
Sorghum	28.2	28.7	22
Millet	25.6	24.4	21.3
Banana beer	16.2	8.7	11.2
Simsim	9.5	11.7	10
Banana sweet	10.4	6.2	7.8
Soy beans	3.6	5.3	6.8
Yam	6	4.9	6.4
Irish potatoes	6.9	6.2	6
Field peas	2.8	6.4	6
Rice	4.8	4.5	5
Sunflower	2.9	3.4	5
Cotton	9.4	2.5	4.2
Pigeon peas	4.6	5.8	4
Sugarcane	3.7	4.5	3.8
Tomatoes	3.3	3.9	3.8
Avocado	3	1.9	3
Pumpkins	1.5	2.2	3
Jack fruit	3.2	1.5	3
Cabbage	1.4	1.7	2
Mango	1.7	1.2	2
Tobacco	1.8	2.3	1.6
Cow peas	4.3	1.7	1.5
Orange	0.8	1.2	1.5
Paw paw	2	0.8	1.5
Pineapples	3.1	1.4	1.4
Onions	1.1	1.2	1.3
Eggplants	0.8	1.5	1
Dodo	0.5	0.9	1
Passion fruit	1.2	0.5	0.6
Vanilla	2.8	0.7	0.4
Cocoa	0.8	0.8	0.6
Tea	0.3	0.19	0.2
Carrots	0.04	/	0.1
Wheat	0.26	0.23	0.05
Chick peas	0.57	0.05	/
Barley	0.04	/	/

Table A2 – Average crop revenue share

Crop:	**2005-2006**	**2009-2010**	**2010-2011**
Cocoa	32.1	41	48
Tobacco	39.3	39.4	40.2
Tea	21.8	21.7	40
Banana food	30.7	32.9	34
Rice	27	26.6	32.2
Cotton	19.8	22.7	26.5
Simsim	17.3	18	22.9
Sunflower	15	16	22.7
Beans	17.5	19.7	22
Passion fruit	13.8	14.8	21
Maize	22.6	25	19.7
Sorghum	19.7	13.4	18
Cassava	19.5	15.8	17.6
Ground nuts	18.15	13.5	17.5
Coffee	17	16.8	18
Millet	13.8	12.75	16.35
Cabbage	11.5	8.45	15.8
Sugarcane	14.5	19	15.4
Sweet potatoes	20.2	16.4	15
Tomatoes	15.9	18.5	14.77
Field peas	11.5	18	14.35
Vanilla	3.2	3	14.2
Dodo	3.7	11.4	12.8
Irish potatoes	13.8	13.5	11
Pineapples	6.7	11.8	9.2
Mango	2.8	3.8	9
Soy beans	9.3	11	7.9
Banana beer	7.4	11	7
Onions	18.4	9.45	7
Yam	6.6	9	6.6
Pigeon peas	7.8	8.3	6.5
Oranges	4.5	8	6.25
Paw paw	3.2	9	6
Chick peas	8.9	9.3	5.6
Banana sweet	4.1	5	5
Eggplants	5.1	3.7	4.6
Jack fruit	5.6	5.3	4
Pumpkins	6.3	10.2	3.4
Avocado	2.25	/	1.2
Ginger	0	26.9	0
Wheat	6.8	2.5	0
Cow peas	7.4	6.7	
Barley	/	/	/

Chapter 3

Do Remittances Promote Fertilizer Use?

3.1 Introduction

A key factor that improves agricultural productivity is land fertility. If a given land does not possess sufficient nutritive components, then fertilizer is an appropriate input that can be applied to overcome poor land fertility. Even though benefits of using fertilizer are well documented and widely accepted, a low level of adoption and use is observed among farmers on the African continent. According to the World Bank, during the period 2011-2013, the average level of fertilizer used in Sub-Saharan Africa is 18 kilograms per hectare of arable land which is very low compared to the world average (296.153 kg/acre) or other developing countries such as India (388.3 kg/acre) or Vietnam (922.5 kg/acre). Fertilizer use in economies that are heavily based on agricultural activities is crucial for improving agricultural productivity and food security, and thus reducing persistent poverty.

Several constraints can explain why fertilizer use is limited. Liquidity and credit constraints are among the main factors that prevent farmers from purchasing this input [Mwangi, 1996, Croppenstedt et al., 2003, Morris, 2007].[1] Because of imperfect credit markets, farmers have difficulties to cover upfront costs of fertilizer purchase. In addition to credit constraints, limited ability of farmers to cope with risk restricts fertilizer adoption. Lack of access to insurance excludes risk-averse farmers, especially poor ones, from using modern profit-enhancing inputs [Lamb, 2003]. Fertilizer is considered as a risky input as it generates a higher mean and higher variance of agricultural yields [Dercon and Christiaensen, 2011]. In addition, its price can be volatile and it is not always easily accessible. As agriculture in the developing world is mostly rain-fed, fertilizer can be unprofitable investment in periods of poor rainfall intensity [Alem et al., 2010]. The uncertainty of fertilizer return can prevent its adoption not only because of the weather variability, but also because of the lack of farmers' knowledge and fixed costs linked to the learning process. Fertilizer can generate benefits if it is used in a correct manner and if there is enough available water.[2] Dercon and Christiaensen [2011] show that not only credit constraints but also negative shocks to consumption discourage farmers to adopt fertilizer. Given that credit and insurance constraints prevent farmers from using fertilizer, the objective of this chapter is to test whether remittances received by households can potentially relax these constraints, and enhance fertilizer use.

How can remittances overcome credit and insurance constraints? According to the New Economics of Labor Migration literature, behind the surge for migration as a livelihood

[1] Duflo et al. [2011] show that saving difficulties can also be a constraint to fertilizer use for Kenyan present-biased farmers. Lowering the cost of fertilizers just after the harvesting season, and not during the cropping season, can increase fertilizer adoption significantly. Time costs cannot be neglected as farmers have to travel to markets where fertilizer is supplied.

[2] Learning about the adequate quantity that farmers should apply on their plot is time demanding and costly [Duflo et al., 2008].

strategy stands a risk-sharing agreement between the remaining household and its migrant(s). This agreement enables the household and its migrants to overcome credit and insurance constraints [Stark, 1991]. We might expect that households that receive more remittances will invest more in riskier inputs such as fertilizer. This chapter aims at studying whether remittances have the double potential to remove risk and credit constraints by promoting fertilizer use among farmers.

The insurance role of remittances remains an open question. To the best of my knowledge, the only similar work is Mendola [2008] that addresses the insurance character of migration and its impact on the adoption of high yield varieties (HYV) in Bangladesh. Using a cross-section analysis, she finds that wealthier households are better-placed to engage in costly international migration and therefore to employ HYV compared to poorer households. The main contribution of this chapter is to take into account the amount of past remittances as a risk insuring strategy in the case of fertilizer use in a panel data analysis on rural Uganda. Using only a variable that indicates whether a household has a migrant (local or international) may not be a sufficient condition for whether the household is insured or not, as remittances are uncertain. In this chapter I focus on remittances received prior to the decision-making concerning input use of the household. I consider both the probability and the intensity of fertilizer use. Therefore, I use a Tobit estimation model where I also account for the endogeneity of remittances by using an instrumental variable approach (IV). The results indicate that remittances significantly increase the probability and the intensity of fertilizer use by Ugandan farmers. These results contribute to the strand of literature that studies the determinants and constraints of fertilizer use and adoption by including remittances as an important factor that relaxes financial constraints. The credit constraint variable is not

significant indicating that remittances might mainly serve to overcome insurance constraints.

The results of the chapter have policy implications in terms of poverty reduction. Households in developing countries are exposed to highly risky environments where access to credit and insurance is limited. As a consequence, households may opt for low-risk/low-return rainfed agricultural production. The low-risk/low-return aspect of the agricultural production limits the investment in the productivity of their assets. As a result of low agricultural revenues, households are not able to accumulate savings that can be invested in productive assets in order to improve production and welfare. Hence, agricultural households are not capable of escaping poverty and remain instead in poverty traps [Carter and Barrett, 2006]. If access to credit and insurance cannot be improved, then lowering the cost of sending remittances can facilitate poverty reduction through investment in productive inputs.

3.2 Fertilizer use in Uganda

According to an analysis made in 2013 by the World Food Program in Uganda and the Uganda Bureau of Statistics, almost half of the Ugandan population is food insecure and this is likely to increase as agricultural productivity remains low. In the period between 2011 and 2015, the agricultural sector contributed to the Ugandan GDP by 27.2 percent as reported by the World Bank. The population growth is expected to increase in the future which increases the demand for more arable land and therefore leads to deforestation. The Ugandan agricultural sector is characterized by soil degradation accompanied by a low agricultural productivity [Olson and Berry, 2003]. Nonetheless, a low rate of fertilizer use is observed in Uganda. According to the World Bank, in 2011 the intensity of fertilizer used

per hectare was 2.1 kilogram.

There are several reasons that could explain why the adoption rate of fertilizer in Uganda is low. Fertilizer prices in Uganda are higher compared to prices in the rest of the world [Namazzi, 2008]. One of the reasons for such a high fertilizer price is that the fertilizer in Uganda is mostly imported from Kenya and it includes high transportation costs. However, the highly volatile output prices, especially for maize, do not allow to offset the high fertilizer prices which lowers the profitability of using fertilizer. Poor information and education on the how and why using fertilizer is beneficial is another constraint for Ugandan farmers. Ugandan agriculture is risky because it lacks irrigation infrastructure and relies directly on rainfall intensity. Compared to other countries in the region, Uganda has quite stable rainfalls though, and it does not often suffer from crop failure. However, there is variability in seasonal rains, and pests and crop disease are sources of risk which discourage application of fertilizer.

3.3 Descriptive statistics

Table 3.1 describes the summary statistics of the dependent variables used in the analysis. Two sets of dependent variables are included. The first set contains dummy variables that take value 1 if a given household applies any kind of fertilizer/organic fertilizer/inorganic fertilizer and 0 otherwise. According to Table 3.1 , only 20 percent of the households apply any kind of fertilizer, 17 percent apply organic fertilizer and four percent apply inorganic fertilizer. Regarding the amount of fertilizer applied, on average farmers apply 59 kg/acre of organic fertilizer and 0.82 kg/acre of inorganic fertilizer. Among those farmers that use

Table 3.1 – Descriptive statistics of the dependent variable

Variable name	Description	Mean	Standard Deviation	Min.	Max.
Fertilizer use					
Any fertilizer	equals 1 if a HH is using any kind of fertilizer, 0 otherwise	0.20	0.40	0	1
Organic	equals 1 if a HH is using organic fertilizer, 0 otherwise	0.17	0.37	0	1
Inorganic	equals 1 if a HH is using inorganic fertilizer, 0 otherwise	0.04	0.20	0	1
Fertilizer intensity					
Organic per acre	the total quantity of organic fertilizer in kg divided by the total size of plots of the HH	59.5	339.17	0	7167.33
Inorganic per acre	the total quantity of organic fertilizer in kg divided by the total size of plots of the HH	0.82	10.77	0	500

organic or inorganic fertilizer, the average use of fertilizer per acre is respectively 343.6 and 18.4 kg/acre.

The main hypothesis is that remittances have a positive impact on fertilizer use. Table 3.2 presents descriptive statistics on different explanatory variables depending on whether a household uses fertilizer or not. A difference in means between these two groups is reported, to test for any differences of their characteristics. There are indeed some systematic differences between these two categories of households. Agricultural households that apply fertilizer received higher amount of remittances in the previous period compared to households that do not apply any fertilizer. Also, fertilizer-applying households live in districts where the amount of remittances received is higher. A larger proportion of households that have access to extension services, that cultivate cash crops, fruits and vegetables, that are better educated and that live closer to a road are among the households that use fertilizer than among the households that do not apply any fertilizer. Households that use fertilizer are richer in terms of off-farm income, assets, they have higher level of livestock and they are

less likely to be credit constrained. However, households that use fertilizer live in districts that received lower amounts of rainfall and have higher negative rainfall deviation and lower positive rainfall deviation on average.

Table 3.3 presents definitions and summary statistics of the explanatory variables used in the estimations. The summary statistics are given for the whole sample (column (All HHs)), for the households that do not receive remittances (column (Non-Rem HHs)) and for the households that receive remittances (column (Rem HHs)). The main variable of interest is the lagged level of remittances that a household receives from its migrants. About 35 percent of the households in the data-set reported they received remittances locally or from abroad. The mean value of remittances is 96 000 UGX per household. Among the households receiving remittances, the average is 281 000 UGX. The district average of remittances is lower for households that do not receive remittances compared to those that receive remittances. In this chapter, I focus only on the transfer of remittances as an insurance strategy and not on migration, as having a migrant is necessary but not a sufficient condition to receive remittances and thus to be insured. Also, in the LSMS-ISA data, only the annual flow of migrants is recorded and not the stock of migrants. This past stock is probably behind the remittances transfers as there are more households in the sample that report to receive remittances than those that have at least one migrant. Remittances receiving households are better educated, the average educational level as well as the maximal educational level of their members are higher compared to the households that do not receive remittances.

Based on the descriptive statistics of the whole sample, household heads have on average 48 years and are mostly male (about 70 percent). There are 24 percent of the households that received extension services. The average assets are around 5 463 000 UGX and the average

Table 3.2 – Descriptive statistics of the dependent variable by group of HHs

Variable	Non-Fert HHs	Fert HHs	Dif in Means
Remittances			
remittances	84.3	144.4	60***
ditlevelremit	98.3	125.5	27***
Household characteristics			
sex	0.70	0.77	0.07***
age	48	48	0
extension services	0.21	0.31	0.10***
average educ.	4.41	5.47	1.06***
HH labor	3.43	4.06	0.63***
cash crops	0.27	0.77	0.20***
fruits and vegetables	0.47	0.83	0.36***
distance	2.97	3.64	0.67***
Wealth characteristics			
off-farm income	72	105	33***
assets	4 303	9 960	5 655***
livestock	1.73	3.22	1.49***
credit constraint	0.52	0.48	-0.04**
Land characteristics			
land	5.18	6.33	-1.15**
quality index	1.46	1.41	-0.05
irrigation	0.03	0.05	0.02***
Weather characteristics			
rain	1 201	1 109	-91***
rain dev	-0.06	-0.34	-0.28***
rain dev (positive)	0.09	0.02	-0.07***
rain dev (negative)	0.16	0.36	0.2***
Observations	3226	662	2564

Table 3.3 – Definition and descriptive statistics of the explanatory variables on the whole sample and by group of HHs

Variable	Definition	All HHs	Non-Rem HHs	Rem HHs	Dif in Means
Remittances					
remittances	received by the HH from migrants locally or abroad in *t-1* (UGX)	96	0	281	
ditlevelremit	mean district level of remittances *t-1* (UGX)	103	92	126	33.6***
Household characteristics					
sex	the gender of the HH head; equals 1 if the HH head is male, 0 otherwise	0.71	0.80	0.54	-0.25***
age	the age of the HH head	48.6	46.36	52.84	6.5***
extension services	equals 1 if a HH member received advice/information about agricultural activities, 0 otherwise	0.24	0.23	0.24	0
edumax	maximal educational level of HH	8.55	8.46	8.71	0.25**
average educ.	average educational level of HH	4.63	4.55	4.77	0.22**
HH labor	the maximal number of HH members working on any plot	3.56	3.65	3.39	-0.26**
cash crops	equals 1 if the household cultivates cash crop, 0 otherwise	0.31	0.30	0.31	0.01
fruits and vegetables	equals 1 if the household cultivates fruits and/or vegetables, 0 otherwise	0.54	0.54	0.54	0
distance	distance in kilometers to the nearest road	3.51	3.67	3.18	-0.49**
Wealth characteristics					
off-farm income	income coming from non agricultural activities (UGX)	794	835	716	-118***
assets	total assets in monetary value (UGX)	5 463	3 842	8 562	4 719***
livestock	livestock ownings of the HH expressed in livestock units	2.03	1.93	2.24	0.31*
credit constraint	credit constraint dummy; equals 1 if the household is constrained, 0 otherwise	0.501	0.51	0.51	0
Land characteristics					
land	total land (land ownings and rented operated land in acres)	5.41	5.54	5.17	-0.37
quality index	weighted index of soil quality with: level 1 being good quality and level 3 being poor quality	1.44	1.46	1.42	-0.04**
irrigation	equals 1 if the household has at least one plot that is irrigated, 0 otherwise	0.04	0.04	0.04	0
Weather characteristics					
rain	total annual rainfall level in $t-1$ in district d	1182	1169	1208	39***
rain dev	rain deviation in $t-1$ in district d from the long run mean divided by the long run standard deviation	-0.12	-0.13	0.10	0.23**
rain dev (positive)	positive rain deviation	0.08	0.08	0.08	0
rain dev (negative)	negative rain deviation in absolute terms	0.20	0.21	0.19	-0.01**
Observations		3226	2118	1108	

Note: All categories of revenues are in thousands of Ugandan Shillings (UGX). For example the average level of remittances for all households are 96 000 UGX. The exchange rates of Ugandan Shillings per US dollar for January 2009, 2010 and 2011 are respectively 1 976, 1 936 and 2 332.

non-agricultural income is 794 000. About half of the households are credit constrained. The average number of adults working on any plot within a household is around 3.5.

There are also significant differences between households that receive remittances and those that do not in terms of socio-economic characteristics. Households that receive remittances are more likely to have a female head of the household, and they are older than the heads of the households that do not receive remittances. But, households that do not receive remittances have higher level of farm household labor. Concerning the wealth characteristics, households that receive remittances have lower non-agricultural income but higher value of assets. The former is probably due to the fact that households with remittances have lower need of income source diversification through non-agricultural activities compared to households that do not receive remittances. Interestingly, no difference concerning the credit constraint position is found between the two groups, and the same holds for land.

3.4 Econometric specification

If we take into consideration a standard agricultural household model, we can derive a function of fertilizer demand of a given household [Singh et al., 1986]. If markets are well-functioning, including markets for credit and insurance, the first order conditions for profit maximization give a farmer's demand for fertilizer as a function of input and output prices, independent of the household's wealth and preferences. Complete markets imply that consumption and production decisions are separable. An increase in the amount of remittances will not affect input choices.

The separability of consumption and production decisions is unlikely to hold in devel-

oping countries. If credit constraints bind and insurance markets are imperfect, then socio-demographic characteristics and weather conditions influence farmers' investment choices. In addition, in this setting a household's demand for fertilizer is also affected by remittances. To the extent that risk-averse farmers will opt for traditional inputs over modern inputs in order to deal better with ex-ante risk, then any strategy that allows farmers to smooth consumption ex-post will increase the use of modern inputs, such as inorganic fertilizer. Therefore, the demand of fertilizer of a given household that operates in a rainfed environment will depend on its socio-economic characteristics X, input prices P_i and output prices P_o, rainfall outcomes $RAIN$ and the remittances R received in cash and/or in kind. We can write fertilizer demand F as follows:

$$F = (X, P_i, P_o, RAIN, R) \tag{3.1}$$

In order to test the impact of remittances on fertilizer use, I estimate the following equation:

$$F_{ht} = \alpha_0 + \alpha_1 X_{ht} + \alpha_2 R_{ht-1} + \alpha_3 RAINDEV_{dt-1} + \alpha_4 RAIN_{dt-1} + \mu_h + \eta_t + \varepsilon_{ht} \tag{3.2}$$

where F_{ht} stands for the fertilizer outcome variable(s). Two variables are used: a binary variable which takes the value one if household h applied fertilizer in period t, zero otherwise, and a censored variable which represents the amount of fertilizer applied by acre. I also distinguish between organic and inorganic fertilizer. Organic fertilizer can be produced on farm or bought near farm at very low cost or even no cost other than labor cost or other

opportunity costs linked to land use for crop production. In terms of quantity, large amounts of organic fertilizer have to be applied in order to have the desired effects. Its advantages is that it releases nutrient gradually and it increases soil organic matter content. But, its nutrient content is low and sometimes can be released when crops do not need them and it is not sufficient to meet soil fertilization demand. Therefore organic and inorganic fertilizer act as complement rather than substitutes. Organic fertilizer combined with inorganic fertilizer increases fertilizer use efficiency and soil moisture conservation. The inorganic (mineral) fertilizer is purchased on the market and its price can be high and volatile in remote areas. In addition, its availability is not guaranteed, but it is not as labor intensive as organic fertilizer. It can however cause environmental damages if it is poorly managed. Because of their different characteristics, I study the impact of remittances on organic and inorganic fertilizer separately.

The main variable of interest is R_{ht-1}, the lagged value of the level of remittances received by the household h. I consider the lagged value instead of the current value of remittances because I assume that farmers make their fertilizer purchase decisions in t depending on the amount of remittances that they previously received. I expect that a higher amount of remittances, that is associated with higher available liquidities and better insurance, will increase the use and the intensity of fertilizer application. Due to the riskier nature, this impact should be more important in the case of inorganic fertilizer application than in organic fertilizer application. Rainfall variability might prevent farmers from using fertilizer as it increases the risk and the uncertainty. I include a variable $RAINDEV_{dt-1}$ that represents the annual deviation in rainfall in $t-1$ from the long run mean, divided by the long run standard deviation in order to account for this effect. Also, I include the level of rainfall from

the previous period that is an important factor for the outcome of the agricultural production in that period which can in return relax liquidity constraints and increase affordability of fertilizer.

X_{ht} represents the household's socio-economic characteristics such as gender and age of the household head, access to extension services, labor and land endowment, livestock ownings, soil quality, distance to the nearest road as proxy for distance to market and whether a household is credit constrained or not. Men and women might not have the same preferences regarding the use of new technologies. If women are more risk averse than men, we would expect lower use of fertilizer by women-headed households. If men and women share the same preferences, then differences in the rates of adoption of fertilizer might be linked to the differences in access to other inputs such as land, labor, education and credit [Doss, 1999, Doss and Morris, 2001]. In a study of fertilizer adoption of Ghanaian farmers, Doss and Morris [2001] show that there are no significant differences between male and female farmers, but farmers in female-headed households have lower adoption rates of fertilizer than farmers living in male-headed households. The age and the level of education of the household head as a proxy for human capital formation need to be considered when analyzing the determinants of fertilizer use. On the one hand, older farmers might have accumulated more resources and experience and are better positioned to use fertilizer [Alem et al., 2010]. On the other hand, older farmers are likely to be more conservative and less prone to new technologies. Also, off-farm labor market participation as a form of income diversification might favor use of risky inputs, thus off-farm income is included in the analysis as a control variable. Contact with extension services might be a substitute for formal education and promote fertilizer use. However, previous studies showed that extension services do not influence significantly

the use of fertilizer [Freeman and Omiti, 2003, Fufa and Hassan, 2006, Alem et al., 2010]. How easily a household can reach the agricultural market can be a determinant for fertilizer accessibility. I use the distance to the nearest road as proxy for the distance to the nearest agricultural market. A credit constraint variable is included too. It takes value one if a household is credit constrained, and zero otherwise. It includes the households that were refused to obtain credit, but also those that refused to apply for credit because of the fear to loose their collateral or to feel indebted. According to the mechanisms described before, I expect that credit constrained households should have higher probability and intensity to use fertilizer when receiving remittances than non-credit constrained households.

Accounting for land and labor endowment as factors for farmers' fertilizer application decision is essential, especially when land and labor markets are deficient. Fertilizers might induce augmented need of labor for production and harvesting activities. Dercon and Christiaensen [2011] confirmed that labor endowment has a positive impact on fertilizer application by showing that a higher number of adults in the household increases the probability and the intensity of using fertilizer. Other authors find a negative relationship between labor and fertilizer [Freeman and Omiti, 2003]. The authors explain that inorganic fertilizer is less labor intensive compared to other alternative inputs such as manure which enables farmers to allocate labor to off-farm activities. In this analysis, I include the maximal number of adults that the household actually uses as labor on any of its plots to account for the labor endowment. Land is expected to be positively related to fertilizer application as land might serve as collateral for credit contracts which will allow to purchase this input. Land and other assets should be taken into account as indicators of a household's ability to deal with risk. It is well known that richer households can smooth more easily their consumption

when facing a negative shock than poorer households. It has been shown unambiguously that access to land and credit, assets and livestock allow for higher rates of chemical fertilizer adoption and use [Waithaka et al., 2007, Dercon and Christiaensen, 2011, Alem et al., 2010]. Therefore, livestock units and land together with land quality are included in the analysis.[3] I also include a variable indicating whether a farmer cultivates cash crops and fruits and vegetables as crop choices should influence fertilizer use. These kind of crops are more fertilizer demanding compared to subsistence crops.

3.4.1 Empirical method(s)

The choice of an estimation approach depends on the nature of the dependent variable used in this study. There are only 20 percent of households in the sample that use any kind of fertilizer, 17 percent that use organic fertilizer and 4 percent that use inorganic fertilizer. The zero application represents a corner solution to a constrained utility maximization problem of an agricultural household. The standard econometric approach used in the case of censored dependent variables is the Tobit model. An underlying assumption of the Tobit model is that all the determining factors have the same effect on the so-called participation decision and the decision of the amount to apply. A more generalized form of a Tobit model is the double hurdle model and the two-part model. However, I expect that the results will be less significant and less accurate when using these two models because of the fact that the data contain a low percentage of observations of positive fertilizer use in kg/acre.[4] Therefore,

[3] I do not include assets and non-agricultural income in the estimations because of their endogeneity.

[4] As the zero values of the fertilizer use and intensity are corner solutions, there is no need to use a Heckman estimation procedure that treats selection bias. When applying Heckman estimation, the Inverse Mills Ratio is not significant and the null hypothesis of the test of independent equations is rejected, which confirms the absence of a selection bias.

I decide to rely on the Tobit (and probit) estimation when interpreting the results in the Results section.

As I use a Tobit estimation model, I cannot estimate Equation (3.2) by using fixed effects estimation. As a result, I use the Mundlak [1978] and Chamberlain [1984] approach in order to account for household fixed effects. This approach consists in including mean values of time-varying explanatory variables. It assumes that unobserved effects are linearly correlated with explanatory variables as expressed in Equation (3.3).

$$\mu_h = \tau + \gamma \bar{X}_h + \omega_h \tag{3.3}$$

where $\bar{X}_h$ is a vector of the mean of time-varying explanatory variables within each household, τ is a constant, γ is a vector of parameters and $\eta_h \sim i.i.d.(0, \sigma_\eta^2)$ and is independent of ε_{ht}.

3.4.2 Endogeneity issues

Apart from the choice of the empirical method, another empirical problem that arises in the analysis is the endogeneity of remittances. Remittances are not random and are related to household characteristics. In the literature of migration and remittances this endogeneity problem is solved with the use of an Instrumental Variable (IV) approach. Different kinds of instruments are used in the literature, but the choice of instrument is narrowed by the data used in this analysis. For example, the data do not contain information on the destination of migrants and the place from where the remittances are sent. Village level migration propensity is used by Acosta [2011] as instrument for individual remittances. Here, I use

the mean district level of remittances, defined as the total amount of remittances received in a given district divided by the total number of households in the district. This instrument is also adopted in the literature when studying the impact of remittances on agricultural outcomes [for example Rozelle et al., 1999, Atamanov and Van den Berg, 2012]. As in the first chapter, in order to introduce more variability at household level, I interact the district average remittances with the years of schooling of the most educated person in the household[5] in $t-1$. As long as I control for the household's average education in $t-1$, the incidence of maximal education on agricultural risk decisions should be through remittances and migration only [Mendola, 2008]. Also, I assume that extension services might have a stronger impact on fertilizer use than formal education, and extension services are included in both stages of the estimation.[6] In addition, there might be differences in the level and the quality of education between different districts that can affect migration and remittances. In order to account for these differences, I include the quintile at district level in which the maximal education level of a given household belongs. Rainfall variability might generate higher amount of remittances, but it is also related to a farmer's decision making. Therefore, controlling for deviations in the district's rainfall, $RAINDEV_{dt-1}$, reinforces the exclusion restriction of the instrument.

[5]Similarly, Amuedo-Dorantes and Pozo [2006] construct an instrument based on the per capita count of Western Union offices in the state during the previous year interacted with household members' education levels.

[6]The question asked in the survey regarding extension services is "Did anyone in this household receive advice/information for/about agricultural/ livestock activities from any of the following sources in the past 12 months?" The sources that are proposed are: National Agricultural Advisory Services (NAADS), Input supplier, NGO, Cooperative/Farmer's Association, Large Scale farmers.

The first stage estimation of remittances can be written as:

$$R_{ht-1} = \beta_0 + \beta_1 X_{ht} + \beta_2 R_{dt-1} + \beta_3 edumax_{ht-1} + \beta_4 R_{dt-1} * edumax_{ht-1} + \beta_5 RAINDEV_{dt-1}$$
$$+\beta_6 RAIN_{dt-1} + \mu_h + \eta_t + \upsilon_{ht-1} \tag{3.4}$$

where R_{ht-1} stands for the level of remittances received by the household h in the period $t-1$. X_{ht} represents the household characteristics including the credit constraint dummy as in the equation (1). μ_h and η_t are the individual (Mundlak-Chamberlain effects) and time effects. The district level of remittances is represented by the variable R_{dt-1} where d refers to the district where the household h lived in time $t-1$. It is expected that individual remittances increase with district level of remittances and the maximal education witin the household. Higher mean amount of district level of remittances can be a result of stronger migrational network and better financial facilities for receiving remittances such that a household that belongs to that district has a higher probability of receiving higher amounts of remittances, all else equal. Average district level of remittances in $t-1$ are an important determinant for households' remittances received in $t-1$, but do not have an impact on household fertilizer choices, since they are not correlated with unobservable household characteristics.

Equation (3.4) is supposed to be estimated with a Tobit model, as remittances are observed only for about a third of households in the sample. There is a trade-off whether this first stage equation should be estimated by using a Tobit model or panel fixed effects estimation in a context of a two stage least squares estimation strategy (2SLS). If a non-linear

first stage such as Tobit is used, then the results from the second stage will be inconsistent [Angrist, 2001]. Therefore, a fixed effects estimation in the first stage of the model seems more appropriate even though the endogenous variable is censored. An alternative strategy in order to preserve the non-linear nature of the censored endogenous variable is to i) estimate Equation (3.4) by using a Tobit model, ii) obtain the fitted values of R_{ht-1} and iii) to estimate the Equation (3.2) by an IV approach using as instrument the fitted values of R_{ht-1} [Angrist, 2001, Wooldridge, 2010]. This strategy bypasses the problem of non-efficient estimates in the second stage regression when we use a simple non-linear model in a first stage. Thus, the advantages of using this alternative estimation strategy is at the same time to keep the nonlinear nature of remittances, include fixed effects in the first stage and obtain consistent and efficient estimates in the second stage of the IV estimation. I will mainly concentrate on this type of estimation when interpreting the results in the following section.

3.5 Results

In this section, I present the results from Equation (3.2) by using a probit and a Tobit panel estimation without treating the problem of endogeneity of remittances at first, and then I introduce an IV approach which deals with this issue.

3.5.1 Results without treating the endogeneity of remittances

The probit estimations are presented in Table 3.4. We observe that the results are qualitatively similar between any kind of fertilizer use and organic fertilizer adoption, as

Table 3.4 – Panel Probit estimation on fertilizer use

	Any Fertilizer		Organic Fertilizer		Inorganic Fertilizer	
VARIABLES	Coefficients	Marginal effects	Coefficients	Marginal effects	Coefficients	Marginal effects
remittances	0.015	0.003	0.018*	0.003*	0.010	0.000
	(0.010)	(0.002)	(0.010)	(0.001)	(0.013)	(0.000)
rain deviation (positive)	-2.329***	-0.411***	-3.571***	-0.520***	-0.521	-0.015
	(0.533)	(0.093)	(0.694)	(0.101)	(0.709)	(0.021)
rain deviation (negative)	0.896***	0.158***	1.087***	0.158***	-0.691*	-0.021
	(0.242)	(0.043)	(0.259)	(0.038)	(0.391)	(0.013)
rain	-0.001***	-0.000***	-0.002***	-0.000***	0.002***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
cash crops	0.345***	0.061***	0.076	0.011	0.820***	0.024***
	(0.088)	(0.015)	(0.095)	(0.014)	(0.142)	(0.008)
fruits and vegetables	0.667***	0.118***	0.783***	0.114***	0.421***	0.013**
	(0.105)	(0.018)	(0.118)	(0.017)	(0.163)	(0.006)
sex	0.287***	0.048***	0.306***	0.042***	0.293*	0.007*
	(0.104)	(0.017)	(0.112)	(0.015)	(0.170)	(0.004)
age	-0.028	-0.005	-0.025	-0.004	-0.004	-0.000
	(0.017)	(0.003)	(0.018)	(0.003)	(0.031)	(0.001)
HH labor	0.048***	0.009***	0.043***	0.006***	0.026	0.001
	(0.014)	(0.002)	(0.015)	(0.002)	(0.019)	(0.001)
land	-0.002	-0.000	-0.002	-0.000	0.003	0.000
	(0.003)	(0.001)	(0.003)	(0.000)	(0.003)	(0.000)
land quality	0.006	0.001	0.037	0.005	0.116	0.003
	(0.086)	(0.015)	(0.093)	(0.014)	(0.144)	(0.004)
livestock	0.027***	0.005***	0.019**	0.003**	0.018	0.001
	(0.007)	(0.001)	(0.008)	(0.001)	(0.011)	(0.000)
credit constraint	-0.041	-0.007	-0.068	-0.010	0.094	0.003
	(0.077)	(0.014)	(0.083)	(0.012)	(0.122)	(0.004)
irrigation	0.073	0.013	-0.120	-0.017	0.271	0.010
	(0.176)	(0.032)	(0.193)	(0.026)	(0.260)	(0.012)
distance	-0.007	-0.001	-0.001	-0.000	-0.047**	-0.001**
	(0.007)	(0.001)	(0.007)	(0.001)	(0.019)	(0.001)
extension services	0.420***	0.080***	0.447***	0.072***	0.425***	0.015**
	(0.091)	(0.019)	(0.099)	(0.017)	(0.135)	(0.006)
Constant	-0.189		0.328		-4.285***	
	(0.585)		(0.636)		(0.854)	
Observations	3,226	3,226	3,226	3,226	3,226	3,226
Number of hhid	1,613	1,613	1,613	1,613	1,613	1,613

Standard errors in parentheses

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

Note: Mundlak effects, mean values of the time varying explanatory variables, are included in all the regressions.

the proportion of organic fertilizer users is higher. But, there are differences in results between organic and inorganic fertilizer use which justify the separate analysis. Lagged remittances have a positive and slightly significant (10 percent level of significance) impact on the probability of adoption of organic fertilizer but not on inorganic fertilizer use contrary to the ex ante hypothesis. The predicted probability of using organic fertilizer is 0.003 when receiving the average amount of remittances. Regarding the rainfall control variables, positive rainfall deviations affect negatively the probability of using organic fertilizer, but not inorganic fertilizer. A possible interpretation of these results might be that organic fertilizer is more perceived and used by farmers as a substitute to rainfall. Both positive and negative rain deviations affect negatively the adoption of inorganic fertilizer. As expected, adoption of chemical fertilizer is limited by variability in rainfall conditions as its desired effects are dependent on the availability of water.[7] Similarly, Alem et al. [2010] finds that a higher coefficient of variation of rainfall leads to lower use of chemical fertilizer. The effect of the previous period's rainfall on relaxing liquidity constraints to purchase fertilizer is highly significant but close to zero in this sample.

As expected, households cultivating cash crops and fruits and vegetables have greater predicted probability of applying any kind of fertilizer, in particular inorganic. Households with a male household head are more likely to use any kind of fertilizer compared to female household heads which goes in line with the result of Doss and Morris [2001]. Two important determinants of organic fertilizer adoption are livestock and labor. I find a positive and significant effect of household labor and livestock on organic fertilizer adoption. As previously

[7] If there is a high positive rainfall deviations, the applied fertilizer can be "washed out" to some extent and therefore wasted.

Table 3.5 – Panel Tobit estimation on the fertilizer use and intensity

	Organic Fertilizer		Inorganic Fertilizer	
VARIABLES	Coefficients	Marginal effects	Coefficients	Marginal effects
remittances	0.047	0.009	0.024	0.003
	(0.038)	(0.008)	(0.037)	(0.005)
rain deviation (positive)	-15.367***	-3.083***	-1.992	-0.247
	(2.701)	(0.535)	(1.912)	(0.238)
rain deviation (negative)	4.003***	0.803***	-2.538**	-0.315**
	(1.018)	(0.205)	(1.074)	(0.137)
rain	-0.008***	-0.002***	0.004**	0.000**
	(0.001)	(0.000)	(0.002)	(0.000)
cash crops	0.410	0.082	2.255***	0.280***
	(0.367)	(0.074)	(0.396)	(0.056)
fruits and vegetables	3.364***	0.675***	1.059**	0.131**
	(0.464)	(0.092)	(0.439)	(0.056)
sex	1.158***	0.226***	0.840*	0.101*
	(0.437)	(0.083)	(0.469)	(0.056)
age	-0.068	-0.014	0.017	0.002
	(0.066)	(0.013)	(0.083)	(0.010)
HH labor	0.120***	0.024***	0.067	0.008
	(0.043)	(0.009)	(0.053)	(0.007)
land	-0.019	-0.004	0.006	0.001
	(0.016)	(0.003)	(0.010)	(0.001)
land quality	0.232	0.047	0.474	0.059
	(0.347)	(0.070)	(0.387)	(0.048)
livestock	0.058*	0.012*	0.050	0.006
	(0.032)	(0.006)	(0.031)	(0.004)
credit constraint	-0.245	-0.049	0.277	0.034
	(0.314)	(0.063)	(0.331)	(0.041)
irrigation	-0.422	-0.083	0.763	0.099
	(0.738)	(0.142)	(0.709)	(0.097)
distance	-0.004	-0.001	-0.133**	-0.016**
	(0.028)	(0.006)	(0.054)	(0.007)
extension services	1.766***	0.371***	0.996***	0.128**
	(0.376)	(0.082)	(0.368)	(0.050)
Constant	1.941		-23.380	
	(2.426)		(381.470)	
Observations	3,226	3,226	3,226	3,226
Number of hhid	1,613	1,613	1,613	1,613

Standard errors in parentheses

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

Note: Mundlak effects, mean values of the time varying explanatory variables, are included in all the regressions.

discussed, organic fertilizer such as manure is conditional on livestock ownings and needs labor for handling and transportation. Distance to market affects negatively the predicted probability to use inorganic fertilizer, but not organic fertilizer, as expected *ex ante*. Finally, access to extension services plays an important role in the probability to use all types of fertilizer.

Going further to the Tobit results presented in Table 3.5, all the variables have the same sign as in the previous estimations, but for some of them the significance level changes.[8] First, remittances do not have a significant impact on the intensity of fertilizer use. Again, negative rainfall deviation and the rainfall level in $t-1$ have opposite signs for organic and inorganic fertilizer. These results might also be linked to the fact that the application of organic fertilizer yields higher production after the year of application and mineral fertilizers supply immediately nutrients needed by crops. As previously, there are gender effects in the use of fertilizer and access to extension services is a significant factor for the use of the two kinds of fertilizer. Whereas household labor has a positive and significant impact on use of organic fertilizer, livestock ownings are only weakly significant for the intensity of use of organic fertilizer. Distance to the market, proxied by distance to the nearest road, significantly decreases the predicted value of inorganic fertilizer applied per acre.

3.5.2 Results with instrumentation

Before going further to the results of the IV estimation, I start with presenting the first stage estimation results that are included in Table 3.6. The results suggest that the district

[8]The results of the Tobit estimation are similar when running a linear probability model with random effects.

average level of remittances interacted with the maximal education of the household has a positive and significant impact on the level of remittances received by households. The result is the same when a predicted value of remittances is used as an instrument. The F-statistic is higher than 20 in both estimations and higher than the Stock and Yogo 10 percent IV size which indicate that the instruments are valid.

Table 3.6 – First Stage estimation

Remittances	IV Panel FE (1)	IV Panel FE (2)
Instruments		
mean district level of remittances in $t-1$*edumax	0.292***	
	(0.0144)	
predicted value of remittances in $t-1$ from a Tobit estimation		0.590***
		(0.100)
Control Variables		
	YES	YES
Validity Tests		
F-statistic	34.5	34.5
Stock and Yogo 10% IV size	11.7	11.7
Observations	3,226	3,226

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The two columns report the results of a panel fixed effects estimation. In the second column the predicted value of remittances in $t-1$ is obtained as a result of a panel Tobit random effect estimation. Standard errors in parentheses are clustered at district level.The Sargan statistic of both first stages is 0 which indicates that the equations are exactly identified.

In Table 3.7 and 3.8, I adress the endogenity issue by instrumenting the remittances with the interaction term between the mean district level of remittances and the maximal educational level in the household. In each table, a standard Two Stages Least Squares (2SLS) is

Table 3.7 – IV estimation on organic fertilizer use and its intensity

	(1)	(2)	(3)
	2SLS FE	Tobit in 2nd stage (predicted Rem 1st stage)	Probit 2nd stage (predicted Rem 1st stage)
VARIABLES	Organic fert. per acre	Organic fert. per acre	Organic fert adoption
remittances	0.026	0.697***	0.183***
		(0.130)	(0.034)
rain dev (positive)	-2.087	-13.219***	-2.953***
	(1.752)	(2.648)	(0.663)
rain dev (negative)	0.992	1.116	0.314
	(1.519)	(1.150)	(0.298)
rain	0.105	-0.261***	-0.067***
	(0.113)	(0.036)	(0.010)
cash crops	0.128	0.539	0.114
	(0.131)	(0.367)	(0.094)
fruits and vegetables	0.106	3.398***	0.782***
	(0.126)	(0.462)	(0.116)
sex	0.216	0.840**	0.201*
	(0.258)	(0.424)	(0.107)
age	-0.007	0.019	0.005
	(0.012)	(0.013)	(0.003)
HH labor	0.015	0.109**	0.039***
	(0.013)	(0.043)	(0.015)
credit constraint	-0.089	-0.373	-0.098
	(0.072)	(0.315)	(0.082)
irrigation	-0.153	-0.954	-0.241
	(0.179)	(0.744)	(0.191)
livestock	-0.017	0.028	0.014*
	(0.011)	(0.029)	(0.007)
extension services	0.200**	1.912***	0.484***
	(0.096)	(0.376)	(0.097)
distance	0.002	0.002	0.002
	(0.006)	(0.028)	(0.007)
averageeduc	-0.022	0.332***	0.082***
	(0.023)	(0.075)	(0.019)
Observations	3,224	3,226	3,226
Number of hhid	1,612	1,613	1,613

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Mundlak effects, mean values of the time varying explanatory variables are included in all the regressions in column (2) and (3). The average education is included too in order to respect the exclusion restriction regarding the maximal education. The standard errors are bootstrapped.

Table 3.8 – IV estimation on inorganic fertilizer use and its intensity

	(1)	(2)	(3)
	2SLS FE	Tobit in 2nd stage (predicted Rem 1st stage)	Probit 2nd stage (predicted Rem 1st stage)
VARIABLES	Inorganic fert. per acre	Inorganic fert. per acre	Inorganic fert adoption
remittances	-0.005	0.312**	0.117**
	(0.012)	(0.137)	(0.047)
rain dev (positive)	-0.176	-0.848	-0.157
	(0.528)	(1.855)	(0.670)
rain dev (negative)	-0.237	-3.846***	1.183***
	(0.458)	(1.287)	(0.456)
rain	-0.015	-0.028	-0.008
	(0.034)	(0.037)	(0.013)
cash crops	0.027	2.278***	0.815***
	(0.039)	(0.396)	(0.139)
fruits and vegetables	0.021	1.021**	0.405**
	(0.038)	(0.437)	(0.158)
sex	-0.026	0.823*	0.273*
	(0.078)	(0.457)	(0.162)
age	0.003	-0.033**	-0.101**
	(0.003)	(0.014)	(0.005)
HH labor	0.002	0.062	0.024
	(0.004)	(0.053)	(0.019)
credit constraint	0.011	0.220	0.061
	(0.022)	(0.329)	(0.119)
irrigation	0.013	0.632	0.214
	(0.054)	(0.711)	(0.256)
livestock	0.000	0.043	0.016
	(0.003)	(0.029)	(0.010)
extension services	-0.013	1.021***	0.428***
	(0.029)	(0.367)	(0.131)
distance	-0.001	-0.124**	-0.043**
	(0.002)	(0.053)	(0.018)
average education	0.011	0.117	0.043
	(0.007)	0.078	(0.028)
Constant	1.467	-17.070	2.830***
	(3.424)	(409.340)	(0.260)
Observations	3,224	3,226	3,226
Number of hhid	1,612	1,613	1,613

Robust standard errors in parentheses

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

Note: Note: Mundlak effects, mean values of the time varying explanatory variables are included in all the regressions in column (2) and (3). The average education is included too in order to respect the exclusion restriction regarding the maximal education.

used in column (1) by using the interaction variable as instrument. In column (2) and (3) the predicted value of remittances out of a Tobit estimation as explained above is used in a first stage, whereas the second stage is estimated separately with a probit in column (3) and Tobit model column (2). I will focus the discussion on the results in columns (2) and (3) in each table as this method takes into account the censored nature of remittances. Instrumenting remittances increases the significance of the impact of remittances in both Tobit and probit estimations of the two types of fertilizers, organic and inorganic. Remittances increase the predicted value of the organic and of inorganic fertilizer applied by acre, column (2), and the predicted probability to use both types of fertilizers, column (3). When calculating the marginal effects of receiving the average level of remittances, the predicted probability of using organic fertilizer is 0.02 and of using inorganic fertilizer is 0.003. Therefore, the initial hypothesis that remittances promote fertilizer use cannot be rejected. Concerning the other control variables, except for livestock in the case of organic fertilizer, they all have similar impacts in terms of statistical significance and magnitude as in Tables 3.4 and 3.5.

3.5.3 Discussion: a potential mechanism

I find a positive effect of remittances on both organic and inorganic fertilizer use. This might be due to the fact that they act more like complements, than substitutes. However, as discussed above, we would have expected a smaller impact of remittances on organic fertilizer compared to inorganic fertilizer. In this section, I provide some explanation on why organic fertilizer use increases.

Households can either produce organic fertilizer on farm where labor and livestock are

main factors for its production, or it can be purchased on the market. According to Table 3.9, among the households that use organic fertilizer, only a very small share purchases organic fertilizer and this share is decreasing over time. Therefore, the cost of organic fertilizer is small and not other than livestock and labor cost. Receiving remittances might not represent a crucial factor that determines the probability and the intensity of organic fertilizer use. More important factors are therefore livestock and labor availability. There can, however, be an indirect effect of remittances on organic fertilizer via the purchase of livestock. In order to test for this effect, I estimate the impact of remittances on livestock purchase and stock by using the same methodology - instrumenting for remittances. The dependent variable is again censored and it represents purchases of livestock expressed in livestock units in column (1) and the stock of livestock in units in column (2), presented in Table 3.10. The predicted value of livestock purchases (and the stock itself) increases with the level of remittances. Remittances increase the investment in livestock which increases the on farm availability of organic fertilizer in turn.

Table 3.9 – Share of households that purchase org. fertilizer

Purchased fertilizer	2009/2010	2010/2011
Season 1	14%	6.5%
Season 2	11.4%	9.5%

Note: These percentages are calculated among the households that use organic fertilizer and excludes the households of the Northern region (a pastoral region where the organic fertilizer is only produced on farm).

Table 3.10 – The impact of remittances on livestock

Livestock	Purchase (1)	Stock (2)
remittances	0.014***	0.192***
	(0.004)	(0.041)
Control Variables		
	YES	YES
Observations	3,226	3,226
Number of hhid	1,613	1,613

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Mundlak effects, mean values of the time varying explanatory variables, are included in all the regressions in column (1) and (2). The first stage regression and the other control variables are the same as in the analysis of fertilizer use.

An important factor in studying fertilizer demand that is omitted in this study is fertilizer price, but also output prices. Fertilizer market prices are not included in the dataset used in this chapter. There is household information on the value of organic and inorganic fertilizer purchase as well as quantity. From this information, it is possible to derive an average price of both types of fertilizer. In order to reduce subjective bias in the information on price, I compute the community average price of organic and inorganic fertilizer and I introduce it in the previous analysis. The results do not change and prices do not have any significant impact. That is why prices are not included in the final analysis, as better quality data are needed in order to account for them.

3.6 Conclusion

In this chapter, I investigate whether remittances promote fertilizer use, a risky input, among Ugandan farmers given the insurance character of remittances. After instrumenting for remittances, I find that they have a strong and significant impact on the probability and on the intensity of using both organic and inorganic fertilizer. This new result confirms the ability of remittances to replace missing credit and insurance markets, at least partially, and to encourage farmers to adopt fertilizer and to increase the quantity applied. The effect of credit constraint is however non-significant. This might indicate that the impact of remittances on fertilizer passes only through their insurance feature.

The chapter shows the importance of rainfall conditions and access to extension services for farmers' decisions of organic and inorganic fertilizer use. Labor is a significant determinant of organic fertilizer use, whereas distance to the market proxied by the distance to the closest road decreases the use of chemical fertilizer. We might expect that remittances will not affect organic fertilizer if its cost is negligible. In the sample almost all households produce the organic fertilizer on their farm and thus the cost of its production and use is small, but the amount and the availability of the fertilizer depend on livestock endowment. In addition to the main results, I find that remittances increase investment in livestock and therefore we can conclude that it increases indirectly the organic fertilizer application. One limitation of this chapter is that because of lack of good quality price data on fertilizer and output, prices are not included in the analysis of fertilizer use by agricultural households.

The results are important in a context of new technology adoption and poverty trap avoidance in African countries. Ugandan agriculture is mostly rain-fed and relying only

on one low-risk crop can lead farmers into a poverty trap in the presence of insurance and credit limitations. Remittances can therefore overcome these barriers, promote new risky technology adoptions, improve agricultural productivity and by that allow households to avoid poverty. The policy implication of this study for developing countries would be to facilitate the transfer of remittances, by lowering their cost, which would increase agricultural investments.

Chapter 4

Can Land Fragmentation Reduce the Exposure of Rural Households to Weather Variability?

4.1 Introduction

Global warming is a crucial issue for the African continent and it is expected that its impacts will be even more severe in future. At the same time, Africa is the least responsible for global greenhouse gas emissions, but the region would be the most affected by their consequences as its adaptive capacity is very low [Collier et al., 2008]. The majority of the population lives in rural areas and is engaged in the agricultural sector which is highly sensitive to weather variability. Because of the lack of irrigation infrastructure, weather conditions affect directly agricultural production and livelihoods [Barrios et al., 2008, Schlenker and Lobell, 2010, Kahsay and Hansen, 2016]. Also, climate change increases the frequency

and the severity of extreme events. As a result, a great part of the population in Africa experienced already a variety of stresses and shocks [Barrios et al., 2008]. Extreme events, such as floods and drought, have serious impacts on agricultural production, but gradual changes in climate can be consequential on agricultural production too. These effects are amplified by the limited capacity of African countries to deal with it. Possibilities to deal with weather risk through credit and insurance markets are almost inexistent as these markets are imperfect in the African economies.[1] Due to the lack of access to these markets, households employ different arrangements in order to cope with covariate shocks. Among others, they choose sub-optimal low-risk/low-return portfolios, or diversify the sources of income by working in the non-agricultural sector or by migrating. This article aims at verifying whether land fragmentation is an alternative for households to cope with weather shocks.

Land fragmentation is the practice of farming a number of spatially separated plots of owned or rented land by the same farmer [McPherson, 1982]. It is a phenomenon that is observed in many countries especially in developing countries. According to the World Agricultural Census by FAO, the average number of parcels operated by a farmer is 3.5 worldwide during 1995-2005. Land fragmentation is often considered as a barrier to agricultural output and productivity. There is empirical evidence that increases in land fragmentation lead to lower agricultural output and agricultural productivity [Wan and Cheng, 2001, Rahman and Rahman, 2009, Van Hung et al., 2007, Tan et al., 2010]. Another obstacle associated with land fragmentation is the distance between parcels. In particular, when parcels are dispersed, travel time and costs in moving labor and machines can increase. In this sense, it was shown

[1] There are insurance products present on the African continent, such as crop insurance and index-based insurance, but their take-up rate is very low.

in the literature that land fragmentation increases costs of production and cost of labor [Tan et al., 2008]. In addition, land fragmentation can hinder machinery use by farmers [Foster and Rosenzweig, 2011]. Other drawbacks of land fragmentation are fencing costs, small size and irregular shape of parcels, and conflicts among neighbors [Demetriou, 2013]. However, there is not a consensus on whether land fragmentation has a negative impact on agricultural outcomes. Blarel et al. [1992] find that the level of land fragmentation has no significant impact on yield and therefore reject the hypothesis that fragmentation is inefficient in the case of Ghana and Rwanda.

Land fragmentation can in fact also provide benefits to farmers. It can facilitate risk management through seasonal and spatial diversification of crop production [Blarel et al., 1992, Bentley, 1987, Van Hung et al., 2007]. This would reduce the exposure of farmers to climatic variability and disasters as production risk is spatially spread. McCloskey [1976] is among the first economists to document the ability of scattered parcels to reduce the crop production risk. Blarel et al. [1992] found that land fragmentation reduces the variability of agricultural output per acre. Fragmentation also allows for adjustments of household labor across seasons as crop scheduling is feasible when parcels are scattered in different locations with different agro-ecological characteristics [Fenoaltea, 1976]. Furthermore, land fragmentation improves agro-biodiversity as crops are better matched with the operated soil types [Di Falco et al., 2010].

This chapter aims at analysing the ability of fragmented land holdings of farmers to reduce their exposure to weather variability. More precisely, the objective is to study empirically whether households with higher degree of fragmented land incur smaller reductions in the value of crop yield when they are subject to rainfall irregularities compared to house-

holds with more consolidated land. Two dimensions of land fragmentation can improve the ability of farmers to diversify weather risk: the physical distance between the parcels and the different agro-ecological characteristics of the different parcels in terms of slope, land quality, land texture. Because of the distance, parcels might not be exposed to the same weather conditions. But, even if parcels are exposed to the same conditions, having different agro-ecological characteristics might have different consequences on the crop yield. The contribution of the paper is twofold: it does quantitative research on the incidence of fragmentation on agricultural income by taking into account rainfall variability, which, to the best of my knowledge, has not been addressed by the literature; and it contributes to the cost/benefit debate of land fragmentation in the case of Uganda.

In order to test whether land fragmentation may reduce the income loss from exposure to rainfall variability, I estimate the impact of the degree of land fragmentation on the value of crop output per acre of a household. Land fragmentation is measured by the number of parcels that the household owns and also by a Simpson Index calculated for these parcels. This index combines the number of parcels and the distribution of area among the different parcels. An important issue that arises is that land fragmentation can be affected by some unobserved factors that influence agricultural income (management ability, entrepreneurial spirit). Also, farmers may be able to choose their level of land fragmentation in order to deal with production risk. This is the case when land markets exist and land can be traded or rented. In order to deal with this issue, I instrument the fragmentation in operated land with the fragmentation in inherited land as inherited land fragmentation is exogenously imposed on the household through the inheritance process [Foster and Rosenzweig, 2011]. I use data from the Living Standards Measurement Study-Integrated Surveys on Agriculture

(LSMS-ISA) for the years 2005/2006, 2009/2010, 2010/2011 and 2011/2012 established by the World Bank. After instrumenting for the level of fragmentation, I find that higher land fragmentation decreases the loss of the value of crop yield when households experience rain deviations. The preliminary results show that the higher this deviation, the higher the beneficial effect of land fragmentation. These results are found for all the different measures used for land fragmentation.

Because of the widely perceived inefficiencies of land fragmentation, some countries like Kenya, Tanzania and Rwanda, have adopted land consolidation programs. If land, labor and insurance markets are imperfect, land fragmentation offers households a risk mitigating tool with possibility to spread labor over seasons and provide food security. If the labor market is imperfect, labor supply is fixed by the household and there is an important need to spread labor temporally. Moreover, farmers fail to cultivate land due to land market imperfections rather than its small size or fragmentation. Therefore, addressing land, labor and insurance market imperfections can be more suitable for agricultural productivity than land consolidation programs.

4.2 Background

The Constitution of Uganda includes customary, freehold, mailo and leasehold tenure systems recognized by the Land Act of Uganda 1998. The mailo system consists of a subdivision of land where the basic unit is a square mile, hence the name mailo. Mailo land is owned with individual property rights certified by a land title. Similarly, freehold land holders have full powers of ownership over their land. This implies that the holder can use it

for any purpose and sell, let, lease and dispose of it. Leasehold system is a system of owning land for a particular period of time. The leasehold transactions are contractual and allow both parties to define the terms and conditions of access and usage.

Customary tenure system dominates the other systems. According to the FAO, it represents 75 percent of the total land which makes it the most common form of tenure in the country. Land is therefore mainly governed by customs, rules and regulations of the community. Due to these regulations, the main cause of land fragmentation is the inheritance system. In Uganda, population growth together with the traditional inheritance protocols are supposed to be the most important driver of the increased land fragmentation [Nkonya et al., 2004]. For instance, when the head of a household dies, his land is sub-divided among his sons.[2] The higher the number of male members of the family the lower the piece each member gets. But, division of land can be made also pre-mortem through gifts or transfers and sometimes can be unequal among family members. Also, land can be aquired as a gift from other members of the extended family than the father. This phenomenon of land subdivision continues with each passing generation on the customary freehold lands. According to the Ugandan economist Eric Kashambuzi, Ugandan farmers tend to consider fragmentation as beneficial as it allows to grow different crops on parcels with different characteristics. However, in February 2015, the president Yoweri Museveni strongly recommended farmers to stop land fragmentation, following its recent increase due to inheritance practices.

Table 4.1 – Definition and descriptive statistics

Variable	Definition	Mean	Standard dev.	Min	Max
agprod	total agricultural production in Ugandan Shillings (UGX)	2.54e+07	2.54e+08	0	1.80e+10
value of yield	agprod/cultivated land	11799	125000	0	6000432
value of yield in log	agprod/cultivated land in log	6.206	2.464	0	15.607
Land fragmentation					
n	number of parcels	2.28	1.38	1	18
n type	number of parcels with different soil texture	1.29	0.51	1	4
n topography	number of parcels with different slope	1.36	0.57	1	5
Simpson index	calculated as described in Equation (4.1)	0.35	0.27	0	1
Household characteristics					
sex	the gender of the HH head; equals 1 if the HH head is male 0 if it is female	0.712	0.453	0	1
age	the age of the HH head	46.384	15.313	13	100
education	the highest school level achieved by the HH head 0-no education, 1-primary, 2-secondary	1.026	.659	0	2
adults	HH members above 16 years	2.960	1.686	0	24
Land characteristics					
cultivated land	cultivated land in acres	4.614	37.355	0 3000	
soil quality index	weighted index of soil quality with: level 1 being good quality and level 3 being poor quality	1.704	0.703	0	3
Weather characteristics					
rain dev	rain deviation in absolute terms from the long run mean divided by the long run standard deviation at time t in district d	0.668	0.614	0.005	2.628

Figure 4.1 – Distribution of parcels

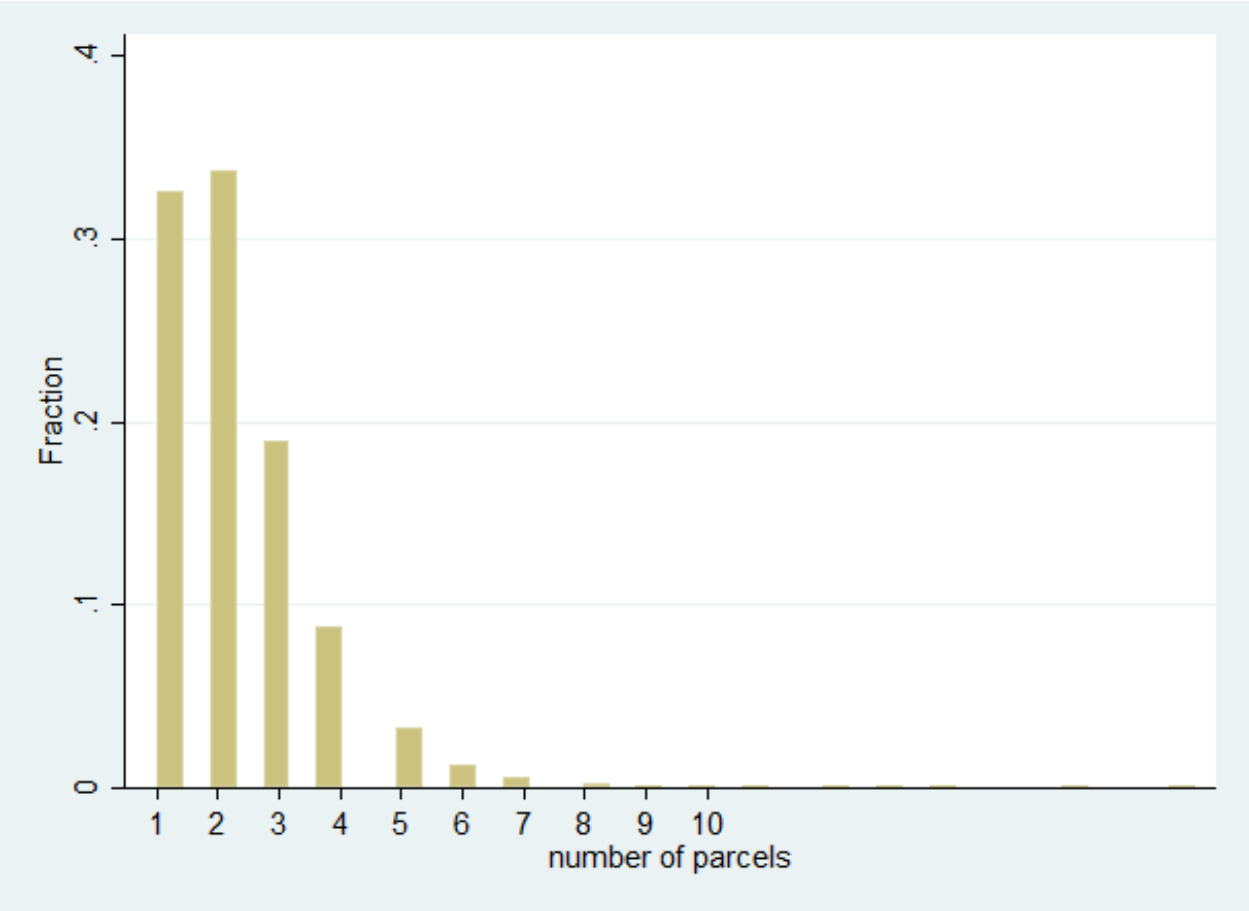
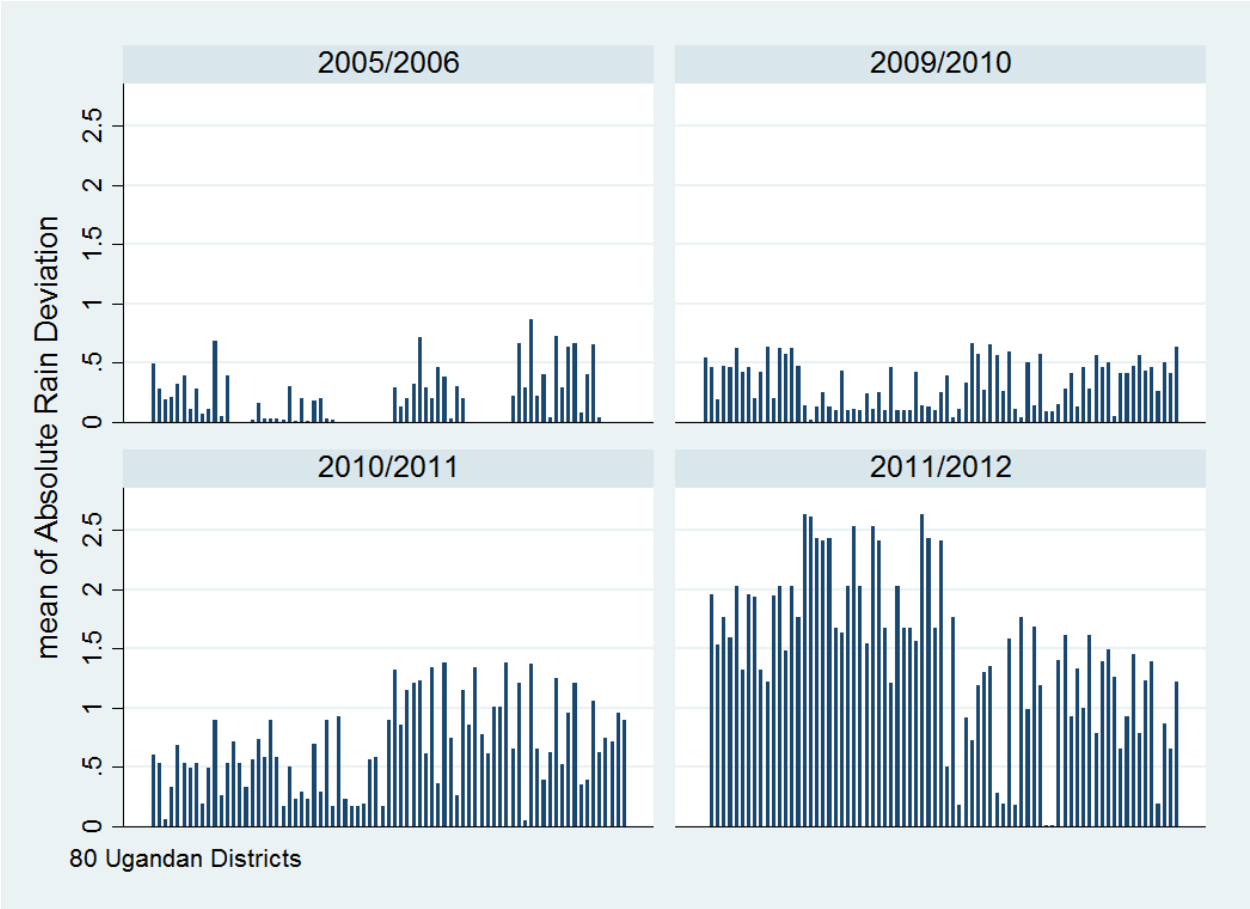


Table 4.2 – Land acquisition

Parcels	2005/2006	2009/2010	2010/2011	2011/2012
Inherited	40%	47%	50%	53%
Purchased	25%	26%	25%	23%
Rented	27%	26%	23%	22%
Other	8%	1%	2%	2%

Figure 4.2 – Rain deviation in absolute terms in the 80 districts



4.3 Data and descriptive statistics

Table 4.1 presents definitions and the summary statistics of the dependent and explanatory variables used in the estimations. Land fragmentation is usually measured simply by the number of parcels that the household operates.[3] This variable includes the parcels that a household owns and rents that are physically separated, as asked in the agricultural questionnaire. Among the owned parcels, households mainly inherit the different parcels and a lower part of them is purchased. A second measure is the Simpson index [Blarel et al., 1992, Tan et al., 2008]. It is defined as:

$$SI_{ht} = 1 - \sum_{i=1}^{n} a_{it}^2 / (\sum_{i=1}^{n} a_{it})^2 \tag{4.1}$$

where n is the number of parcels and a_{it} is the size of parcel i in time t. A Simpson index close to zero means that the land of the household is completely consolidated; there is only one parcel. The closer the value to one, the more fragmented the land of the household is. The value of the Simpson index is therefore determined by the number of parcels, the average size of the parcels and the parcel size distribution. The average number of parcels owned by households in the sample is 2.3 with the maximum being 18. Considering the number of parcels with different texture and different slope, the average number of different parcels is 1.29 and 1.36 respectively. According to Figure 4.1, the distribution of parcels in the sample is skewed. 32.5 percent of the households own and operate 1 parcel, 34 percent own and operate 2 parcels, and 19 percent own and operate 3 parcels. Only 15.5 percent

[2]However, women start to take part in the process of inheritance and have property rights over parcels, even though they mainly get these rights through marriage.

[3]Parcels under fallow are also included in the number of parcels operated by the household.

of households have a degree of fragmentation that exceeds 3 parcels. By definition, the Simpson index is between zero and one and the sample average is 0.35. This means that on average land shares are unevenly distributed among the different parcels. The evolution of land acquisition of the households is given in Table 4.2. The share of inherited land has increased over the years and the share of inherited parcels stands for half of the total parcel holdings of a given household.

Household heads have on average 46 years, are mostly male (about 70 percent) and have attended only primary school on average. Only two percent of the households did not receive any education. The average number of adult members of the households is around 3. The average size of the cultivated land is 4.6 acres and the soil quality is mostly fair.

The precipitation anomalies are constructed as deviations at time t in the district d from the long run annual mean divided by the long run annual standard deviation of the given district:

$$RAINDEV_{dt} = \frac{RAIN_{dt} - \mu_{dLR}}{\sigma_{dLR}} \tag{4.2}$$

where $RAIN_{dt}$ corresponds to the annual level of rainfall in the district d, μ_{dLR} is the long run (LR) rainfall mean in the same district and σ_{dLR} is the standard deviation. From the descriptive statistics in Table 4.1, we can see that the average rain deviation in the 80 districts included in the sample is 0.7 with the minimum being 0 and the maximum rain deviation being 2.6 in absolute terms. Figure 4.2 gives the absolute rainfall deviation for the different districts in Uganda in different years in the sample. The size of absolute rainfall deviation increases over the period.

4.4 Empirical strategy

In order to test whether land fragmentation may reduce the loss of the value of crop yield from rainfall variability, I estimate the following reduced from equation:

$$ln(\frac{Y_{ht}}{A_{ht}}) = \alpha_0 + \alpha_1 X_{ht} + \alpha_2 F_{ht} + \alpha_3 ln(A_{ht}) + \alpha_4 Z_{ht} + \alpha_5 RAINDEV_{dt} + \alpha_6 RAINDEV_{dt} * F_{ht} + \mu_h + \eta_t + \varepsilon_{ht} \tag{4.3}$$

where Y_{ht} represents the value of total crop output of household h in time t. The total crop output is evaluated at mean community prices for each crop that the given household produces. The dependent variable is the ratio between the value of the agricultural production and the total land cultivated in acres, and this equals total agricultural yield per acre in value. A_{ht} represents the total cultivated land net of land under fallow. X_{ht} accounts for the household socio-economic characteristics such as the number of adults which is a proxy for the labor endowment, education, gender and age of the household head and access to extension services.

The degree of land fragmentation of the household is given by the variable F_{ht}. It is measured either by the number of parcels or by the Simpson index. The Simpson index does not take into account the total size of the land holdings of the farmer, the different characteristics of the parcels and the distance to the parcels. Therefore, Z_{ht} controls for one major characteristic of the parcels, e.g., land quality.

I include a variable $RAIN_{dt}$ that measures annual deviation in rainfall from the long run mean at time t in the district d where the household h lives divided by the long run standard deviation. $RAIN_{dt}$ measures the rainfall deviations that households are exposed to. For sake

of simplicity in interpretation, this variable is expressed in absolute terms. In addition, there were more positive (and extreme) rainfall deviations in the different districts of Uganda than negative, on average. The interaction term between the rainfall deviation and the degree of fragmentation tests for a possible difference in impact of rainfall variability on the value of crop yield between households that have different levels of land fragmentation. I expect that when households face the same rainfall deviation, more fragmented land holdings should lower the incidence on income compared to more consolidated land holdings. Finally, μ_h and η_t stand for household and time fixed effects.

A concern when estimating Equation (4.3) is that land fragmentation is affected by some unobserved factors that influence agricultural income (management ability, entrepreneurial spirit). Also, farmers can choose their level of land fragmentation in order to deal with production risk. This is the case when land markets exist and land can be traded or rented. However in the case of Uganda, as land markets are incomplete we can assume that trading land is not entirely feasible. Still, the degree of land fragmentation of the household can be at least partially chosen. In order to deal with this endogeneity issue, I instrument the fragmentation in operated land with the fragmentation in inherited land, as inherited land fragmentation is exogenously imposed on the household through the inheritance process [Foster and Rosenzweig, 2011]. The first stage equation is therefore:

$$F_{ht} = \beta_0 + \beta_1 X_{ht} + \beta_2 Ninherited_{it} + \beta_3 ln(A_{ht}) + \beta_4 Z_{ht} + \beta_5 RAIN_{dt} \ + \mu_h + \eta_t + \varepsilon_{ht} \quad (4.4)$$

where $Ninherited$ is the number of parcels inherited by the household i in time t. The interaction variable, $RAIN_{dt} * F_{ht}$, in Equation (4.3) is also endogenous and it is instrumented

with the interaction term between rain deviation and number of inherited parcels. The other first stage equation is therefore given as:

$$RAIN_{dt} * F_{ht} = \gamma_0 + \gamma_1 X_{ht} + \gamma_2 RAIN_{dt} * Ninherited_{it} + \gamma_3 ln(A_{ht}) + \gamma_4 Z_{ht} + \mu_h + \eta_t + u_{ht} \quad (4.5)$$

4.5 Results

In this section the results from the estimation of Equation (4.3) are presented. In Table 4.4, I use the number of parcels n as a measure for land fragmentation and in Table 4.5 land fragmentation is measured with the Simpson index described before. In both tables Ordinary Least Squares (OLS), Panel fixed effects (FE) and Panel Instrumental Variable (IV) estimations are included. Columns (2), (4) and (6) in each table include the soil quality index that is constructed for the last three rounds, as the data on land quality is missing from the first round, thus these estimations are run on a smaller sample.

4.5.1 First stage results

Before discussing the second stage results, I comment on the results of the first stage estimation and the validity of the instruments. Table 4.3 gives the first stage results of land fragmentation measures and suggests that the number of inherited parcels has a positive and significant impact on the number of owned parcels and on the Simpson index. If the land markets in Uganda were perfect, the coefficient in column (1) in Table 4.3 of the inherited fragmentation would have the value 0 as households can freely decide about the number of parcels they want to operate. The closer this coefficient is to 1, the more the household

land fragmentation is determined by inheritance. The F-statistic is higher than 20 in both estimations and higher than the Stock and Yogo 10 percent IV size which indicates that the instruments are not weak.[4]

Table 4.3 – First stage estimation - Inherited land as instrumental variable

	n	Simpson index
Instruments		
n inherited	0.581***	0.0881***
	(0.0293)	(0.00495)
Controls	YES	YES
Validity Tests		
F-statistic	27.56	25.6
Stock and Yogo 10% IV size	7.03	7.03
Observations	8,342	8,342
R-squared	0.265	0.162
Number of hhid	2,718	2,718

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.5.2 Main results

The estimation results of Equation 4.3 are presented in Tables 4.4 and 4.5. The measure of fragmentation changes between Tables 4.4 and 4.5, but the results are analogous which makes the empirical analysis consistent. Also, taking into account the panel dimension of the data set and treating the endogeneity of the variable(s) of interest improves the statistical significance and increases the magnitude of the coefficients. Therefore, I focus on column (5) in each Table when interpreting the results.[5] In order to quantity the results, we have to take into consideration that the estimation equation is in a semi-log form. According

[4]When regressing inherited land fragmentation on the different household characteristics such as sex, age and education, no single covariate has a significant impact. We can consider this as another validity check that the instrument is exogenous to household characteristics and satisfies the exclusion restrictions.

[5]It is a common finding that panel IV coefficients are larger than a simple panel estimation. Caution is needed when interpretating the size of the different coefficients.

to Table 4.4, one parcel more reduces the value of crop yield by 28 percent if the farmer does not experience any rain deviation. As expected, higher fragmentation leads therefore to lower value of the yield per acre. Regarding the impact of rain variability, if we consider for example that the number of parcels of a farmer equals two, one rain deviation more will decrease the crop income per acre by 24 percent. If the household has the average number of parcels, 2.35, then this decrease of the agricultural income per acre is reduced to the level of 6.7 percent. If we assume a rain deviation equal respectively to 0.5 and 1 standard deviation, then the agricultural yield in value decreases by 3 percent in the first case and increases by 21 percent in the second case when the number of parcels is increased by one unit. These net effects are shown in Table 4.6

These results are robust to the alternative measure of land fragmentation, the Simpson index, in Table 4.5. If there is no rain deviation, an increase of the Simpson index by 0.1 units decreases the agricultural yield in value by 16 percent. When there is one standard deviation in rainfall, then the increase of the index of 0.1 leads to an increase of the crop income per acre by 8.7 percent, which offsets almost by half the impact of the previous case. If the Simpson index is equal to 0.3, 0.35 (its average value) or 0.5, then one standard deviation in rainfall reduces the crop income per acre by 27 percent, 13 percent and increases the crop income per acre by 26 percent in the last case. This confirms the *ex ante* hypothesis that land fragmentation can be beneficial for those households that are exposed to higher weather irregularities. The results demonstrate that the higher the rainfall deviation, the higher the beneficial effect of more fragmented land ownings.

From the estimated model, we can predict the value of crop yield for each level of rain

deviation by considering the degree of land fragmentation. This is illustrated in Figure 4.3.[6] For households that have one parcel and do not face any rain deviation, the predicted value of crop yield is the highest. On the contrary, households that operate 5 parcels have the lowest level of predicted yield when there are no rain deviations. If rain deviation increases, the value of crop yield of the most consolidated land (n=1) decreases and the value of crop yield of the most fragmented land (n=5) increases. Land fragmentation can therefore be perceived as detrimental for households that are not exposed to rainfall variability. But, land fragmentation can be beneficial for households that face higher rainfall variability and do not have access to other forms of insurance.[7] Considering the results in Table 4.4 column (5), the threshold above which a household can realize benefits form land fragmentation is 0.6 standard deviation in rainfall. If a household faces a standard deviation in rainfall that is higher then 0.6, then having more than 3 parcels to operate will not decrease its value of crop yield.

When considering the other covariates in Tables 4.4 and 4.5, having a household head that is older increases the yield. This result should be linked to the experience of the household improving agricultural efficiency. In addition, a household head with primary or secondary education earns a higher agricultural yield compared to household heads with no education. The impact is even higher in the case when the head has secondary education compared to the primary education. Concerning the production factors, labor and land, an increase in the number of adults has a positive impact on the value of crop yield. However, there is a negative relationship between the size of the cultivated land and the yield. In the literature

[6]The illustration is based on the results in Table 4.4, column (3).

[7]Figure 4.3 should be interpreted in relative terms; the predicted yields decrease more for consolidated parcels compared to more fragmented land ownings when rainfall deviation increases.

Table 4.4 – The impact of fragmentation: count measure

Value of crop	OLS	OLS	Panel FE	Panel FE	IV Panel FE	IV Panel FE
yield (ln)	(1)	(2)	(3)	(4)	(5)	(6)
n	-0.0287	-0.0887**	-0.254***	-0.451***	-0.251***	-0.768***
	(0.0276)	(0.0367)	(0.0311)	(0.0484)	(0.0815)	(0.109)
rain deviation	-0.244***	-0.612***	-0.553***	-0.706***	-1.109***	-1.737***
	(0.0856)	(0.102)	(0.0894)	(0.110)	(0.188)	(0.227)
n*rain deviation	0.169***	0.206***	0.181***	0.238***	0.444***	0.697***
	(0.0340)	(0.0399)	(0.0366)	(0.0433)	(0.0867)	(0.0997)
sex	0.160**	0.228***	-0.904***	-1.006***	-0.890***	-0.986***
	(0.0625)	(0.0760)	(0.168)	(0.267)	(0.170)	(0.278)
age	0.00934***	0.00687***	0.0749***	0.0220*	0.0755***	0.0199
	(0.00190)	(0.00235)	(0.00945)	(0.0121)	(0.00847)	(0.0123)
adults	0.0962***	0.0640***	0.0962***	-0.0649*	0.0886***	-0.0706*
	(0.0170)	(0.0205)	(0.0264)	(0.0386)	(0.0274)	(0.0418)
cultivated land (ln)	-0.780***	-0.783***	-0.950***	-0.959***	-1.023***	-0.967***
	(0.0398)	(0.0502)	(0.0603)	(0.0833)	(0.0690)	(0.0947)
primary education	0.957***	0.982***	0.672***	0.669***	0.667***	0.633***
	(0.0732)	(0.0900)	(0.130)	(0.182)	(0.136)	(0.195)
secondary education	1.178***	1.178***	1.281***	1.594***	1.258***	1.496***
	(0.0873)	(0.107)	(0.187)	(0.250)	(0.196)	(0.270)
land quality index		-0.561***		-0.933***		-0.897***
		(0.0479)		(0.0508)		(0.0551)
Constant	5.530***	7.370***	4.299***	9.702***		
	(0.137)	(0.191)	(0.417)	(0.602)		
Observations	8,342	6,251	8,342	6,251	8,342	6,251
R-squared	0.071	0.090	0.080	0.139	0.070	0.115
Number of hhid			2,718	2,477	2,718	2,477

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.5 – The impact of fragmentation: Simpson index

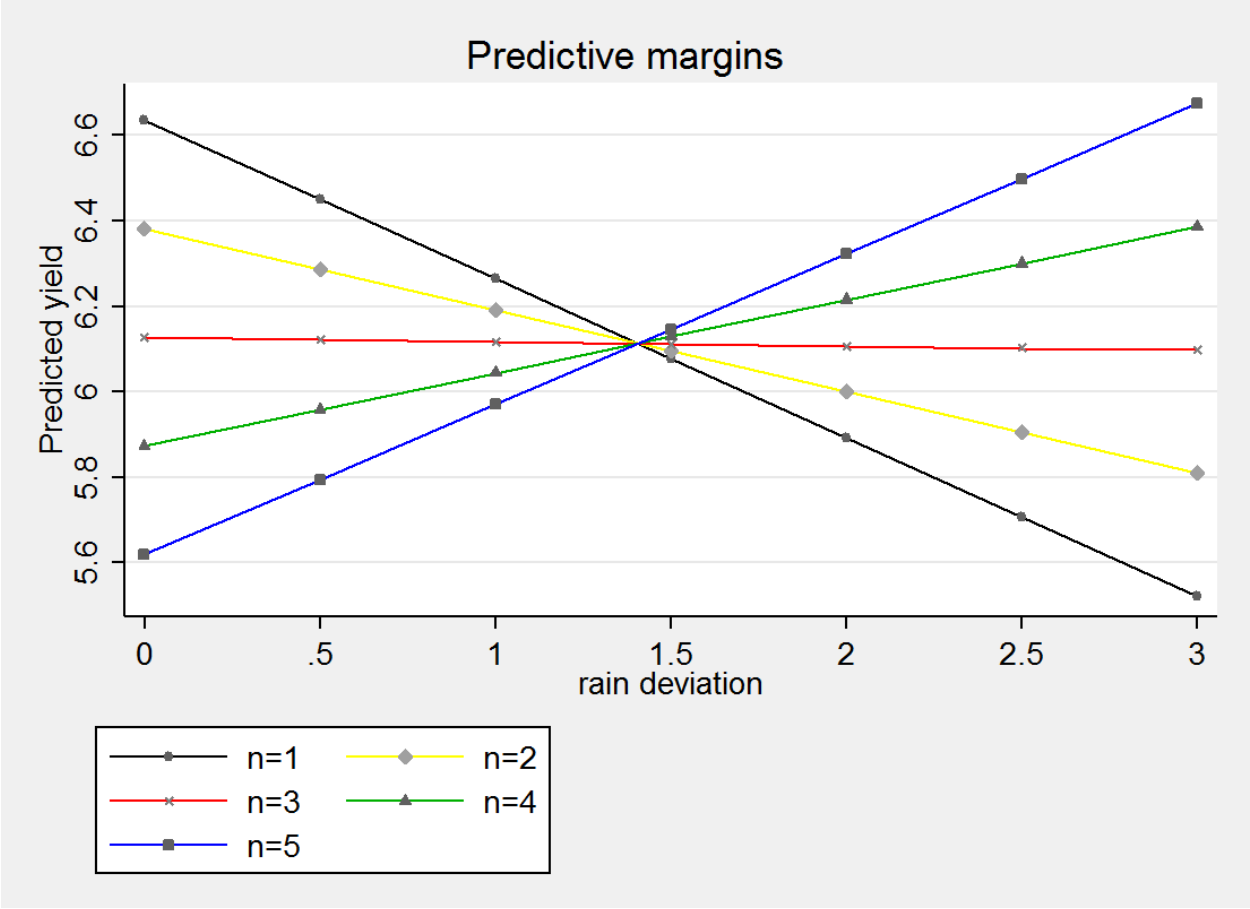
Value of crop yield (ln)	OLS (1)	OLS (2)	Panel FE (3)	Panel FE (4)	IV Panel FE (5)	IV Panel FE (6)
Simpson index	0.105	-0.238	-0.917***	-1.694***	-1.506***	-4.744***
	(0.142)	(0.189)	(0.176)	(0.263)	(0.537)	(0.697)
rain deviation	-0.0167	-0.349***	-0.362***	-0.447***	-0.945***	-1.568***
	(0.0681)	(0.0822)	(0.0679)	(0.0841)	(0.154)	(0.193)
Simpson*rain deviation	0.407***	0.537***	0.635***	0.824***	2.343***	3.932***
	(0.156)	(0.183)	(0.153)	(0.182)	(0.435)	(0.512)
sex	0.162***	0.232***	-0.916***	-1.016***	-0.880***	-0.936***
	(0.0625)	(0.0761)	(0.168)	(0.271)	(0.172)	(0.291)
age	0.00944***	0.00679***	0.0757***	0.0236*	0.0749***	0.0198
	(0.00190)	(0.00236)	(0.00946)	(0.0122)	(0.00851)	(0.0124)
adults	0.0976***	0.0652***	0.0925***	-0.0657*	0.0813***	-0.0816*
	(0.0170)	(0.0206)	(0.0263)	(0.0387)	(0.0276)	(0.0426)
cultivated land (ln)	-0.768***	-0.767***	-1.001***	-1.025***	-1.030***	-1.006***
	(0.0392)	(0.0497)	(0.0591)	(0.0829)	(0.0634)	(0.0911)
primary education	0.956***	0.986***	0.674***	0.687***	0.658***	0.630***
	(0.0733)	(0.0901)	(0.130)	(0.183)	(0.137)	(0.202)
secondary education	1.179***	1.183***	1.292***	1.652***	1.246***	1.545***
	(0.0874)	(0.107)	(0.187)	(0.251)	(0.197)	(0.274)
land quality index		-0.567***		-0.933***		-0.874***
		(0.0480)		(0.0505)		(0.0565)
Constant	5.408***	7.239***	4.076***	9.247***		
	(0.133)	(0.185)	(0.417)	(0.600)		
Observations	8,342	6,251	8,342	6,251	8,342	6,251
R-squared	0.069	0.088	0.076	0.131	0.059	0.079
Number of hhid			2,718	2,477	2,718	2,477

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.6 – Quantifying the effects

Rain deviation	0	0.5	1
↑ n by 1 parcel	↓ 28%	↓ 3%	↑ 21%
	value of crop yield		

Figure 4.3 – Predicted yield for different levels of rain deviation and number of parcels



it was shown that in the case of some developing countries there is an inverse relationship between farm size and productivity [Carletto et al., 2013]. The higher the soil quality index, that refers to a worse soil quality, the lower is agricultural yield, as expected.

4.5.3 Robustness tests

As a robustness check, instead of only taking into account the number of parcels, Table 4.7 includes the number of parcels with different soil type and soil topography which gives a more detailed aspect of risk diversification of a land holding. The results are consistent with what was previously found. With a higher number of parcels with different soil types,

the lower is the impact on the value of crop yield of a rain deviation. However this is not verified for the number of parcels with different topography. Even land with low degree of steepness can contribute to lower water infiltration and water runoffs. This might be a possible explanation for why a higher number of parcels with different slope does not reduce the impact of rainfall variability on the value of crop yield. The other covariates have similar impacts as in the previous estimations.

Another robustness check is to include the average distance to the parcels in order to account for the time cost. The information on distance is only given for the three last survey years, the sample size is thus lower. The results are given in Table 4.8. The average distance is calculated as the average of the time that it takes for a farmer to arrive to the different parcels. As expected, the higher this average distance, the lower the value of crop yield. The previous results and conclusions on land fragmentation and its interaction with rain deviation do not change when I control for the distance.

We might expect that households that hold higher number of parcels can potentially overestimate the size of their holdings. Subjective appreciation of the size of land holdings might be biased and therefore the calculation of the value of crop yield could be inaccurate. One of the advantages of the dataset used in this chapter is that GPS measurements of parcel size are included for 70 percent of the parcels. In order to verify whether the previous estimates are robust, I test whether there is a significant difference between the subjective measures of acreage of farmers and the GPS measurement.[8] I only take into account households that have both measures for each of their parcels (which is the case for 45-55 percent of the households in the sample). I test the difference between the two measures and the

[8] I run a paired t-test in STATA for both measures.

Table 4.7 – The impact of fragmentation: different soil type

Value of crop yield (ln)	OLS (1)	OLS (2)	Panel FE (3)	Panel FE (4)
n soil type	-0.408***	-0.404***	-0.773***	-0.762***
	(0.109)	(0.108)	(0.116)	(0.116)
n topography	0.323***	0.351***	-0.180	-0.154
	(0.103)	(0.101)	(0.126)	(0.126)
rain deviation	-0.808***	-0.501***	-1.306***	-0.737***
	(0.147)	(0.147)	(0.146)	(0.157)
n soil type*rain deviation	0.517***	0.461***	0.639***	0.530***
	(0.117)	(0.115)	(0.128)	(0.129)
n topography* rain deviation	-0.163	-0.198*	-0.0117	-0.0704
	(0.106)	(0.105)	(0.121)	(0.124)
sex	0.223***	0.235***	-0.925***	-1.024***
	(0.0769)	(0.0760)	(0.268)	(0.269)
age	0.00608**	0.00680***	0.0171	0.0207*
	(0.00237)	(0.00235)	(0.0115)	(0.0123)
adults	0.0610***	0.0641***	-0.0488	-0.0621
	(0.0208)	(0.0205)	(0.0406)	(0.0387)
cultivated land (ln)	-0.758***	-0.761***	-1.044***	-1.025***
	(0.0500)	(0.0494)	(0.0906)	(0.0839)
primary education	1.010***	0.990***	0.747***	0.665***
	(0.0910)	(0.0901)	(0.181)	(0.182)
secondary education	1.238***	1.177***	1.707***	1.617***
	(0.108)	(0.107)	(0.256)	(0.254)
quality index		-0.564***		-0.949***
		(0.0481)		(0.0510)
Constant	6.452***	7.198***	8.751***	10.03***
	(0.219)	(0.225)	(0.612)	(0.634)
Observations	6,251	6,251	6,251	6,251
R-squared	0.070	0.090	0.072	0.133
Number of hhid	2,477	2,477	2,477	2,477

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.8 – The impact of fragmentation including distance

Value of crop yield (ln)	Panel FE (1)	IV Panel FE (2)	Panel FE (3)	IV Panel FE (4)
n	-0.441***	-0.760***		
	(0.049)	(0.110)		
Simpson index			-1.412***	-4.703***
			(0.247)	(0.703)
rain deviation	-0.710***	-1.726***	-0.518***	-1.559***
	(0.110)	(0.226)	(0.107)	(0.193)
land frag.*rain deviation	0.242***	0.694***	0.169***	3.916***
	(0.043)	(0.099)	(0.042)	(0.511)
distance	-0.118*	-0.136*	-0.126*	-0.104
	(0.068)	(0.073)	(0.069)	(0.078)
sex	-1.014***	-0.994***	-1.043***	-0.942***
	(0.266)	(0.278)	(0.270)	(0.291)
age	0.022*	0.020	0.024**	0.020
	(0.012)	(0.012)	(0.012)	(0.012)
adults	-0.064*	-0.069*	-0.062	-0.081*
	(0.039)	(0.042)	(0.039)	(0.043)
cultivated land (ln)	-0.955***	-0.958***	-1.045***	-1.000***
	(0.083)	(0.094)	(0.082)	(0.090)
primary education	0.671***	0.634***	0.695***	0.631***
	(0.182)	(0.195)	(0.183)	(0.202)
secondary education	1.591***	1.493***	1.659***	1.542***
	(0.250)	(0.270)	(0.252)	(0.274)
land quality index	-0.930***	-0.895***	-0.933***	-0.871***
	(0.051)	(0.055)	(0.051)	(0.057)
Constant	9.868***		9.339***	
	(0.608)		(0.604)	
Observations	6,250	6,250	6,250	6,250
R-squared	0.139	0.116	0.131	0.080
Number of hhid	2,477	2,477	2,477	2,477

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

null hypothesis that this difference is equal to zero cannot be rejected for each year of the survey and all years combined. Moreover, I run the test for each year of the survey by level of land fragmentation and no significant difference is found for the different number of parcels. These tests seem to indicate that the main results are robust, at least with regard to measurement error in land holdings.

In order to account for another climatic factor than rainfall, temperature deviations are included in the estimation in Table 4.9. When comparing the previous results to the results included in Table 4.9, we observe that there is no difference in terms of magnitude and statistical significance. The coefficients of the interaction terms between rain deviations and temperature deviations with the degree of fragmentation are positive and statistically significant which confirms the *ex ante* hypothesis. Compared to rainfall deviations, it is puzzling that annual temperature deviations are not harmful as such for agricultural productivity in Uganda.

4.5.4 Discussion: Indirect effects of land fragmentation

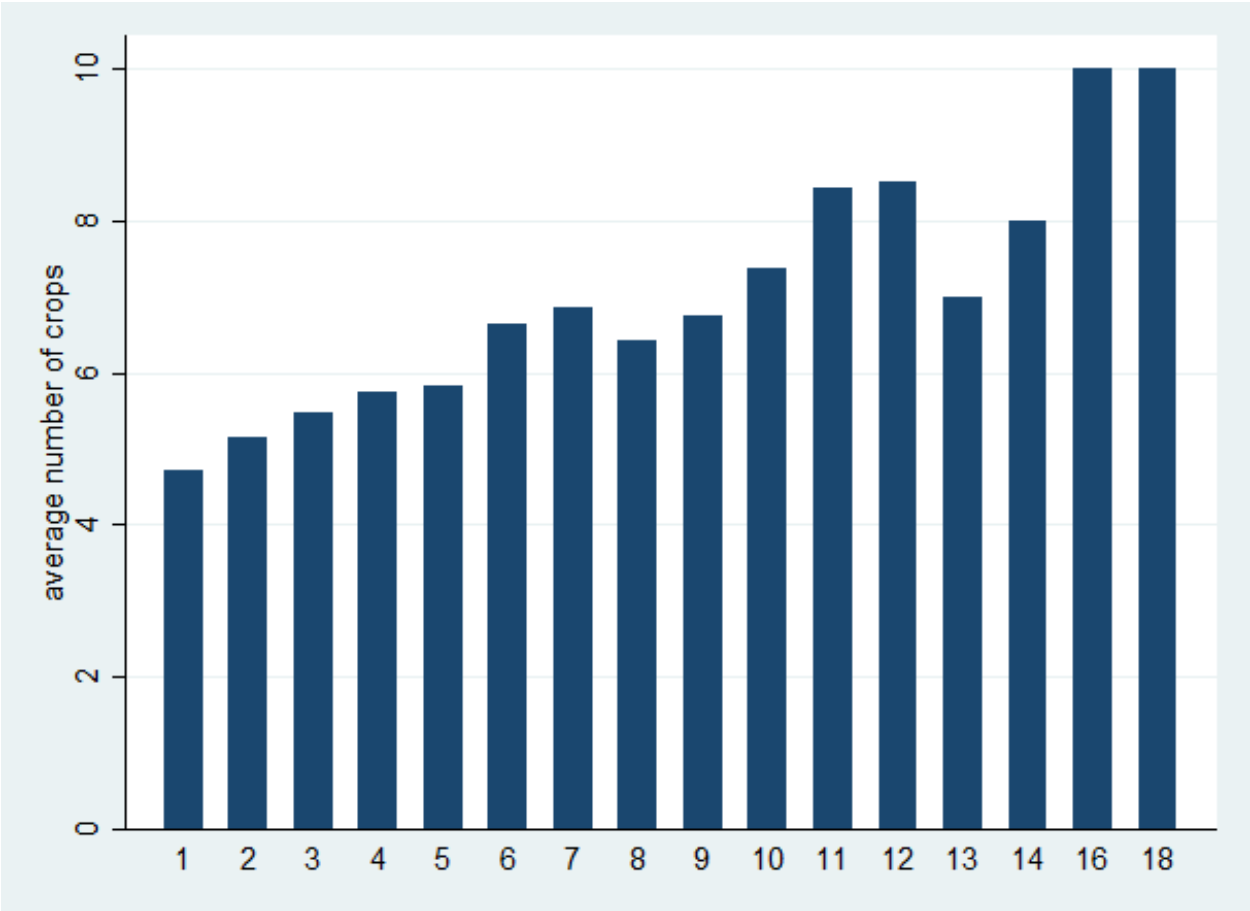
Finally, as discussed previously, the literature that studies the benefits of land fragmentation has argued that it leads to higher crop diversity [see amongst others Di Falco et al., 2010]. Because of the different agro-ecological characteristics of the fragmented parcels, crop diversification is more feasible because it matches the soil type and quality to the features of the crops. Land fragmentation could therefore have an indirect effect on the exposure of households to rainfall variability through the ability to increase the crop diversity. Figure 4.4 represents the average number of crops cultivated for each number of parcel. The num-

Table 4.9 – The impact of fragmentation including temperature

Value of crop yield(ln)	IV Panel FE (1)	IV Panel FE (2)
n	-0.646***	
	(0.191)	
Simpson index		-3.804***
		(1.049)
rain deviation	-1.728***	-1.651***
	(0.171)	(0.134)
temp. deviation	2.518***	2.569***
	(0.188)	(0.148)
land frag.*rain deviation	0.236***	1.259***
	(0.079)	(0.378)
land frag.*temp. deviation	0.203**	1.173***
	(0.083)	(0.402)
sex	0.135	0.157
	(0.193)	(0.197)
age	-0.011	-0.012
	(0.008)	(0.008)
adults	0.047	0.040
	(0.029)	(0.029)
cultivated land (ln)	-1.027***	-1.027***
	(0.066)	(0.063)
primary education	-0.106	-0.133
	(0.147)	(0.147)
secondary education	0.095	0.076
	(0.201)	(0.201)
land quality index	-0.283***	-0.276***
	(0.041)	(0.041)
Observations	6,250	6,250
R-squared	0.600	0.594
Number of hhid	2,477	2,477

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 4.4 – Crop diversification



ber of cultivated crops increases with the level of fragmentation. For households cultivating only one crop, the average number of parcels for these household is 1.5. More consolidated/fragmented land holdings lead to higher crop specialization/diversification. In Table 4.10, I present the results from a reduced-form estimation that tests the impact of land fragmentation on crop diversity. The impact of the number of parcels on the number of cultivated crops is positive and significant at one percent level of statistical significance. These estimations seem to confirm that one of the mechanisms by which land fragmentation reduces the impact of rainfall deviations on agricultural yield in value could indeed be through an increase in crop diversity.

Table 4.10 – The impact of fragmentation on crop diversity

Number of crops	Panel FE (1)	IV Panel FE (2)
number of parcels	0.224***	0.255***
	(0.029)	(0.061)
Control Variables		
	YES	YES
Observations	6,250	6,250
Number of hhid	2,477	2,477

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The set of controls are cultivated land, labor, sex, age and education of the HH head and land quality index.

4.6 Conclusion

The aim of this chapter is to explore the role of land fragmentation when agricultural households face rainfall variability. Even though land fragmentation is mainly considered as detrimental for agricultural productivity, there is some evidence that it can allow for reduction in production risk. I use the LSMS-ISA data from Uganda to analyze the question. After instrumenting for the level of fragmentation, I find that higher land fragmentation decreases the loss of crop yield in value when households experience rain deviations. The results show that the higher the deviation, the higher the beneficial effect of land fragmentation. The results are robust when including different alternative measures of land fragmentation, average distance between the parcels and temperature deviation. I also find that labor endowment and education are crucial for the agricultural productivity.

The results in this chapter indicate that developing countries should be cautious with

the policy of land consolidation. If insurance markets are missing, then land fragmentation can be an alternative for farmers operating in rain-fed environments. Therefore, instead of focusing only on land consolidation programs, the imperative of policy makers might be more focused on improving other imperfect or missing markets that influence agricultural productivity.

Chapter 5

Water inequality and conflict[1]

5.1 Introduction

Scarcity of water can create inter-state conflict, as is well known from international conflicts in regions with transboundary water sources, so called 'water wars' [Delbourg and Strobl, 2014]. For example, Soubeyran and Tomini [2012] find that the risk of inter-country conflict increases with freshwater scarcity, and that the effect is more important the more asymmetric the countries are. Delbourg and Strobl [2014] incorporate streamflow in an analysis of bilateral water events in Africa and find that decreases in current water streamflow increases the likelihood of conflict rather than cooperation.[2] Recently, attention has turned to intra-country conflict - civil war - and water resources. Several articles analyze the causality between civil war and the absolute quantity of water resources, either in terms of rainfall

[1] co-authored with Katrin Millock

[2] We focus only on water resource availability and conflict here. The literature has also used the exogeneity of rainfall as an instrument to assess the role of economic shocks in explaining conflict [Miguel et al., 2004, Ciccone, 2011] and more recently, measures of climate and climate anomalies, e.g., Hendrix and Glaser [2007]. See the review by Burke et al. [2014].

measures, the Palmer drought index in Couttenier and Soubeyran [2013], precipitation levels in Berman and Couttenier [2015] or precipitation and temperature [Burke et al., 2009, O'Loughlin et al., 2012]. Some studies focus on indirect measures in the form of the number of displaced people following a flood [Ghimire et al., 2015].

Compared to absolute water scarcity, relative water scarcity has not been analyzed before. The objective of this chapter is to test whether water inequality may be a factor of low-level civil conflict using detailed household data. In doing so, we extend the existing literature in three ways. First, we study relative water scarcity using household surveys, whereas existing studies rely on aggregate country measures or, in the more disaggregated studies, absolute water scarcity at a geographical grid level. The other original contribution of the paper is to analyze relative water scarcity, since previous analyses rely on absolute measures of water scarcity. We match the household-based measure of water inequality with micro level conflict data at a district level from one country, Uganda. This enables a micro level analysis of the causality between water inequality and civil conflict. In this manner, we wish to contribute to the research on inequality and civil conflict [Blattman and Miguel, 2010]. Inequality in income as a trigger of civil war has been examined by several authors [Blattman and Miguel, 2010] and studies of civil conflict normally control for inequality as one important factor explaining the occurrence of civil war. For example, Ghimire et al. [2015] control for inequality proxied by the infant mortality rate in a country-level analysis of flood-induced migration and civil war.[3] Cramer [2003] criticizes the analyses on income inequality and civil conflict, since most often cross-country data are used, and problems in the quality of the

[3]The PRIO - Uppsala Conflict Data Program (UCDP) defines a conflict as civil war when there are more than 25 battle-related deaths in a year.

data used on income distribution and civil conflict may suggest a causal relationship between the two phenomena. A final contribution of the chapter is thus to use panel household level data aggregated to district level distributions to test whether there exists a relation between inequality in water use and civil conflict. In analyzing the relation between inequality in the use of water and civil conflict, we test a grievance-based argument. A well-known typology from Collier and Hoeffler [2004] categorizes the roots of civil conflict either in greed motives related to capturing natural resource rents [Caselli et al., 2015, Welsch, 2008] or in motives based on grievances related to distributional outcomes and a lack of political rights.

Water is defined as a basic human right in the United Nation's Sustainable Development Goals that were launched in 2016. As concerns water access, the goal is to provide clean water for the world's population by 2030. In economic terms, water is a necessity good for which a basic consumption can be defined. It is therefore plausible that smaller allocations, compared to others, in a major basic good can create grievances against the political system in charge of its distribution. We thus wish to test the effect of water inequality on a measure of low-level conflict, i.e., social unrest in the form of demonstrations or riots. Koubi et al. [2013], amongst others, argue that there is a need for studies of the role of natural resource scarcity in social conflict using disaggregated household data. We use data on domestic water consumption of rural and urban households. The data include all uses for domestic purposes, but not for agriculture.

In order to test the impact of inequality in water consumption on social unrest we combine three sources of data: household data on water consumption and land ownership from the Living Standard Measurement Studies-Integrated Survey on Agriculture (LSMS-ISA) on Uganda, established by the World Bank, data on riots and protests from the Uppsala Armed

Conflict Location and Event Dataset (ACLED) and weather data from the TS3.21 dataset from the Climatic Research Unit of the University of East Anglia. We use two different dependent variables in order to empirically address the research question, a binary variable that indicates if a district faced an event of rioting or protesting in a given year, and a count variable measuring the number of events of riots and protests. Following the literature, the incidence of riots and protests is estimated using a linear probability model, whereas the frequency is estimated with a negative binomial model because of the high number of zeros in the data.

The results indicate that inequality in water consumption does not affect significantly the incidence and the frequency of social unrest in Ugandan districts. This is also the case when testing the other measure of inequality in natural resource use - inequality in land distribution - and income inequality. We find strong evidence that deviations in temperature increase the incidence and the frequency of social unrest in the same year. The percentage of households located in urban areas in the district also increases the incidence and the frequency of riots and protests. In comparison to temperature, precipitation does not have a robust significant effect on riots and protests in Uganda. The significant effect of only temperature found here on disaggregated data is similar to a result from the literature using international data on high-level conflict, i.e., that changes in temperature caused by climate change increase the incidence of civil war in Africa [Burke et al., 2009]. This particular effect of deviations in temperature has not been established earlier on low-level conflict data such as protests and riots on district level data.

5.2 Water resources and inequality in Uganda

Compared to other African countries, Uganda is water abundant. According to the Nile Basin Initiative, about 8 percent of the Nile basin lies within Uganda. There are several major lakes among which the most important one is Lake Victoria. The different water bodies represent a total inland water area that covers 17 percent of the total country. According to the World Bank Development Indicators for 2015, the renewable fresh water resources per capita in cubic meters are 1 102, which nevertheless is five times less than the world average of 5 925 cubic meters per capita. Even if there are high rainfall intensities, especially around Lake Victoria, there is a moisture deficit within the year according to the country profile from the FAO. In 2015, the percentage of population with access to improved water sources was 79 percent compared to the average in Sub-Saharan Africa of 68 percent or the world average of 91 percent, according to the World Bank Development Indicators. Differences in access to improved water resources exist between the urban population, among which 96 percent have access, and the rural population, for whom 76 percent have access to improved water resources. Indeed, according to a USAID country report on Uganda, access to land and water is highly variable between different regions and population groups. Although the country has sufficient water resources, they are unevenly distributed. For example, in the Central region of Uganda, there have been conflicts over pastures and access to water sources [Lwanga-Ntale, 2014].

If there are conflicts and inequalities in water consumption in Uganda, there are also important income inequalities. The Gini coefficient according to the World Bank was 0.424 in 2012. Even though GDP has grown consistently since two decades, income inequality

is persistent. Similarly to inequality in access to water, income inequality exists between different ethnic groups, regions and activities [Lwanga-Ntale, 2014, Ssewanyana and Kasirye, 2014]. In the analysis, we will therefore also test the impact of income inequality on social unrest.

5.3 Specification

We use two measures of social unrest from the ACLED data. The first definition of the dependent variable is the incidence of social unrest, for which the variable is set equal to one if there is at least one riot or demonstration observed in district i at time t. The second definition of the dependent variable is a count variable of the number of riots and demonstrations that occurred in district i at time t.[4] The basic specification we estimate is the following:

$$y_{it} = \alpha_i + \beta_t + \gamma x_{it} + \delta wineq_{it} + \epsilon_{it} \tag{5.1}$$

where y_{it} is the measure of social unrest in district i at time t, α_i are district fixed effects, β_t are year fixed effects to capture any macro-economic shocks that affect districts in a common manner, x_{it} is a vector of time-varying control variables, $wineq_{it}$ is the measure of water inequality among the households in district i in year t and ϵ_{it} the error term. The coefficient of interest is δ, the coefficient on the measure of water inequality among households in the district.

[4]Research on conflicts normally estimates the incidence and the intensity of conflict, as well as its onset and end. Given the short time period used here, it is not meaningful to estimate the beginning or the end of a conflict.

The argument we test on the data is that inequality in domestic water consumption brings grievances that may find an outlet in demonstrations and rioting, and thus feed civil conflict at a lower scale than outright civil war. As a measure of inequality in water consumption we calculate the Gini coefficient among rural and urban households at a district level.[5] The Gini coefficient is a common measure of income inequality, but its application to natural resource consumption is rare. Some measures of land inequality have been calculated in the literature [Erickson and Vollrath, 2004, Zheng et al., 2013]. For water consumption, Cullis and Van Koppen [2007] calculate Gini coefficients to quantify the distribution of water resources in a water-stressed area in South Africa. In this article, we calculate Gini coefficients for water consumption of households based on the distribution at a district level. We prefer this measure of water inequality as an indicator of grievances compared to a composite indicator, such as the water poverty index [Sullivan, 2002]. The problem with a composite indicator is the choice of variables to include and the lack of comparability, whereas the Gini coefficient is a commonly used and well-understood measure of inequality. The water consumption is given in the data set as the daily consumption of a given household in liters. We compute three different Gini coefficients on the data: a standard Gini coefficient and two coefficients that are scaled in order to account for the household size. The two alternative scaled measures are adjusted either through dividing by the square root of the total number of members or by using the OECD household member equivalence scale[6].

Following the literature we control for other explanatory variables linked to social unrest: agricultural productivity [Bohmelt et al., 2014], as captured by precipitation, ethnic

[5]The Gini coefficients for household water consumption in different districts are computed using the command *ineqdeco* in STATA.

[6]The OECD equivalence scale assigns a weight of 1 to the first household adult member, a weight of 0.7 to each additional adult and a weight of 0.5 to each child.

fractionalization [Esteban et al., 2012] or polarization [Reynal-Querol and Montalvo, 2005], urbanization and population size [Fearon and Laitin, 2003]. Since agricultural productivity on district level is endogenous, we prefer to use precipitation instead following the literature [Miguel et al., 2004, Couttenier and Soubeyran, 2013]. The other reason to include precipitation is that we wish to make sure that we capture only a possible effect from inequality in water consumption, for a given level of overall scarcity, and that we exclude other potential omitted variables capturing a general drought situation or an agricultural income shock. As underlined in Auffhammer et al. [2013], when testing the impact of climate variables on different outcomes, such as conflict, all aspects of climate should be considered, and we thus include both temperature and precipitation anomalies. The precipitation and temperature anomalies included in the specification are constructed as deviations at time t in the district i from the long run annual mean divided by the long run annual standard deviation of the given district, following Marchiori et al. [2012].

Ethnic diversity is one of the most important variables for social unrest in the literature [see, for example, Collier and Hoeffler, 2004, Reynal-Querol and Montalvo, 2005]. An ethno-linguistic fractionalisation index, constructed as follows:

$$F = 1 - \sum_{k=1}^{N} \pi_k^2 \tag{5.2}$$

is used in the literature to account for ethnic diversity. π_k represents the proportion of individuals who belong to the ethnic group k, and N is the number of groups. Reynal-Querol and Montalvo [2005] argue that a measure of ethnic polarization may be more relevant than an index of ethnic fractionalization. When societies are highly homogeneous or highly

heterogeneous, there is less probability of conflict compared to societies with one ethnic minority facing one ethnic majority. Therefore a polarization index calculated as follows is also used in the estimations:

$$P = 1 - \sum_{k=1}^{N} \left(\frac{(1/2 - \pi_k}{1/2} \right)^2 \pi_k \tag{5.3}$$

$$P = 4 \sum_{k=1}^{N} \pi_k^2 (1 - \pi_k) \tag{5.4}$$

The aim of the polarization index is to capture how far the distribution of ethnic groups is from a bipolar distribution that is the highest level of polarization. If population is transferred from one group to another, the effect on the conflict level is different depending on the size/weight of the groups. If population is transferred from one small group to another small group, conflict increases, and if population is transferred from one big group to another, conflict decreases. In the first case, even if the transfer implies that the distribution is more unequal in the new situation, one of the small groups is larger, with respect to the other small group, which means that polarization has increased. In the second case, the transfer implies that one of the big groups becomes smaller, and therefore the new situation is less polarized. In the estimations, we test both indices to check which one influences more the incidence and the frequency of riots and protests.

Finally, as other controls we use the total population size in the district, as reported by the Ugandan Bureau of Statistics, and the level of urbanization of the households in the district.[7] The urbanization rate is calculated as the percentage of households at a district

[7]The two variables population size and level of urbanization are highly correlated. We finally decide to use only the level of urbanization as it has a higher significant impact on riots and protests in the different estimations.

level whose place of residence is classified as 'urban' rather than 'rural' according to the LSMS survey instrument.

The dependent variable that measures the frequency of conflict in equation (5.1) is a count variable, and the most appropriate method to estimate this equation is a Poisson model. Given the presence of over-dispersion of the count variable[8], a negative binomial estimation model should be considered. When running a likelihood-ratio test of the over-dispersion parameter α, the null hypothesis of an α that equals zero is rejected as the chi-squared value of the test is 53.31. This strongly suggests that the negative binomial model is more appropriate than the Poisson model on the data analyzed here. Regarding the binary variable that indicates whether there is a conflict in the district or not, we use a linear probability model that allows us to introduce district and time fixed effects (FE).[9]

5.4 Data

5.4.1 Sources

In order to estimate the equation (5.1), we use data from three different sources. The household data that allow us to construct the Gini coefficients on water consumption come from the Living Standard Measurement Studies-Integrated Survey on Agriculture (LSMS-ISA) on Uganda, established by the World Bank. The data cover the period from 2009 to 2012 and are representative on a national, regional, rural and urban level. The LSMS-ISA

[8]The variance of the dependent variable is almost five times higher than the mean.

[9]Bircan et al. [2010] discuss a potential problem of reverse causality in an analysis of the impact of war on income inequalities. The authors analyze civil war, though, which is conflict at such a level that an effect on income equality can be expected. For the low-level internal conflict analyzed here, it is unlikely that there is reverse causality between the inequality measures and social unrest.

data is also used to construct the ethnicity indicators on a district level and the degree of urbanization of each district.

The second source of data is the Uppsala Armed Conflict Location and Event Dataset (ACLED), version 6, that covers the period from 1997-2015. It records the exact location of an event, with its longitude and latitude. The unit of observation in the ACLED is an event and there are nine types of events coded according to different degrees of violence. In this paper, we focus on low-level conflict such as riots and protests. The data set measures the number of events that occurs at district level in each year. The sources for this dataset are diverse, and come mainly from media-based sources, humanitarian agencies and research publications. The dataset is widely used in the conflict literature as it is less aggregated than country level data and contains high quality information on the different events. Despite the high quality information, one potential concern with the dataset is possible selection in the reporting of the events. For regions where the media coverage is low, there can be under-reporting of events.

Finally, the data used to construct deviations in precipitation and temperature are drawn from the TS3.21 dataset from the Climatic Research Unit of the University of East Anglia. It is monthly average data on precipitation and temperature from high-resolution grids, 0.5 x 0.5 degrees, that cover more than one century (1901-2012).

5.4.2 Descriptive statistics

According to Table 5.1, social unrest is unevenly distributed among districts with an average of 0.5 riots and protests in the different districts in Uganda over the years studied

here, and a maximum of 24 events. Among the districts that faced riots and protests, the average number of such events is 5.7. The district that faced the largest number of riots and protests is Kampala, unsurprisingly. The average number of any conflict event (including also high-level civil conflict) is 1.5 and the average number of events among the districts that faced at least one general conflict event is 4.3. On average, 15 percent of the districts faced riots and protests and 35 percent faced any kind of conflict event.

Table 5.1 – Summary statistics for the dependent variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Count variable					
number of riots/protests	240	.496	2.472	0	24
total number of any conflict event (low and high level)	240	1.479	4.107	0	30
Binary variable					
incidence of riots/protests	240	.146	.354	0	1
incidence of any conflict event (low and high level)	240	.346	.477	0	1

Table 5.2 – Summary statistics for the explanatory variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Gini coefficients					
gini water	231	.292	.093	0	.775
gini water scaled (number of members)	231	.251	.09	0	.786
gini water scaled (OECD equivalence scale)	231	.269	.096	0	.808
Other controls					
ethnic fractionalization	231	.356	.26	0	.854
ethnic polarization	231	.467	.279	0	.989
urban HH percentage	231	.149	.19	0	1
deviation in precipitation	240	.451	.946	-1.384	2.628
deviation in temperature	240	2.64	.561	1.594	3.665

The summary statistics on the explanatory variables in Table 5.2 show that the use of scaling in the calculation of the Gini coefficients (to account for the composition of each household) decreases the Gini coefficients compared to the unscaled calculation, but that

there are very small differences between the different calculations of the scaled Gini coefficients. Depending on the measure, the average Gini coefficient of water consumption ranges from 0.25 to 0.3.

The average score of ethnic fractionalization is 0.36. This indicates that the probability that two randomly selected individuals do not belong to the same ethnic group is about 36 percent. The average value for the polarization index is 0.47. Compared to the fractionalization index, the probability of two individuals belonging to different groups is weighted by the size of the ethnic group from which an individual comes in the calculation of the polarization index. On average, 15 percent of the households in the sample live in urban areas in the different districts which indicates that the majority of the households are rural. The most urbanized districts are Kampala and Kitgum, but 60 percent of the districts have a percentage of urban households that is lower than 15. The average deviation in precipitation is 0.82 in absolute terms and the average deviation in temperature is 2.64.

Table 5.3 – Differences in means depending on the incidence of riots

Variable	Mean	No riots	With riots	Diff in means
Gini coefficients				
gini water	.292	.285	.331	-.046***
gini water scaled (number of members)	.251	.243	.295	-.052***
gini water scaled (OECD equivalence scale)	.269	.260	.315	-.055***
Other controls				
ethnic fractionalization	.356	.341	.437	-.096**
ethnic polarization	.467	.451	.556	-.105**
urban HH percentage	.149	.128	.264	-.135***
deviation in precipitation (absolute value)	.820	.779	1.065	-.286***
deviation in temperature	2.640	2.590	2.927	-.337***

There are significant differences between the means of each variable included in equation (5.1) depending on whether a district faced an event of rioting or not (Table 5.3). The

most significant differences are for the Gini coefficient of water consumption, the weather variables and the percentage of urban households. Districts with riots have significantly higher inequality in water consumption, larger deviations in precipitation and temperature, as well as a higher number of urban households compared to districts that did not face such events.

5.5 Results

In this section we discuss the results of the impact of inequality in water consumption on the incidence and the frequency of riots and protest. In a second part, we run different robustness tests, in which we test the initial hypothesis with other types of inequalities and enlarge the dependent variable to include all conflict events that occurred in a given district i in time t.

5.5.1 Social unrest and inequality in water consumption

The results of the impact of the Gini coefficient for water consumption are presented in Table 5.4. In column (1), the only explanatory variable that is included in the regression is the Gini coefficient for water consumption and it has a positive and significant impact on the frequency of riots and protests in the same year at a significance level of 5 percent. Its significance disappears when other control variables are added in columns (3) and (4). Columns (5) and (6) include also time and district fixed effects.[10]

In the year t, deviations in temperature have a positive and significant effect on the

[10]The number of observations diminishes when we add time and district fixed effects because for some of the districts there is no variability in the level of riots and protests during the years of the sample.

Table 5.4 – Impact of the Gini coefficient of water use on the frequency of riots in t and $t+1$ (negative binomial regression)

VARIABLES	(1) riots in t	(2) riots in $t+1$	(3) riots in t	(4) riots in $t+1$	(5) riots in t	(6) riots in $t+1$
gini water	2.994**	0.913	0.644	-0.953	-0.432	-1.143
	(1.427)	(1.332)	(1.316)	(0.861)	(1.695)	(1.037)
dev precipitation			0.289	0.244**	0.254	0.211
			(0.194)	(0.121)	(0.204)	(0.143)
dev temperature			1.184***	-0.080	1.200***	-0.079
			(0.430)	(0.244)	(0.422)	(0.283)
ethnic polarization			1.512*	2.056**	-3.395	-1.761
			(0.864)	(0.982)	(3.167)	(2.486)
urban HH percentage			2.730***	4.738***	1.096	4.419**
			(0.896)	(0.944)	(1.967)	(2.145)
Constant	-1.468*	0.182	-5.986***	-1.414	-1.681	0.732
	(0.863)	(0.837)	(1.703)	(1.027)	(2.677)	(2.042)
Observations	231	231	231	231	75	78
Number of Districts	77	77	77	77	25	26
Fixed effects	No	No	No	No	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

number of riots and protests at the level of one percent in both types of estimation, with and without fixed effects (columns (3) and (5)). For one additional standard deviation of temperature, the difference in the logs of expected counts in rioting and protesting events is 1.2. This result goes in line with the result found by Burke et al. [2009] that the incidence of conflict increases in warmer years. Many studies have focused only on the role of precipitation on conflict via its effect on agricultural productivity. Auffhammer et al. [2013] argue that including both temperature and precipitation is crucial because they may be correlated and including one variable without the other may cause omitted variable bias. When including both variables, similarly to Burke et al. [2009], we find only a significant effect of temperature at a one percent significance level.

A higher degree of ethnic polarization[11] leads to a higher number of riots and protests

[11] As ethnic fractionalization and ethnic polarization are strongly correlated, we include only one of the measures in order to capture ethnic diversity. Ethnic fractionalization is always less significant than the ethnic polarization variable in the different specifications, and we therefore choose to include only ethnic

in the current year and also in the following year (Table 5.4), but the effect is no longer significant once district fixed effects are controlled for, since the measure varies little over time. Finally, the percentage of households that live in urban areas in a given district i, used as a proxy for urbanization, increases significantly, at a level of one percent, the frequency of riots and protests in the same year and in the following year (columns (3) and (4)), although the effect is not robust when adding fixed effects.

In Table 5.5, a Gini coefficient for water consumption that takes into account the structure of a given household is used as explanatory variable.[12] The estimation results with the scaled measure also reject the ex ante hypothesis of a link between inequality in water consumption and riots. The estimated coefficients of the other control variables are similar to the ones using the unscaled Gini coefficient in terms of magnitude and statistical significance.

Table 5.5 – Impact of the scaled Gini coefficient of water use on the frequency of riots in t and $t+1$ (negative binomial regression)

VARIABLES	(1) riots in t	(2) riots in $t+1$	(3) riots in t	(4) riots in $t+1$	(5) riots in t	(6) riots in $t+1$
gini water scaled	2.678**	0.294	0.256	-0.940	-0.660	-1.107
	(1.332)	(1.206)	(1.157)	(0.731)	(1.342)	(0.832)
dev precipitation			0.268	0.240**	0.253	0.215
			(0.198)	(0.120)	(0.201)	(0.138)
dev temperature			1.171***	-0.044	1.204***	-0.046
			(0.427)	(0.248)	(0.417)	(0.280)
ethnic polarization			1.540*	2.061**	-3.523	-1.796
			(0.874)	(0.983)	(3.186)	(2.463)
urban HH percentage			2.839***	4.754***	1.135	4.514**
			(0.907)	(0.936)	(1.904)	(2.094)
Constant	-1.333	0.474	-5.765***	-1.548	-1.552	0.592
	(0.837)	(0.772)	(1.662)	(1.041)	(2.696)	(2.044)
Observations	231	231	231	231	75	78
Number of Districts	77	77	77	77	25	26
Fixed effects	No	No	No	No	Yes	Yes

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

polarization in the estimations.

[12]The scaling consists of dividing the household water consumption by the square root of the number of members in the household. The results are similar when the OECD equivalence scale is used.

Table 5.6 – Impact of the Gini coefficient of water use on the incidence of riots in t and $t+1$ (linear probability estimation)

VARIABLES	(1) riots in t	(2) riots in $t+1$	(3) riots in t	(4) riots in $t+1$	(5) riots in t	(6) riots in $t+1$
gini water	0.559**	0.418	0.455*	0.311	0.241	0.202
	(0.255)	(0.323)	(0.248)	(0.327)	(0.315)	(0.377)
dev precipitation			0.045**	-0.016	0.024	-0.028
			(0.023)	(0.027)	(0.024)	(0.029)
dev temperature			0.147***	0.036	0.124***	0.017
			(0.037)	(0.045)	(0.039)	(0.047)
ethnic polarization			0.113	0.004	-0.122	-0.274
			(0.088)	(0.134)	(0.198)	(0.236)
urban HH percentage			0.419***	0.652***	-0.736	-0.254
			(0.132)	(0.210)	(0.481)	(0.575)
Constant	-0.012	0.250**	-0.505***	0.095	-0.092	0.448*
	(0.079)	(0.104)	(0.134)	(0.177)	(0.204)	(0.244)
Observations	231	231	231	231	231	231
Number of Districts	77	77	77	77	77	77
Fixed effects	No	No	No	No	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

If we consider only the impact of the Gini coefficient on the incidence of rioting and protesting, i.e., the likelihood of there being at least one such event, inequality in water consumption on its own has again a positive and significant impact at a level of five per cent in linear probability estimations of the incidence (Table 5.6 and 5.7). The significance disappears when other control variables are introduced in the estimations, as was the case for the frequency of riots and protests. Deviations in temperature remain an important determinant of the incidence of riots and protests in the same year, in both estimations with and without fixed effects. One standard deviation in temperature increases the probability of an event of rioting to occur by 12.4 percentage points. In addition, deviations in precipitation have also a positive and significant effect at a significance level of five percent on the incidence of riots and protests but only directly, in the same year (column (3)). The percentage of households located in urban areas in the district is consistently significant for the year t and the year $t+1$ at a statistical significance level of one percent, but not when district fixed

effects are controlled for, as expected.

Table 5.7 – Impact of the scaled Gini coefficient of water use on the incidence of riots in t and $t+1$ (linear probability estimation)

VARIABLES	(1) riots in t	(2) riots in $t+1$	(3) riots in t	(4) riots in $t+1$	(5) riots in t	(6) riots in $t+1$
gini water scaled	0.701***	0.439	0.480*	0.297	0.217	0.027
	(0.260)	(0.327)	(0.253)	(0.330)	(0.312)	(0.373)
dev precipitation			0.044**	-0.016	0.024	-0.027
			(0.023)	(0.028)	(0.025)	(0.029)
dev temperature			0.140***	0.031	0.121***	0.013
			(0.037)	(0.045)	(0.039)	(0.046)
ethnic polarization			0.117	0.010	-0.114	-0.274
			(0.087)	(0.133)	(0.198)	(0.237)
urban HH percentage			0.414***	0.653***	-0.744	-0.241
			(0.131)	(0.209)	(0.482)	(0.577)
Constant	-0.025	0.262***	-0.476***	0.120	-0.069	0.507**
	(0.070)	(0.093)	(0.125)	(0.165)	(0.193)	(0.231)
Observations	231	231	231	231	231	231
Number of Districts	77	77	77	77	77	77
Fixed effects	No	No	No	No	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We conclude that the initial hypothesis of a link between inequality in water consumption and social unrest is rejected on the Ugandan data over the period of 2009 to 2012. The main result, on the sample analyzed here, is that temperature deviations from the long run average consistently have a significant effect on social unrest in the same period. The estimations thus confirm a result from international studies on an analysis using data at a lower level of aggregation, in this case district level data. Deviations in precipitation do not seem to contribute as significantly as deviations in temperature in explaining the frequency of social unrest. It is likely that positive and negative rain deviations may not have the same impact on the incidence and frequency of riots and protests. We therefore did a separate analysis of positive and negative deviations in rainfall, but the previous results do not change: neither positive nor negative deviations have a significant impact when including them separately. Compared to part of the literature, deviations in precipitation matter less than temperature

deviations for low-level conflict, which goes in line with the results of Burke et al. [2009] that temperature is correlated with high-level conflict such as civil war, based on analysis at a country level. As for the other control variables, another important factor in explaining social unrest is urbanization, which varies over time in the data, contrary to the measure of ethnic polarization.

5.5.2 Robustness tests

In this section, we run two different robustness tests. The first one is to re-estimate the main equation using a Gini coefficient of land inequality and income inequality instead. The objective is to verify whether social unrest depends on other types of inequality than inequality in water consumption. As regards other natural resources, ownership of land may be more important than inequality in water consumption in Uganda. In addition, the two measures of inequality related to natural resource use may be secondary to overall income inequality in determining social unrest. The second robustness test consists in defining the dependent variable using all conflictual events that are included in the ACLED data and not only riots and protests.

Table 5.8 – Summary statistics of the other inequality measures

Variable	Obs.	Mean	Std. Dev.	Min	Max
Gini coefficients					
gini income	231	.592	.128	0	.924
gini income scaled (number of members)	231	.574	.134	0	.915
gini income scaled (OECD equivalence scale)	231	.573	.137	0	.911
gini land	240	.491	.149	0	.779
gini land scaled (number of members)	240	.486	.148	0	.770
gini land scaled (OECD equivalence scale)	240	.492	.149	0	.798

Table 5.9 – Impact of the income Gini coefficient (unscaled and scaled) on the frequency of riots in t and $t+1$ (negative binomial regression)

VARIABLES	(1) riots in t	(2) riots in t	(3) riots in $t+1$	(4) riots in $t+1$	(5) riots in t	(6) riots in t	(7) riots in $t+1$	(8) riots in $t+1$
gini income	1.870		3.371**		0.760		0.589	
	(1.673)		(1.637)		(1.555)		(1.467)	
gini income scaled		1.376		3.596**		0.580		0.767
		(1.616)		(1.520)		(1.493)		(1.415)
dev precipitation					0.260	0.259	0.278**	0.287**
					(0.183)	(0.184)	(0.132)	(0.134)
dev temperature					1.193***	1.185***	-0.255	-0.253
					(0.429)	(0.428)	(0.222)	(0.218)
ethnic polarization					1.547*	1.556*	1.944**	1.961**
					(0.877)	(0.878)	(0.956)	(0.957)
urban HH percentage					2.768***	2.814***	4.258***	4.186***
					(0.885)	(0.881)	(0.959)	(0.979)
Constant	-1.553	-1.211	-1.611	-1.646	-6.174***	-6.027***	-1.608	-1.679
	(1.264)	(1.222)	(1.225)	(1.118)	(1.899)	(1.855)	(1.249)	(1.229)
Observations	231	231	231	231	231	231	231	231
Number of Districts	77	77	77	77	77	77	77	77

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Following the estimation results on water inequality, the question naturally arises whether other measures of inequality in natural resource use, or even, general income inequality, are more important determinants of social unrest, compared to inequality in water consumption. In the case of Uganda, income inequality is higher than inequality in land distribution and inequality in water consumption as seen in the summary statistics in Table 5.2 and 5.8 based on the distributions at a district level. The average level of the Gini coefficient for income inequality is around 0.6 and for land around 0.5. We therefore consider it relevant to test measures of inequality in land distribution as well as more general income inequality on social unrest in the Ugandan case.[13]

In order to test this empirically, we re-estimate the same specifications, but instead of using the Gini coefficient of inequality in water consumption, we introduce the measures of land and income inequality. The Gini coefficients for income and for owned land are

[13]Since the level of inequality is higher in the distribution of income and land than in the distribution of water consumption, one may argue that they should be more important drivers of social unrest. Yet, water is a basic necessity good and even small inequalities in its distribution might lead to stronger grievances.

calculated on household data at a district level, as previously. We also test scaled measures of these Gini coefficients in order to account for the structure of households. The estimations in Table 5.9 show that income inequality on its own in year t has an impact on conflicts in year $t+1$ (column (3) and (4)). Its significance disappears when we introduce other control variables. The impact of the other control variables are similar to those in the estimations using the Gini coefficient of water consumption. The degree of urbanization and ethnic polarization have positive and significant impacts in the different specifications. Deviations in temperature have an immediate positive and statistically significant impact at a level of one percent, whereas deviations in precipitation increase the frequency of riots and protests in the lead year, but at a lower level of statistical significance. Concerning the incidence of protests and riots (Table 5.10), deviations in precipitation and temperature increase the probability of riots and protests in the same year, whereas urbanization has a positive effect in the same year as well as in the next year.

Table 5.11 includes the results of the impact of land inequality on the intensity of riots and protests. The different control variables have consistently the same impacts as previously independently of the main variable of interest. This is the case for both intensity and incidence of riots and protest in the same and in the lead year (Table 5.11 and Table 5.12). Land inequality has no significant impact, even without including other control variables.

In a second robustness test, rather than including only riots and protests in the dependent variable, we take into account all the conflictual events that occur in the year t in the district i.[14] According to Table 5.13, the percentage of urban households in a given district is a

[14]The different events are: battle-no change of territory, battle-non-state actor overtakes territory, battle-government regains territory, headquarters or base established, strategic development, riots/protests, violence against civilians, non-violent transfer of territory and remote violence.

Table 5.10 – Impact of the income Gini coefficient (unscaled and scaled) on the incidence of riots in t and $t+1$ (linear probability estimation)

VARIABLES	(1) riots in t	(2) riots in t	(3) riots in $t+1$	(4) riots in $t+1$	(5) riots in t	(6) riots in t	(7) riots in $t+1$	(8) riots in $t+1$
gini income	0.236		0.246		0.069		0.124	
	(0.194)		(0.255)		(0.189)		(0.258)	
gini income scaled		0.193		0.396		0.035		0.255
		(0.186)		(0.244)		(0.182)		(0.248)
dev precipitation					0.046**	0.047**	-0.016	-0.017
					(0.023)	(0.023)	(0.028)	(0.027)
dev temperature					0.141***	0.140***	0.032	0.033
					(0.037)	(0.037)	(0.045)	(0.045)
ethnic polarization					0.128	0.129	0.012	0.013
					(0.089)	(0.089)	(0.133)	(0.133)
urban HH percentage					0.449***	0.454***	0.661***	0.631***
					(0.136)	(0.137)	(0.213)	(0.214)
Constant	0.012	0.041	0.227	0.145	-0.409***	-0.389**	0.117	0.046
	(0.118)	(0.110)	(0.157)	(0.146)	(0.157)	(0.153)	(0.209)	(0.202)
Observations	231	231	231	231	231	231	231	231
Number of Districts	77	77	77	77	77	77	77	77

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5.11 – Impact of the Gini coefficient of land distribution (unscaled and scaled) on the frequency of riots in t and $t+1$ (negative binomial regression)

VARIABLES	(1) riots in t	(2) riots in t	(3) riots in $t+1$	(4) riots in $t+1$	(5) riots in t	(6) riots in t	(7) riots in $t+1$	(8) riots in $t+1$
gini land	2.775		2.774		1.195		0.179	
	(2.299)		(2.646)		(2.032)		(2.235)	
gini land scaled		1.860		1.616		0.408		-0.464
		(2.188)		(2.662)		(1.995)		(2.238)
dev precipitation					0.245	0.250	0.277**	0.275**
					(0.183)	(0.184)	(0.128)	(0.128)
dev temperature					1.171***	1.168***	-0.231	-0.232
					(0.421)	(0.424)	(0.212)	(0.211)
ethnic polarization					1.586*	1.567*	1.967**	1.958**
					(0.887)	(0.881)	(0.960)	(0.958)
urban HH percentage					2.943***	2.935***	4.394***	4.398***
					(0.845)	(0.840)	(0.894)	(0.898)
Constant	-1.722	-1.221	-0.855	-0.219	-6.266***	-5.849***	-1.417	-1.084
	(1.249)	(1.195)	(1.443)	(1.435)	(1.863)	(1.869)	(1.560)	(1.536)
Observations	240	240	240	240	231	231	231	231
Number of Districts	80	80	80	80	77	77	77	77

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5.12 – Impact of the Gini coefficient of land distribution (unscaled and scaled) on the incidence of riots in t and $t+1$ (linear probability estimation)

VARIABLES	(1) riots in t	(2) riots in t	(3) riots in $t+1$	(4) riots in $t+1$	(5) riots in t	(6) riots in t	(7) riots in $t+1$	(8) riots in $t+1$
gini land	0.192		0.284		0.069		0.079	
	(0.051)		(0.285)		(0.218)		(0.358)	
gini land scaled		0.133		0.199		-0.005		-0.044
		(0.184)		(0.288)		(0.220)		(0.361)
dev precipitation					0.047**	0.047**	-0.015	-0.015
					(0.023)	(0.023)	(0.027)	(0.027)
dev temperature					0.140***	0.140***	0.031	0.031
					(0.037)	(0.037)	(0.045)	(0.045)
ethnic polarization					0.129	0.129	0.012	0.012
					(0.089)	(0.089)	(0.134)	(0.134)
urban HH percentage					0.460***	0.462***	0.680***	0.682***
					(0.132)	(0.132)	(0.209)	(0.209)
Constant	0.051	0.081	0.223	0.266*	-0.404**	-0.366**	0.150	0.211
	(0.093)	(0.093)	(0.146)	(0.147)	(0.157)	(0.157)	(0.233)	(0.233)
Observations	231	240	240	240	231	231	231	231
Number of Districts	77	80	80	80	77	77	77	77

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

key determinant that increases the frequency of conflictual events. There is less significant evidence that temperature has an impact on the number of any conflict events in the same year t. On the disaggregated data used here, temperature deviations thus seem to affect only contemporaneous riots and protests, and not higher-level conflict.

5.6 Conclusion

The objective of the paper is to investigate the role that inequality in water consumption can play in social unrest. We use district level data from the Ugandan Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) of the World Bank for the period 2009-2012 in order to construct a Gini coefficient for water consumption. We also calculate another measure of inequality in natural resource use, in this particular case, land ownership, and also general income inequality. All the inequality measures are calculated based on household data for a given district. We combine this data with weather data and

Table 5.13 – Impact of the different Gini coefficients on the frequency of any conflict events in t and $t+1$ (negative binomial regression)

VARIABLES	(1) events t	(2) events t	(3) events t	(4) events $t+1$	(5) events $t+1$	(6) events $t+1$	(7) events t	(8) events t	(9) events t	(10) events $t+1$	(11) events $t+1$	(12) events $t+1$
gini water	1.283			0.614			0.255			-0.892		
	(1.128)			(1.103)			(0.924)			(0.828)		
gini income		1.368			0.790			0.830			0.002	
		(1.053)			(1.083)			(1.095)			(1.115)	
gini land			0.151			1.705			-0.945			0.008
			(1.645)			(1.630)			(1.994)			(1.880)
dev precipitation							0.135	0.133	0.133	0.112	0.090	0.090
							(0.102)	(0.102)	(0.100)	(0.101)	(0.108)	(0.107)
dev temperature							0.307*	0.311*	0.309*	0.182	0.119	0.119
							(0.182)	(0.181)	(0.179)	(0.165)	(0.158)	(0.157)
ethnic polarization							0.153	0.109	0.158	-0.537	-0.532	-0.532
							(0.629)	(0.643)	(0.623)	(0.703)	(0.702)	(0.707)
urban HH percentage							2.129**	2.049**	2.227***	3.205***	2.712***	2.712***
							(0.850)	(0.823)	(0.802)	(0.923)	(0.841)	(0.790)
Constant	-0.076	-0.488	0.264	0.291	-0.016	-0.369	-1.251*	-1.627*	-0.711	-0.130	-0.207	-0.210
	(0.494)	(0.718)	(0.882)	(0.505)	(0.785)	(0.867)	(0.738)	(0.919)	(1.278)	(0.759)	(1.007)	(1.293)
Observations	231	231	240	231	231	240	231	231	231	231	231	231
Number of Districts	77	77	80	77	77	80	77	77	77	77	77	77

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

with the Uppsala Armed Conflict Location and Event Dataset (ACLED) that allows us to calculate the number of riots and protests for the different districts in Uganda over the given period. We use a negative binomial regression in order to account for the high presence of zero events of rioting in the dataset and a linear probability regression to estimate the impact of water inequality on the incidence of riots and protests. The analysis presented here contributes to the literature in proposing a disaggregated analysis on data that allow for the calculation of inequality measures based on household data and an assessment of their impact on low-level conflict. On the one hand, we thus test for the role of inequality in natural resource use in explaining low-level conflict. On the other hand, the estimations permit to draw conclusions on the impacts of commonly used weather variables on low-level conflict.

The estimation results show the following. First, inequality in water consumption does not lead to a higher level of rioting on the Ugandan sample. Second, an alternative measure of inequality in natural resource use, a Gini coefficient of land distribution, does not have a significant impact either, nor does income inequality. A possible explanation for these first results may be the level of aggregation used and the short time period studied here. The distribution in water use (or land ownership) may be more unequal between districts than within districts (the measure used here), but because of the short time span of the data we cannot calculate inequality measures on a higher level of aggregation (regions) to test for this. Third, a larger percentage of households localized in urban areas of the district also increases the occurrence of riots and protests in the same year and in the following year. Fourth, we find strong evidence that deviations in temperature increase the incidence and the frequency of social unrest in the same year. The effect of temperature is

immediate, with no significant effect in the following year. Deviations in precipitation are not a significant factor in explaining conflict, when adding fixed effects. These last results show that when analyzing the impact of weather conditions and climate change on conflicts, it is not sufficient to use only rainfall data but that temperature and rainfall measures should be included simultaneously. The estimations presented here do not allow us to distinguish the mechanism by which temperature affects low-level conflict, though. Future research should try to distinguish by what potential mechanisms such a result occurs.

The limitations of the analysis include the short time span in the dataset, which implies that there is low variability in the number of conflictual events and social unrest that occur in the different districts. The use of a longer panel of data would improve the analysis. There may also be selection bias in the reporting of the different events in the districts. For instance, urban areas are more covered by the media than rural areas. The ACLED dataset is nevertheless the most widely used in the literature because of its completeness and highly disaggregated information on conflicts. Another limitation is that we do not have data on the degree of observability of water consumption among the different households which should affect local tensions. Future work should aim at including agricultural water use, which may be better observed and for which the economic stakes are higher.

Finally, we would have liked to extend the analysis to include all the countries covered over at least two years in the LSMS-ISA of the World Bank, but the survey instrument for the other countries did not contain the same detailed questions on the quantity of water consumed as the Ugandan LSMS-ISA. Future research should test the hypothesis of water inequality as a factor of social unrest on a larger sample with different country and institutional characteristics, in particular severely water-constrained countries.

Chapitre 6

Résumé

Le risque attaché à de potentiels chocs futurs de consommation et production a un effet important sur la subsistance des ménages ruraux dans les pays en développement. Il peut provenir de sources climatiques, économiques, politiques ou individuelles. Un risque non-assuré peut engendrer une baisse de revenu et de consommation, et ainsi créer une trappe à pauvreté. Cependant, les agents économiques peuvent prendre des mesures pour se protéger contre les risques. Ces mesures sont diverses selon le type de risque ou choc auquel font face les ménages. En particulier, la variabilité des revenus peut être causée par un risque agrégé, risque auquel sont confrontés tous les membres d'une communauté, ou un risque individuel.

Les marchés du crédit et de l'assurance sont incomplets, voire absents dans ces pays [Bell, 1988, Besley, 1995]. Les ménages ont ainsi développé diverses stratégies afin de se protéger contre le risque. Les chocs individuels peuvent être lissés au sein d'une collectivité grâce à des stratégies de partage des risques entre ses membres. Par contre, si tous les membres d'une communauté sont touchés par un choc commun, le risque ne peut plus partagé. Dans ce cas, les transferts inter-temporels ou ceux provenant de l'extérieur de la communauté

constituent l'un des seuls moyens permettant aux ménages d'amortir les chocs et de lisser leur consommation au cours du temps.

Dans cette thèse, nous réalisons une étude microéconomique de l'impact du risque agrégé qu'engendrent les aléas climatiques sur les décisions des ménages agricoles en Ouganda. Ce travail a pour but de contribuer à la littérature se situant à l'intersection de l'économie de l'environnement, de l'économie du développement et de l'économie agricole. Elle fournit de nouveaux résultats sur les facteurs influençant la prise de décision des ménages agricoles en termes d'assurance et de diversification du risque. Dans le deuxième chapitre de cette thèse, nous examinons l'impact des transferts des migrants sur le degré de diversification ou de spécialisation des cultures ainsi que sur le degré de risque d'un portefeuille de cultures que les ménages choisissent de cultiver. L'objectif est de déterminer si les transferts des migrants peuvent alléger les contraintes des ménages en termes de crédit et d'assurance. Dans un troisième chapitre, nous étudions également l'impact des transferts de fonds sur les décisions des ménages concernant l'utilisation des intrants plus risqués, comme les engrais par exemple. Dans le quatrième chapitre, nous analysons si le morcèlement des terres peut améliorer le rendement des cultures des ménages les plus exposés à de fortes variabilités des précipitations. Enfin, l'objectif du cinquième chapitre est d'examiner l'impact de l'inégalité d'accès à l'eau sur l'intensité et l'incidence des émeutes au sein d'un pays.

Le deuxième chapitre de cette thèse s'attache à déterminer dans quelle mesure les transferts de fonds encouragent les ménages agricoles à spécialiser leurs cultures de production et/ou à se tourner vers des cultures plus risquées. La New Economics of Labor Migration a montré que la migration et les transferts de fonds qui y sont associés peuvent se substituer aux marchés d'assurance et de crédits : ils permettent des stratégies informelles de partage

du risque entre les migrants et leur famille. Selon cette littérature, la décision de migrer se prend à l'échelle du ménage. Le ménage peut décider d'envoyer un membre dans un autre endroit (village, région ou pays) afin d'éviter un choc négatif simultané. La migration est ainsi considérée comme une stratégie d'assurance : les transferts de fonds que procure le migrant à sa famille peuvent être utilisés pour pallier aux effets négatifs d'un choc et lisser la consommation de sa famille. On peut naturellement s'attendre à ce que les ménages agricoles qui reçoivent un niveau de transferts élevés soient aussi ceux qui s'engagent dans les productions agricoles les plus risquées.

Nous essayons de comprendre si les transferts de fonds, en diminuant la contrainte de crédit, peuvent inciter les ménages agricoles à prendre des décisions plus risquées en termes de culture de production. L'objectif et les contributions de ce chapitre sont multiples. Nous cherchons en premier lieu à comprendre si les agriculteurs s'engagent dans un processus de spécialisation de leurs cultures dès lors qu'ils perçoivent des transferts de fonds. Une des contributions de ce chapitre est l'utilisation de mesures de diversification plus détaillées : l'indice de Shannon, de Simpson et celui de Berger-Parker. Ces indicateurs présentent l'avantage de ne pas uniquement tenir compte du nombre de cultures, mais aussi d'intégrer l'égalité des proportions du terrain dédiées à chaque culture. Dans un deuxième temps, nous cherchons à tester si les transferts de fonds augmentent le degré de risque des portefeuilles de culture. La nouveauté de la méthodologie employée ici réside dans la construction d'une nouvelle mesure de risque de ce portefeuille. Nous mesurons le risque que présente chaque culture pour le ménage agricole et cherchons à évaluer la contribution de celle-ci au risque global du portefeuille en utilisant le Single Index Model initialement développé par Turvey [1991] et utilisé par Bezabih and Di Falco [2012].

Les transferts de fonds ne sont pas distribués selon un processus aléatoire. Les ménages qui les perçoivent diffèrent systématiquement des autres. Nous contournons ce problème d'endogénéité à l'aide de la méthode des variables instrumentales (IV). Nous utilisons comme instrument la moyenne des transferts des fonds au niveau du district interagi avec le niveau d'éducation maximal du ménage. Le niveau moyen des transferts des fonds au niveau du district tient compte des réseaux de migrants initialement établis ou encore des établissements financiers, ce qui pourrait encourager l'envoie des transferts de fonds. Le niveau maximal d'éducation au sein d'un ménage est un des déterminants majeurs de la décision de migrer. Ces deux dernières variables impactent la décision de diversifier sa production agricole uniquement à travers le montant des transferts perçus par les ménages agricoles. Afin de prendre en compte la nature tronquée (censurée à gauche) de la variable endogène que sont les transferts de fonds, nous les représentons à l'aide d'un modèle Tobit comme fonction de la moyenne des transferts de fonds du district interagi avec le niveau maximal d'éducation au sein du foyer. Nous obtenons ainsi les valeurs prédites des transferts des ménages agricoles. Ces valeurs sont ensuite réutilisées en tant qu'instrument dans la procédure two stage least squares [Angrist, 2001, Wooldridge, 2010]. Cette stratégie alternative d'estimation présente l'avantage de préserver la nature non-linéaire des transferts de fonds et d'inclure les effets fixes dans la première étape et d'obtenir ainsi des estimations convergentes et efficientes dans la deuxième étape de l'estimation.

Un premier résultat émerge : les transferts de fonds n'ont pas d'impact direct significatif sur la diversification de la production agricole ni sur le choix d'une production de cultures agricoles plus risquées. Cependant, nous mettons en évidence que l'impact marginal négatif des transferts de fonds sur la diversification des cultures agricoles est plus important pour

les ménages qui subissent des contraintes de crédit. L'impact des transferts de fonds est donc hétérogène et dépend de l'accès ou non des ménages au crédit. Cela implique que ces transferts permettent de réduire le risque agricole encouru par les ménages soumis à des contraintes d'assurance et de crédit.

Le chapitre 3 de cette thèse est complémentaire au deuxième. Nous cherchons à analyser l'impact des transferts de fonds sur l'utilisation des entrants risqués comme les engrais. La littérature agronomique a mis en lumière le faible recours aux engrais dans la production agricole en Afrique. Les contraintes de crédit, souvent associées aux pays en développement, sont l'une des raisons principales avancées afin d'expliquer le refus d'utiliser ces inputs de productions efficaces mais souvent chers [Mwangi, 1996, Croppenstedt et al., 2003, Morris, 2007]. Un autre argument mis en avant est la capacité limitée des ménages agricoles à gérer efficacement le risque. Les engrais sont en effet considérés comme un input risqué car ils génèrent une variance des revenus agricoles plus élevée [Dercon and Christiaensen, 2011]. Sachant que l'agriculture des pays en développement est principalement pluviale, les engrais peuvent constituer un investissement peu profitable en période de faibles précipitations [Alem et al., 2010]. Enfin, Dercon and Christiaensen [2011] ont montré qu'en plus des contraintes d'accès au crédit, les chocs négatifs de consommation pouvaient aussi décourager les ménages agricoles à utiliser des engrais.

L'objectif de ce chapitre est de tester si les transferts de fonds générés par les migrants peuvent potentiellement alléger les contraintes de crédits et d'assurance, et ainsi permettre l'utilisation d'engrais. De précédents travaux ont montré que les transferts de fonds ont augmenté la productivité agricole et les investissements agricoles en améliorant la liquidité à la disposition des ménages [Rozelle et al., 1999, Atamanov and Van den Berg, 2012].

Cependant, les propriétés des transferts de fonds en termes d'assurance sont toujours inexplorées. A notre connaissance, le seul travail qui étudie une question similaire est le papier de Mendola [2008]. Il étudie la migration en tant que substitut à l'assurance ainsi que ses impacts sur l'adoption de high-yield varieties (HYV) en Bangladesh. L'auteur trouve que les ménages riches s'engagent davantage dans une migration internationale et donc utilisent davantage d'HYV que les ménages pauvres. Cette étude s'appuie sur des données transversales des ménages agricoles au Bangladesh. Une des contributions du chapitre est de prendre en compte les transferts des migrants en tant que stratégie d'assurance et de tester leur impact sur l'utilisation des engrais grâce à des données de panel sur les ménages agricoles ougandais. Une autre contribution est la séparation des engrais organiques et chimiques dans cette analyse. Cette séparation est nécessaire car les engrais chimiques sont commercialisés et sont plus chers que les engrais organiques, qui eux sont produits à la ferme. Après avoir instrumentalisé les transferts des fonds, nous trouverons un impact significatif sur la probabilité d'utiliser ces deux types d'engrais, ainsi que sur les quantités respectives dans lesquelles ils sont utilisés. Les résultats montrent que les transferts de fonds ont la capacité d'alléger les contraintes de crédit et d'assurance en encourageant l'utilisation d'engrais.

Le morcèlement des terres est un phénomène fréquent dans les pays en développement. Le morcèlement des terres peut être défini comme une fragmentation des terrains en parcelles qui sont physiquement séparées. La littérature empirique a montré que le morcèlement des terres a un impact négatif sur la production et la productivité agricole [Wan and Cheng, 2001, Rahman and Rahman, 2009, Van Hung et al., 2007, Tan et al., 2010]. Ce phénomène ne permet pas aux agriculteurs de réaliser des économies d'échelle. La fragmentation des terres engendre des coûts liés à la distance que les agriculteurs doivent parcourir entre les différentes

parcelles. Cela empêche aussi les agriculteurs d'utiliser des machines car il est difficile de les déplacer d'une parcelle à l'autre. Cependant, d'autres études montrent que la fragmentation n'a pas nécessairement que des impacts négatifs. Dans le cas du Ghana et du Rwanda, Blarel et al. [1992] trouve que le morcèlement des terres n'a pas d'impact significatif sur les rendements agricoles. En outre, les auteurs montrent que la fragmentation des terres réduit la variabilité des revenus agricoles. Elle permet de faciliter l'ajustement de la main-d'œuvre entre les saisons, de gérer le risque à travers la diversification des cultures et d'améliorer l'agro-biodiversité [Fenoaltea, 1976, Di Falco et al., 2010, Blarel et al., 1992, Bentley, 1987, Van Hung et al., 2007].L'objectif du quatrième chapitre est de tester si un morcèlement des terres plus élevé réduit l'impact de la variabilité pluviométrique sur les rendements agricoles. Cette question n'a pas été abordée quantitativement dans la littérature.

Afin de mesurer la capacité de la fragmentation des terres à neutraliser l'effet négatif de la variabilité des précipitations, nous estimons l'impact de la fragmentation des terres sur la valeur du rendement agricole. Deux problèmes empiriques sont rencontrés. Le premier est la mesure de la fragmentation de la terre. En s'inspirant de la littérature, j'utilise deux mesures : le nombre de parcelles qu'un ménage possède et exploite, et l'indice Simpson. L'avantage de l'indice Simpson est qu'il ne prend pas seulement en compte le nombre de parcelles mais aussi le caractère uniforme de leur répartition en termes de superficie. Nous nous attendons à ce que les deux mesures aient un impact semblable sur les rendements agricoles, ce qui confirmerait que les résultats sont robustes. La variable qui mesure la variabilité des pluies est construite comme l'écart du niveau annuel de précipitations à la moyenne de long terme divisé par l'écart-type de long terme du district auquel le ménage appartient. Nous ajoutons une variable d'interaction entre la fragmentation des terres et la variabilité

des précipitations afin de prendre en compte une différence éventuelle qui pourrait exister entre les ménages aux niveaux de fragmentation différents. Le deuxième problème empirique est que le morcèlement des terres n'est pas complètement exogène dans la mesure où les agriculteurs peuvent décider du niveau de fragmentation auquel ils veulent faire face. En Ouganda, presque la moitié des parcelles est héritée et l'autre moitié est achetée ou louée. Pour traiter ce problème d'endogénéité, j'instrumente le degré de fragmentation des terres avec le nombre de parcelles héritées par le ménage. Nous supposons que les parcelles héritées sont reçues de manière exogène par le ménage à travers le processus d'héritage traditionnel en Ouganda citepfoster2011indian.

Les résultats montrent qu'un degré de morcèlement des terres plus élevé réduit la perte du rendement agricole. Ceci est vérifié dans les deux cas : l'estimation sans utilisation de l'instrument et celle avec. Cependant, le morcèlement des terres a des effets négatifs sur les rendements agricoles parmi les ménages qui ne sont pas sujets à la variabilité climatique. Les résultats montrent aussi que les avantages de la fragmentation des terres sont amplifiés si les agriculteurs sont confrontés à une variabilité des pluies élevée. Les résultats sont confirmés pour les deux types de mesures de fragmentation des terres. Ils suggèrent que les pays en développement devraient s'attacher à améliorer leurs marchés d'assurance et de crédit afin de promouvoir des programmes de consolidation foncière. S'il y a des marchés manquants ou incomplets, la fragmentation des terres peut être considérée comme une alternative pour les agriculteurs qui produisent dans un environnement risqué.

Le changement climatique va augmenter la variabilité des précipitations et de température. Une plus grande variabilité des précipitations peut limiter la disponibilité en eau, ce qui accentue l'inégalité d'accès à l'eau potable. Le sujet du dernier chapitre de thèse consiste

à vérifier si l'inégalité d'accès à l'eau potable peut provoquer des conflits sociaux tels que des émeutes ou des protestations. Une partie de la littérature s'est intéressée à la rareté absolue de l'eau et les conflits internes. Ces études utilisent des mesures de pluviométrie, comme par exemple l'indice de sécheresse de Palmer dans Couttenier and Soubeyran [2013], précipitations dans Berman and Couttenier [2015] et température [Burke et al., 2009, O'Loughlin et al., 2012] pour évaluer la pénurie d'eau et tester son impact sur les conflits internes. L'objectif du dernier chapitre est de tester l'impact de la pénurie relative d'eau sur les conflits sociaux. La première contribution du chapitre est l'utilisation de données désagrégées au niveau des ménages pour mesurer la pénurie relative d'eau. Les études existantes utilisent des données au niveau des pays ou, dans les cas des études les plus désagrégées, la pénurie d'eau est mesurée au niveau du maillage géographique. Une deuxième contribution est que nous testons l'impact de la pénurie relative d'eau sur les conflits internes alors que les études précédentes reposent sur des mesures absolues de la pénurie d'eau. Pour construire les variables de conflit social, j'utilise des données au niveau du district et les associe aux données des ménages. Ainsi, nous pouvons construire des indices d'inégalité de consommation d'eau au niveau du district. Ce faisant, notre objectif est de contribuer à la littérature générale sur l'inégalité et les conflits civils, qui a été largement fondée sur les données transnationales.

Nous testons si l'inégalité de consommation d'eau potable entraîne des griefs qui peuvent mener à des conflits intérieurs comme des protestations ou des émeutes. Nous utilisons deux types de variables dépendantes : une variable binaire qui indique si un district a fait face à un événement d'émeute ou de protestation au cours d'une année donnée ; et une variable qui mesure le nombre d'émeutes et de manifestations. Nous utilisons en conséquence un modèle de probabilité linéaire pour tester l'incidence des émeutes et des protestations, et un modèle

binomial négatif pour tester la fréquence des événements.

Les résultats montrent que l'inégalité de consommation d'eau potable n'a pas d'impact significatif sur l'incidence ainsi que sur la fréquence des émeutes et protestations dans les districts ougandais. Ceci est également le cas lorsque nous étudions l'impact de l'inégalité de la répartition des terres et des revenus sur les émeutes et les protestations. En revanche, la variabilité de la température augmente de façon significative l'incidence et la fréquence des émeutes et protestations. La littérature qui étudie les conséquences du changement climatique sur l'incidence des guerres civiles en Afrique a aussi identifié le même effet [Burke et al., 2009]. Toutefois, elle se base sur des données plus agrégées que celles utilisées dans ce chapitre.

Nous utilisons trois sources différentes de données pour étudier les différentes questions de recherche posées à travers cette thèse : les données des ménages ougandais proviennent de l'enquête Living Standard Measurement Studies-Integrated Survey on Agriculture (LSMS-ISA), les données sur les conflits sont issues de la base Uppsala Armed Conflict Location and Event Dataset (ACLED), et les données climatologiques sont issues de la base de données TS3.21 établies par l'unité de recherche climatique de l'Université de l'East Anglia.

Le point central et commun aux différents chapitres est la variabilité climatique. Le marché d'assurance étant imparfait dans les pays africains, les chapitres 2 et 3 étudient le rôle des transferts de fonds des migrants en tant que protection des ménages contre les aléas agricoles y compris les aléas climatiques. Le chapitre 4 s'intéresse à la fragmentation des terres en tant que stratégie d'assurance contre la variabilité des précipitations. Ces stratégies peuvent protéger les ménages, mais généralement se ne révèlent pas suffisantes pour amortir complètement les chocs et assurer parfaitement les ménages contre le risque. Au vue des prévisions pessimistes des différents rapports de l'Intergovernemental Panel on Climate

Change sur la variabilité climatique, ses impacts sur la production agricole, la disponibilité de l'eau potable et les conflits vont probablement être amplifiées dans le continent Africain. L'investigation d'autres stratégies d'adaptation devient donc nécessaire afin de promouvoir une sécurité alimentaire. Enfin, une autre question qui se pose est comment améliorer les marchés formels d'assurance et proposer des produits d'assurance adéquats aux ménages agricoles.

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Résumé

Dans le cadre de cette thèse, nous nous intéressons à l'étude des décisions des ménages ruraux Ougandais en termes de gestion des risques climatiques. Dans un premier temps, nous testons l'impact des transferts des fonds des migrants sur le niveau de spécialisation des cultures agricoles ainsi que le niveau de risque du portefeuille des cultures des ménages contraints par l'accès aux marchés du crédit et de l'assurance. Nous complétons cette première analyse avec une étude sur la capacité des transferts des migrants à encourager les ménages à utiliser des inputs plus risqués tels que les engrais. Dans un troisième temps, nous explorons si le morcèlement des terres peut réduire les effets négatifs de la variabilité des précipitations sur les rendements des cultures agricoles. Le dernier objectif de cette thèse est d'analyser l'impact de l'inégalité d'accès à l'eau sur l'intensité et l'incidence des manifestations et des émeutes au sein d'un pays. Le point central et commun aux différents chapitres est la variabilité climatique : quelles sont les conséquences pour les ménages agricoles ; comment les ménages peuvent se protéger contre les aléas climatiques et quelles sont les implications pour la disponibilité de l'eau et les conflits. Telles sont les questions que la thèse vise à aborder à travers une approche micro-économétrique.

Mots clefs : gestion des risques, transferts de fonds, diversification des cultures, engrais, variabilité des précipitations, fragmentation des terres, inégalité, conflit.

Abstract

The dissertation provides evidence on the agricultural decisions of rural Ugandan households in terms of risk management against weather variability. First, I study the impact of remittances sent by migrants on households' degree of crop specialization and crop riskiness, as remittances may, to some extent, relieve credit and risk constraints. I complete the first objective with a second analysis that explores if remittances can motivate households to use risker inputs – fertilizers. Third, I examine whether land fragmentation can reduce the negative impacts of rainfall variability on farmers' crop yields. In the final chapter, I test whether inequality in access to water for consumption may increase the incidence and the intensity of low-level conflicts. The central and common theme of the different chapters is weather variability : what are the consequences for agricultural households, how can households protect themselves against weather fluctuations and what are the implications for water availability and social conflict. Those are the questions that the dissertation aims at addressing with a micro-level empirical approach.

Keywords : risk management, remittances, crop diversification, fertilizer, rainfall deviation, land fragmentation, water inequality, conflict.