

UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

**EFFECT OF WEATHER RISK ON ASSETS AND LABOUR ALLOCATION
DECISIONS AMONG SMALLHOLDER FARM HOUSEHOLDS IN
DEVELOPING COUNTRIES: EVIDENCE FROM BURKINA FASO**

BY

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DECLARATION

This thesis is the result of research work undertaken by Soumaila Gansonré in the Department of Agricultural Economics and Agribusiness, University of Ghana, under the supervision of Prof. Ramatu M. Al-Hassan, Dr George T-M. Kwadzo, Dr. Edward Ebo Onumah and Prof. Idrissa M. Ouédraogo.. It has never been submitted in whole or in part for any degree in this University or elsewhere. References to other people's work have been duly acknowledged.

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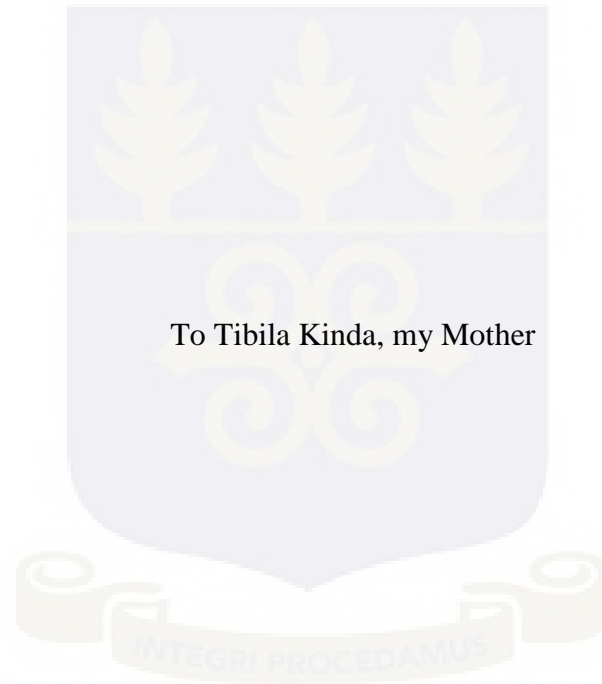
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ABSTRACT

Around the developing world, poverty remains an overwhelming rural issue. Rural dwellers rely heavily on agricultural activities and related assets as main source of livelihoods. They also have widely differing capacities to combine off-farm activities in their income generation process. However, diversification makes households better-off only if it implies increased investment in high return portfolios. An important concern is that high yielding investments are either high risk or exhibit severe entry barriers. In the absence of risk markets, liquidity constrained households may pursue low risk investments to self-insure against income volatility which may create poverty. This study explores how this risk induced behaviour may lead to poverty among smallholder farm households in Burkina Faso by analysing the effect of rainfall risk on their asset holdings and attitudes towards low risk off-farm activities. Two theoretical models are developed using stochastic dynamic programming methods to highlight the mechanisms through which risk implies resource diversion towards less risk but also less profitable agricultural investments. Optimal allocation decisions appear to be determined by the relative profitability of available options which is function of the risk. This implies that consumption smoothing is indirectly pursued by smoothing returns to assets and activities. It is also shown that the household more readily enters off-farm activity as volatility of return to farming increases. Empirical analysis uses a two-year panel data collected in 2010 and 2011 in Burkina Faso. Results suggest that households accumulate liquid assets as a long-term strategy to deal with anticipated rainfall outcomes. Liquidity constraints also contribute to shape the composition of households' portfolio as well as transaction costs. In addition to these factors, off-farm labour supply is influenced by rainfall uncertainty and rainfall shocks. However, the data suggest that productive farm assets (farm equipment and draught animals), and farming in general, have better returns than less productive liquid assets (livestock, poultry and grain stocks) and off-farm activities as the latter are less attractive to wealthier households. The tendency to accumulate increased level of liquid unproductive assets or work more off-farm will therefore result in lower income paths which may explain why poverty persists. Enabling households to accumulate more farm productive assets and work more on farm is necessary to boosting their income generation capacities. This implies addressing the rainfall risk they face. In the short-term, policies may promote groundwater pump irrigation and fodder crop cultivation to mitigate yield volatility and improve returns from livestock breeding. In the medium term, the development of a rural credit market will encourage high yielding investment directly by enabling households to overcome liquidity constraints and indirectly by enhancing ex-post risk management. Regulatory policies that improve returns to riskless options (liquid assets and off-farm work) are needed. This includes provision of veterinary care, establishment of guaranteed minimum wage and efforts to reduce transaction costs. In the long-term, a structural transformation of the farming system that lowers the reliance on rainfed farming through the development of irrigation schemes and the development of agricultural insurance and irrigation schemes may be pursued.

DEDICATION



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TABLE OF CONTENTS

DECLARATION	i
ABSTRACT	ii
DEDICATION	iii
ACKNOWLEDGMENTS	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF APPENDIXES.....	xii
ABBREVIATIONS AND ACRONYMS	xiii
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement.....	8
1.2.1 State of Poverty in Burkina Faso.....	8
1.2.2 State of Agriculture, Policy Context and Weather Challenges	9
1.3 Research Questions.....	13
1.4 Research Objectives.....	14
1.5 Relevance of the Study	14
1.6 Organization of the Thesis.....	15
CHAPTER TWO	17
LITERATURE REVIEW.....	17
2.1 Introduction.....	17

2.2	Definitions of key Concepts and Terms.....	17
2.2.1	Risk and Uncertainty	17
2.2.2	Wealth and Assets	18
2.2.3	Non-Farm and Off-Farm Activities.....	19
2.3	Risk and Poverty.....	20
2.4	Non-Market Risk Management Strategies.....	23
2.4.1	Informal Risk Sharing	23
2.4.2	Inter-Cropping and Crop Diversification	25
2.5	Risk and Asset Portfolio Selection	26
2.5.1	Theoretical Literature of Portfolio Selection under Risk	26
2.5.2	Empirical Literature on Asset Portfolio under Risk.....	32
2.5.2.1	Income risk and consumption smoothing.....	32
2.5.2.2	Weather risk and ex-ante asset portfolio selection	35
2.6	Risk and Households' Labour Allocation.....	39
2.6.1	Theoretical Literature on Labour Allocation under Risk	39
2.6.2	Empirical Literature on Labour Allocation under Risk.....	44
2.7	Conclusion	49
CHAPTER THREE.....		51
METHODOLOGY.....		51
3.1	Introduction.....	51
3.2	Conceptual Framework	51
3.3	Model of Smallholder Farm Household' Asset Portfolio Selection under Risk.....	58
3.3.1	Returns to Farm Capital.....	59

3.3.2	Returns to Livestock Assets	60
3.3.3	Problem of the Household	65
3.3.4	The Dynamic Programming Model	65
3.3.4.1	Model summary	66
3.3.4.2	Solving the model	67
3.4	Empirical Analysis of Households' Asset Holdings.....	74
3.4.1	Econometric Specification.....	74
3.4.2	Risk Variables.....	79
3.4.3	Other key Variables	81
3.5	A Model of Smallholder Farm Households' Labour Allocation under Risk.....	85
3.5.1	The Model.....	85
3.5.2	Problem of the Household	86
3.5.3	The Dynamic Programming Model	87
3.5.3.1	Model summary	87
3.5.3.2	Implication of the model.....	94
3.5.3.3	Optimal off-farm entry-exit	94
3.5.3.4	Optimal labour allocation	100
3.6	Empirical Analysis of Households' Labour Allocation.....	103
3.6.1	Econometric Specification.....	103
3.6.2	Estimation Issues	106
3.6.3	Measurement of key Variables	109
3.7	Source of Data.....	111
3.7.1	Household Level Data	111

3.7.2	Rainfall Data and Other Information	112
3.8	Conclusion	112
CHAPTER FOUR.....		114
RESULTS AND DISCUSSION		114
4.1	Introduction.....	114
4.2	Descriptive Statistics.....	114
4.2.1	Households' Characteristics	114
4.2.2	Inter-Wealth Quartile Mobility.....	116
4.2.3	Inter-Income Quartile Mobility	118
4.2.4	Households' Wealth	120
4.2.5	Households' Income	124
4.2.6	Off-Farm Activity Participation	128
4.2.7	Work Transition Probabilities	129
4.2.8	Households Characteristics by Work Status.....	130
4.2.9	Off-farm Labour Supply	136
4.3	Empirical Results	138
4.3.1	Rainfall Variability and Households' Wealth Portfolio	138
4.3.2	Rainfall Variability and Off-Farm Labour Supply	149
4.4	Conclusion	161
CHAPTER FIVE		162
CONCLUSIONS AND POLICY RECOMMENDATIONS		162
5.1	Introduction.....	162
5.2	Summary	163

5.3	Conclusions.....	166
5.4	Policy Recommendations.....	167
5.5	Suggestion for Further Research.....	169
	REFERENCES	171
	APPENDIXES	xiv

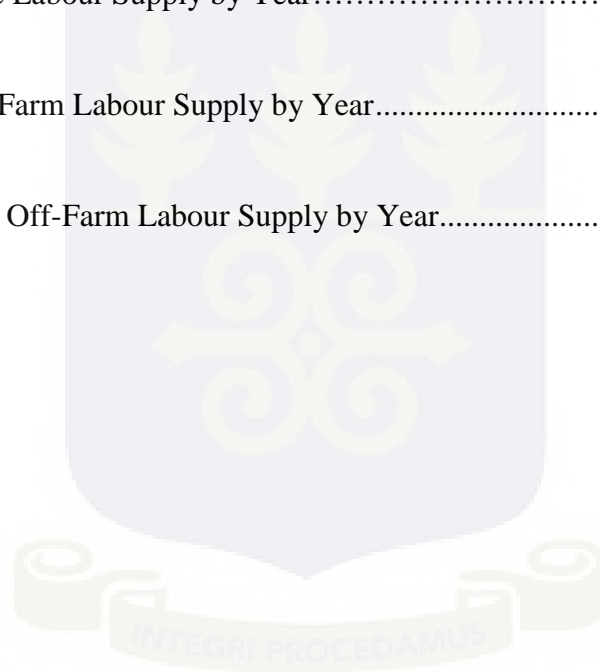


LIST OF TABLES

3. 1: List of Explanatory Variables used in the Regression to Explain Liquid Asset Holdings	84
3. 2: List of Explanatory Variables used in the Regression Explaining Off-Farm Labour Supply	110
Table 4. 1: Households' Characteristics	116
Table 4. 2: Inter-Wealth Quartiles Transition Probabilities.....	118
Table 4. 3: Inter-Income Quartile Transition Probabilities.....	119
Table 4. 4: Sources of Households' Wealth.....	123
Table 4. 5: Sources of Households' Income by Wealth Quartile	127
Table 4. 6: Off-Farm Labour Participation Decision.....	129
Table 4. 7: Work Transition Probabilities.....	130
Table 4. 8: Households' Characteristics by Off-Farm Work Category by Year	134
Table 4. 9: Results of the Regression of the Liquid Wealth Share	147
Table 4. 10: Results of the Regression of Off-Farm Labour Supply	159

LIST OF FIGURES

Figure 1. 1: Poverty Rates in Burkina Faso (1994-2014)	9
Figure 1. 2: Evolution of Cereal Yield and Rainfall in Burkina Faso (1990-2012)	11
Figure 3. 1: A Conceptual Framework of Asset and Activity Choice under Risk and Liquidity Constraints	57
Figure 4. 1: Wage Labour Supply by Year.....	137
Figure 4. 2: Non-Farm Labour Supply by Year.....	137
Figure 4. 3: Total Off-Farm Labour Supply by Year.....	138



LIST OF APPENDIXES

Appendix 1: Households' Characteristics by Off-Farm Work Category and by Year	xv
Appendix 2: Determinants of Households' Income.....	xvii
Appendix 3: Determinants of the Share of Liquid Wealth	xviii
Appendix 4: Estimation of Labour Supply Equations	xxiii



ABBREVIATIONS AND ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
CAADP	Comprehensive Africa Agriculture Development Program
CRRA	Constant Relative Risk Aversion
FCFA	Franc of the Financial Community of Africa
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
INSD	Institut National des Statistiques et de la Démographie
LAQAD-S	Labouratory of Quantitative Analysis of Applied to Development in Sahel
MAH	Ministry of Agriculture and Hydraulic Resources
MEDD	Ministry of Environment and Sustainable development
MRA	Ministry of Animal Resources
MAFAP	Monitoring African Food and Agriculture Policies
NGO	Non-Governmental organization
OECD	Organization for Economic Cooperation and Development
PANA	National Adaptation Program of Action
PNDS	National Economic and Social Development Plan
PNGT	Community-based Rural Development Project
PNSR	Programme Nationale du Secteur Rural
SCADD	Strategy for Accelerated Growth and Sustainable Development
SOFITEX	Société Burkinabè des Fibres Textiles
SP/CONED	Secrétariat Permanent du Conseil National pour l'Environnement et le Développement Durable

CHAPTER ONE

INTRODUCTION

1.1 Background

The largest share of the world's poor lives in rural areas. According to IFAD (2016), about 75 per cent of the world's hungry poor live in rural areas. Majority of them are smallholder farmers who rely on agriculture and related activities as a main source of livelihood. Although recent progress against global poverty across the world has been steady, there are significant differences across regions of the world in terms of the poverty declines. Asia and Pacific showed the highest performance by reducing poverty rate from 50.4 to 19 per cent between 1990 and 2010. On the other hand, over the same period, Sub-Saharan Africa barely achieved a 10 per cent drop from the 60 per cent baseline in the early 1990s.

Levels of poverty and hunger vary considerably, not only across regions but also across and within countries. Generally, poverty rates in rural areas are higher compared to those in urban areas. The social development goal of eradicating poverty and hunger will therefore be won or lost in the rural areas, particularly in Sub-Saharan Africa, where the incidence of poverty is highest. This implies equipping the smallholder farmers and other rural dwellers with the resources to face the challenges to sustaining their livelihoods but also to play their role in feeding the urban poor.

Learning from the experience of the successful Green Revolution policies from 1960s and 1970s which benefitted smallholders in southern Asia and Latin America, agricultural

development policies still offer a potential to be explored. According to Diao *et al.* (2010), there is no viable alternative to the development process in African countries that could bypass the agricultural sector while; Christiaensen *et al.* (2011) and Valdés & Foster (2010) show that growth in agriculture is more effective for reducing poverty and that this poverty reduction is higher than its contribution to economic growth.

The role of productive farm assets is more often emphasized as the way to overcome rural poverty (Dawson *et al.*, 2016; Finan *et al.*, 2005; Jayne, Mather, & Mghenyi, 2010; McKay, 2009; Quisumbing & Baulch, 2013). The getting in and out of poverty may therefore occur because households are unable or unwilling to accumulate assets as argued by Hoddinott (2006). From a much broader perspective, rural poverty is seen as the consequences of the lack of assets and limited economic opportunities (Beverly *et al.*, 2008 and Stein & Horn, 2012). However, rural households have also shown widely differing capacities to combine non-farm sources in their income generation process (Barrett *et al.*, 2001; Haggblade *et al.*, 2010; Lanjouw & Feder, 2001).

Several studies have shown that access to assets, particularly when it is combined with diversity of activities, is the key to boosting income of rural households (Barrett *et al.*, 2001). Furthermore, a large body of the literature has shown that, beyond income, well-being of households in the rural settings are closely related their asset holdings (Carter & Lybbert, 2012; Dercon & Christiaensen, 2011; Zimmerman & Carter, 2003) as well as their to access non-farm sources of income (Bezu *et al.*, 2012; Reardon *et al.*, 1992). Addressing rural poverty, and more generally improving rural households' well-being, requires policies that support personal initiatives which enable rural people to access and

accumulate assets, and undertake higher return activities. This does not only enable movement out of poverty but also enhances resilience to shocks, the main determinant of falling back into poverty.

Focus should therefore be on the assets that rural households accumulate, the activities they undertake and how they invest in those assets and activities for their livelihood within their communities. According to Beverly *et al.* (2008) and Sherraden *et al.* (2004), in the developed countries, policy-makers are increasingly interested in exploring asset-accumulation strategies to reduce poverty that were outside the realm of means-tested policies (cash and food transfers). This argument is emphasized by Pender *et al.* (2012) who point out that rural development researchers and practitioners have recognized that investing in a broad range of assets is critical for long-term improvement of well-being of rural farm households and to a large extent, economic growth and prosperity in rural communities.

Nevertheless, rural development policies have often focused either on enhancing farm productivity or attracting external capital into rural areas (Mikulcak *et al.*, 2015), but in a less sustainable way. Former category of policies is largely involved in promoting access to improved technologies (mainly improved seed and fertilizers) through subsidization or free distribution; but beneficiaries are often left without enough capacity to take over. Among other reasons, the cost and risk associated with such technologies may be mentioned. The latter category of policies, the exogenous rural development strategies, also shows low performance in terms of poverty reduction as it is often restricted to the creation of low unskilled paid work. As indicated by Haggblade *et al.* (2010), for the poor to take

advantage of the rural non-farm growth, this process must induce more than simple low productivity employment.

Although the role of the external capital must not be neglected in efforts to achieve rural development goals, all development strategies should start from harnessing local resources to achieve high impact and sustainability. Indeed, the success of any development strategy will depend on the extent to which the social planner understands and uses information about the local context and the structure of the local economy. Those are determined by the endowment of households in different types of assets, the interrelationships among those assets and the households' decision making with respect to the allocation of those assets to their income generation process. The prevalence of high levels of poverty, despite a continuously positive economic growth in Sub-Sahara Africa, suggests that growth has not been inclusive enough. This implies that there is a need to implement more pro-poor growth policies for the post-2015 development agenda. Such policies must target the rural population, enable them to acquire and build wealth. The question of why some households can take advantage of high return assets and activities, and accumulate wealth over time while others are unable to do so is therefore relevant to investigate, particularly in communities where poverty is high and persistent.

The literature discusses two key factors, often treated separately and sometimes combined, to address the issue of why households behave differently in asset accumulation and labour allocation. The first thread focuses on the role of liquidity constraints in explaining differences in asset holdings (Carroll & Summers, 1991; Carter & Zimmerman, 2000; Dercon, 1998) and occupational choices (Dercon, 1998; Dercon & Krishnan, 1996), and

therefore poverty. According to this thread of the literature, differences in assets and activity choice over time reflect how liquidity constraints interact with differences in initial endowment to determine who can afford each type of asset and activity. High return assets and activities usually exhibit high entry constraints unlike those with low yields, implying that initially less endowed households may find themselves restricted to low yielding assets and activities while wealthier households can enter high yielding assets and activities. This ultimately creates large inequalities.

The second thread in the literature emphasises the role of risk as the key explanation of the persistence of poverty in developing countries which are generally characterized by the absence of risk markets risk (Deaton, 1991; Dercon, 2005; Dercon & Christiaensen, 2011; Kochar, 1995; Morduch, 1994; Rijkers & Soderbom, 2013; Townsend, 1995) as the prominent explanation of the persistence of poverty in developing countries which are generally characterized by the absence of risk markets. One way risk contributes to creating rural poverty is directly by being responsible for large income fluctuations (Morduch, 1994). More indirectly, the lack of insurance (either formal risk markets or informal risk insurance) causes households to pursue costly risk-reducing strategies in terms of forgone consumption and returns (Deaton, 1991; Dercon & Christiaensen, 2011; Kochar, 1995; Rosenzweig & Binswanger, 1993; Rosenzweig & Wolpin, 1993). In other words, to smooth consumption or income, households may intentionally pursue lower income generation strategies, provided they are relatively stable. Such attitudes are particularly more valuable when, in addition to the missing formal risk markets, informal risk insurance mechanisms are also not functioning effectively.

Finally, little effort has been made to explain how these features (liquidity constraint and missing risk market) may interact to determine the long-run social equilibrium. According to Zimmerman & Carter (2003), when liquidity constrained households have to endogenously generate income given a stochastic random shock, the cost of accumulation can be considerably higher than suggested by above mentioned authors. That is, the liquidity constraint and missing risk markets exacerbate the risk induced poverty. This suggests that risk management strategies must also reflect the presence of proactive behaviour. On the one hand, the ex-ante asset and activity portfolios decisions reflect the household's risk-returns preferences, given one's asset endowment. Risk averse households will more readily trade high risk for lower stable returns. On the other hand, the inter-temporal consumption smoothing may still involve consumption reduction when households face downside risk. Therefore, risk reducing strategies are not only costly for poor households, they may also create poverty traps.

With respect to asset accumulation, the empirical literature has, however, extensively approached the problem of households' behavioural response to risk by analysing ex-post shock coping strategies; presumably because if risk predetermines the structure of the income generation strategy, then this should be reflected in the assets' response to risk realization. Moreover, the ex-post approach to understanding the effect of risk on households' asset holdings has also focused on identifying the potential of specific asset in providing insurance against income fluctuation, omitting the potential portfolio effects (Deaton, 1991; Fafchamps *et al.*, 1998; Kazianga & Udry, 2006; Mogues, 2011). Few exceptions are Jalan & Ravallion (2001); Kazarosian (1997); Rosenzweig & Binswanger

(1993) and Zimmerman & Carter (2003) who have analysed the effect of risk induced behaviour on agricultural assets' portfolio decisions of farm households.

With respect to livelihood activities, the literature has also extensively discussed off-farm work either as an ex-post response to farm income shortfalls or as a result of differences in initial asset endowment. Few attempts to unfold the proactive labour allocation in response to potential farm risk are found in Ito & Kurosaki (2009); Menon (2009); Mishra & Goodwin (1997); Rijkers & Soderbom (2013) and Rose (2001). Despite the extensive literature on off-farm work decisions, household surveys usually do not investigate in greater detail the issue of off-farm labour; thereby limiting the scope of the empirical literature on cross-sector labour allocation by smallholder farm households. Indeed, the largest body of the empirical literature is restricted to the decision to participate in off-farm activities. However, unlike households' fixed assets, labour may be reallocated with less cost, at least as regards explicit cost, in response to change in the rural environment. Labour may therefore be even more responsive to weather risk than any other resource of the households. Extending the framework of risk induced behavior to analyse households' labour allocation may provide a better understanding about the effect of risk on households' resource allocation.

The challenge that remains therefore is to investigate the household's consumption-investment decision in ways that reflect the trade-offs that a rural household would actually face. Assets are chosen with regards to their risk-return structure and their liquidity. The latter may be enough to justify the presence of precaution as far as consumption is

concerned, while the former reflects the potential causal effect of risk on creating and perpetuating poverty. Inter-sector labour mobility may also reflect these key features.

1.2 Problem Statement

1.2.1 State of Poverty in Burkina Faso

Despite decades of continuous growth, more than 5 per cent on average since 2000, poverty persists in Burkina Faso. The latest Households Living Standard Survey (INSD, 2016), showed that in 2014, about 40.1 per cent of the total population lived below the poverty line which is less 1 USD per day. Though this indicates a drop of about 5 points in the average poverty rate over the two decades (45.725 per cent), poverty level remains far from the target of the commitment of reducing poverty (less than 38 per cent in 2020)¹. Figure 1.1 presents the evolution of the proportion of people living below the poverty line over the last two decades.

Figure 1.1 reveals that poverty in Burkina Faso is overwhelmingly a rural issue. Although rural poverty declined in 2014, there is still more than 47 per cent of the rural dwellers who live below the poverty line. Between 1994 and 2009, rural poverty was consistently more than 50 per cent, with a peak of 52.8 per cent in 2009. At the same time, around 13.7 per cent of urban dwellers were reported poor in 2014 while it has been on average less than 20 per cent; despite a transitory spike in 2009. Furthermore, this average rural poverty ignores significant disparities across the different regions of the country. For instance, in

¹ For the Strategy of Accelerated Growth and Sustainable Development (SCADD) launched in the beginning of the 2010s aimed at reducing poverty at less than 35 per cent by 2015. In 2016, the new development agenda defined through the National Economic and Social Development Plan (PNDES) has revised this target to 38 per cent in 2020

the northern region, poverty rates have been closer to 70 per cent between 2003 and 2010 (INSD, 2016). This rural bias is a concern given that in 2014, more than three quarters of the estimated 18 million inhabitants of Burkina Faso lived in rural areas (INSD, 2016). As a matter of fact, more than 90 per cent of the poor in Burkina Faso are located in rural areas, implying that poverty in Burkina Faso is driven by rural poverty (Figure 1.1). The goal of poverty reduction will therefore be achieved by implementing policies and programs that promote income growth and improved livelihoods in the rural areas of Burkina Faso.

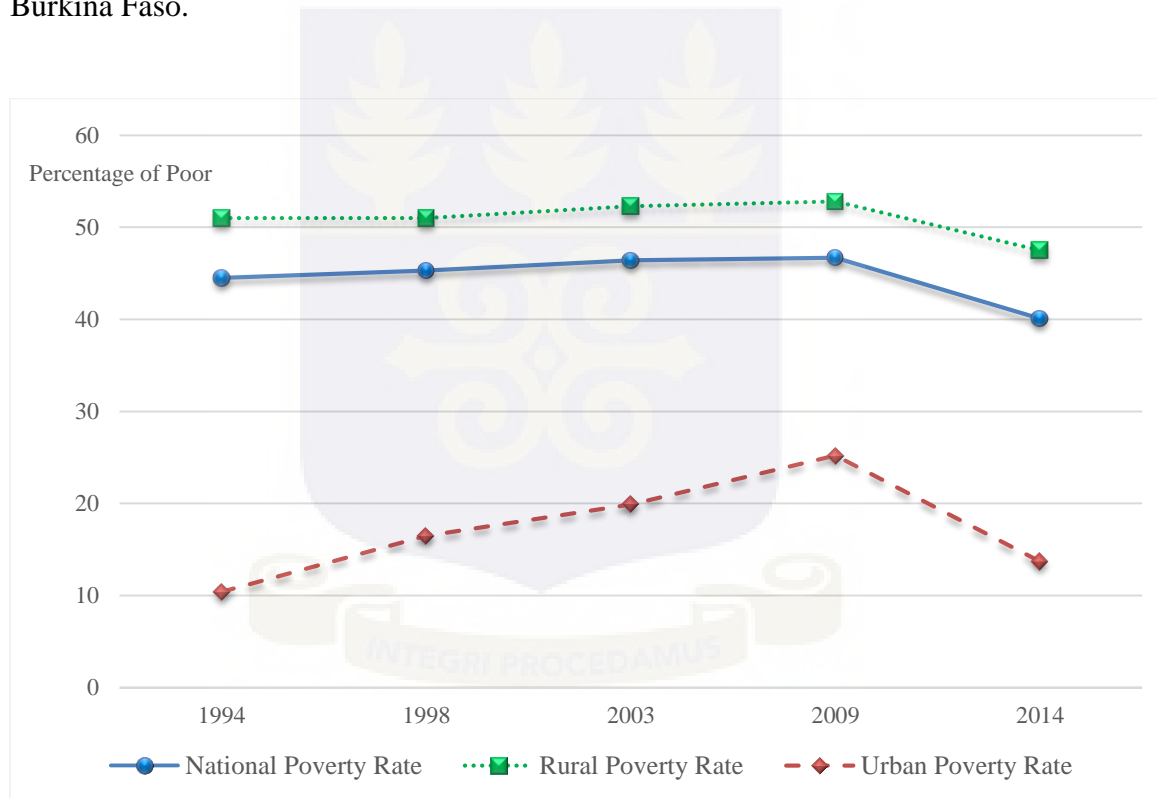


Figure 1. 1: Poverty Rates in Burkina Faso (1994-2014)

Source: Constructed by author based on data from INSD (2016)

1.2.2 State of Agriculture, Policy Context and Weather Challenges

Agriculture constitutes the main source of livelihood of households in rural Burkina Faso.

According to MAH *et al.* (2012), rural households generate around 61.5 per cent of their

income (monetary) from agricultural activities; of which cropping constitutes 67 per cent and livestock about 31 per cent. The sector employs more than 80 per cent of the total active population and contributes to about 33 per cent to the GDP. Yet, according to MAFAP (2013), agricultural products represent about 48 per cent of total exports despite the increasing role of the mining sector over the last decade.

Agriculture is mainly smallholder based and not modernized. Indeed, about 72 per cent of the farmers hold less than 5 ha while less than 0.2 per cent of farms use motorized traction (MAFAP, 2013). It is the use of animal traction that is relatively widespread; around 44 per cent according to MAH *et al.* (2012). In addition, technology adoption is also reported to be low. The rate of access to improved seed is less than 15 per cent while consumption of fertilizer is still less than 40 kg/ha. According MAH *et al.* (2012), cereals (millet, sorghum, maize, and fonio) represent 77 per cent of total land under cultivation against 19 per cent for cash crops (cotton, sesame, ground nut, soya, etc). The remaining 4 per cent are allocated to rice (1 per cent) and other food-crops (yam, cowpeas, wandzu, etc). The contribution of cereals to the total calorie consumption is 73 per cent against 4 per cent from animal products (MAH *et al.*, 2012a), indicating the important role of agriculture in the households' food security.

Given the overwhelming role of agriculture in the economy, any poverty reduction strategy should focus on the agricultural sector. In accordance with the global commitment through the Millennium Development Goals (MDG), and more recently the Sustainable Development Goals, and the Comprehensive African Agriculture Development Program

(CAADP), a 10.7 per cent growth of the GDP of the agricultural sector is targeted with at least 10 per cent of total budget to be allocated to the agricultural sector (MEF, 2010).

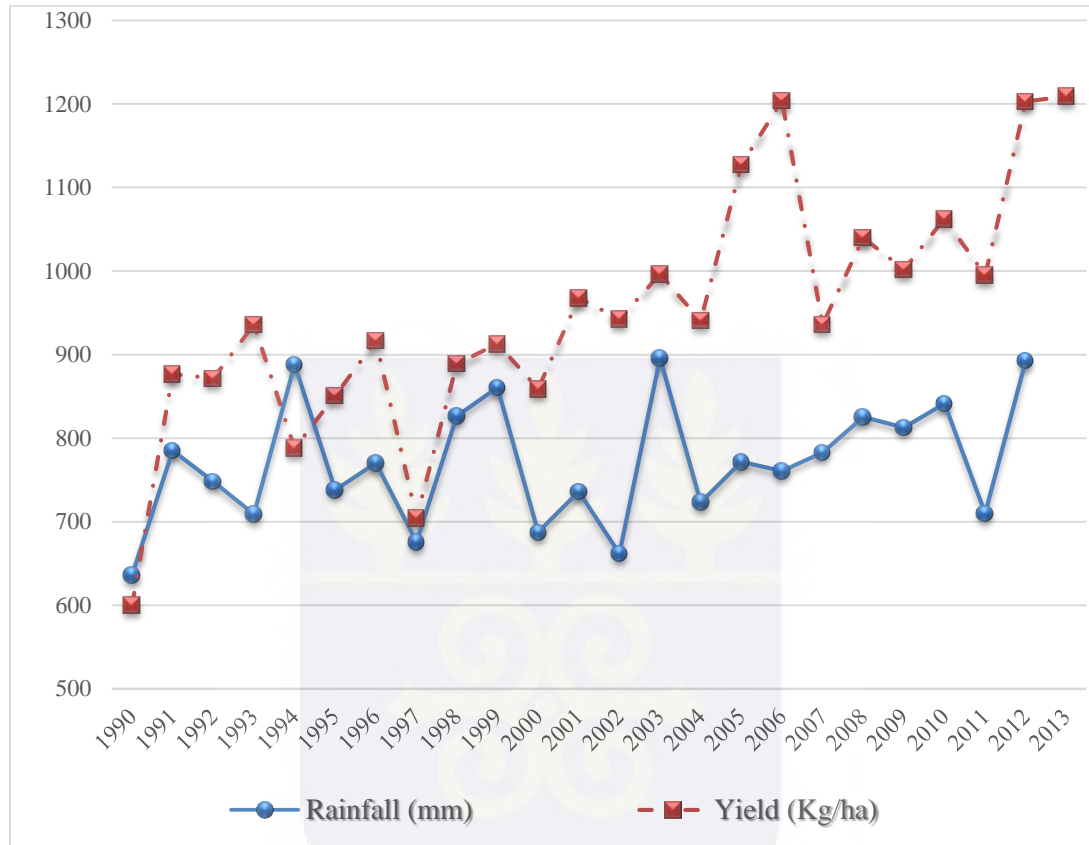


Figure 1. 2: Evolution of Cereal Yield and Rainfall in Burkina Faso (1990-2012)

Source: Constructed by author based on World Development Indicators (World Bank, 2017)

Over the last decade, a notable effort has been made to meet the budget allocation commitment². However, agricultural productivity growth is aimed by means of promoting improved technology (fertilizer, improved seed), land management technics (*zai* and *demi-lune*) and fodder-crop for livestock breeding. Despite some achievements, the overall

² On average, 14 per cent of the budget has been allocated to the agricultural sector between 2006 and 2010 (MAH *et al.*, 2012). A growth rate of 5.2 per cent has been achieved in 2010 for the GDP of the agricultural sector

performance of the sector remains low and very far from expectations as mentioned above. Given that agriculture remains mainly rainfed, the vagaries of the weather may be responsible for a large part of this poor performance and therefore the persistent poverty.

Figure 1.2 shows the trends in cereals' yield and rainfall between 1990 and 2012 in Burkina Faso. While the figure shows an upward trend in cereal yield, it also shows that cereal yield fluctuations track closely that of rainfall with magnitudes that are highly unpredictable. According to MAH *et al.* (2012), the coefficient of variation of the agricultural production is estimated at about 38 per cent over the last three decades. There is therefore a possibility that smallholder farm households are less responsive to some policy incentives because of the increasing risk involved. For example, Dercon & Christiaensen (2011) have shown that, notwithstanding their high impact on agricultural productivity, fertilizers are also risky investment; and expectations of low rainfall reduces households consumption of such inputs. Similar attitudes towards improved seeds, and more generally investment for which returns are strongly correlated with the weather outcomes may be observed. Such behavioural response to risk may increasingly push farm households to diversify away from such cropping investments.

As households' livelihood strategies are concerned, there are two issues. First, weather uncertainty has significantly increased since the 1990s, characterised by sudden alternations between years of high rainfall and years of low rainfall (see Figure 1.2). In contrast, the previous decades were characterised by either a persistence in the years of high rainfall (1950-1970) or a persistence in the years of low rainfall (1970-1990). The current variability is expected to continue into the futures decades along with (i) a general decrease

in the annual rainfall levels, (ii) a decrease in the number of rainy days and (iii) an increase in the number of consecutive days without rain (MERH, 2015). Moreover, temperatures (minima and maxima) are on the upward trend. An increase by between 0.5 and 5.0 Celsius degree by 2065 is expected and this will result in an increase of the potential monthly evapotranspiration by between 2 to 10 millimetres (MERH, 2015; SP/CONED, 2007). This implies that agricultural risk is expected to increase.

Another concern is that the alternative income sources available to smallholder farmers are generally low yielding. This is the case for example of off-farm activities and liquid assets such as livestock and grain. However, data on returns to off-farm activities are not readily available. This is also the case regarding the returns to the various non-land assets that are held by smallholder farm households. Nevertheless, it is widely recognized that segments of the off-farm sector in which the rural poor work yield far lower returns than farming (Dercon, 1998; Shi *et al.*, 2007). Therefore, though they may provide the means to achieve more stable livelihood opportunities, associated lower average returns may limit households' ability to lift themselves out of poverty. Also, if this uncertainty reduces on-farm resource allocation, this may partly explain why poverty persists in Burkina Faso.

1.3 Research Questions

Given the potential risk induced poverty, the main research question of this thesis relates to how weather risk affects smallholder farm households' resource allocation in Burkina Faso. The study addresses this main research question by answering the following specific research questions:

- i. What is the effect of rainfall risk on smallholder farm households' asset holdings' decisions in Burkina Faso?
- ii. What is the effect of rainfall risk on smallholder farm households' labour allocation across farm and off-farm activities in Burkina Faso?

1.4 Research Objectives

The purpose of this study is to analyse the effect of weather risk on smallholder farm households' resource allocation in Burkina Faso. More specifically, the study aims to analyse:

- i. The effect of rainfall risk on asset holding decisions among smallholder farm households in Burkina Faso; and
- ii. The effect of rainfall risk on labour allocation between farm and off-farm activities by these households.

1.5 Relevance of the Study

Empirical literature on asset accumulation among households has shown mixed conclusions. Most of the studies from Burkina Faso have focused on testing the hypothesis that livestock and grain are accumulated as a self-insurance strategy against crop income fluctuations (Carter & Lybbert, 2012; Fafchamps *et al.*, 1998; Kazianga & Udry, 2006). Little evidence is, however, found. Only Zimmerman & Carter (2003), using stochastic dynamic programming methods, have been able to characterise this risk induced poverty in a framework of grain-land accumulation, by showing that initial endowment matters for wealth accumulation under risk. Also, very little attention has been paid to labour allocation

across farming and off-farm activities in rural Burkina Faso. Few exceptions are Reardon *et al.* (1992) and Zahonog (2011), even though the role of risk was not the focus of their studies. However, except Zahonog (2011), all those studies were based on data from the first half of the 1980s; and households off-farm labour allocation has not been linked with rainfall risk despite its potential effect on households income, their wealth and growth of the national economy. There is therefore a dearth of research about how weather risk, the main challenge facing smallholder farm households in Burkina Faso, affects their resource allocation decisions. Such knowledge is essential to designing and implementing policies that enable rural households to invest in high return asset and activities, a means of unlocking potential poverty traps.

1.6 Organization of the Thesis

This thesis is organized as follow. The next chapter reviews the relevant literature as it is related to the research problem. First, it discusses the risk induced poverty literature and the role of social risk articulation in shaping the households' wealth holdings. This is followed by the role of risk in asset portfolio holdings, discussed both from the theoretical and empirical literature perspective. Finally, the relevant theoretical and empirical literature about the effect of risk on labour allocation is presented. Chapter three presents the methodology of the study. This section is subdivided into three main sub-sections. First, and with respect to assets, a theoretical model of portfolio selection under risk is developed using standard stochastic dynamic programming methods. Based on this theoretical framework, an estimable empirical econometric model is proposed and the related econometric issues are discussed. Second, the real options approach and stochastic

dynamic programming methods are combined to propose a theoretical framework for analysing off-farm entry-exit decision; and characterize the optimal labour allocation. An empirical model is also proposed, based on theoretical conclusions. The last sub-section presents that data used in the empirical analysis. Results are presented in chapter four which begins with descriptive statistics of the data. Then, econometric results of the asset model are presented. Finally, econometric results of the labour model are discussed. The last chapter presents general conclusions, summarizes the major findings and discusses policy recommendations.



CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of the areas of the literature that are related to research problem; that is, the role of uncertainty in smallholder farm households' resource allocation decision and how this may hinder their ability to accumulate wealth over time. The review first explains how risk may cause poverty by preventing households from building high yielding asset and activity portfolios. This is followed by a review of the theoretical literature and empirical literature on asset portfolio selection under risk. Finally, the theoretical and empirical literature on activity choice and labour allocation under risk is discussed.

2.2 Definitions of key Concepts and Terms

2.2.1 Risk and Uncertainty

Risk and uncertainty, major components of analysis of resource allocation decisions, are two types of imperfect knowledge of the outcome streams of an investment decision (Hardaker, 1982). Since Knight (1921), the fundamental difference between the two depends on the knowledge of the subjective probabilities that decision makers can attach to the outcome streams from their decisions. The concept of risk is used when the probabilities of the uncertain outcomes are known while uncertainty is more adequate when they are not (Hardaker, 1982; Hardaker *et al.*, 2015; Knight, 1921). However, this distinction between risk and uncertainty is more conceptual than practical. As stated by

Jehele & Reny (2011), if decision makers may know the probabilities that can be assigned to possible outcomes, the actual results cannot be known before it occurs. Therefore, while risk and uncertainty should be conceptually separated, they are closely related in practice. In fact, according to Hazell & Norton (1986), this distinction is not useful for farm investment analysis since information from which reliable estimates of income distribution can be obtained is generally not available. In the real world, the concept of uncertainty may be more adequate to describe this more general state of ambiguity. However, several authors have used these two concepts distinctively to describe similar situations (Ito & Kurosaki, 2009; Jalan & Ravallion, 2001; Rosenzweig & Binswanger, 1993). This study is also closer to the concept of risk in terms of the theoretical background but much closer to the latter in terms of empirical analysis. To reflect this, both concepts of risk is extensively used and terms used by authors are preferred in the literature review. In the discussion of results, the concept of uncertainty is more used to reflect the information conveyed by the risk measure; that is, the coefficient of variation.

2.2.2 Wealth and Assets

Some definitions of wealth emphasize the value of marketable assets, while others include all valued assets, regardless of their marketability Pender *et al.* (2012). Wealth may refer to part or the total worth, net of liabilities, that can be accumulated and dissipated through investment and disinvestment decisions; and which can be devoted to expanding the entire asset base. A comprehensive definition of wealth would therefore include all assets, including non-tangible ones such as human capital, social capital and intellectual capital that contribute to generate all flows (income, consumption and amenities) that contribute

to the well-being of households (Arrow *et al.*, 2012; Pender *et al.*, 2012; World Bank, 2011). However, this thesis focuses on the tangible components of wealth. Also, few assets are considered, mainly land, livestock, farm equipment, food stocks and cash. For instance, it does not include housing, one of the most important component of wealth, because of data availability. This thesis therefore deals with partial rather than comprehensive wealth. Furthermore, the value of any of these assets or a subset of these assets may be referred to as wealth, provided that the concept of stock is emphasized instead of the flows generated by the ownership of such assets (Pender *et al.*, 2012). The literature, for instance, has often extensively used the concept of wealth to refer to the holdings of liquid assets such as livestock, grain or cash (Deaton, 1991; Dercon, 1998; Dercon & Christiaensen, 2011; Kazarosian, 1997). An asset is considered liquid if it can be readily converted into cash or the prevailing medium of exchange in an economy. This is generally in contrast to non-liquid asset which cannot be readily converted into cash. Total wealth is the total asset value.

2.2.3 Non-Farm and Off-Farm Activities

The literature often distinguishes non-farm activities from farming to refer to all economic activities in the rural economy except agriculture, livestock breeding and hunting (Lanjouw & Feder, 2001). Haggblade *et al.* (2010) rather prefer the concept of activities other than the production of primary agricultural commodities. The rural non-farm sector may therefore refer to the broad range of activities including, but not confined to, manufacturing, industrial activities, commerce, transportation, utilities, etc. However, according to Barrett *et al.* (2001), an important distinction may be that between primary

agricultural activities and activities away from own farm, particularly if the attention is paid to understanding the role of risk in explaining the diversity of households' livelihood. Indeed, as a means of spreading income risk, households may engage resources, labour for instance, in agricultural activities in farm of other households for payment. In this case, return to labour will not be affected, at least conceptually, by the sources of own farming risk. This more general concept refers to off-farm economy. The concept is particularly suitable for this study as it focuses on risk. Indeed, hired farm labour is generally paid before harvesting, and therefore return to labour in such work would not be affected by weather outcome.

2.3 Risk and Poverty

There is an extensive literature on the role of risk in creating and perpetuating poverty, and poverty on attitudes towards risk as well. Risk and poverty, more generally, may interact such that a poor in a high risk environment may find it hard to move out of poverty by own "Victorian Bootstrap"³. The way risk creates poverty is context dependent. For instance, Morduch (1994) indicates that in developed countries, poverty is less explained by risk than households' structural characteristics such as low education and idiosyncratic shocks induced by lifecycle events (birth, divorce, death of family member, etc.). On the other hand, in developing countries, in addition to households' structural characteristics, factors related to the vagaries of weather, failure of financial markets and lack of insurance contribute to poverty. Risk per se may therefore be a major determinant of poverty.

³ This expression employed by Zimmerman & Carter (2003, P.234) means success after repeated tries

The main channel through which risk creates poverty is on its effects on returns to investment. In a more direct way, weather risk may be responsible for large fluctuations on returns. However, this direct effect does not prevent the household from obtaining higher returns on average and improve one's poverty status. Since Markowitz (1952), it is widely acknowledged that return to portfolio and portfolio risk are positively correlated. This positive relationship is supported by dynamic portfolio models (Dercon, 1996, 1998; Zimmerman & Carter, 2003) and empirical research (Rosenzweig & Binswanger, 1993). This suggests that ability to abide risk matters for achieving high average returns.

In the absence of formal risk markets, the importance of risk induced behaviour depends on the availability and the effectiveness of informal risk coping mechanisms and household self-insurance capacity. Dercon (1996) and Dercon & Christiaensen (2011), for instance, have found that ability to cope with ex-post risk, proxied by wealth holdings (livestock assets), encourages investment in high risk and high yielding activities.

However, risk may neither be the only reason nor the most important determinant of poverty among low income households (Dercon & Krishnan, 1996; Maertens, 2000). These authors have argued that binding liquidity constraints (lack of capital) rather explained better the observed patterns of activity portfolios in rural areas. Rural economies are characterized by various market failures. Therefore, in the typical rural economy, households have no means of contract enforcement in the form of access to formal risk markets to deal with income risk. The potential effect of risk on households' accumulation would therefore be reinforced by the absence of proper ex-post risk coping mechanisms. In the presence of market failures, risk and poverty interact to create poverty over time

(Zimmerman & Carter, 2003). That is, initial endowment matters for wealth accumulation over time. For instance, Dercon (1998) has shown that inability to finance lumpy costs prevents households in western rural Tanzania from investing in cattle rearing which is a high yielding asset. Since there was no explicit risk regarding return to cattle, the author could conclude that lumpiness suffices to prevent some households from holding such high return assets and that this may restrict them into low yielding assets. This does not only create chronic poverty but also contributes to growing inequalities over time, given any differences in initial endowment; as well-endowed households are only able to take advantage from such opportunity. Similar results arise from Carter & Zimmerman (2000) and Zimmerman & Carter (2003). Using dynamic programming methods, these authors have shown that wealth portfolio bifurcates, creating various stable equilibria. Household's location in any equilibrium is determined by its initial asset endowments.

In developing countries, the main risk faced by smallholder farmers is related to the vagaries of weather. Agriculture remains essentially rainfed based, making farmers accumulation paths to depend on both intra and inter-annual rainfall distributions. Smallholder farmers may be subject to recurrent income shortfalls that highly affect their well-being if they cannot afford to insulate consumption from this short-run income variations. Where risk markets are absent or incomplete, households must develop endogenous mechanisms to cope with income shocks (Carter, 1997; Coate & Ravallion, 1993; Ligon *et al.*, 2002). However, risk management strategies are not without consequences on future prospects. Being poor might be the likely option when households tend to avoid extreme consequences of uninsured risk.

2.4 Non-Market Risk Management Strategies

There are several types of informal risk management strategies that households may adopt in the absence of formal risk markets. They can be broadly divided into two main categories: informal risk sharing and self-insurance strategies. The former category refers to strategies that use informal social institutions such as reciprocity to pool risk. The latter category refers to endogenous risk spreading or mitigation strategies undertaken at the individual level.

2.4.1 Informal Risk Sharing

When risk markets are absent, households must develop endogenous mechanisms to counter the effects of income variations. Informal institutions may therefore take place, often at community level or within smaller circles of individuals to serve this purpose of spreading risk in the form of gift giving (in kind or cash) and interest free reciprocal loans. The use of reciprocity arrangements as means of dealing with risk has been subject to considerable theoretical and empirical literature (Carter, 1997; Coate & Ravallion, 1993; Fafchamps & Lund, 2003; Kazianga & Udry, 2006; Ligon *et al.*, 2002). The effectiveness of any of this social risk articulation appears to be context dependent; depending on the type and the size of the social network involved in the reciprocity arrangement but also the degree of commitment. While one or some of this informal risk insurance might work in some context, they are generally not fully efficient (Fafchamps & Lund, 2003; Kazianga & Udry, 2006). The findings by Fafchamps and Lund (2003) suggest that risk-sharing may be well suited for small groups, friends and relatives; but, it is also likely that their effectiveness depends on the nature of the shock being mediated.

Although the literature tends to support the idea that the use of informal risk sharing protects households from the full effects of shocks on their income, this is neither to the extent required by a Pareto efficient allocation of risk (spatial) nor by the permanent income hypothesis (over time) (Kazianga & Udry, 2006). As argued by Zimmerman & Carter (2003), reciprocity may be only suitable to insure against idiosyncratic risks. When a shock strikes an entire community, part of the residuals will always be left by informal risk insurance mechanisms to be borne individually. The importance of the residual left by those social arrangements will depend on the infrastructural development across the agro-ecological boundaries. This suggests that informal risk insurance may be less reliable and that households must individually develop risk management strategies.

One kind of risk management strategy involves pursuing a smoother consumption path over time. The consumption smoothing approach of risk reduction implies that households facing future downside consumption risk reduce current consumption following the standard Euler equation (Deidda, Lee, & Sawada, 2010). Such households are considered to have a preference for the utility of average consumption over the average utility of consumption. This reflects the fundamental assumption of concavity of utility underlying the precautionary savings theory (Carroll & Kimball, 2001; Deaton, 1991) which has been largely used in empirical studies. Such risk management strategy may be used by households in rural Burkina Faso (Kazianga & Udry, 2006) as previous studies suggest that volatility of consumption observed may be intentional.

Another kind of risk management relates to avoiding disaster (Zimmerman & Carter, 2003). Since falling below some minimum consumption may have irreversible

consequences such as labour inefficiency, or even death, households would like to avoid complete depletion of assets. The cost of alienating an asset in the wake of income shock ultimately depends on its role in the households' income generation process. With a disaster avoidance strategy, households primarily manage to keep previously accumulated wealth or income above certain threshold and only smooth consumption above this threshold. From labour allocation perspective, households may tend to get involved in increased ex-ante labour allocation to lower risk production structure. For low income households, the need to protect assets and smooth consumption may result in potentially high welfare implication.

2.4.2 Inter-Cropping and Crop Diversification

While inter-cropping may be aimed to improve crop productivity, crop diversification, through the cultivation of multiple crops, may be aimed at spreading the risk faced by the farm households. This may be achieved through re-allocation of households' productive resources (mainly land and labour). For instance, Dercon (1996), has shown that risk averse households may grow riskless crops along with risky but high yielding crops as a means of reducing crop income volatility. Furthermore, Di Falco & Chavas (2009), have found that crop genetic diversity has a skewing effect on farm production risk among barely farmers in the highlands of Ethiopia. This effect of diversity on skewness appeared to dominate its effect on the first two moments (mean and variance), suggesting a reduction of the cost of risk. Finally, empirical estimation of farm production (or profit) functions largely support the idea that inter-cropped and mono-cropped lands respond differently to similar levels of

rainfall (Carter, 1997; Dercon & Christiaensen, 2011; Di Falco & Chavas, 2009; Fafchamps *et al.*, 1998; Kazianga & Udry, 2006).

However, it is still reasonable to argue that, though crop management strategies may alter the structure of the risk faced by rainfed smallholder farmers, they are also less equipped against covariate rainfall risk. For extreme weather conditions, all lands will be severely affected and so will be any cropping structure. Effective weather risk management must rely on risk management strategies to lower the potential effect of such risk on households' total wealth. This suggests investing in assets and (or) activities that are not affected in the same way by the risk factor. The following sections discuss the theoretical foundations and the empirical evidence about how the risk shapes households' asset holdings and their labour allocation across activities.

2.5 Risk and Asset Portfolio Selection

This sub-section reviews successively the theoretical and empirical literature on risk and asset portfolio selection. The theoretical literature includes work from the broader field of economics and finance that are useful to understanding investor behaviour in general. The empirical literature includes analyses of the directly effect of weather risk measures on asset portfolios and indirect investigation of the effect of weather risk through its effect on household consumption and income.

2.5.1 Theoretical Literature of Portfolio Selection under Risk

When selecting a portfolio, an investor is concerned with the level of the portfolio performance (mean return) but also with the variance of return which reflects the portfolio

riskiness. In a static framework, Markowitz (1952) has shown that there is a trade-off between portfolio return (expected return) and portfolio risk (variance of return) as they are positively correlated. Here originates the argument that to reduce risk, the investor must forgo return. An important conclusion from this static model is the prediction that in the presence of multiple investments with different riskiness, for investors with different risk preferences, the best portfolio always includes more than a single investment. This is the principle of superiority of diversification; that is, holding a single asset is optimal only when uncertainty is absent. In other words, the efficient portfolio is diversified, suggesting that the investor can always find a combination of investments that has the highest return for a given level of risk. Even though all households are expected to diversify, *ceteris paribus*, differences will remain in portfolio composition and such differences will reflect differences in risk preferences. Since risk aversion is negatively correlated with wealth (Jensen & Pope, 2004; Rosenzweig & Binswanger, 1993), distinctive endowments may suffice to explain observed differences of portfolio strategies across wealth classes (between poor and rich).

However, static models suffer from the limitation that they fail to incorporate the possibility that households might use time and savings to enter superior portfolio strategies (Bardhan *et al.*, 1999; Carter & Zimmerman, 2000). Time may also function as an arena of vulnerability (Dercon, 1998; Russo, 2014; Zimmerman & Carter, 2003). This suggests that investor behaviour must be analysed in a multi-period setting. In addition to the time limitation, the Markowitz framework does not also incorporate some key characteristics of the farm households; particularly non-separability of consumption and income generation process (Huffman, 1980; Rosenzweig & Wolpin, 1993).

Samuelson (1969) developed and solved analytically a dynamic model of portfolio selection, using stochastic dynamic programming methods. The author was, however, concerned with whether position in the life-cycle would matter for the optimal portfolio selection. For the case of iso-elastic marginal utilities, he showed that the chance to recoup losses and the tendency for the law of large numbers to operate are irrelevant in the case of repeated investment. Therefore, investing for many periods does not alter attitudes toward risk at any stage of life; that is, in individuals' prime of life, they have the same risk tolerance as towards the end of their life. This argument does not, however, contrast the idea of using savings and time to move across various portfolios. The model simply rejects the hypothesis that young individuals may have higher propensity to embrace risk than aged individuals.

Although the Samuelson's framework predicts the diversification under risk in inter-temporal consumption setting, it is inadequate explaining the empirical consumption-saving behaviour of rural households for several reasons. The main one is that the existence of perfectly operating financial markets is not a tenable assumption in developing countries in general, and in rural areas of developing countries in particular. While risk is ubiquitous in rural areas, possibility to borrow to smooth consumption, or, to a large extent, borrow to finance investment is not readily available. Admittedly, if credit market imperfections make borrowing impossible or prohibitively costly, recourse to less volatile investment may be a rational choice against consumption volatility.

The buffer stock model (Deaton, 1991) instead is built on the assumption of liquidity constraints. The model is aimed at explaining that when risk markets are absent, households

may still inexpensively achieve insurance against income fluctuation by means of wealth accumulation. Within a single-asset framework, the author showed that this may be achieved by accumulating a liquid asset during good times and drawing down the asset when times are bad. The countercyclical approach to adjusting the asset makes its holdings to exhibit some patterns that can be quite different from the prediction of the Life Cycle Model (Modigliani & Ando, 1957). Indeed, while the Life Cycle Model predicts an inverted U-shaped profile of accumulated wealth over the life cycle, the buffer stock model predicts a flatter path over time. According to Deaton (1991), the level of the asset will be particularly low and might not exceed 10 per cent or one standard deviation of income. Using simulations, he showed that consumption can be quite smoother with a standard deviation barely half of that of income. Nevertheless, assets are repeatedly exhausted but held more often.

The merit of the buffer stock model is to characterize the behaviour of impatient households; households whose discount rate exceeds the return to wealth. The role of borrowing constraints in wealth holding is studied by Carroll & Summers (1991) while wealth holdings for precautionary motive is extensively investigated by Kimball (1990). The buffer stock framework has been extensively used in the empirical literature of consumption smoothing in developing countries. Despite the solid theoretical foundations for the notion that low income, borrowing-constrained households will inter-temporally manage assets to smooth consumption, the consumption-smoothing hypothesis has not always withstood empirical scrutiny. Indeed, neither full depletion of potential buffer assets nor full protection against income fluctuation is empirically observed (Carter & Lybbert,

2012; Fafchamps *et al.*, 1998; Kazianga & Udry, 2006). Households even often destabilize consumption to protect assets (Kazianga & Udry, 2006).

Carter & Lybbert (2012), have suggested that there may be different asset regimes according to whether a household is below or above certain threshold of the asset holdings. This is largely suggested by empirical findings that predictions of theoretical models often fit differently, households in different wealth classes (Rosenzweig & Wolpin, 1993). However, this may reflect the possibility that the cost associated with accumulation and dissipation can be potentially higher or considerably more complex if the liquid asset is also productive or when the households have to choose among multiple assets.

Dercon (1998) has extended these inter-temporal consumption settings to include activity choice. In his model, there was no risk associated with the high yielding assets. This high yielding asset was rather assumed to exhibit some indivisibility; that is, households have to invest a relatively large amount of cash for each unit of the asset. On the other hand, aside the risky farming activity, the households have the opportunity to allocate labour into a low yielding low cost asset. The model predicts that wealthier households will likely combine the risky farming activity with investment in the high yielding assets as they can relatively serve the purpose of a buffer. To reduce farm income risk, less endowed households will have recourse to the low cost, low yielding assets. Over time, the economy widens any significant differences in initial endowments.

However, this argument that the economy is split into two groups, one evolving around the asset and the other around off-farm activities is contrasted by the observed patterns of activity choice and asset holdings as well. If there is a relatively high liquid assets, small

livestock or grain, a relatively large proportion of the population may be involved in such investment, although not with the same intensity as found by Carter & Zimmerman (2000); Jalan & Ravallion (2001); & Zimmerman & Carter (2003). A non-negligible proportion of households may combine riskless activity and riskless asset as well. Indeed, some conclusion from the crop selection framework by Dercon (1996) may be extended here, when access to the liquid asset encourages risk taking behaviour. In an earlier paper, Dercon (1996) showed that allowing for asset accumulation alters the optimal labour allocation to riskless low yielding crop. A similar model of technology adoption by Dercon & Christiaensen (2011) also supports the idea that ability to cope with ex-post consumption risk, captured by the holdings of liquid assets, encourages adoption of risky high yielding technologies.

Russo (2014) in a stochastic model of wealth accumulation with class division showed that, even with equalitarian initial wealth distribution, an economy may still evolve into an unequal long-run equilibrium with a few rich and many poor. This ultimate social outcome depends on the income generation process of each class. The first class, capitalists, accumulate wealth through a multiplicative stochastic process governing returns to capital investment. Wealth of the second class, workers, on the other hand is generated by an additive stochastic process. This study re-emphasies the role risk in the problem of wealth accumulation. The risk structure is of key importance. Risk alone may therefore suffice to create and perpetuates low-income status. This general theoretical framework is easily extended to analyse the effect of risk on activity portfolio as well. Likewise, with assets, returns to activity portfolios exhibit positive relationships with portfolio risk.

2.5.2 Empirical Literature on Asset Portfolio under Risk

2.5.2.1 Income risk and consumption smoothing

In the original work by Deaton (1991), the household was assumed to face a random income flow. The patterns of the household's wealth accumulation typically mimics that of the random income, suggesting that the accumulation of the liquid asset only responds to the precaution against income shocks. As he argued, with no uncertainty about income flows, the households would run down the asset and set consumption equal income as argued earlier by Schechtman & Escudero (1977).

Mogues (2011) has tested the effects of weather shocks on asset holdings among households in rural northern Ethiopia over the period 1999-2003. He distinguishes assets with respect to their level of liquidity, that is, grain, small livestock assets (sheep and goats) and large livestock assets (cattle). Empirical results indicate that the effect of shocks on assets differs as to whether the shocks are idiosyncratic or collective. For either shock, the magnitude of asset adjustment differs across assets also. For instance, households' respond to idiosyncratic shock by reducing grain stock by about 48 per cent while they would use between 16 and 18 per cent of livestock assets. In the case of covariate shocks, households would use almost 9 per cent of the grain holdings while the use of livestock would barely reach half of this magnitude. These results suggest that various types of assets may be accumulated as buffer but that the precautionary motive for wealth accumulation may be more prevalent for more liquid and less productive assets.

However, it is worth noting that, when used in same equation, idiosyncratic shock has no explanatory power on the accumulation path of any assets, and that covariate shocks have similar effects as when idiosyncratic effects are ignored, despite both being measured in terms of crop loss experiences. First, using a dummy to measure idiosyncratic shock experience at plot level overlooks the extent of the shock and will likely confuse normal asset adjustment and response to shock. Households may be subject to loss in a particular land parcel while aggregate output from all lands is enough to cover household consumption needs. Also, households may still sell or use grain, which is mistakenly consider to be the effect of the shock. As suggested by Wauters *et al.* (2014), risk management is to a substantial degree performed at the household level, rather than at farm level. These limitations apply for the covariate shock measure as it replicates the idiosyncratic shock variables at the community level.

Hoddinott (2006) also studied the effect of weather shock on households' livestock asset holdings in rural Zimbabwe using longitudinal data over the period 1994-1999. In this study, shocks are directly measured as the district level rainfall deviation from long-run mean. More than 50 per cent of households who held more than two oxen sold at least one following the 1994-1995 drought; while only 15 per cent of the households having just one or two oxen sold at least one. Barely a quarter of households holding at least two cows or heifers sold at least one. On the other hand, against less than 5 per cent of the households with only one or two. This is however lower than what is reported by Fafchamps *et al.* (1998) in the case of rural Burkina Faso. In the later, about 70 per cent of household reported consumption as the motive of selling cattle and about 80 per cent for sheep and goat sales. Livestock sales were also high when households were subject to positive

weather income shock (39 and 57 per cent respectively still sold cattle and small livestock for consumption purposes).

Econometric results from Hoddinott (2006) suggest that households still sell livestock irrespective of the weather outcomes; but also that the sales are relatively higher for bad than for good weather outcomes (0.253 and 0.199 respectively). While these results tend to suggest that poor and wealthier households may respond differently to income shock by means of intertemporal asset management, they also point out the potential costs associated with asset depletion; particularly when the assets yield return. It is indeed reasonable to say that higher returns are associated with cow or heifer (offspring and milk for instance) than oxen.

Whether livestock is ex-ante accumulated to enable coping with weather shocks ex-post is more puzzling in rural Burkina Faso. Indeed, Fafchamps *et al.* (1998), did not find any significant statistical relationship between cattle sales and income shock induced by rainfall shortfalls. Only sales of small ruminants had a very small statistically positive effect. They estimated that all sales of large and small livestock offset at most 30 per cent and probably closer to 15 per cent crop income shortfalls. This limited role of livestock in protecting consumption from income variability as is caused by rainfall variability is confirmed by Kazianga & Udry (2006) who showed that households rather recourse to grain stock which also appeared to have a little role to play. The authors further tested the use of reciprocity but found no statistical evidence. Carter & Lybbert (2012), using a threshold estimation approach found that there is a critical wealth level which splits households into consumption smoothers and asset smoothers. However, such thresholds seem too high,

respectively the 80th and 85th percentile of livestock holdings which, representing 15.5 and 24.1 Tropical Livestock Unit (TLU), to consider households below the threshold as poor.

2.5.2.2 Weather risk and ex-ante asset portfolio selection

Another way of testing the effect of weather risk on households' assets holding decision, which has been subject to little attention in the literature, involves testing directly how asset holdings vary with the likelihood of shock occurrence. Indeed, to the extent that risk is not insured, it should be reflected in ex-ante decisions.

Rosenzweig & Wolpin (1993), have analysed the effect of weather risk on investment in pump-sets and bullocks among households in rural India, using 10-year period survey. In their model, bullocks were supposed to perform a double function. On the one hand, the asset could be used as buffer for consumption smoothing purposes in the occurrence of the hazard like was assumed in Carter & Lybbert (2012); Fafchamps *et al.* (1998); Hoddinott (2006); Kazianga & Udry (2006); and Mogue (2011). On the other hand, bullock could be combined with pump-set in the farm income generation process like in Dercon (1998). While regression of bullock stock adjustment tends to confirm the procyclical move with farm profit, in contrast to what is shown in Fafchamps *et al.* (1998) and Hoddinott (2006), a drop in farm income increases the likelihood of divestiture, confirming the presence of consumption smoothing motive. Also, a 1000 rupees increase of farm profit increases the likelihood of investing in pump-set by about 0.913 per cent (against 0.824 per cent for getting one more bullock⁴). However, there were considerable under-investments in both

⁴ In the studies by Rosenzweig & Wolpin (1993), net bullock investment includes purchase and offspring while divestment includes sales and death

assets despite their high potential. For instance, while owning a pump would increase the annual farm profit by about 70 per cent of the mean profit, only 31 per cent of households held a pump-set and less than 20 per cent purchased one over the survey period. Also, while owning two bullocks increases farm profit by about five times compared to that of owning one (1800 rupees against 326 rupees), one bullock is held on average. According to the authors, much of this underinvestment is due to credit constraint but also weather risk factors. The study revealed that experiencing a bad weather shock, which probability of occurrence was about 30 per cent, drops farm profit by more than half the minimum consumption requirement. Combined with the higher risk aversion, estimated at 0.964, households would reasonably seek for investment on which rainfall has minor impact⁵ or investments that are relatively more liquid and less costly.

However, the restriction to bullock as liquid wealth limits understanding the weather effect on households' wealth structure, particularly for relatively poor households which may not afford to own such assets. Not surprisingly, their empirical model could not include all households but only those households in the middle range of landholdings. To investigate the risk induced portfolio, there is a need to extend the buffer asset model to include all types of assets reported in the literature (grain, cash, small livestock, poultry, etc.).

⁵ The authors reported that no significant effect can be associated with interaction between pump and bullocks as well as between and lagged weather. While the former tends to reject potential portfolio effects, the latter suggests an indirect effect of weather on profit through its effect on bullocks. This supports the assumption that rainfall shock only affects farming outcome made in the theoretical model.

Rosenzweig & Binswanger (1993) attempted to explain how risk influences the composition of agricultural investments by farm households. In their study, households' assets are first aggregated into nine categories with respect to liquidity and sensitivity to weather variability. Using measures of rainfall risk, they have shown that the composition of households' asset portfolios reflects aversion to risk and is significantly influenced by weather variability. For instance, one standard deviation increase in the coefficient of variation of the timing of rainfall reduces portfolio riskiness by about 0.884 per cent. This result suggests that households facing higher weather risk tend to diversify away from assets for which returns are significantly correlated with weather outcomes. Differences in wealth levels also appear to have important effects. This is reflected by a positive and significant coefficient associated with the interaction term between wealth and weather risk; that is, higher wealth holding enables risk taking. The results suggest similar effects when inherited wealth is used instead of contemporaneous wealth. This implies that households may still shift toward less risky portfolio in the face of increasing weather risk.

This study also provides evidence that insured risk may cause loss of efficiency and lead to lower average incomes as argued by Dercon & Christiaensen (2011) and Rosenzweig & Wolpin (1993). In particular, one-standard-deviation increase in the standard deviation of the timing of the onset of the rainy season would lower farm profit by about 35 per cent of households in the lowest quartile. Furthermore, rainfall variability generates more unequal wealth distribution as a consequence of the ability of wealthier households to absorb more risk than poorer ones as pointed out by Dercon (1998). The latter result contrasts the common supposition of efficiency of small farmer when the analysis deals with return to

agricultural investments. Their results suggest that limitation of ex-post consumption mechanisms also plays a role in the asset holding decisions.

Zimmerman & Carter (2003), using the same dataset as Carter & Lybbert (2012); Fafchamps *et al.* (1998) and Kazianga & Udry (2006), studied the effects of risk and subsistence on wealth accumulation over time. Numerical solution from dynamic programming indicates that optimal grain-land portfolio bifurcates exhibits some particular pattern, given initial asset distribution. Given the weather risk patterns, households may resort to one of three strategies. The first strategy is characterized by households that will be severely adversely affected if they fail to meet consumption needs for all periods of their lifetime. The second strategy involves accumulation of low yielding portfolio, that is, more grain and less land. This implies reconverting land to grain. For these households, income path over time is smoother than consumption, against the prediction of the buffer stock model that consumption is rather smoother (Deaton, 1991). The last portfolio strategy is characterized by higher rate of accumulation despite the prevailing risk. Those households accumulate more land and are able to smooth consumption over time. This study points out the importance of risk on households' accumulation strategies and on their welfare as well. Households in the first group may be considered as trapped into poverty.

Jalan & Ravallion (2001) studied behavioural response to income risk using a panel data from the Rural Households' Survey (RHS) of China over the period 1985-1990. Following Carroll & Samwick (1997), income risk was computed as the residuals of households' income model. Regressing the share of wealth held in unproductive form against the income risk, using quantile regression methods, they found a significant and positive

relationship. The regression coefficient of the income risk factor, however, implies that share of liquid wealth will only reduce from 26.5 to 25.8 per cent as a result of removing total income risk; that the risk is quantitatively small. They further indicated that health and yield risk were relevant to portfolio behaviour; and that the estimate of income risk is similar when these risk measures are ignored.

The study by Jalan & Ravallion (2001) is one of the rare investigations into the direct effect of risk on rural households' portfolio decision encountered in the literature but the focus was on households' idiosyncratic risk. The small quantitative effect of risk suggests that risk only matters for poverty to a little extent. However, the authors might have underestimated the risk faced by households by using income regression approach, biasing downwards the effect of risk. Also, the approach ignores the potential of informal risk coping mechanisms which might work, though not fully efficient, implying that part of idiosyncratic shocks are dealt through such mechanisms (Carter, 1997; Coate & Ravallion, 1993; Fafchamps & Lund, 2003).

2.6 Risk and Households' Labour Allocation

2.6.1 Theoretical Literature on Labour Allocation under Risk

A large body of the literature on off-farm work decisions is empirical. Studies on participation in off-farm activities have extensively used the random utility framework (Ahituv & Kimhi, 2002; Bezu & Barrett, 2010; Liao, Barrett, & Kassam, 2015) where decision to work off-farm appears as a latent variable which is observed when an unobserved utility associated with participation, at any time period, is greater than

otherwise (Greene, 2012). However, with the random utility approach, risk measures are viewed as potential attributes whose mechanisms of interaction are often overlooked.

The theoretical literature on migration also offers a good setting for analysing off-farm labour allocation by smallholder farm households. Labour allocation cross activities by smallholder farmers may indeed respond to wage differentials as predicted by labour migration models. In this case, when deciding whether to allocate labour in the off-farm sector, households compare the net present value of earnings from working on-farm against the net present value of off-farm earnings. The role of income uncertainty may be analysed using the Harris-Todaro model. Considering that the assumption of efficient labour market is not tenable in the institutionalized settings of developing countries, Harris & Todaro (1970), argued that out farm migrants rather compare probabilistic outcomes. However, the Harris-Todaro model still relies on the assumption that decision-makers evolve in a world of perfect information and that risk may be captured by unemployment rate in the competing non-farm sector. This drawback, however, may be overcome by simply allowing stochastic uncertainty in the model.

On the one hand, labour inertia is more often observed while significant gaps exist between economic sectors (Basile & Lim, 2006; Önel & Goodwin, 2014). Also, increased labour mobility may be observed as well while being unexpected (Harris et al., 1970). This may suggest that investment decision are not made as soon as net expected present value of benefits exceeds the net present value of associated costs as argued by the underlying neoclassical theory of investment decision under risk: the Net Present Value (NPV) approach.

As argued by Dixit & Pindyck (1994a) and McDonald & Siegel (1986), given uncertainty, using NPV approach for this theoretical framework to generate the empirical inter-sectoral labour mobility, it is required that either: i) shifts' decisions are completely reversible (or does not involve any sunk cost valuable in the point of view of the decision maker) or; ii) there is no flexibility, that is, the opportunity to shift is lost forever when not exercised at the first instance (Dixit, 1992; Dixit & Pindyck, 1994).

First, there is uncertainty associated with working off-farm. As argued by Dixit & Rob (1994) the fact that the shock hits one sector does not necessarily mean that workers in the competing sector are exempt from the consequences of the risk. Similarly, working in the off-farm sector reduces one's chance of getting higher income when it is a positive shock that hits the economy instead. Second, switching between farm and off-farm activities may not be without costs. Entering the off-farm sector may involve some costs that cannot be fully recovered when one decides to exit. This may include transportation and psychics costs (Dennis & Işcan, 2007). Finally, potential off-farm workers have some leeway about the timing of their decision. These characteristics associated with the decision to allocate resources out of the farm interact to determine the optimal decision. And this may explain the observed discrepancy between the actual behaviour of farm households and the prediction of the net present value approach of investment decision under uncertainty. Therefore, households may engage labour in off-farm activities when expected return to labour is still greater in farming.

The real option approach aims at explaining why households may engage labour off-farm earlier or later than is predicted by the NPV models. Irreversibility, uncertainty and

flexibility interact to determine the optimal timing of investment (Dixit, 1992). Holding on to the status quo gives the opportunity to take advantage of potential future rise in the value of investing but also the opportunity to avoid the negative effects of a downside move of the value.

It is largely accepted, in the real option literature, that increased uncertainty has an inhibiting effect on investment presumably because waiting provides more insights about the future. When recurring shocks affect earnings in a two-sector economy differently, there should be incentives to switch occupation as the relative desirability of each sector falls and rises as shocks continuously hit the economy. However, the observed resource mobility across activities is not always as quickly as predicted by the NPV approach.

Dixit (1989) has analysed firms' optimal entry and exit decisions when the output price in the industry follows a geometric Brownian Process. The model assumes the existence of two different lumpy costs, one incurred while entering the industry and the other incurred while exiting. He shows that the optimal entry and exit triggers differ; that is, it is no longer neither optimal for an idle firm to enter the industry as soon as the market price is greater than the cost incurred to enter; nor for an active firm to exit as soon as the variable cost is greater than the market price of the output. In particular, the random output price must exceed the sum of variable cost and interest on entry cost for entry to be exercised. On the other hand, it is optimal to operate until the unit price of the output is lower than the sum between the variable production cost and the interest on exiting cost. Firms may therefore operate even if they incurred negative profit in the short-run; while potential firms may be

less ready to operate despite a positive short-run profit. As he concludes, these gaps create hysteresis.

Dixit & Pindyck (1994) and McDonald & Siegel (1986) provide an extended theoretical framework for analysing the role of the “value of waiting” in investment decisions. Simulation-based results from McDonald & Siegel (1986) show that, for irreversible investment, option value may be considerable. For some reasonable parameters value, it may be optimal to wait until the benefits are twice the cost of investing. Dixit & Pindyck (1994) provide further discussion about how these three characteristics of investment interact to determine the optimal decision to invest. They show that increased uncertainty has an inhibiting effect on investment.

Dixit & Rob (1994), in a continuous time model, showed that in the absence of risk markets, and for risk averse workers, the dynamic equilibrium of the economy exhibits some inertia. That is, the movement of labour across working sectors is sluggish. This is so because shifts are only relevant when the sectoral productivity differential exceeds certain thresholds, as suggested by Dixit (1989) and Dixit & Rob (1994).

Dennis & Işcan (2007) extended the model by Dixit & Rob (1994) and showed that the presence of subsistence consumption is also relevant to reallocation decision. Using the canonical model of real options, Sarkar (2000), showed that the investment-uncertainty relationship is not always negative. Specific features of his theoretical model are the consideration of earning rather than a firm value as state variable and explicit account for systemic risk. He showed that the relationship between investment and uncertainty is more likely to be positive when current uncertainty is low. This implies that, for low risk projects,

increased volatility might encourage investment. This appears to be the case for low-growth projects as well. The possibility of uncertainty shortening the timing of investment decision is also argued by Kwon *et al.* (2006) who show that the critical value of an investment that triggers the “put” option of investing exhibits some U-shaped relationships against the associated uncertainty. However, contrary to Sarkar (2000), this positive relationship appears to be less likely for low growth projects than high growth projects.

2.6.2 Empirical Literature on Labour Allocation under Risk

Most of the empirical literature has focused on testing whether households’ off-farm allocation reflect ex-post response to weather risk. However, as suggested by the theoretical model, households’ attitudes towards risk may be tested by investigating the ex-ante responses to unanticipated aspects of the risk. Though the model developed in this thesis exploits arguments about the latter, it is worth exploring both, particularly as the former is the most widely encountered.

Bianchi & Bobba (2013) studied decision to engage in non-farm entrepreneurship among households in rural Mexico. They found that cash transfers significantly increase entry to entrepreneurship. This finding, although in line with Bojnec & Fertő (2013) on rural Slovenia, contrasts results from previous studies in the U.S (Mishra & Goodwin, 1997), Cote d’Ivoire and Kenya (Barrett *et al.*, 2001) and Ireland (Hennessy & Rehman, 2008). The latter studies have largely argued that direct payment programmes discourage search for off-farm employment. However, their argument that government payment provides some kind of insurance that helps farmer to deal with farm income variability is very plausible. Negative effect of direct payment on off-farm income is indeed likely when the

competing off-farm sector is characterized by lower returns to labour and therefore not attractive unless for risk coping motives. Conversely, if the competing sector is as profitable as farming, there would be incentive to allocate labour to this sector as well, if entry constraints are removed. This increased entry to entrepreneurship may then reflect an enabling effect on risk bearing than relaxation of liquidity constraints as they have concluded.

Using a two-wave panel data (1999/2000 and 2003/2003) in rural Kenya, Mathenge & Tschirley (2015) have found that long-term mean of rainfall of a region were negatively and significantly associated with off-farm participation (both wage employment and informal business activities and total off-farm work participation). However, their results did not support any short-term adjustment in off-farm participation as a response to unanticipated weather shocks. These results suggest that households engage in off-farm work as a long-term response to weather conditions on their farming operation in rural Kenya. They also found that for participants, earning from non-farm business is higher in region with agricultural potential; suggesting some synergies among the two sectors. Finally, human capital factors (education), other household characteristics (age of the head, household size), landholdings, spatial integration (access to market, roads, telecommunication) and the value of other assets had also significant effect on participation and earnings.

Menon (2009) also found that occupational choice by households in rural Nepal is highly correlated with rainfall uncertainty, using cross-sectional data for the period 1995-1996. According to their results, there is less chance that other members also select agriculture

as an occupation in communities with high rainfall variability if the household head is self-employed in agriculture as main activity. In particular, their results revealed that a one per cent increase in the coefficient of variation of rainfall decreases by 0.61 per cent the probability that another member works in farming. This relationship diversification-rainfall variability is however less evident for households that have access to credit and have relatively high level of human capital, highlighting the importance of liquidity constraints as well.

The effect of weather on off-farm labour supply in rural India has been investigated by Ito & Kurosaki (2009) using a household survey for the year 1997, distinguishing different types of off-farm labour markets. Their results show that off-farm labour supply increases with rainfall variability for all segments of off-farm works. However, the effect is sharper for in kind paid work than cash paid labour employment (2.32 and 1.40 respectively). This suggests that off-farm employment reflects also farm households' concerns about food shortages caused by weather shocks. This study also reveals that the value of livestock holdings affects negatively and significantly labour supply in any type of off-farm work but affects positively self-employment in agriculture. This result may be related to two different things. On the one hand, as argued by Dercon (1998); Rosenzweig & Binswanger (1993) and Rosenzweig & Wolpin (1993), livestock holdings can contribute to raise farm productivity, providing increased incentives for livestock keepers to work more in farming than off-farm. On the other hand, as suggested by Dercon & Christiaensen (2011), differences in livestock holdings may reflect differences in ability to cope with potential weather shocks. High livestock values may therefore encourage risk taking, that is, working more on farm than off-farm.

In addition, households which were subject to rainfall shock in the previous year significantly decreased agricultural labour (by about 2.5 hours) and significantly increased non-agricultural wage labour supply (by about 3.54 hours). Occurrence of rainfall shock on current period does not affect on-farm labour supply, but increase agricultural wage employment and decreases non-agricultural wage labour supply. The magnitude of the response is however lower than the labour adjustment with respect to previous shock and unanticipated shock, suggesting that there may be costs associated with relocation (search time). Landholding was positively associated with agricultural labour and negatively with off-farm labour. The effect of the ratio of land under irrigation on agricultural wage in cash employment was only significant (and negative).

A similar approach, testing both ex-ante and ex-post response to weather risk, were used by Rose (2001) in a three-waves panel data analysis over the period 1968-1971 on Indian farm households. The results indicate a positive and significant relationship between off-farm work participation and rainfall variability, that is, ex-ante response to weather risk. For instance, a marginal increase in the coefficient of variation of rainfall increases the likelihood of off-farm work by about 1.4 per cent. The results also suggest a negative and significant ex-post response to weather shocks. A marginal increase in the rainfall deviation decreases the likelihood of participation by at least 12 percent.

Using a theoretical framework for income decomposition suggested by Paxson (1992), Kwon *et al.* (2006) found that both husbands and wives tend to work less off-farm when they are subjected to positive shock in permanent income among Iowa farm households, almost in the same proportion. According to their results, a marginal increase of permanent

income reduces the probability of working in any off-farm activity by about 0.642 and 0.673 per cent, respectively for husbands and wives. On the other hand, off-farm labour supply declines with transitory income shocks for wives only. The magnitude is however, higher than the effect of permanent income shocks. Indeed, a marginal increase of transitory income reduces their likelihood of off-farm work by about 0.822 per cent. It is likely that the lower magnitude in the case of the permanent income shock is somehow compensated for by the increase in the husbands' work as well.

Richards & Patterson (1998) examined the cause of alleged labour shortages in the fruits and vegetable industry in the U.S. Their empirical results revealed a higher likelihood of labour shortages due to uncertainty in non-agricultural jobs and additional incentives required by workers to engage in inter-sectoral migration.

Luong & Tauer (2006) have investigated the decision to engage in growing coffee among farmers in Vietnam. Their results indicate that farm households enter coffee farming when the farm gate price rises above 47.2 cents/lb and only exit when the farm gate price drops below 14.2 cent/lb for variable cost and total cost of about 19 and 29.3 cent/lb respectively. Meanwhile, there is no entry-exit, confirming the possibility of hysteresis.

Song *et al.* (2011) also studied farm households' decision to convert traditional cropland (corn and soybean) into growing perennial energy crop (switchgrass) under risky crop returns and fixed conversion costs. Consistent with the real option theory, they found that the option value of sticking to the current use of lands delays converting corn-soybean lands to perennial switchgrass as well as converting out of it. Farmers appear to be less ready to shift than the net present value rule of investment predicts. An introduction of

irreversibility implies a greater reluctance to conversion. These findings are in line with conclusion from Musshoff, Odening, Schade, Maart-Noelck, & Sandri (2013) who studied the timing of disinvestment decisions, using experimental methods. However, the latter pointed out that the reluctance in the experiments is more pronounced than the theoretical prediction; suggesting that non-monetary aspects such as attachment to farming may be important as well.

Reardon *et al.* (1992), using ICRISTAT data have shown that non-farm activities constitute an important share of households' income in the three agro-ecological zones in Burkina Faso. They found that harvest shortfalls were a significant driver of income diversification, providing evidence about the role of weather on households' labour allocation decisions, though in the form of ex-post response. Diversification was also associated with higher and more stable income and consumption. This finding tends to contrast our assumption that more off-farm work will be associated with lower income. However, one needs to take into account the fact the survey took place in the middle of some of the worst drought in recent history (Kazianga & Udry, 2006) and therefore may have coincided with some of the lowest recorded farm income. This rather supports the assumption that in the wake of weather shock it pays better to work off-farm than on-farm.

2.7 Conclusion

This chapter has reviewed the broad theoretical and empirical literature on risk induced poverty, risk management strategies and the effect of risk on farm household resource allocation. Risk may push farm households to pursue costly risk reduction strategies, in the absence of reliable formal and informal risk insurance mechanisms, in terms of forgone

returns. This leads to lower income on average, limiting ability of households to move upwards. This is because there is a positive relationship between portfolio riskiness and return, such that ability to abide risk matters for wealth accumulation. Holdings of liquid unproductive assets and work in low risk activities are positively correlated with portfolio risk and negatively with the value of total assets. The effect of risk is exacerbated in the presence of liquidity constraint which may increase the need of relatively stable returns. With respect to asset portfolio, the largest body of the literature exploits the established inter-linkages between production and consumption to explain asset accumulation by consumption or income risk. The mixed empirical findings suggest that consumption may not necessarily be the most important factor in wealth accumulation decisions. This thesis provides an explicit theoretical basis to explain this discrepancy. As labour allocation is concerned, the existing theoretical and empirical literature extensively support the idea that smallholder farm households maximize net present outcomes, which contrast with the observational diversification patterns. Real option approach may therefore provide a better setting for understanding off-farm labour allocation. This is the aim of the theoretical framework developed in the next section.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the theoretical framework of the study and the empirical methods of analysis. It is sub-divided into four main sections. The first subsection presents the conceptual framework. Next, the theoretical and empirical approaches for addressing the first objective are discussed. The third sub-section presents the theoretical and empirical approaches for the second objective; and the last sub-section describes the data used for the empirical analyses.

3.2 Conceptual Framework

Asset and activity diversification reduces poverty by improving wealth prospect. Wealth is improved by sustaining the asset endowments. This may be achieved by means of spreading risk through asset and activity portfolio decisions. The range of assets accumulated by smallholder farm households is usually circumscribed around farm and agricultural related assets because rural households do not hold traditional financial assets such as bonds, stocks or bank deposits. Also, the growing off-farm sector offers an additional means of mediating risk in the rural environment. Off-farm diversification may therefore make wealth accumulation faster by enlarging the set of risk management instruments.

The following conceptual framework (Figure 3.1) analyses livelihood development and poverty reduction based on asset accumulation and the role of activity diversification under

uninsured weather risk. It builds on the literature of the precautionary wealth accumulation (Deaton, 1988; Kimball, 1990). The combination of liquidity constraints and uninsured risks influences the composition of smallholder households' asset and activity portfolios and therefore the ability to accumulate wealth over time.

Asset and activity portfolios depend on the household preferences. Since assets and activities have different risk-return structures, risk preference will determine the household's investment strategies. More risk averse households have high preference for less volatile consumption, and therefore investment returns streams. Indeed, risk aversion is generally identified by preference for the utility of average consumption over the average utility of consumption (Kimball, 1990; Zimmerman & Carter, 2003). This implies that the more risk averse a household is, the higher the proportion of the resource it will invest in the low risk investment (Dercon, 1996; Jalan & Ravallion, 2001; Kazarosian, 1997; Rosenzweig & Binswanger, 1993). Finally, though impatience does not prevent a household from accumulating (Deaton, 1991), it can be expected that more impatience results in less gross investments.

Households' preferences are influenced by their initial endowment in the various assets; that is, total wealth. Indeed, according to Jensen & Pope (2004) and Rosenzweig & Binswanger (1993), aversion to risk is negatively correlated with wealth. It comes out that wealthier households are less risk averse than poorer households.

The household investment decision also depends on the prevailing market conditions. More directly, financial market failure limits ability of households to invest in high yielding assets and activities because such investment generally exhibit high entry constraints in the

form of capital requirement (Dercon & Krishnan, 1996; Maertens, 2000; Zimmerman & Carter, 2003). Indirectly, missing financial risk market may push households to pursue low risk accumulation strategies by ex-ante diversion of productive resources towards less risk but also less profitable agricultural investments such as livestock assets and off-farm activities (Dercon, 1998; Eswaran & Kotwal, 1986; Kochar, 1995; Morduch, 1994).

In addition to the financial market conditions, both assets and agricultural commodity market conditions influence households' asset and activity portfolios decisions because, ultimately, they determine the relative profitability of investment alternatives. For instance, as pointed out by Zimmerman & Carter (2003), thin livestock market may create positive correlation between returns of livestock and other farm assets. When a covariate shock which affects negatively the return to farm assets is experienced, the collective tendency to disinvest the riskless liquid asset may create pressure on its price to fall. Conversely, when the market is well integrated, this collective behaviour will have a very little effect on the asset price. Finally, households which have limited access to agricultural commodity market will have less incentive to invest in farm assets as output surplus could not be marketed. This applies to livestock assets as well.

Finally, the existence of an alternative source of income generating activity, which returns are not affected by the weather source of agricultural risk appears as potential insurance mechanism and can encourage risk taking behaviour Ji *et al.*, (2012). This is the case of off-farm opportunities. On the other hand, access to a liquid asset which return is less affected by the weather outcomes may reduce the incentive to work more in the low yielding off-farm activity in favour of increased investment in the risky high yielding

activity (Dercon, 1996; Dercon & Christiaensen, 2011). The effect may be also by directly expanding the households budget constraint.

Given this background, at the beginning of period and prior to the risk realization, the household selects a combination of farm and livestock assets as well as a combination of farm and off-farm work, which define its accumulation strategy. If, ex-post, no shock is experienced, the returns to assets add up to the assets stocks, leading to an increase in the asset stock. But if a shock is experienced, total return will be lower depending on the proportion of resources allocated ex-ante to the lower investments; and the household must cope with the adverse effects. This may be achieved through a dissipation of the liquid livestock assets, since farm assets have no resale value. This leads to a decrease in the total asset stock. Depending on the magnitude of the shock, full dissipation might be required and therefore households with very small stock of livestock may suffer severe consumption loss. Coping with adverse effects of weather risk may also be achieved by increasing, ex-post, off-farm work at the expense of leisure. The intensity of off-farm work will also depend on the magnitude of the shocks.

The effect of eventual shocks goes beyond the short-term response. Indeed, the likelihood of full dissipation of the liquid wealth is positively correlated with the magnitude of the shock. The cost of full asset dissipation is very high since the household may be subject to loss of labour power next season or even death. Shock may therefore lead to restructuring asset portfolio towards more liquid assets holdings and (or) the activity portfolio towards more off-farm work. The presence of off-farm resources may reduce the risk of low

consumption associated with severe shocks. This can reduce the effect of risk in the further portfolio selection and therefore mitigate the tendency to accumulate buffer as precaution.

The levels of assets achieved at end of period affect the structure of the local economy as well as the policy making. First, policies supporting households' asset accumulation for next period are shaped by the outcome observed at the end of current period and policy maker might not behave in the same way according to whether a shock is experienced or not. For instance, when a shock occurs, depending on the magnitude, specific incentives are required to limit the dissipation (or encourage the accumulation) of assets. Second, local institutions might also be challenged by household risk coping behaviour. Institutions in a community may range from property rights, norms, and the corresponding relationships between individuals that define their participation in market as buyers or sellers. Strong institutions stimulate a system of fair negotiation, trust, and enforcement of contract; improving therefore market conditions (lower transaction costs, increased economic opportunities). They affect the market conditions.

Policies and local institutions are influenced by the village characteristics and together they influence exposure to risk and its magnitude. On the other hand, exposure to climatic risk is a function the specific agro-climatic conditions and its effect depends on the development of agricultural infrastructure. For instance, exclusive rainfed farmers will be worse affected than farmers who have access to some irrigation facilities. On the other hand, exposure to and effect of idiosyncratic shocks depend also on the state of the rural infrastructure (water and sanitation for instance). Both are in turn affected by the both likelihood and magnitude of risks. This might be indirectly through their effect on the

household behaviour or more directly through the damages that they may have on the rural infrastructure. The social planner responds by undertaking decisions that affect the market conditions, which will ultimately affect the trade-off to be set between consumption and saving and between assets.

Implication of the Conceptual Framework

The buffer stock model predicts that consumption smoothing may lead to a complete dissipation of the buffer assets (Deaton, 1991): this is the consumption smoothing strategy of risk reduction by means of asset accumulation. According to (Zimmerman & Carter, 2003), with uninsured risk, consumption smoothing might become a secondary goal for liquidity constrained households who would be managing assets primarily to avoid falling below certain minimum stock of assets; this is the disaster avoidance strategy of risk reduction.

Both approaches are theoretically and empirically documented but the main difference may lie in the asset attributes. As a matter of fact, with exclusive buffer assets (“grain” for instance), consumption smoothing may be the primary motive of accumulation; and accumulated stocks may be readily dissipated along with the length of the impact of shocks as found by Kazianga & Udry (2006) and Mogues (2011).

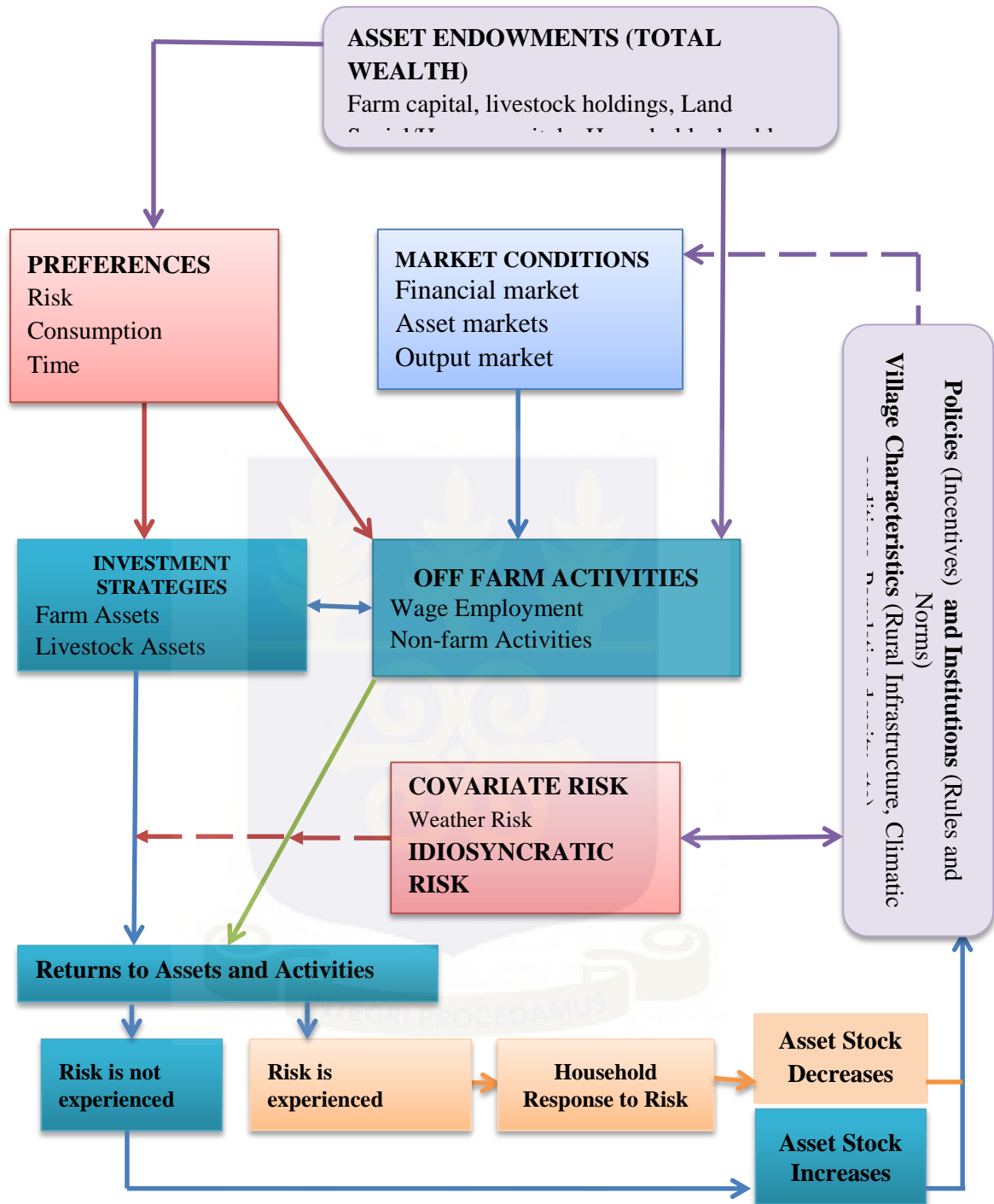


Figure 3. 1: A Conceptual Framework of Asset and Activity Choice under Risk and Liquidity Constraints

Source: Author

However, as pointed out by Rosenzweig & Wolpin (1993), because of the inter-linkages between production and consumption created by the features of the rural environment,

households would tend to hold assets that contribute, either directly or indirectly, to their production process. Selected buffer asset may therefore be semi-productive either in the sense of being used in the farm output generation process or yielding positive return by itself. Full divestiture of such assets could have irreversible consequences and looms large on the household's entire lifetime. The nature of the buffer asset could then imply the coexistence of both consumption smoothing and asset smoothing. This framework therefore conciliates the empirical discrepancy on liquidity constrained household portfolio management strategies with missing insurance markets.

Also, though the use of off-farm income to hedge against farm risk is documented, the empirical approaches have often focused on ex-post risk decisions to work off-farm. Findings suggest that off-farm work could be an alternative to buffer accumulation and therefore a potential substitute (or complement). Even though very little evidence on off-farm diversification on farm asset accumulation is available (Ji *et al.*, 2012), a combination of both may be more promising than relying on either. This framework shows how off-farm work may provide an implicit insurance and help liquidity constrained households to accumulate wealth faster by encouraging risk taking behaviour.

3.3 Model of Smallholder Farm Household' Asset Portfolio Selection under Risk

Consider a risk averse household in an environment characterized by missing financial and risk markets. Such a household is limited in its ability to borrow to consume (or to invest) and lacks access to any contract enforcement to guarantee risk transfers. The household have access to two types of assets. The first, farm capital, is essential in the crop farm production technology; while the second, livestock, is not. Further, it is assumed that land

market is missing; that is, the household only inherits land and can neither reduce it by means of sales nor increase it by means of purchases.

Purchases of farm assets are irreversible investments; that is, they have no resale value. In addition, returns on investment in farm assets is subject to weather outcome. On the other hand, livestock may be sold in any period and their returns are not subject to the weather uncertainty. Returns to farm capital is on average greater than the return to livestock, but for some weather outcomes, return to livestock is better. Unlike in Jalan & Ravallion (2001), total crop failure is not allowed in this model. This implies that the minimum output obtainable from farming is always strictly non-negative.

3.3.1 Returns to Farm Capital

Returns to farm assets is determined by the agricultural production technology. Farm assets are also considered to remain productive for more than one production season and the asset survival is additive to wealth in the next period. A full production function specification may include labour, land, other farm assets, farm inputs and other factors. However, without loss of a generality, a single-input model can highlight most of the dynamics in the effect of weather variability on wealth accumulation decision.

Farm capital held at the beginning of period t , K_t , is subject to depreciation at a rate ϕ . Given an investment ΔK_t undertaken at the beginning of period t , the capital available at beginning of period $t + 1$, K_{t+1} , is given by:

$$K_{t+1} = (1 - \phi)(K_t + \Delta K_t) \quad (1)$$

Equation (1) reflects the assumption that the economic life of farm asset is not limited to a single production period. At the end of each production period, part of the investment undertaken at the beginning of period remains and contributes to the wealth stock. Though missing market would make farm asset residual (salvage value) irrelevant to current consumption decision, as one approaches the optimal level of asset holdings, the rate of additional investment declines, increasing consumption opportunities.

Returns to farm capital which are a direct function of the level of capital holdings is determined accordingly:

$$W^f = F(D, p^f, K_t + \Delta K_t, \theta_{t+1}) \quad (2)$$

In equation (2), W^f denotes the farm wealth, D is the total factor productivity, p^f is the unit price of farm output and θ_{t+1} the random shock. Farm output price is assumed to be constant. This assumption may not necessarily be in line with actual agricultural commodity markets. But it remains a reasonable assumption if one considers the predominance of subsistence farming in rural Burkina Faso. Households are highly concerned with food stocks volatility than market price. Very few smallholder farmers sell farm output to market and many participants sell a very small proportion of the harvested farm output. For instance, MAH *et al.* (2012) reports that at the national level, cereals commercialization represents less than 16 per cent of total production.

3.3.2 Returns to Livestock Assets

Physical return to herding (r_t) may be denoted as $r_t = r(s_t)$ where s_t describes the state of the economy. This implies that livestock holdings may gain or lose value depending on

the state of the economy which is determined by the rainfall weather as well. Fafchamps *et al.* (1998), for instance, considered that the periodic rate of return depends on the previous season rainfall, that is, $r_t = r(s_t|s_{t-1})$. Therefore, this rate of return may reflect offspring and weight gain if positive, and death or weight loss if negative (Fafchamps *et al.*, 1998; Rosenzweig & Wolpin, 1993). Milk consumption is also often conflated with physical returns (Fafchamps *et al.*, 1998). For simplicity, other benefits associated with livestock holdings such as manure are assumed in the physical returns.

Though physical livestock gain would seem to depend on both collective (past and current rainfall for instance) as well as idiosyncratic (e.g. disease, death of herders) shocks as the above specification suggests, there are less arguments that this will be the case as rural Burkina Faso is concerned. First, the development of grazing lands does not require continuous and high level of rainfall like cropping. Therefore, a rainfall distribution that may lead to poor crop harvest may still allow for the development of enough pasture for grazing. Second, the length of the dry season does not vary with time, making the grazing cycle to have similar patterns over time. Finally, livestock may be accumulated primarily for buffer motives; in which case, relatively small numbers will be held from year to year. This limits the potential effect of rainfall on return to livestock even in the context of a general equilibrium. Even though, the effect can be remarkable with extreme events; that is, severe drought or flood, it is still reasonable to assume a constant rate of return. Livestock physical asset return evolves according to the following law of motion:

$$Z_{t+1} = (1 + r^z)(Z_t + \Delta Z_t), \quad r^z > 0 \quad (3)$$

In equation (3), ΔZ_t represents investment in livestock undertaken at the begin of current period. This adds to previously accumulated stock Z_t to determine the stock attainable in the following period, given the constant growth rate r^z .

Given investment decision on current period, wealth available next period is determined as follows:

$$W_{t+1} = F(K_t + \Delta K_t, p^f, \theta_{t+1}) + (1 - \phi)(K_t + \Delta K_t) + p^z(1 + r^z)[Z_t + \Delta Z_t] \quad (4)$$

The smallholder farm household is concerned with determining the levels of ΔK_t and ΔZ_t that maximises the wealth sequence (Equation (4)) over an infinite horizon, subject to the inter-temporal budget constraint:

$$\Delta K_t + p^z \Delta Z_t \leq W_t - C_t \quad (5)$$

Where C_t and W_t represent respectively current consumption and available wealth. In Equation (5), the price of farm capital has been normalized to be the numeraire; therefore livestock price (p^z) may be seen as a relative price.

Borrowing constraints imply that each asset must be non-negative. This implies that in each period, we must have:

$$0 \leq \Delta K_t \leq W_t \quad (6)$$

$$-Z_{t-1} \leq \Delta Z_t \leq \frac{1}{p^z} W_t \quad (7)$$

Moreover, consumption in each period has to be non-negative. The constraint is often assumed as never binding. Rosenzweig & Wolpin (1993) for instance assumed the existence of a minimum consumption level to guarantee survival even after complete divestiture of the tradable asset. This can be achieved by assuming the existence of a kind of a disaster insurance that may take the form of governmental safety nets. According to Dercon (1998), it suffices that net income from activities in each period be always positive. Zimmerman & Carter (2003) included an additional state variable indicating whether the household's consumption falls below a specified minimum subsistence level. In their model, such a household receives zero utility for that period and for every period thereafter. In other words, a household will live in year t only if consumption in any year before t has not fallen under this minimum consumption level.

In this study, the assumption of risk aversion implies a convexity in the marginal utility function. Because the marginal utility tends to infinity as consumption tends to zero, zero consumption will never be a feasible option for the household. This condition is imposed by concave preferences. In terms of numerical computation of the optimal decision, zero or negative consumption is associated with a value of “*minus infinity*” as a sum of current and future rewards implied by the associated action. Under these conditions, a strictly positive consumption is always preferred to a non-positive one; so, this constraint is never binding.

To understand better the decision-making process, the time period may be split into two distinctive seasons as in Carter & Zimmerman (2000) and Rosenzweig & Wolpin (1993): a production season and a post-production season. At the beginning of each production

period, households have a predetermined (but ultimately endogenous) endowment in farm capital and livestock assets; and *cash* defined as the income flows from assets held in previous period. They maximize utility flows through the short-term consumption and factor allocation (fixed farm assets and livestock assets). The realization of the random shock that affects returns to farm assets occurs after current accumulation decision has taken place. This shock, which also describes the state of the system at any given period, is weather related and is assumed to affect only the crop production; that is, investment in livestock is safe with respect to this source of risk. However, though solving the optimization problem with all these choices and states is feasible, it is analytically and computationally very intense.

Nevertheless, without loss of generality, the dimensionality of the dynamic program can be reduced in an attempt to reduce the complexity of the analytical and numerical solution (Stokey *et al.*, 1990). This requires accommodating the timing and the resolution of the uncertainty. Let's assume that accumulation decisions are made in the post-production season. Though, uncertainty seems to have been resolved, this does not clear the risk because the decision to be made in the next post-production season depends on the realization of the shock during the preceding production season. In this case, however, the decision-maker can be viewed as *choosing directly the level of next period's state variables* (Stokey *et al.*, 1990). And for a household, what will be observed are sequences of consumption, farm capital, livestock holdings and shock values.

3.3.3 Problem of the Household

The problem of the household is to determine the optimal asset holdings and consumption sequences that maximize utility flows over the planning horizon.

$$\max_{\{c_t, K_t, Z_t\}} E_t \left\{ \sum_{t=0}^{\infty} \delta^t u(c_t) \right\} \quad (8)$$

where u is concave, with curvature reflecting risk aversion; and δ the household's subjective discount factor. Without borrowing constraints, the convexity in the marginal utility controls the degree of precautionary motive. The presence of borrowing constraints interacts with and reinforces this precautionary motive (Deaton, 1991). Liquidity constraint therefore provides an additional motive for building asset stocks when times are good, even for impatient consumer.

3.3.4 The Dynamic Programming Model

The household's investment decisions can be analysed using dynamic programming methods based on Bellman's principle of optimality (Bellman, 1957). Applying the principle of optimality yields the well-known Bellman's recursive functional equation. This functional equation, $V_t(w)$, called Value Function, captures the essential of the problem faced by dynamically optimizing agents which reflects the need to balance optimally immediate and expected future rewards. The Bellman Equation can be written as follow:

$$V_t(w) = \max \{ u(c_t) + \delta E_t V(w_{t+1}) \} \quad (9)$$

A key trade-off to be captured in the model is that between current consumption and asset accumulation for future wealth. Another trade-off is that between assets that will comprise the portfolio. Bellman's principle of optimality shows that the optimization problem defined in Equation (1) over the infinite horizon can be reduced to the optimal policy over two consecutive periods (t and $t + 1$); that is current asset holdings $\{K_t, Z_t\}$ and wealth in the immediately subsequent period $\{w_{t+1}\}$.

3.3.4.1 Model summary

Horizon

- $T = \infty$ Planning horizon

The household is assumed to maximize utility flows over an infinite horizon. This reflects the concern that parents have for the welfare of their children.

State and action variables

In each period t , wealth must be divided into consumption $\{c_t\}$ and gross investment in either or both assets which determines the total assets available for the production season $\{K_t, Z_t\}$. Next period wealth is determined by the level of currently held assets and the ultimate shock $\{\theta_t\}$ realization. The shock is assumed to be a Markov chain.

The state variable is therefore the wealth at w_t the beginning of period.

- $w_t \in \mathbb{R}^+$ Total wealth at beginning of period

While the action variables are:

- $K_t \in \mathbb{R}^+$ Value of farm capital
- $Z_t \in \mathbb{R}^+$ Number of livestock unit held

All state and action variables are assumed to be continuous and perfectly divisible.

State Transition

$$w_{t+1} = f(K_t, p^f, Z_t, \theta_t) + (1 - \phi)K_t + p^z(1 + r^z)Z_t \quad (10)$$

Next period wealth is made of the return to assets in addition to the value of assets carried over that period.

Reward function

$u(c_t)$: Instantaneous utility of consumption

Budget constraint

$$C_t + K_t + P^z Z_t \leq w_t \quad (11)$$

3.3.4.2 Solving the model

Budget Constraint

At an optimum, output will not be wasted; and all returns are either consumed or invested in either or both assets for the sake of future consumption. The budget constraint therefore will always be binding and inter-temporal budget constraint will always hold with equality.

$$C_t + K_t + p^z Z_t = w_t \quad (12)$$

Euler Conditions

The Euler conditions are obtained by applying the Karush-Kuhn-Tucker Conditions and the Envelop Theorem to the optimization problem embedded in the Bellman Equation (Miranda & Fackler, 2002). Since the value function of a discrete time infinite horizon continuous state Markov Decision Model will be the same for every period according to the principle of optimality (Bellman, 1957), the time index may therefore be discarded such that the value function simplifies to

$$v(w) = \max\{u(c) + \delta E_{\theta} v(w)\} \quad (13)$$

Karush-Kuhn-Tucker Conditions

$$\mu_K = -u'(c) + \delta E \lambda_w (E_{\theta} F_K + \psi) \quad (14)$$

$$\mu_Z = -u'(c)p^z + \delta \lambda_w p^z (1 + r^z) \quad (15)$$

μ_K (respectively μ_Z) is the shadow price of capital (respectively livestock). It measures the current and expected future rewards from a marginal increase in current gross investment in farm capital (respectively livestock assets). Investing in a “unit” of farm capital today implies forgoing $u'(c)$ this period but is worth $\lambda_w (E_{\theta} F_K + \psi)$ the next. A marginal increase in current livestock investment implies forgoing $u'(c)p^z$ for the sake of $\lambda_w * p^z (1 + r^z)$ next period.

Envelop Theorem

The Envelop Theorem summarizes gains obtained from a marginal increase in the current stock of wealth.

$$\lambda_w = u'(c) + \max(\mu_K, 0) + \max(\mu_Z, 0) * \frac{1}{p^z} \quad (16)$$

Current consumption could increase, which is worth $u'(c_t)$. Increase in the wealth stock might also serve the purpose of investment in either or both assets. The latter is captured the sum of the maxima resulting from marginal increases in the respective asset stocks.

Complementarity Conditions

Since actions are subject to bounds, there is a need to take into consideration the possibility that these constraints would be binding (corner solutions). The complementarity conditions summarize the inter-temporal arbitrage conditions. The following complementarity conditions need to be satisfied at an optimum:

$$K_t > 0 \Rightarrow \mu_K \geq 0 \quad (17)$$

$$K_t < w_t \Rightarrow \mu_K \leq 0 \quad (18)$$

Equation (17) and (18) reflect the necessity that at the optimum, there will be no worth in changing asset holdings, that is, the portfolio composition. In fact, at an optimum μ_k must be non-negative if K is greater than its lower bound ($k > 0$). Otherwise, there is incentive to lower K because rewards are increased by doing so. Similarly, if K is lower than its upper bound (all wealth is not held in farm assets), μ_k must be non-positive; otherwise,

rewards can be increased by increasing the stock of capital. Therefore, at an optimum, K must neither be at its lower bound nor at its upper bound, that is, μ_K must be zero. These conditions apply to the shadow price of livestock as well.

By substituting the shadow prices by their expression from Equation (14) and (15), the intertemporal arbitrage function can be summarized as

$$K_t \geq 0 \perp \delta E_t \lambda_{w,t+1} (E_t F_K + \psi) \leq u'(c_t) \quad (19)$$

$$Z_t \geq 0 \perp \delta E_t \lambda_{w,t+1} (1 + r^z) \leq u'(c_t) \quad (20)$$

At the optimum, both μ_Z and μ_K must be non-negatives if actions exceed their respective lower bounds. Similarly, if actions are lower than their upper bounds, μ_Z and μ_K must be non-positive. Only where a corner solution is applicable should we have either asset at any extreme. For an interior optimum, K and Z must neither be at their lower bounds nor at their upper bounds; i.e. μ_K and μ_Z must be zero. Applying these optimality conditions to the Karush-Kuhn-Tucker conditions and the Envelop Theorem yields, given some algebraic rearrangement, the following results:

$$K_t < w_t \Rightarrow \mu_K \leq 0 \quad (21)$$

$$K_t > 0 \Rightarrow \mu_K \geq 0 \quad (22)$$

$$Z_t < \frac{1}{p^z} w_t \Rightarrow \mu_Z \leq 0 \quad (23)$$

$$Z_t > 0 \Rightarrow \mu_Z \geq 0 \quad (24)$$

$$\delta u'(c_{t+1})(E_{t+1}F_K + \psi) \leq u'(c_t) \quad (25)$$

$$p^z(1 + r^z)\delta u'(c_{t+1}) \leq u'(c_t)p^z \quad (26)$$

Equation (21) to (26) may be summarized as follow:

$$K_t \geq 0 \quad (27)$$

$$Z_t \geq 0 \quad (28)$$

$$\delta u'(c_{t+1})(E_{t+1}F_K + \psi) \leq u'(c_t) \quad (29)$$

$$p^z(1 + r^z)\delta u'(c_{t+1}) \leq u'(c_t)p^z \quad (30)$$

As long as farm capital is held, Equation (29) holds with strict equality. This follows from the discussion on the complementarity conditions. This equality reflects the fact that utility derived from the consumption of a unit of wealth in the current period must be equal to the discounted expected utility of investing it in farm capital and consuming the yield in the following period. If livestock are held at the same time, Equation (30) also holds with strict equality. Similarly, utility derived from the consumption of a unit of wealth in the current period must be equal to the discounted expected utility of investing it in livestock and consuming the yield in the following period. The standard portfolio model is therefore obtained with the household selecting quantities of assets that equalise the marginal utilities obtained from each asset; that is:

$$\delta u'(c_{t+1})(E_{t+1}F_K + \psi) = (1 + r^z)\delta u'(c_{t+1}) \quad (31)$$

From the production perspective, Equation (31) also reflects the optimality condition that marginal rate of substitution between assets must be equal. By just using simplification, Equation (32) is readily found:

$$E_{t+1}F_K + \psi = (1 + r^z) \quad (32)$$

Indeed, if the expected returns to the assets composing the portfolio are not balanced, the optimally behaving households will find incentives to shift investment towards the highest yielding asset.

Equation (29) and (30) can help highlight the reasons why the household may not invest in either asset. Let's reconsider the general first-order Karush-Khun-Tucker conditions.

Livestock Asset Holdings

$$p^z(1 + r^z)\delta u'(c_{t+1}) \leq u'(c_t)p^z \quad (30)$$

This relationship is the inter-temporal asset arbitrage under borrowing constraints and concave utility (Deaton, 1991; Dercon, 1998). The household will invest in an additional unit of the asset only if the discounted marginal utility exceeds that of consuming the investment value today.

As long as the assumption that the household is a price-taker in all existing markets and that livestock price is constant holds, livestock price will not matter. Livestock holdings are therefore determined by return and consumption opportunities. If current consumption is sufficiently low, relative to the future consumption, the right-hand side of Equation (30) gets higher, implying that investment must be forgone, or that previous stock must be

alienated, in order to raise current consumption. Conversely, if the household is facing future downside consumption, it is the left-hand term that rises; and the household has more incentive to invest in livestock, or more disincentives to alienate previously accumulated assets, in an attempt to rise next period consumption. In addition, for a given level current and future consumptions, the return to livestock may weigh against current consumption. The higher the certain rate of return, the higher the incentive to invest in (the disincentive to alienate) livestock. However, if livestock is kept mainly for consumption smoothing, higher rate of return would provide less incentive to invest in large amount as insurance is quickly achieved. Nevertheless, because marginal utility tends to infinity as consumption tends to zero, and to zero as consumption approaches infinity, the consumption utility may likely outweigh the returns opportunities.

Farm Capital Holdings

It suffices that the assumption on the return to livestock is relaxed by allowing risk to find the equation related to farm capital investment decision.

$$\delta u'(c_{t+1})(E_{t+1}F_K + \psi) \leq u'(c_t) \quad (29)$$

The relationship (29) shows how risk and liquidity constraints interact to provide disincentive to hold higher levels of farm capital. Because farm outcome and consumption will be necessarily linked in agricultural economy, so will be their expectations. For instance, when the household faces unfavourable weather conditions, the likelihood of lower future consumption is higher and therefore the marginal utility, everything being equal, will go on increasing. It becomes optimal to reduce current investment in farm

capital. But because farm assets are intrinsically irreversible investment, the household may often only have the option to let held assets depreciate.

Let's assume that none of the asset constraints is binding. The optimal investment is described by Equation (32). When the household faces unfavorable weather conditions, the disincentive to invest in farm capital is higher because of the risk of crop failure; while return to livestock remains unchanged. The relative return to livestock therefore rises and the household may "readjust" the portfolio away from the risky asset and towards the riskless asset (or invest more in livestock).

In sum, liquidity constraints and (or) lack of insurance may encourage investment in lower risk production structure. This may go along with implicit risk avoidance behaviour where consumption smoothing would become a secondarily objective. This may likely be the case in rural Burkina Faso as previous studies have found less evidence of consumption smoothing. This effect goes beyond basic risk preferences as where the social risk articulation offers appropriate means for risk pooling, risk averse households may still be able to abide risk and invest in high yielding asset portfolios. When these social mechanisms are not effective, the tendency to lower risk will result in lower return portfolios which may create and perpetuate poverty.

3.4 Empirical Analysis of Households' Asset Holdings

3.4.1 Econometric Specification

Despite the effort to analyse the determinants of each asset of the portfolio, in the empirical approach, the intensity of the riskless low yielding asset is considered as the dependent

variable. In addition, accumulated livestock are augmented by grain stock holdings to define the total liquid wealth of households. Let's recall that a key assumption in this study is that aversion to risk may push households to hold increasingly riskless non-productive or low yielding assets and that this may cause poverty. For this reason, the model gets simplified.

When a household holds both assets, the optimality conditions imply that assets must be held in quantities that equalise their respective marginal returns; that is, $E_{t+1}F_K + \psi = (1 + r^z)$. The portfolio is therefore determined by the relative profitability of assets. As long as the return to riskless assets is constant like the survival rate of the productive assets, this relative profitability will be entirely driven by the distribution of the risk. It can be argued that the main risk variable affects the relative attractiveness of the assets in the opposite direction. For instance, while increased rainfall volatility reduces the desirability of the productive farm asset, it increases that of assets which return distribution is not tight to the distribution of the rainfall. Therefore, a positive relationship between the uncertainty measure and the proportion of the portfolio held in the riskless asset form will reflect that the households will tend to hold more the lower return asset as a means of ex-ante risk reduction. More generally, the portfolio will be influenced by other factors influencing the marginal return of the risky assets.

Let's define s_{it} the share of the value of liquid assets in the household wealth portfolio. In a linear specification, the portfolio choice may be written as follow:

$$s_{it} = \beta_0 + X'_{it}\beta_1 + \beta_2\theta_i + \beta_3\zeta_{it} + \beta_4\bar{\xi}_v + e_{it} \quad (33)$$

Where X_{it} is a set of exogenous variables of households' characteristics and, θ_i , ζ_{it} , and $\bar{\xi}_v$ are respectively the coefficient of variation of the rainfall, the rainfall deviation from its long-run mean and the long-run mean of the village level rainfall. In Equation (33), $e_{it} = v_i + \varepsilon_{it}$ where v_i is the household specific effect and ε_{it} is an error term. The individual fixed effects are assumed to be uncorrelated with the set of covariates, that is:

$$E(v_i|X_{it}) = E(v_i|\theta_i) = E(v_i|\zeta_{it}) = E(v_i|\bar{\xi}_v) = 0 \quad (34)$$

It is likely that the effect of a mean-preserving shift in the variability of rainfall on the portfolio composition depends on the households' total wealth as argued Jalan & Ravallion (2001) and Rosenzweig & Binswanger (1993). This suggests that, at any given point in time, accumulated wealth and portfolio will both reflect cross households subjective risk preferences. Therefore, the assumption $E(v_i|X_{it}) = 0$ will likely not hold if X_{it} includes total wealth. Furthermore, there may be some self-selection of less risk averse households into riskier portfolio situations. Since less prudent households may be less responsive to rising rainfall uncertainty, there may be a potential downwards bias in rainfall risk effects (Kazarosian, 1997).

As indicated earlier, fixed-effect cannot be used to wipe this risk heterogeneity while allowing to identify the effect of rainfall uncertainty. According to Rosenzweig & Binswanger (1993), recourse to inherited wealth may help reduce biases associated with subjective risk heterogeneity, as long as inherited wealth is orthogonal to households' risk preferences. Unfortunately, such information is not available in the context of this study. These authors have also used the stock of current wealth but obviously, such estimates are biased and inconsistent as the correlation between the stochastic term structure and wealth

is very likely as mentioned above. In order to minimize the intrusion of these potential source of bias, a two-stage approach is used as it is common in the literature. The approach by Jalan & Ravallion (2001) will be used here, estimating, first, the households' income equation following Equation (35).

$$\ln y_{it} = \alpha_0 + x'_{it} \alpha_1 + \mu_i + \gamma_v + \varepsilon_{it} \quad (35)$$

In this specification, the left hand is the logarithm of the households' total income, x'_{it} is a set of exogeneous variables, including households' socio-demographic characteristics and endowments. The error structure is assumed to be

$$E(\varepsilon_{it}) = 0 \text{ and } \text{var}(\varepsilon_{it}) = \sigma_\varepsilon^2 \text{ and } E(\varepsilon_{it} x'_{it}) = E(\varepsilon_{it} \theta_{vt}) = E(\varepsilon_{it} \mu_i) = E(\varepsilon_{it} \gamma_v) = 0$$

From the income equation, a permanent income measure is derived to be used as the proxy of wealth. The household permanent income is measured as

$$\ln \hat{y}_i^p = T^{-1} \sum_{t=1}^T \ln \hat{y}_{it} \quad (36)$$

Where \hat{y}_{it} is the predicted income for households i in year t .

Therefore, exclusion restrictions are necessary to identify the income and portfolio equations. There is also the concern as to whether the time-invariant risk variable (and other time-invariant variables) are not proxying for unobserved household fixed effects. Ideally, one would have liked to test for fixed effects but, in this case, the variable of interest is time-invariant which are not identified under a fixed-effects specification. Nevertheless, if the regression is sufficiently well specified at both household and community levels, this gives some confidence that the risk variables are not substituting

for unobserved household heterogeneity. The portfolio equation is therefore estimated using random effect estimation as in Kazarosian (1997) and Rosenzweig & Binswanger (1993).

The choice of the random effects model is also suggested by the nature of the data which have been collected over two consecutive years. This implies that most of the variations in the data are between rather than within households. Therefore, fixed-effect estimators are less likely to be efficient as they rely, by construction, on within variation (Cameron & Trivedi, 2009). The random-effect model is the most appropriate for this data because the model addresses the complications that observations are correlated over time for a given household.

In estimating the portfolio equation, it is controlled for the household structure (number of male and female adults, dependency ratio, gender, age and the ethnical group of the head of the households). It is also controlled for ex-post risk coping ability (remittances, off-farm income). To control for transaction costs, distance to paved road and a dummy variable indicating whether there is a market within the particular village are included. Another village level variable is the number of inhabitants of the village. While this variable may control for the demand of liquid assets, it may also account for some constraints for herd sizes. With respect to public policies and programs, I include dummy variables indicating respectively whether SOFITEX⁶, and an NGO intervenes; and whether there is an ongoing public development programme in the village.

⁶ SOFITEX is the national company (parastatal) for textiles. It provides input and seed to cotton farmer in the form of credit that is repaid after harvesting

3.4.2 Risk Variables

Identification of the risk faced by farm households is the first step in testing the prediction that, *ceteris paribus*, higher weather risk will lead to increased liquid asset holdings. This information will be used in a second step to explore the empirical relationship between the risk measure and portfolio composition. Empirical investigations of the presence of precaution motive on households' accumulation decision mostly assess households' income risk by the innovation error of the households' income equation (Jalan & Ravallion, 2001) or the transitory component of their income (Carter & Lybbert, 2012; Kazianga & Udry, 2006; Kwon *et al.*, 2006) following the income decomposition framework by Paxson (1992).

But it is likely that all variability in the households' income is not only due to weather. Idiosyncratic factors such as diseases, animal damage, and input dosages etc. may play a non-negligible role as well. Inability to account for the potential effect of such risk factors may underestimate the actual income risk faced by the households (Kazianga & Udry, 2006). Furthermore, according to Dercon & Christiaensen (2011), potential correlation between the shock variable and some of the explanatory variables in the households' income equation may have similar consequences. Finally, the use of households' idiosyncratic risk measures may overlook the potential risk reduction effect of informal risk sharing mechanisms on the household attitudes towards risk.

A key assumption of this study is that covariate rainfall shock remains the most important source of uninsured weather risk and that much of the effect of related shocks is borne individually presumably because of ineffective social risk articulation. While missing risk

markets is a natural assumption for rural economies in developing countries, the weakness of the social risk articulation mechanisms is empirically documented (Kazianga & Udry, 2006) in the case of rural Burkina Faso. This is the main reason why a risk averse household will forego high-return assets at the expense of lower return portfolio.

Obviously, for subsistence rainfed farmers, return to farming will necessarily exhibit high correlation with rainfall as suggested by previous findings (Carter, 1997). Information on actual rainfall data is therefore a good proxy for weather risk as farming is concerned (Menon, 2009) and will be used to estimate the risk variables.

Rainfall is a random variable which the household cannot observe prior to its realization when investment decision has to be made at the beginning of farming season. However, the household has knowledge about the long-run mean and the variability of the rainfall distribution. The latter is indeed the coefficient of variation of rainfall. In the ex-ante perspective, this represents the aspects of the risk variable that will affect the decision as to whether and how much to invest across in each asset type. From the discussion on the theoretical framework, the rainfall variability may affect the decision in two ways. On the one hand, there may be a portfolio adjustment towards the riskless asset and away from the productive risky asset as uncertainty rises. On the other hand, there may be a precautionary motive as the household will likely invest more, and consume less, to increase the chance of getting high income. These two effects may interact to generate a positive effect of rainfall variability on the intensity of the riskless asset. But if the return to the riskless asset is too low, the precautionary behaviour may imply increased investment in the risky asset.

After harvesting, the household can observe the actual rainfall level and may respond more directly to the rainfall shock. The rainfall shock will actually be the rainfall deviation from its long-run mean. On the one hand, for low level of the shock or for positive shock, higher income will be achieved and the household will not need to alienate the liquid asset (or invest more in either or both assets). On the other hand, if the household experiences a bad shock, lower income will be achieved. There are incentives for the households to alienate assets to supplement consumption

3.4.3 Other key Variables

Total Wealth

Households' wealth is measured as the value of total asset holdings: land, farm equipment, livestock assets, grain and other non-farm assets. The measurement follows from the concept of sustainable wealth measurement by Arrow *et al.* (2012).

Land value is estimated as crop wealth following (Arrow *et al.*, 2012; World Bank, 2011). For a household holding a land of size s in an area where the average crop yield is y and the market price of agricultural output is p , land value (cw) is given by:

$$cw = s * y * p \quad (37)$$

Farm equipment and non-farm assets is valued using Perpetual Inventory Method (PIM). Consider an initial investment K_{i1} in an asset i which economic life is T_i . With the linear depreciation approach, each period, the asset value is reduced by $\frac{1}{T_i} * K_1$. Note $\phi_i = \frac{1}{T_i}$ the rate of depreciation. After t period of use, the actual value of the asset, also called capital

survival, is therefore $K_{it} = (1 - \phi_i)^{t-1} * K_{i1}$. For a stock of N assets, the total value of assets is simply the summation of all asset survivals; that is:

$$K_t = \sum_{i=1}^N K_{it} = \sum_{i=1}^N (1 - \phi_i)^{t-1} * K_{i1} \quad (38)$$

Livestock, according to the theoretical background is, on the other hand considered to get appreciated over time. However, livestock growth rate is not available. Because a livestock asset price depends on its age, to overcome this limitation of the data, the market value of livestock holdings is considered. For instance, the market price of an asset of age a would be p_a . The relationship between age and price should be inverted U-shaped, as reflected by the data. For n units of an asset i of age a , the value is

$$L_{ait} = p_{ait} * n \quad (39)$$

For N types of livestock assets, the total livestock value is

$$L_t = \sum_{i=1}^N L_{ait} \quad (40)$$

Value of poultry is also simply computed as the market price multiplied by the number of units held, accounting for differences in prices of different poultry assets (mainly chicken birds and guinea fowls). Consider a household holding N different poultry assets. Each asset i , which the market price of asset is p_{it}^{poul} is held in n_{it}^{poul} units. the value of poultry is

$$poul_t = \sum_{i=1}^N p_{it}^{poul} * n_{it}^{poul} \quad (41)$$

The value of poultry is added to this to make the total livestock wealth.

The value of grain stock is the grain equivalent value of all stock of agricultural commodities held by the household. According to (Carter, 1997), the grain equivalence of agricultural output can be obtained as follow. Consider p_g (respectively q_g) the price (respectively the quantity held) of grain, referred to sorghum in this thesis. For a different agricultural commodity h held in quantity q_h and which market price is p_h , its value in grain equivalence is

$$G_h = \frac{p_h}{p_g} * q_h \quad (42)$$

Total grain stock is given by

$$G_w = p_g (\sum_{h=1}^N G_h) \quad (43)$$

Liquid Wealth is the value of liquid assets; that is, livestock, poultry and grain stocks. Liquid Wealth1 is the value of small livestock; poultry and grain. Liquid Wealth2 is Liquid Wealth1 augmented by the value of large livestock. The value of draught animal owned is considered as farm capital.

3. 1: List of Explanatory Variables used in the Regression to Explain Liquid Asset Holdings

VARIABLES	Definition	Measurement	Expected Sign
RISK FACTORS			
Rainfall (CV)	Coefficient of variation of rainfall		(+)
Mean Rainfall	District level long-run mean of rainfall	Millimeters	(-)
Rainfall Deviation	Rainfall deviation of from its long-run mean	Millimeters	(+/-)
HOUSEHOLD			
Age of the head	Age of the head of the household	Years	(+/-)
Age of the head (squared)	Age of the head of the household (squared)	Year	(+/-)
Access to Credit	1 if household did receive a loan, 0 otherwise		(-)
Net Regular Transfers	Net received amount on regular base	CFA	(-)
Net Occasional Transfers	Net received amount occasionally	CFA	(+/-)
Access to Fertilizer	1 if household uses fertilizer, 0 otherwise		(+/-)
Access to Seed	1 if household uses improved seed, 0 otherwise		(+/-)
Use of Manure	1 if household uses manure, 0 otherwise		(+/-)
Household Size	Number of household' s adult member	Adult equivalent	(+/-)
Dependency Ratio	Number of dependents per adult		(+/-)
Ethnical Group	1 if the head of the household belongs to ethnical groups which are traditionally involved in farming		(-)
Marital status of the head	1 if the head live in union, 2 if separated or widowed, 0 otherwise		(+/-)
Source of Energy	1 if household has access to energy, 0 otherwise		(+)
Gender of the Head	1 if the head of household is male		(+/-)
Primary Education	1 primary education, 2 secondary education, 3 Medersa, 0 otherwise		(+/-)
VILLAGE CHARACTERISTICS			
Population Size	Number of inhabitants of the village		(+/-)
Distance to Paved Road	Distance to the nearest paved road		(+/-)
Sofitex	1 if SOFITEX intervenes in the village, 0 otherwise		(+)
NGO	1 if an NGO intervenes in the village, 0 otherwise		(+/-)
Public Program	1 if there is an ongoing public development program in the village, 0 otherwise		(+/-)
Village access	1 if village is accessible by vehicle all the year, 2 only during dry season, 0 if not accessible		(+/-)
Market Dummy	1 if there is a market within the village, 0 otherwise		(+/-)
Agro-ecology	0 household is in the soudanaian zone, 1 if in the soudano-sahelian and 2 if in the Sahelian		(+)

3.5 A Model of Smallholder Farm Households' Labour Allocation under Risk

This section models the smallholder farm household's labour allocation decision. The previous assumptions about risk aversion, liquidity constraints and weather risk are maintained. The household, which is already engaged in the risky farming activity has the possibility to undertake off-farm work which return is lower on average but is not subject to weather vagaries.

3.5.1 The Model

At the beginning of each period t , a household that is already involved in farming decides whether or not to engage part of its labour resources in off-farm activities. Labour is considered as the sole input in both activities. However, a unit of labour-time allocated on the family farm returns ω_t^a which depends on the realization of a weather related stochastic shock while a unit of labour employed in the off-farm activity returns a certain wage ω_0 . Labour allocation decisions must occur prior to the realization of the shock; that is, the actual return to labour, attainable at the end of period depends on this random shock.

It is assumed that there is no direct synergy between these working sectors, that is, there is no direct benefit on return to farming as a result of working off the farm and vice-versa. This implies that production in the two activities are independently carried over, depending on the amount of input provided to the related activities. For simplicity, technology is assumed to exhibit constant return to scale patterns.

In each year, depending on the amount of labour allocated to each activity, the potential return to labour can be described by the following equation

$$w_t = \omega_t^a l_t^a + \omega_0 l_t^o \quad (44)$$

s.t

$$l_t^a + l_t^o \leq L \quad (45)$$

where l_t^i represents the amount of labour allocated to activity $i \in \{a, o\}$, respectively for farming and off-farm work. L is the total labour available to the household, which includes family labour and hired labour.

For convenience, let's normalize L to unity and define therefore l_t as the share of household labour employed in the off-farm activity. Expressions (44) and (45) become

$$w_t = \omega_t^a (1 - l_t) + \omega_0 l_t \quad (46)$$

$$0 \leq l_t \leq 1 \quad (47)$$

3.5.2 Problem of the Household

The household is assumed to maximize, over an infinite horizon, the flows of utility of consumption:

$$\max_{l_t} E_t \left\{ \sum_{t=0}^{\infty} \delta^t u(c_t) \right\} \quad (48)$$

Where $u(c_t)$ is concave with curvature reflecting risk aversion; and δ the household subjective discount factor. The smallholder farmer problem is therefore to select the optimal labour allocation decision consecutive to the decision to work off the farm. The

household decision making can be analysed in the setting of a dynamic programming model.

3.5.3 The Dynamic Programming Model

3.5.3.1 Model summary

Horizon

$T = \infty$ Planning horizon

As mentioned above, the household maximizes utility flows over an infinite horizon; reflecting inter-generational well-being considerations.

State Variables

The household decision making is based on:

- $\omega_t = \frac{\omega_t^a}{\omega_0} \in (0, +\infty)$ The potential relative return to labour.

The relative return to labour is the ratio of return to labour on farm to that of labour in the off-farm sector. The positive relative return to labour implies that the lowest return to labour on farm is strictly non-negative. But in some states of the economy, labour return from the off-farm sector is higher than that from the farming sector; i.e. the marginal return to labour in farming is positive for some values of shock and negative for some others.

- $$i_t = \begin{cases} 0 & \text{Household did not work off – farm last period} \\ 1 & \text{Household did work off – farm last period} \end{cases}$$
Past off-farm work status

The binary discrete state variable i_t defines the off-farm work status of the household during the preceding period as it is observed at beginning of current period. At the beginning of period t , the household has a status i_t that takes the value $i_t = 1$ if the household had some labour in the off-farm activity during last period and $i_t = 0$ if the household did not engage labour resources in the off-farm activity.

Action Variables

The action j_t defines the household off-farm work status in the current period, a decision made at beginning of t . If the household decides to engage resources off the farm this period, then $j_t = 1$; and $j_t = 0$ otherwise.

- $$j_t = \begin{cases} 0 & \text{household does not work off the farm} \\ 1 & \text{household does work off the farm} \end{cases}$$
Current work status

The household must also decide the proportion of labour to be employed in the off-farm sector. The labour demand in the off-farm sector is assumed inelastic, that is, all possible labour supplied by the household will get employed at the constant wage ω_0 .

- $l_t \in [0,1)$ Proportion labour supplied to the off-farm activity.

Transition Functions

The state of the economy in the next period depends on the actions undertaken in the current period and a purely random shock which realization takes place after all decisions for current period have been made. On the one hand, current work decision (j_t) defines beginning of next period work status (i_{t+1}). On the other hand, the fact that the next period potential relative return would be greater than, less than or equal to the current one is entirely determined by the level of the random shock (ε_t). Although the household does not observe the actual level of the relative return, it knows about its distribution. In particular, the household knows the long-run trend of the relative return as well as its variability as measured by the standard deviation. The next period state can be described by the following system:

- $\omega_{t+1} = h(\omega_t, \varepsilon_{t+1})$ beginning of next period potential relative return
- $i_{t+1} = j_t$ change in the work status

If there is no restriction to resource movement, the inter-temporal nature of the decision will be irrelevant. The optimal behaviour will be to wait until the period potential relative return is revealed before taking the move. Some theoretical approaches to job searching simply do not allow “quits” or “fires”. This allows computation of the cost, and therefore the benefit of delaying decision even where absence of entry sunk costs and shut-down costs is assumed. If the assumption of no entry sunk costs and shut-down costs may fit a rural labour market analysis, it appears less plausible that households may get stuck forever in a work status. But an introduction of firing possibility would also better reflect an urban

employment market feature than a rural one. To keep the dynamics of the problem relevant, the existence of switching cost between farm and off farm sectors appears necessary.

Some segments of the off-farm working sectors exhibit entry barriers in the form of lumpy investment or skill requirement (Dercon & Krishnan, 1996). To capture this important characteristic of off-farm activities, a relocation cost is introduced. Switching cost may depend on the number of moves (Dixit & Rob, 1994) or a periodic outcome (Dennis & İşcan, 2007). However, without loss of generality, a fixed switching cost may be assumed. Therefore, it is assumed that a household that re-enters the off-farm sector, after exiting, incurs a cost, s . This switching cost may actually be viewed as a combination of various types of costs including transportation, skills' improvement, opportunity costs which go beyond any start-up capital cost. Particularly, the assumption of a fixed switching cost does not alter the theoretical insight of the role of uncertainty, although one can expect that this affects the equilibrium wage gap.

Another important feature of this model is the absence of savings. The household does not have access to savings neither in the form of cash in hand nor in the form of buffer assets. This assumption is important as asset may provide some kind of protection which may alter attitude towards risk. Therefore, the household would set consumption equal to total return to labour in each year; such that inter-temporal budget constraint satisfies:

$$c_t = w_t \tag{49}$$

where

$$w_t = \omega_0[(1 - \omega_t)j_t l_t + \omega_t] - s(1 - i_t)j_t \tag{50}$$

This implies that, in each period t , consumption must not exceed net return to labour.

Reward Function

- $u(c_t)$: Immediate rewards associated with the labour allocation decision is the household's instantaneous utility of consumption

Bellman Equation

The household searches the maximum attainable current and expected future rewards from the decision to allocate labour off the farm or not. This household's decision problem may be analysed using dynamic programming methods based on Bellman's principle of optimality. Applying the principle of optimality yields the Bellman's recursive functional equation (Miranda & Fackler, 2002).

$$V_i(\omega) = \max_{j,l} \{u(c_t) + \delta E_\varepsilon V_{t+1}(\omega_{t+1})\} \quad (51)$$

This functional equation, called Value Function, $V_i(\omega)$, captures the essential of the problem faced by dynamically optimizing agents, that is, the need to balance optimally immediate and expected future rewards. Here, the household compares the value of allocating part of the production factor to the off-farm activity, given its past work status, the current relative return to labour; and chooses which one, working off-farm or not, provides the greater value. More specifically, a diversified household is concerned with when to exit the off-farm activity and; an exclusively farming household with when to undertake the off-farm activity.

The opportunity to work off-farm is akin to an American call option, that is, the right but not the obligation to undertake the off-farm activity at a strike wage rate. In this perspective, the household endogenously devises its timing to maximize the option value. The optimal decision rule is that the household should exercise the off-farm work option at the moment when the value of doing so reaches a critical level.

$$V_i(\omega) = \max_{j,l} \{u(c_t) + \delta E_\varepsilon V_{t+1}(\omega_{t+1})\} \quad (52)$$

s.t (47) and (49)

$$i_t \in \{0,1\} \quad (53)$$

$$j_t \in \{0,1\} \quad (54)$$

$$V_{i0}(\omega) \equiv u(\omega_0 \omega_t) + \delta E_\varepsilon V_{i0}(\omega_{t+1}) \quad (55)$$

$$V_{i1}(\omega) \equiv u(\omega_0 [(1 - \omega_t)l_t + \omega_t] - s(1 - i_t)) + \delta E_\varepsilon V_{i1}(\omega_{t+1}) \quad (56)$$

Equation (55) and Equation (56) represent respectively the value associated with being inactive in the off-farm sector and the value associated with being active in that sector. That is, the action-contingent value functions indicating respectively the values associated with being idle and being active in the off-farm sector. The index associated with V indicates therefore a combination of past and current work status. On the one hand, being idle over the current period, $V_{i0}(\omega)$, implies that all labour is allocated to farming in which case consumption will tally completely with the income stream from farming. Consumption will be purely random. On the other hand, the decision to share labour across

activities, $V_{i1}(\omega)$, provides a certain minimum of consumption resulting from income stream from riskless activity. Beyond the short-run returns, to make the decision, an idle household must compare the expected life-time rewards of getting active to that of postponing the decision to enter the off-farm sector.

Four types of households can be identified. First category refers to households which did not work off-farm during the preceding period and are also not working off-farm currently:

$$V_{00}(\omega) = \{u(\omega_0\omega_t) + \delta E_\varepsilon V_{00}(\omega_{t+1})\} \quad (57)$$

Second category refers to households which did not work off-farm last period but do work off-farm currently. The value is

$$V_{01}(\omega) = \{u(\omega_0[(1 - \omega_t)l_t + \omega_t] - s(1 - i_t)) + \delta E_\varepsilon V_{01}(\omega_{t+1})\} \quad (58)$$

Third category refers to households which did work off-farm last period but do not work off-farm currently. The value is

$$V_{10}(\omega) = \{u(\omega_0\omega_t) + \delta E_\varepsilon V_{10}(\omega_{t+1})\} \quad (59)$$

Finally, there are households which worked off-farm last period and are working off-farm currently. The value is

$$V_{11}(\omega) = \{u(\omega_0[(1 - \omega_t)l_t + \omega_t]) + \delta E_\varepsilon V_{11}(\omega_{t+1})\} \quad (60)$$

The household will allocate labour to off-farm activities if the value of doing so is greater than otherwise. Beyond the short-term return to labour, this value includes all future consequences of the action undertaken today. Delaying off-farm work decision may give

the opportunity to take advantage from future upward move of the relative return though this must be traded against the consequences of potential downside risk.

3.5.3.2 Implication of the model

The critical relative return level at which a farm household decides to supply labour across activities and at which a household which has engaged labour in the off-farm activity withdraws are characterized by

$$v_{i,0}(\omega_i^*) = v_{i,1}(\omega_i^*) \quad (61)$$

On the left hand lies the value of being active currently in one working sector (farming) while at the right hand lies the value of being active in both, for whatever past work status. An off-farm idle household therefore becomes active if the value of getting active in the off-farm sector is greater than that of working exclusively on the farm; otherwise the household remains only active in farming. Similarly, an off-farm active household will exit if the value of doing so is greater than otherwise. As indicated in Equation (57) to (60), this value can be significantly different from the short-run return that is generally considered in the traditional NPV approach or by a simple random utility framework. The following sub-sections highlight how such value is affected by the return uncertainty.

3.5.3.3 Optimal off-farm entry-exit

To analyse the optimal entry-exit decision, the case where the household has a single unit of labour may be considered. This unit can be either allocated to farming or off-farm activities but not shared across both at the same time.

Case 1: The unit of labour is on farm; when is it optimal to allocate it to off-farm activities?

From the definition of the relative return to labour, return to labour in the off-farm activity may be considered to be the numeraire. Considered that, during last period, the household did employ that unit of labour to farming. For the current period, the household must decide whether to keep its labour unit on farm or to relocate it to the off-farm activity. The optimal shift decision requires that the value of moving out of the farm be greater than that of remaining on farm. More formally:

$$u[1 - s(1 - i_t)] + \delta E_\varepsilon V_{01}(\omega_{t+1}) > u(E_t \omega_t) + \delta E_\varepsilon V_{00}(\omega_{t+1}) \quad (62)$$

$$u[1 - s(1 - i_t)] > u(E_t \omega_t) + \delta E_\varepsilon [V_{00}(\omega_{t+1}) - V_{01}(\omega_{t+1})] \quad (63)$$

If uncertainty is low, it pays to focus on the risky high yielding farm activity as the event that actual average return to labour on farm be lower than the certain off-farm return appears unlikely. Utility obtained from labour on farm is therefore higher and relatively less volatile. At the same time, the discounted future relative return to labour is higher if kept on farm than moved into the low yielding activity, $V_{i0}(\omega_{t+1}) > V_{i1}(\omega_{t+1})$. Both right-hand terms are strictly non-negative and higher. This implies that relatively low relative return, that is a higher return off-farm, is required for off-farm relocation option to be exercised. The second term in the right hand of equation (63) is the value of waiting. Because this value is non-negative, equation (63) suggests that the household may keep the labour on the farm even if the net return from the off-farm activity $[1 - s(1 - i_t)]$ is greater than the expected return from farming $E_t \omega_t$. Holding on to the status quo therefore has

value. With low level of uncertainty, off-farm relocation occurs later than predicted by the traditional Marshallian rule of decision.⁷

On the other hand, if uncertainty is high, the event that actual return to labour on farm falls far below the certain off-farm return becomes more likely because, though the return to labour on farm remains higher on average, its variance has become larger. The utility attainable from the labour on the farm become more volatile and less desirable, because of the efficiency loss. Because risk averse household is much concerned with stabilizing income, the discounted relative return to labour, if kept on farm, reduces. For the risk averse households, this tends to reduce the value of holding on the status quo. The household may therefore shift the labour into the off-farm activity at a relatively higher level of the relative return, provided that part of the uncertainty is vanished. This implies that increased uncertainty would prompt the off-farm reallocation decision.

For example, as we move from a good to a bad state of the economy, consumption (expected return to labour) tends to decrease, and utility as well. At the same time, the value of waiting decreases. This is so because, when the labour is on farm, the discounted value $V_{i0}(\omega_{t+1})$ reduces as its argument does so. On the other hand, the $V_{i1}(\omega_{t+1})$ associated with relocating off farm before is known and fixed. The overall right-hand value gets lower such that a relatively lower net-return to labour off the farm is required for the inequality to hold. The option of off-farm relocation will be more readily exercised.

⁷ The NPV rule of resource allocation predicts off-farm relocation as soon as $1 - s(1 - i_t) > E_t \omega_t$

And the Random Utility Theory as soon as $u[1 - s(1 - i_t)] > u(E_t \omega_t)$

Conversely, from a bad to a good state, the reverse is observed; and higher levels of the return to labour off-farm is required for relocation to be the preferred option.

The critical relative return at which relocation occurs depends also on the past-work status. Because the household that reenters the off-farm activity incurs the sunk cost, the net off-farm return depends on the relevance of the sunk cost in the particular period⁸.

The model indicates that utility of working off-farm must exceed the expected utility of working on farm of a certain amount before off-farm shift is undertaken. This value is decreasing with the level of uncertainty. Because this value is non-negative, models that predict that households' shift decisions are driven by the option providing individuals with the highest utility of consumption (Random Utility Theory) or the highest net discounted present value of earnings (NPV Theory) may be less adequate in explaining actual off-farm labour decision. The model suggests that for lower uncertainty, off-farm relocation occurs later than predict those models; and that with higher uncertainty it occurs earlier than they predict.

Case 2: The unit of labour is off-farm; when is it optimal to relocate it on farm?

Consider now that the household has exercised the off-farm shift option during last period. What matters is the optimal timing about shifting back on farm. There is no cost associated with moving to the farm. Relocation must therefore occur only when

⁸ Indeed, from Equation (11), for household which is exercising the off-farm relocation for the first time ($i_t = 0$), the value is $u[1] + V_{01}(\omega_{t+1})$. On the other hand, for household that has already exercised the off-farm work ($i_t = 1$), the value is $u[1 - s(1 - i_t)] + V_{01}(\omega_{t+1})$.

$$u(E_t\omega_t) > u(1) + \delta E_\varepsilon[V_{11}(\omega_{t+1}) - V_{10}(\omega_{t+1})] \quad (64)$$

Instantaneous utility of working in the riskless off-farm activity is constant. However, for very low level of risk it pays less to keep working in the lower yielding activity; because the likelihood that the return to labour off the farm be greater than the actual average return to labour employed in farming is too low. Moreover, and for this reason, the discounted value of the relative return is higher if the labour is allocated to the high yielding activity, $V_{i0}(\omega_{t+1})$, than to the low yielding activity, $V_{i1}(\omega_{t+1})$. The value of waiting is therefore non-positive. This implies that it is worth relocating on farm even though the instantaneous utility of working off the farm is greater than that of working on farm. Therefore, on farm relocation may occurs when relative return is still less than unit, that is, $E_t\omega_t < 1$. The household will exercise the on-farm shift decision more readily.

Even if uncertainty is high, the instantaneous utility received from off-farm work remains constant. But the probability that certain return from the off-farm activity be greater than the actual average return from farming becomes significant. The discounted value of the relative return to labour becomes relatively interesting if kept in the riskless activity. Holding on to the status quo for some time provides an opportunity to take advantage from a potential up rise while allowing to avoid some downside risks. The household may remain in the off-farm activity while the expected relative return is greater than one, that is, higher level of the return to labour on farm is required for shifts to become relevant even though the household does not bear any cost as a consequence of the decision to exit. The household will be more reluctant to relocate to farming.

For instance, from a good to a bad state of the economy, current reward remains constant if labour is in the riskless activity. At the same time, the discounted value of the relative return to labour associated with staying in the riskless activity increases as the return to labour on farm decreases. On the other hand, the discounted value of the relative return to labour conditional on relocating on-farm decreases as its argument does so. Therefore, the overall right-hand component gets higher. There will be less incentive to relocate on farm. The reverse is observed if there is rather an improvement of the state of the economy, and the household will be more readily to relocate on farm.

However, this is not only due to risk aversion. Even under risk-neutrality, the optimal decision must account for the value of waiting. To see that this is the case, recall that risk-neutral household would maximize expected return. The main difference between this option value approach and the traditional Marshallian approach to decision-making concerns the trigger point at which it becomes optimal to take the relocation decision (Dixit & Pindyck, 1994). While the latter assigns a zero value to non-action, the former considers that the flows of profit over some time can be traded against the realization of some upside potential or the avoidance of some downside risk (i.e. waiting); and that this has value. Reconsidering case one and case two in this perspective yield the following outcome: the optimal relative return at which the household switch off the farm is:

$$\omega_t < 1 + \frac{V^*(\omega) - s}{\omega_0} \quad (65)$$

while the optimal relative it switches back is⁹:

$$\omega_t > 1 + \frac{V^*(\omega)}{\omega_0} \quad (66)$$

The discrete time model developed in this thesis is consistent with, and conciliates, findings from the literature on continuous time models. First, increased uncertainty has a negative effect on decision timing when the uncertainty is associated with investment cash flows as argued Dixit (1989); Dixit & Pindyck (1994); Dixit & Rob (1994); McDonald & Siegel (1986); Musshoff *et al.*, (2013) and Song *et al.*, (2011). Second, increased uncertainty has a positive effect on investment timing as argued by Kwon *et al.* (2006) and Sarkar (2000) when resources are being moved away from the risky investment and toward a riskless investment.

Another factor that contributes to the decision-making is the rate of time preference. Indeed, $V^*(\omega)$ is the net discounted value associated the action taken today. If discount rate is high, present is valued more and options that have negative impact on current outcomes becomes less valuable.

3.5.3.4 Optimal labour allocation

Consider the case where the unit of labour may be allocated cross-activities. The first order conditions, conditional on participation, suggests that the shadow price of labour is given by:

⁹ With $V^*(\omega) = \delta E_{\varepsilon}[V_{i0}(\omega_{t+1}) - V_{i1}(\omega_{t+1})]$. The option value of waiting still matters; and as it depends on the return uncertainty, the timing of the shift decision will depend on it as well.

$$\mu_l = \omega_0[(1 - E_t\omega_t)u'(c_t)] \quad (67)$$

The shadow value of labour summarizes all current and future rewards associated with a marginal increase of the share of labour allocated to the riskless activity. As expected, this value is increasing with the return to the riskless activity and decreasing with the expected return to labour from the competing working sector ($\omega_t = \frac{\omega_t^a}{\omega_0}$). This highlights the need to balance the resources allocation between both activities as their relative desirability rises and falls with the history of the risk realizations. Though the risk is assumed to affect one wing of the economy, all workers in the economy are subject to the risk. Indeed, as workers the risky activity run the risk of getting lower income in the occurrence of a bad shock, workers in the riskless activity run the risk of not getting higher income when the economy is hit by a positive shock.

For a given level of the off-farm return ω_0 , it is clear, from Equation (49) and Equation (50), that any factor that pulls down the relative return also lowers consumption. And the higher the labour on-farm, the lower will be consumption. Since low levels of consumption weight higher with risk aversion, the overall right-hand term is increasing. This provides incentives for increased labour in off-farm activities. That is, household facing higher likelihood of downside farm income will increase labour allocation in the off-farm sector.

If uncertainty is low, the probability of earning less from the farming sector (compared to outcome form off-farm) is lower. The term $(1 - E_t\omega_t)$ is relative stable and around zero. At the same time, the likelihood of experiencing lower consumption is smaller, and therefore marginal utility is also relatively stable. These two terms interact, on the one hands, to reduces any incentive to readjust the portfolio towards the riskless activity. On

the other hand, they reduce the potential effect relating the presence of any precautionary behaviour which would push the household to work more in an attempt to reduce the likelihood of obtaining lower income. This encourages farm households to work more on farm and less off-farm.

If uncertainty is high, the potential outcome is completely reverse. Considering that risk averse households are more concerned with protecting income from getting too low, let's consider the effect of an expected downside risk. As we discussed earlier, this provides incentives of increasing off-farm work. On the one hand, an expected downside risk encourages readjusting the labour away from the risky farm activity and towards the riskless off-farm activity. On the other hand, the potential effect of the presence of precautionary behaviour is amplified. These two effects generate a positive effect of return variability on off-farm labour supply.

This optimality condition provides further insights about the potential critical relative return to labour as discussed in the entry-exit decision. First, as long as the expected relative return exceeds unity, there is no incentive to increase off-farm labour. It is even optimal to withdraw some labour until the shadow price is non-negative. This suggests that in the case of the single unit of labour, the household will exit the off-farm activity as the relative return gets closer to unity because the shadow price of labour off farm becomes negative as this line is crossed (the value of exiting is greater than the value of entering the off-farm sector). On the other hand, if the potential relative return is less than unity, it is optimal to increase off-farm labour until there is no worth in any marginal increase. Conditional on participation, optimal labour allocation is achieved when the shadow price is neither

positive nor negative, that is zero. Otherwise, there will be worth either in increasing or decreasing the labour in off-farm activities.

$\mu_l = 0$ implies that optimal labour allocation is given the condition:

$$E_t \omega_t = 1 \quad (68)$$

The result suggests however that once a decision to work off-farm is taken, the optimal decision is to allocate labour until the marginal return from each sector is equal. Neither consumption nor switching cost really matters at an optimum. This is in line with arguments from the literature according to which the main difference between the traditional net present value approach of decision making and the real option value approach is in the trigger at which the decision is made, that is, the timing of the decision. Furthermore, the risk affects the labour and the decision in the same direction. As the uncertainty prompts the off-farm work decision, it implies increased share of labour to be allocated in this activity.

3.6 Empirical Analysis of Households' Labour Allocation

3.6.1 Econometric Specification

From the theoretical model, one may expect that households be more (less) active in off-farm activities as they face higher (lower) uncertainty about relative return to labour. This means that the higher the variance of the sector's relative return to labour, the higher will be the likelihood of working off-farm and the amount of labour employed off-farm as well.

Empirical implementation of this model must, however, accommodate some practical issues. For instance, off-farm work does not always compete with farm work, particularly, in a single rainy season farming system in which the dry season lasts far longer than the farming season as is the case of Burkina Faso. In such a case, farmer would still have the possibility to undertake off-farm activities after realization of the uncertain event, when labour is not required on farm. What may matter more will be consumption of leisure. In fact, the off-farm labour in these data reflects both ex-ante and post-harvest labour allocation decision. Therefore, it would not be adequate to use proportion. The empirical model uses the number of off-farm workers and allows for ex-post response as well.

The risk is measured as discussed in objective one. Again, the key assumption remains that covariate rainfall risk is the most important source of uninsured weather risk and that much of the effect of related shocks is borne individually, presumably because of ineffective social risk articulation mechanisms. While missing risk markets is a natural assumption for rural economies in developing countries, the weakness of the social risk articulation mechanisms is empirically documented (Kazianga & Udry, 2006) in the case of rural Burkina Faso. This is the main reason why a risk averse household will forego high-return activities at the expense of lower return activities portfolio. For subsistence rainfed farmers, return to farming will necessarily exhibit high correlation with rainfall as suggested by previous findings (Carter, 1997). Information on actual rainfall data may therefore provide a good proxy for weather risk as farming is concerned (Menon, 2009); and will be used to estimate the risk variables.

Rainfall is a random variable which the household cannot observe prior to its realization when labour allocation decision has to be made at the beginning of farming season; but the household has knowledge about the long-run mean and the variability of the rainfall distribution. The latter is the coefficient of variation of rainfall. In the ex-ante perspective, this represents the aspects of the risk that will affect the decision as to whether and how much labour to allocate across farming and off-farm activities. From the discussion on the theoretical framework, the rainfall variability may affect the decision in two ways. First, there may be a portfolio adjustment towards the riskless off-farm activities and away from the on-farm risky production. Second, there may be a precautionary motive as the household will likely work more, and consume less leisure, to increase the chance of getting high income. These two effects generate a positive effect of rainfall variability on off-farm ex-ante labour supply. Similar arguments are discussed by Rose (2001).

After harvesting, the household can observe the actual rainfall level and may respond more directly to the rainfall shock. The rainfall shock will actually be the rainfall deviation from its long-run mean. For low level of the shock or for positive shock, higher income will be achieved and the household will reduce off-farm labour, either as an attempt to smooth income or consume more leisure as income is sufficiently high. However, if the household experiences a bad shock, lower income will be achieved. There are incentives for households to increase off-farm work to supplement the farm income. Therefore, negative shocks are expected to be associated with increased off-farm work.

In estimating the off-farm labour supply decision, we also controlled for the structure of the household, its endowment in various productive and non-productive assets and other

community-level pull and push factors. To control for the household structure, the dependency ratio, the household size and the gender, age, education, marital status and ethnical group of the head of the household are included. Endowment in productive assets are measured by total landholdings, the value of transportation assets, farm equipment and grain stock. Other capacity variables such as remittances, livestock income, access to information, source of energy, access to credit, the number of literate and trained household members are included in this subset.

Village level controls include size of population, distance to paved road and market. I also included dummy to capture location differences. The locational dummy reflects the agricultural potential of the agro-ecological zone in which the village is located. Other dummy variables, indicating whether the village is accessible for vehicle, whether there is an ongoing public development program, whether a Non-Governmental Organization, and SOFITEX, intervene in the village.

3.6.2 Estimation Issues

The empirical model is a panel count data model. Empirical studies are mostly restricted to discrete choice models to analyse participation decision (Ahituv & Kimhi, 2002; Menon, 2009) and tobit models are often used to model off-farm work time or income (Mishra & Goodwin, 1997; Rose, 2001). Data used in this thesis contains information about the number of people the household has engaged in a particular off-farm activity including hired and family labour, irrespective of age, gender and work duration. The resulting variable (off-farm labour) is a count as it takes only few non-negative integer values. More than 95 per cent of the values of the dependent variable lies in the range of the interval

[0;5] and about 99 per cent are on the first tenth integers. Therefore, assumption of normality will be obviously untenable; making it less appropriate to use Tobit models.

Count data models are non-linear in parameters with properties and features connected to discreteness and non-linearity (Cameron & Trivedi, 2001) making inappropriate to use linear regression methods (Wooldridge, 2013). In addition, all standard count data distributions are intrinsically heteroskedastic which non-linear least squares methods do not exploit (Wooldridge, 2013). Maximum likelihood methods are rather more reliable. The nominal distribution of count data is the Poisson distribution.

Consistent Panel Poisson estimates are based on the assumption of equi-dispersion, that is, equality of mean and variance. For this, the Poisson Model may be seen as too restrictive because count data are generally over dispersed (Cameron & Trivedi, 2001, 2009; Wooldridge, 2013). Alternative models like Negative Binomial Model are explicitly designed to handle over-dispersion (Cameron & Trivedi, 2009) as it does assume equality of mean and variance. However, the robustness property of the Poisson distribution still holds even when the actual data is not a Poisson and Poisson estimates will be consistent and asymptotically normal (Wooldridge, 2013). Quasi-Maximum Likelihood Estimation Methods may be used instead. Moreover, with over dispersion, Poisson regression grossly deflates standard errors and by the way grossly inflates t-statistics (Cameron & Trivedi, 2001). The Poisson estimates therefore need to be adjusted.

Another issue with count data relates to the violation of independence of events, that is, when different processes generate the first and subsequent events. Hurdle models (also known as two-part models), which assume independence between the process generating

the zeros and the process generation the positive counts, may be more adequate to handle many zeros (but also small). However, Hurdle models are more fragile because any distributional misspecification leads to inconsistency in the Maximum Likelihood Estimates (Cameron & Trivedi, 2009). Moreover, the theoretical framework suggests that participation and labour amount are likely generated by similar process, at least in terms of risk.

Finally, as with linear regression models, there is a need to address the issue of unobserved fixed households' heterogeneity. While statistical inference can help determine which process fits better the data distribution, the choice become more challenging when each of these approaches is required to handle a particular issue with the empirical model. Fixed effects model is widely applied for handling unobserved heterogeneity, but it does not allow, by construction, time-invariant covariates. However, random effects model estimates are inconsistent if households' fixed effects are correlated with some of observables.

Cameron & Trivedi (2013) has suggested, the conditional correlated random effect framework (Chamberlain, 1982; Mundlak, 1978) for linear panel models can be extended to non-linear count data models. The correlated random effect model is actually a fixed model though caution is required in interpretation of time invariant variables' coefficients (Wooldridge, 2013). In particular, they are not necessarily estimates of causal effects. Furthermore, unlike with linear model, coefficients of time variant variables in the correlated random effect models are not those of fixed effects model.

In addition, with data on two consecutive periods, most of the variations in the data are between rather than within variations. Fixed-effect estimators are less likely to be efficient as they rely, by construction, on within variation (Cameron & Trivedi, 2009). The most relevant model for this data is the random-effect approach which, in this particular case, essentially handle the panel complications that observations are correlated over time for a given household.

3.6.3 Measurement of key Variables

Wage labour supply: a household wage labour supply is the number of household member that worked for salary, in cash or in kind, during the year. This is irrespective of age, gender and profession. **Non-farm labour supply:** household non-farm labour supply represents the number of people the household has employed in all non-farm business in which it is engaged. This includes family and hired labour, irrespective of age, gender and activity. **Livestock income:** value of livestock sales¹⁰

¹⁰ See section 3.4 for other variables

3. 2: List of Explanatory Variables used in the Regression Explaining Off-Farm Labour Supply

VARIABLES	Definition	Measurement	Expected Sign
RISK FACTORS			
Rainfall (CV)	Coefficient of variation of rainfall		(+)
Mean Rainfall	District level long-run mean of rainfall	Millimetres	(-)
Rainfall Deviation	Deviation of from long-run mean	Millimetres	(-)
HOUSEHOLD			
Male Adults	Number of Male Adults		(+/-)
Female Adults	Number of Female Adults		(+/-)
Young Members	Members between the age of 6 and 14		(+/-)
Literates	Number of literate members		(+/-)
Trained	Number of trained members		(+)
Health Shock	Number Injured or ill members		(+)
Education of the Head	1 primary education, 2 secondary education, 3 Madrasa, 0 otherwise		(+/-)
Gender of the Head	1 if the head is male, 0 otherwise		(+/-)
Age of the head	Age of the head of the households	Years	(+/-)
Age of the head (squared)	Square of the age of the head of the households	Years	(+/-)
Marital Status of the Head	1 if the head live in union, 2 if separated or widowed, 0 otherwise		(+/-)
Children Under 5	Number of Children under the age of 5		(+/-)
Number of Aged	65 and above aged members		(+/-)
Source of Energy	1 if household has access to energy, 0 otherwise		(+)
Access to information	1 if household has access to information, 0 otherwise		(+)
Net Regular Transfers	Net received amount	CFA	(-)
Net Occasional Transfers	Net received amount	CFA	(+/-)
Permanent Income	Predicted average income	CFA	(-)
Permanent Income (Squared)	Square of the predicted average income	CFA	(+/-)
Access to Credit	1 if household did receive a loan, 0 otherwise		(+/-)
Land Size	Total land holdings	Hectares	(+/-)
Land Size (Squared)	Square of total land holdings	Hectares	(+/-)
Transport Assets	Value of transport assets	CFA	(+)
Livestock Income	Value of livestock sales	CFA	(+/-)
VILLAGE			
CHARACTERISTICS			
Population Size	Number of inhabitants of the village		(+)
Distance to Paved Road	Distance to the nearest paved road	Km	(-)
Sofitex	1 if SOFITEX intervenes in the village, 0 otherwise		(+/-)
NGO	1 if an NGO intervenes in the village, 0 otherwise		(+/-)
Public Program	1 if there is an ongoing public development program in the village, 0 otherwise		(+/-)
Village access	1 if village is accessible by vehicle all the year, 2 only during dry season, 0 if not accessible		(+)
Market Dummy	1 if there is a market within the village, 0 otherwise		(+/-)
Agro-ecology	0 household is in the Soudanaian zone, 1 if in the Soudano-Sahelian and 2 if in the Sahelian		(+/-)

3.7 Source of Data

3.7.1 Household Level Data

The data used for this study was collected in 2010 and 2011 by the Laboratory of Quantitative Analysis Applied to Development in Sahel (LAQAD-S) of the faculty of economics of University of Ouaga 2 for the Community-based Rural Development Project (PNGT-II) evaluation in Burkina Faso. The project was co-funded by Ministry of Agriculture in Burkina Faso, the International Fund for Agricultural Development (IFAD) and the World Bank. The data was collected nation-wide, covering all the 13 regions and 45 provinces of the country, using a multi-stage sampling strategy. First, villages were chosen using cluster sampling according to the mode of intervention of the PNGT and on the basis of the representativeness of the population at the national and regional level in order to allow for spatial comparison. Then, two to seven villages were selected by province using three criteria: villages of provinces where the project intervenes directly, villages of provinces of indirect intervention of the project and villages of provinces where that are neither directly or indirect affected by the intervention. In total, 270 villages were selected. At the second stage, three strata were first constructed per village to group households regarding the possession of animal traction equipment, households which use but no own traction equipment and households which neither own nor use traction equipment. Therefore, eight households were randomly selected within each selected village to be surveyed, making a sample of 2160 households per round.

In the second wave, the sample has been refreshed. Among the 2160 households, 1200 were kept from and a new sub-sample of 960 households was selected using the same

sampling approach, and added to make the full sample. For this study, only households that have complete information over the two rounds of the survey, 1101, were considered to balance the panel.

3.7.2 Rainfall Data and Other Information

Historical rainfall data was obtained from the National Institute of Statistics and Demography (INSD), covering the period 1990-2011. From this historical data, data for the years 2009 and 2010 are used to compute the coefficient of variation of rainfall. This reflects the need to take into consideration the fact that, the survey being held in the middle of each year, information on households' farm outcome as well as off-farm work decisions depend on rainfall distribution over the previous year. The data represents the annual rainfall recorded from 10 meteorological stations distributed across the agro-ecological zones of the country. For each village, information on rainfall are taken from the nearest station. Information on the farm assets economic life has been obtained from the Ministry of Agriculture and Hydraulic Resources. For the areas average yield, data are obtained from INSD per crop and per province; and averages are computed over the period 2000 and 2011.

3.8 Conclusion

This section has discussed the theoretical and empirical methods of analysis and presented the data that will be used. The conceptual framework showed that, under financial market imperfection, weather risk encourages investments which have more stable returns

although those return would be lower. This is revealed by both models of asset accumulation and labour allocation under risk.



CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter has three main sections. The first presents the descriptive statistics of the study sample. The second presents and discusses estimation results of objective one. Finally, results of second objective are discussed.

4.2 Descriptive Statistics

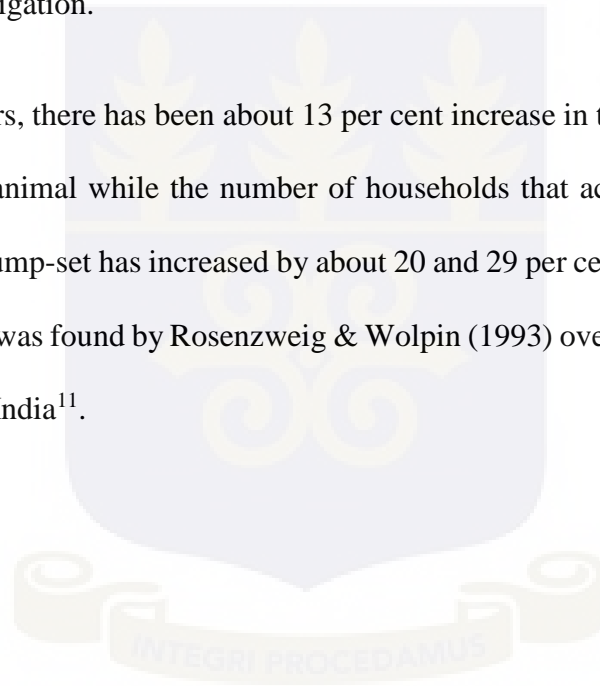
4.2.1 Households' Characteristics

Table 4.1. presents the characteristics of the surveyed households. Almost all households are headed by males; barely 1.5 per cent of the surveyed household are headed by female. More than 96 per cent of these heads of households are married while the remaining are either single (1 per cent) or separated or widowed (3 per cent).

The level of education of households is low with about 93 per cent of the head of households not having attended any formal schooling. Around 2 and 0.3 per cent have respectively attended primary and secondary education. The remaining (around 4.8 per cent) have attended Madrasa education. About a quarter of them is literate, that is, are able to read or write in any languages (French, English, Arabic and any local language). Moreover, about 10 per cent of these households have benefited from a training related to capacity building or skills improvement. This indicates that informal education is used to help households build human capital that can help them improve their working capacities.

The statistics also indicate that the number of households owning at least one draught animal has increased from 94 in 2010 (out of the 1101) to 106 in 2011. On average, less than 10 per cent of the households own at least one draught animal. This suggests an underinvestment in draught animal despite their role in farming (land tillage, transportation). The data also shows that there is underinvestment in the adoption of other agricultural technologies. For instance, less than 1 per cent of the households own a motorized agricultural machinery while fewer than 1.5 per cent own a pump-set (motorized or manual) for irrigation.

Over the two years, there has been about 13 per cent increase in the number of households owning draught animal while the number of households that acquired a motorized farm equipment or a pump-set has increased by about 20 and 29 per cent respectively. These are higher than what was found by Rosenzweig & Wolpin (1993) over a 10-year survey among small farmers in India¹¹.



¹¹ Despite the need for spatial and time consideration, this study remains one of the few that use a similar approach to analyse households' accumulation decision.

Table 4. 1: Households' Characteristics

	2010		2011	
	Frequency	Percentage	Frequency	Percent
Gender of the Head				
Female	17	1.55	16	1.45
Male (=1)	1083	98.45	1084	98.55
Education of the Head				
None	1023	92.92	1022	92.91
Primary School	23	2.09	22	2
Secondary School and above	3	0.27	3	0.27
Madrassa	52	4.72	53	4.82
Literacy Status of the Head				
Illiterate	826	75.02	827	75.11
Literate (=1)	275	24.98	274	24.89
Head Training Status				
No training	974	88.47	1000	90.83
Training	127	11.53	101	9.17
Marital Status of the Head				
Single	12	1.09	12	1
In union	1061	96.37	1061	96.45
Separated or widow	28	2.54	27	2.45
Ownership of draught animal				
No draught animal	1007	91.46	995	90.37
At least one draught animal	94	8.54	106	9.63
Ownership of Machinery				
No Machinery	1091	99.09	1089	98.91
Own Machinery	10	0.91	12	1.09
Ownership of Pump-Set				
No Pump-Set	1087	98.73	1083	98.37
Possess Pump-set	14	1.27	18	1.63
Total	1101	100	1101	100

4.2.2 Inter-Wealth Quartile Mobility

Table 4.2. presents inter-wealth quartiles mobility between the two years¹². The results show a considerable persistence of wealth status over the two years. More than 80 per cent

¹² Element (i,j) represents the probability that a household in the i^{th} quartile in the first years (row) moves to the j^{th} wealth quartile in the second year (column).

of the households in the lowest wealth quartile in 2010 remains the lowest wealth quartile in 2011. Barely 13 and 5 per cent respectively moved to the second and third wealth quartiles. Finally, less than 0.5 per cent have moved to the highest quartile, that is, nearly four households.

About three quarters of the households that were in the highest quartile in 2010 remain in this quartile in 2011. Around 21 per cent fell into the 3rd quartile and 4 per cent into the second. Finally, around 1 per cent fell into the lowest quartile. However, the probability of falling from the highest to the lowest quartile is thrice higher than that of moving from the lowest to the highest.

The persistence is relatively low in the second and the third quartile. Over 58 per cent households in the second quartile in 2010 remains in the second quartile in 2011 while nearly 55 per cent from the third quartile in 2010 remains in the third quartile in 2011. The probability of falling from the second to the first quartile is around 16 per cent while the probability of moving to the next higher quartile is more than 18 per cent. Nearly 7 per cent have moved to the highest quartile. A household in the third quartile has less than 20 per cent chances of moving to the highest wealth class, almost 25 per cent chance of falling back to the immediately lower wealth class and around 1 per cent probability of falling into the lowest class of wealth.

In sum households in the second wealth class had improved more than the other classes. More than a quarter of them have moved towards higher classes while about 16 per cent fell back into the lowest wealth class. Households in the third quartile have experienced more backward move but most of them remained in the second class. The situation is

particularly worst for households in the lowest wealth class regarding the persistence of the poverty level for that class.

Table 4. 2: Inter-Wealth Quartiles Transition Probabilities

Wealth Quartile (2010)	Wealth Quartile (2011)				Total
	1 st Quartile	2 nd Quartile	3 rd Quartile	4 th Quartile	
1 st Quartile	81.45	13.09	5.09	0.36	100
2 nd Quartile	16.30	58.33	18.48	6.88	100
3 rd Quartile	1.09	24.73	54.91	19.27	100
4 th Quartile	1.09	4.00	21.45	73.45	100
Total	24.98	25.07	24.98	24.98	100

4.2.3 Inter-Income Quartile Mobility

Table 4.3 presents the inter-income quartile transition probabilities. The results suggest that inter income quartile mobility is more readily. There is a relative persistence regarding the lowest and the highest income classes although this is almost half of the probabilities of inter wealth quartile mobility. Table 4.3 indicates that only 42 per cent of households in the lowest income quartile in 2010 remain in the lowest income quartile in 2011. Almost 60 per cent have moved towards higher income classes, with the majority (around 29 per cent) limited to the second income quartile.

The reverse mobility is also high. Around 30 per cent of households in the highest income quartile have fallen back into the first two lowest income classes. The mobility is higher for the second and third income classes where barely 30 per cent remained in their respective income classes for the two consecutive years. A quarter of the households that were in the second income class in 2010 fell in the lowest in 2011 while about 45 per cent have moved to the higher income classes. The reverse is however observed for households

in the third income class. About a quarter of those households moved to the highest income class in 2011 while around 45 per cent fell into the lower income classes. On the one hand, households in the two lowest income classes have more chance of moving up than staying in their previous income class or falling into lowest income status. On the other hand, households in the two highest income classes find it harder to be in an income class at least as desirable as they had in the first year.

Table 4. 3: Inter-Income Quartile Transition Probabilities

Income Quartile (2010)	Income Quartile (2011)				Total
	1 st Quartile	2 nd Quartile	3 rd Quartile	4 th Quartile	
1 st Quartile	41.82	28.73	19.27	10.18	100
2 nd Quartile	25	30.8	27.17	17.03	100
3 rd Quartile	21.82	22.91	29.82	25.45	100
4 th Quartile	11.27	17.82	23.64	47.27	100
Total	24.98	25.07	24.98	24.98	100

Compared with inter-wealth quartile mobility, it comes out that households' income status is less stable than their wealth status; that is, income is more volatile than wealth. For example, while almost 60 per cent of the households in the lowest income class in 2010 experienced an improvement of their income flows in 2011, the results show that less than 20 per cent of the same households experienced an improvement of their total asset's stock. Households in the other wealth classes have gotten worse-off in term of income status between the two years. This supports the argument that income is less relevant for households' welfare analysis (Pender *et al.*, 2012).

4.2.4 Households' Wealth

Table 4.4 presents the composition and the distribution of households' wealth by wealth quartile. The results are per adult equivalent (AE) and are expressed in 1000 FCFA. Land constitutes the highest contributor to wealth of all classes. For all wealth quartiles, land represents more than 96 per cent of farm capital. For the two highest quartiles, land represents more than 99 per cent of the farm capital. However, in absolute terms, the value of both equipment and the value of draught animal are increasing with wealth on average and over time. All components of farm capital have experienced change, in absolute terms. Their values are increasing on average with wealth and over time except for the highest quartile where only the value of draught animals increased. For this latter wealth quartile, total farm capital decreased between 2010 and 2011, unlike for the other classes. A plausible explanation for this decrease may follow from the approach used to value farm equipment (see section 3.5). Households which have attained certain level physical capital stock in a 2010 may not need to investment in similar assets in the following year. Accounting for depreciation, a kind of disinvestment, may therefore explain why value of farm equipment decreased for households in the highest wealth class.

Table 4.4 also indicates that households in all wealth classes hold more than 60 per cent of livestock wealth in small livestock (value of sheep, goats, pigs and poultry) than large livestock (cattle, donkeys, horses and camels), suggesting a consideration for liquidity. The value of non-land farm capital (Farm Equipment + Draught Animal) is on average greater than the value of livestock for the two highest wealth classes while for the two lowest wealth classes, the value of livestock rather outweighs the value of non-land farm capital.

This supports the hypothesis that poor households tend to hold increasingly liquid assets as compared to richer households, though lower in absolute terms (Jalan & Ravallion, 2001; Rosenzweig & Binswanger, 1993). The latter is particularly emphasized regarding grain stocks.

Non-farm assets are also a major contributor to households' wealth. Non-farm assets are calculated as the value of transportation assets. The value is increasing with wealth classes. Between the two years, there has been an increase, except for the highest quartile where the value has decreased from 5490.2 to 4987.30 FCFA, a 10 per cent decrease.

Two values for households' liquid wealth are computed. The first liquid wealth measure (Liquid Wealth1) sums the values of all livestock holdings and grain stocks. The latter (Liquid Wealth2) excludes the value of large livestock from the former. With respect to the latter, the absolute values are greater for higher wealth quartiles. There has been a decrease in this liquid wealth for all quartiles between 2010 and 2011 with the highest decrease being among households in the fourth quartile (70 per cent against less than 10 per cent for the other wealth classes). This decrease seems to be a response to a negative shock on households' farm income (see Table 4.5) and might reflect the differentiated risk coping abilities presumed to exist between poor and wealthy households but also depending on the amount of previously accumulated wealth (Carter & Lybbert, 2012; Zimmerman & Carter, 2003). This general decreasing trend is observed for the first liquid wealth value, except the third where there was an increase (around 7.4 per cent increase against decrease in similar proportion for the other classes). The decrease in the value of the higher liquid

assets in the third quartile may reflect a readjustment of the liquid wealth composition toward large livestock holdings.

Though wealthier households appear to hold more liquid assets than poorer households, this represents a very small proportion of their total wealth. Households in the lowest quartile hold more than 10 per cent of their total wealth in liquid form while liquid wealth represents less than 2 per cent of wealth in the two highest quartiles. Liquid wealth also represents less than 5 per cent of wealth in the second quartile. This also supports the assumption regarding risk associated with each asset. If livestock, and more generally available liquid assets, were high yielding, their share would be increasing with wealth. If they were high yielding but high risk, wealthier households would still hold more of such assets as they have more means to cushion potential shocks. It is likely that much of these asset categories are held because of liquidity considerations, and to some extent as a means of risk management.

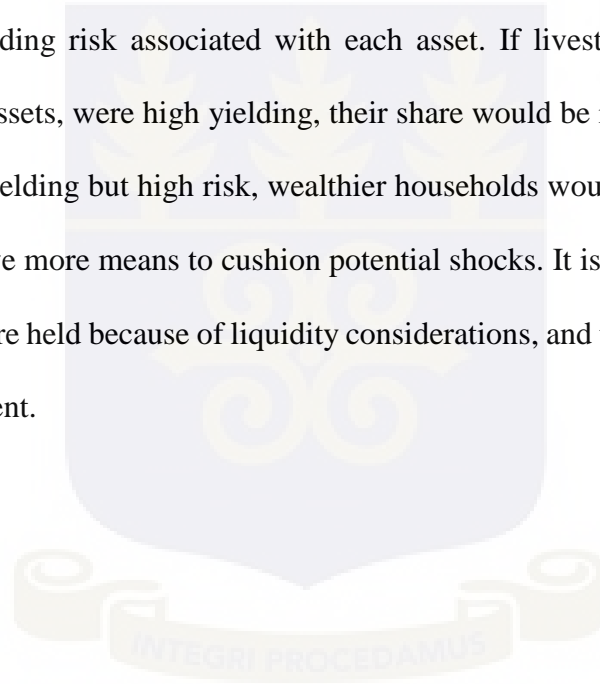


Table 4. 4: Sources of Households' Wealth

Variables	1 st Quartile (n=275)		2 nd Quartile (n=276)		3 rd Quartile (n=275)		4 th Quartile (n=275)	
	Mean		Mean		Mean		Mean	
	2010	2011	2010	2011	2010	2011	2010	2011
Land	278.37	281.77	891.17	966.41	1954.1	2095.45	5286.275	4836.56
Farm Equipment	7.13	6.93	9.36	7.78	9.97	19.01	39.70	27.06
Draught Animal	2.56	3.06	4.18	6.8	2.15	8.58	6.76	10.75
Farm Capital	288.06	291.76	904.72	981.00	1966.22	2123.04	5332.74	4874.41
Small Livestock	8.30	9.29	9.17	9.4	8.828	10.5	10.5	13.54
Large Livestock	3.75	5.24	7.95	2.87	3.05	7.82	8.53	5.84
Livestock	12.05	14.53	17.12	12.28	11.87	18.32	19.02	19.38
Value of Grain Stock	26.00	21.74	27.79	24.43	30.83	27.52	96.76	49.61
Non-Farm Assets	24.44	26.86	24.84	30.11	24.36	29.42	41.66	43.90
Wealth	350.56	354.89	974.47	1047.81	2033.3	2198.32	5490.2	4987.30
Liquid Wealth1	38.04	36.27	44.91	36.71	42.70	45.85	115.8	69.00
Liquid Wealth2	34.29	31.03	37.0	33.83	39.66	38.03	107.26	63.15
Liquid Wealth1 (%)	10.85	10.22	4.61	3.50	2.1	2.08	2.11	1.38
Liquid Wealth2 (%)	9.78	8.74	3.79	3.23	1.95	1.73	1.95	1.26

4.2.5 Households' Income

Table 4.5 presents the sources of households' income. The results show that farm income (Farm Inc.) represents the greatest contributor to household income in all wealth classes. Within the farm income category, crop income (Crop Inc.) represents more than 93 per cent of farm income of the first wealth class. The share of crop income in the total farm income increased to more than 94 per cent for the second wealth class. Crop income share for the third class is slightly lower (92.2 per cent) but nearly 98 per cent for the highest wealth class. This also strongly supports the assumption that returns to investment are higher in crop farming than in livestock holdings; otherwise, wealthier households would have been much more involved in livestock asset accumulation.

With respect to total income (TOT INC.), crop income represents between 54 and 84 per cent of households' income. This is clearly higher as compared to what has been reported by Reardon *et al.* (1992) in rural Burkina Faso (37, 49 and 60 per cent respectively in the Sahel, the Soudano-Sahelian and the Soudanian zones). The results also suggest that households in the higher wealth classes derive more income from livestock than do households in the lower quartiles. However, livestock income, is almost 2 per cent of households' total income for the wealthiest class while it accounts on average for more than 4 per cent in the lower wealth classes. This is lower than the average 13 per cent reported by Reardon *et al.* (1992). Given the occurrence of drought in the period studied by Reardon *et al.* (1992), this may emphasize on the role of shocks on livestock sales as found by Hoddinott (2006).

As expected, remittances are decreasing with wealth. From about 6 per cent for the second wealth class, remittances represent just around 1 per cent of income for the wealthiest class. For the first three income quartiles, the shares of remittances in household income are closer to the 6 per cent stated by Haggblade, Hazell, & Reardon (2009) for Africa and Latin America, and relatively higher than the average 2 per cent found by Reardon *et al.* (1992) for rural Burkina Faso in the early 1980s¹³.

Off-farm work is the second most important source of households' income. Table 4.5 indicates that for the first three wealth classes, off-farm income represents respectively 34, 36.5 and 31 per cent of total income. Though this is lower than what has been indicated by Lanjouw & Feder (2001) for Burkina Faso during the first half of the 1980s (52 per cent for the Sahelian zone), they are relatively closer to the 34 per cent indicated by Haggblade *et al.* (2009) for Africa. However, off-farm income represents barely 13 per cent of wealthiest households' income. While Reardon *et al.* (1992) argues that share of off-farm income varies significantly across agro-climatic zones, these results show that it varies significantly across wealth class. The results also support the hypothesis that rural off-farm activities are less profitable than farming; otherwise wealthier households would be increasingly engaged in. Table 4.5 shows that the share of off-farm income is decreasing with level of wealth.

Between the two years, total income reduced following from a drop in farm income except for the two highest wealth class. For the third class, income remained relatively stable while

Despite the need to take into account the temporal dimension, this study remains one on the rare study in the context of Burkina Faso. In fact, statistics from most recent papers concerning rural Burkina Faso (Haggblade *et al.*, 2009; Lanjouw & Feder, 2001) are consistent findings of this study.

income of households in the highest class increased by about 40 percent. This increase in incomes of the richest households was a result of an improvement of flows from all income sources but most importantly from cropping. Crop income increased by more than 51 percent. In absolute terms, the income fall has been higher for the poor than for the rich. Therefore, though there seems to be a very modest “hit” to the rural economy, wealthiest households seem to have taken advantage from that unlike poorer. This may be explained by their wealth structure. This suggests that wealth accumulation not only reduces vulnerability, it also improves resilience. However, while these changes may reflect intra-quartile changes, they may also be a result of inter-quartile mobility.

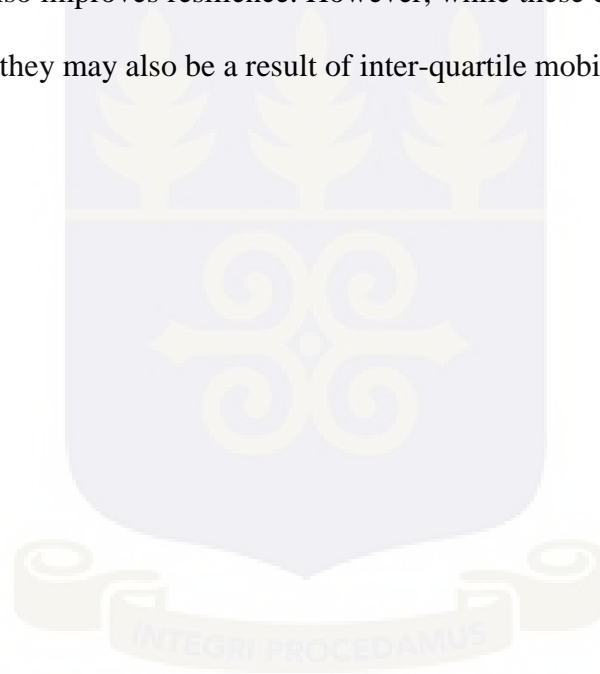
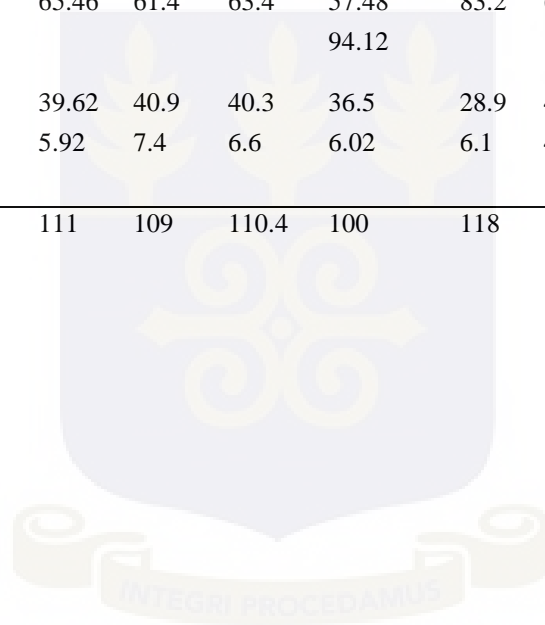


Table 4. 5: Sources of Households' Income by Wealth Quartile

Variable	1 st Quartile				2 nd Quartile				3 rd Quartile				4 th Quartile			
	Mean				Mean				Mean				Mean			
	2010	2011	Av.	%	2010	2011	Av.	%	2010	2011	Av.	%	2010	2011	Av.	%
Crop Inc.	58.4	48.3	53.4	57.1	61.74	57.7	59.7	54.10	77.2	63.5	70.3	59.6	215	325.1	270	84.0
Liv. Inc.	4.12	3.6	3.9	4.16	3.72	3.7	3.7	3.38	5.9	5.8	5.9	4.98	5.2	7.1	6.1	1.91
Farm Inc.	62.5	52	57.2	61.2	65.46	61.4	63.4	57.48	83.2	69.3	76.2	64.6	220.2	332.2	276	86
Crop Inc.%				93.3				94.12				92.2				97.7
Off-f Inc.	30.2	33.2	31.7	34	39.62	40.9	40.3	36.5	28.9	44.2	36.5	31	39.8	44.2	42.1	13
Remittanc.	3.35	5.7	4.5	4.8	5.92	7.4	6.6	6.02	6.1	4.3	5.2	4.4	7	-0.5	3.2	1
TOT INC.	96	91	93	100	111	109	110.4	100	118	118	118	100	267	375	322	100



4.2.6 Off-Farm Activity Participation

Table 4.6 presents results of off-farm participation decisions. Wage labour shows the lowest rate of participation. Wage labour employment includes both agricultural and non-agricultural employment. Over the two years, around 12 per cent have, on average engaged labour in this segment of the off-farm labour market. But between the two years, there was about 31 per cent increase in the number of households that undertook wage labour employment, likely in response to the decrease of income of some households (Table 4.5)

Non-farm activities constitute the main employer in the rural off-farm sector. On average, almost 35 per cent have engaged labour resources in some non-farm activities on average. Non-farm activities are diverse and include truck farming, petty trade, handicraft, restaurant, local breweries etc. Although non-farm participation increased between 2010 and 2011, this increase is very low (around 2 per cent). The overall off-farm participation is up to 42 per cent on average with an increase of about 7 per cent between the between 2010 and 2011. This may be explained by the drop in crop income (see Table 4.5) which might have pushed smallholder farm households to work off-farm to supplement their farm income.

In a study of off-farm labour supply among small farmers in rural India, Ito & Kurosaki (2009) reported higher rate of participation. More than 55 per cent of the labour force were involved in some off-farm work. Moreover, wage work accounted for almost 38 per cent of off-farm employment against less than 18 per cent for non-agricultural self-employment.

This suggests that significant differences may appear when it is rather hours of work that has been recorded. Also, most of the non-farm activities reported in this study also exhibit lower start-up costs. Less than a quarter have reported a start-up cost more than 80 000 FCFA, which is nearly half of the national poverty line (153 530 FCFA, barely 250 US Dollars).

Table 4. 6: Off-Farm Labour Participation Decision

	2010		2011		Overall	
	Freq.	Percent	Freq.	Percent.	Freq.	Percent.
Wage Labour						
Do Not Supply Wage labour	985	89.46	949	86.19	967	87.83
Supply Wage labour	116	10.54	152	13.81	134	12.17
Nonfarm Activities						
No Non-Farm Activity	721	65.49	713	64.76	717	65.12
Any Non-Farm Activity	380	34.51	388	35.24	384	34.88
Off-Farm Activities						
Only Farming	644	58.49	613	55.68	628.5	57.09
Any Off-farm activities	457	41.51	488	44.32	472.5	42.91
Observations	1101	100	1101	100	1101	100

4.2.7 Work Transition Probabilities

Table 4.7 indicates that there is relatively high persistence in non-farm employment. More than half the households which were in some non-farm business activities were still in some activity the following year. On the other hand, the likelihood of remaining in wage work is less than 20 per cent. About 87 per cent of households that did not supply wage labour in 2010 still did not do so in 2011 while around 74 per cent of household that did not have any non-farm business activity in 2010 did not have any in 2011. For households which were neither engaged in work nor in non-farm activities in 2010, the likelihood of keeping

the same status is however lower (about 66 per cent), suggesting households also move across off-farm sectors.

However, the persistence is relatively higher for off-farm labour participation in general than for work segments. Indeed, the likelihood of being involved in any off-farm activity during the two years is about 58.42 per cent against 52.37 and 19.83 respectively for non-farm activities and wage work.

Table 4. 7: Work Transition Probabilities

	Wage Work		Non-Farm Activities		Any Off-Farm Work		Total
	No	Yes	No	Yes	No	Yes	
Not Participate (No)	86.9	13.1	73.79	26.21	65.68	34.32	100
Participate (Yes)	80.17	19.83	47.63	52.37	41.58	58.42	100
Total	86.19	13.81	64.76	35.24	55.68	44.32	100

4.2.8 Households Characteristics by Work Status

Table 4.8 presents households' characteristics by work choice¹⁴. The study sample is divided into two main groups. The first group, participants (the first column), are households which were engage in any off-farm work; and the second group, non-participants (the second column), were households which did only farming. The third column presents the difference between the second and first group; that is, (column 2)-(column 1).

¹⁴ Appendix 1 shows households' characteristics for each work status (wage and non-farm labour) and per year.

Unexpectedly, the results suggest that off-farm participants were households that were expecting higher rainfall on average (Rain mean). Over the period of the survey, the long-run mean of the rainfall for off-farm participants was about 11 millimetres higher than that of exclusively farming households. For the second round, it was more than 21 millimetres higher while it was not significantly different in the first round of the survey. This suggests that off-farm participants were households that were expecting good rainfall outcomes. A plausible explanation for this may be that those trends hide important inter-annual fluctuations of the rainfall as indicated by Figure 1.2; in which case, the higher moments of its distribution become more relevant to decision-making.

As expected, off-farm participants were households which were subject to lower positive rainfall shocks (Rain dev.). Over the survey period, the rainfall shock of non-participants was about 12 millimetres higher than that of participants; while in first year it was about 38 millimetres higher. However, there was not significant difference in the second year. In fact, positive rainfall shocks may be associated with higher return on farm, implying some income smoothing behaviour as indicated in section 3.7.

On the other hand, while off-farm participants were households which received lower rainfall during the first round of the survey (Rainfall), they were households whose received higher rainfall during the second round. But difference in yearly received rainfall by off-farm participants and non-participants on average. This result has similar implications as the rainfall shock. Indeed, part of participation decision is a response to the actual rainfall.

Throughout the survey, off-farm participants were households that were facing riskier rainfall distribution (Rainfall CV). Volatility may therefore be the most important parameter of the decision making as the trade-off between farm and off-farm activities are concerned. Rainfall levels may be higher in a particular community, higher volatility may weigh against the first moment of the rainfall distribution.

The results also indicate that non-participants in off-farm activities were households for which crop average yield was lower on average. Table 4.8 shows that in 2010, off-farm participants had yield that was about 200 kilogrammes higher than households that did not have any non-farm activities while at the same time average yield of off-farm participants were about 240 kilogrammes higher. In an ex-post response perspective, households may be pushed into the off-farm sector because of poor farm performances (Bezu & Barrett, 2010). A plausible explanation for this may be that off-farm participation decisions are taken ex-ante when actual return to farming cannot be known. Also, over time, off-farm participation may be associated with high farm investment, particularly regarding inputs such as fertilizers, which improve farm yield in turn (Ji *et al.*, 2012; Lamb, 2003; Phimister & Roberts, 2006). Indeed, the results indicate that off-farm participants hold more farm equipment (up to 6.5 FCFA per hectare higher) and consume more fertilizer (up to 30 FCFA per hectare higher).

Table 4.8 shows that off-farm participants hold lower land on average. This is unexpected when a profitable off-farm sector is growing; as higher landholdings may enhance access to credit (being used as collateral) to take advantage from investment opportunities. But this does not suggest the absence of liquidity constraints. In fact, the results show that off-

farm participants tend to have more access to credit than exclusively farming households. Because off-farm is riskless, this may explain why off-farm participants have more access to credit than farmers. Though the results show no difference in terms of livestock holdings, off-farm participants received less remittances (up to 4.25 FCFA per adult lower) and holds more grain stocks on average (up to 13.74 FCFA per adult higher). This suggests that binding liquidity constraints may be related to consumption smoothing. Table 4.8 indicate that off-farm participants spend more on both food (almost up to 84 FCFA higher per adult) and non-food (almost up to 78 FCFA higher per adult) consumption as compared to non-participants. These activities therefore complement farm outcome to improve households' food security and their well-being as suggested by Porter (2012).

Off-farm participants were households headed by younger people on average. This result may reflect lifecycle effects; that is, older households had the opportunity to accumulate farm assets (livestock inclusive) which enhance farm return and provide them with other means of risk coping. The results show no difference in dependency ratio among these two groups of households. Participants in off-farm activities are households living in densely populated villages (up to 555 inhabitants or more). Higher population density may imply high demand for non-farm goods and the need to meet such demand may pull the supply of off-farm labour. But there was no significant difference in terms of distance to paved roads, and between off-farm participants and non-participants. First, this may suggest that there is a minimum distance for connection with urban cities to operate and that all villages fall beyond this minimum distance. Second, this may suggest that practicable non-paved roads enable village accessibility. Finally, demand for off-farm labour may be driven by local factors.

Table 4. 8: Households' Characteristics by Off-Farm Work Category by Year

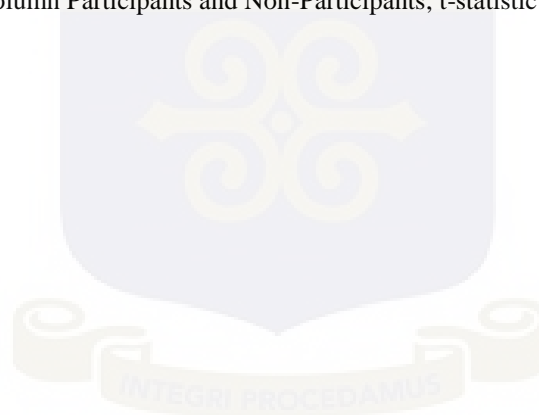
Variables	2010			2011			All Years		
	Participants (457)	Non- Participants (644)	Difference	Participants (488)	Non- Participants (613)	Difference	Participants (945)	Non- Participants (1257)	Difference
Rain Mean	831.55 (150.3)	831.28 (134.51)	-0.26 (-0.03)	841.72 (145.83)	820.17 (134.95)	-21.55** (-2.54)	836.8 (148.01)	825.86 (134.78)	-10.93* (-1.8)
Rainfall	858.89 (149.33)	896.83 (135.89)	37.94*** (4.38)	991.72 (197.92)	961.98 (184.95)	-29.74*** (-2.56)	927.48 (188.12)	928.6 (164.87)	1.11 (0.14)
Rainfall_dev	27.34 (97.74)	65.55 (86.02)	38.20*** (6.86)	150 (94.56)	141.8 (91.28)	-8.2 (-1.45)	90.68 (113.97)	102.73 (96.45)	12.05*** (2.68)
Rainfall CV	124.55 (72.60)	102.88 (59.30)	-21.73*** (-5.45)	127.2 (120.9)	99.63 (94.93)	-27.57*** (-7.03)	125.92 (71.64)	101.27 (59.25)	-24.65*** (-8.82)
Yield	1153.45 (58.15)	946 (31.49)	-207.55*** (-3.36)	1189.22 (4332.26)	915.81 (2791.86)	-273.41 (-1.26)	1171.92 (3229.45)	931.22 (2031.03)	-240.7** (-2.13)
Land Holdings	1.13 (1.02)	1.05 (0.87)	-0.07 (-1.34)	1.09 (0.84)	0.99 (0.70)	-0.1** (-2.03)	1.11 (0.93)	1.02 (0.79)	-0.08** (-2.28)
Real Capital	19.49 (2.95)	14.02 (1.22)	-5.47* (-1.9)	21.22 (146.7)	14.05 (32.95)	-7.17 (-1.17)	20.38 (114.12)	14.03 (31.91)	-6.35* (-1.87)
Fertilizer C.	22.68 (20.15)	7.89 (13.52)	-14.8* (-1.85)	39.28 (28)	10.70 (26.51)	-28.58** (-2.51)	31.25 (24.52)	9.26 (20.93)	-21.99*** (-3.16)
Access to Credit	0.51 (0.5)	0.37 (0.48)	-0.14 (-4.66)	0.42 (0.49)	0.31 (0.46)	-0.11*** (-3.75)	0.46 (0.5)	0.34 (0.47)	-0.12*** (-5.83)
Remittances	3.11 (39.6)	7.36 (29.77)	4.25** (2.03)	5.72 (32.71)	2.35 (23.76)	3.37** (1.97)	2.72 (36.19)	6.56 (27.007)	3.84*** (2.85)
Value of Grain	58.29 (38.7)	36.13 (48.72)	-22.16 (-1.43)	34.33 (47.46)	28.03 (39.8)	-6.3** (-2.39)	45.92 (272.04)	32.18 (44.76)	-13.74* (-1.75)
Livestock Value	13.93 (26.14)	15.79 (36.93)	1.86 (0.92)	17.59 (34.05)	14.95 (36.33)	-2.64 (-1.23)	5.003 (12.17)	4.84 (12.05)	-0.15 (-0.3)
Food Exp.	551.65 (450.42)	467.67 (373.31)	-83.97*** (-3.37)	195.79 (189.16)	157.63 (130.94)	-38.16*** (-3.94)	367.88 (384.86)	316.48 (322.08)	-51.40*** (-3.40)
Non-Food Exp.	44.53 (55.15)	33.47 (24.82)	-11.06*** (-4.49)	364.13 (471.8)	286.38 (454.61)	-77.75*** (-2.77)	209.57 (376.62)	156.80 (342.07)	-52.77*** (-3.43)
Age of the Head	47.06 (13.3)	49.18 (14.32)	2.12** (2.49)	48.43 (13.52)	50.03 (14.13)	1.6* (1.9)	47.77 (13.43)	49.6 (14.23)	1.83*** (3.05)
Hhd Size	6.28 (3.76)	5.43 (2.71)	-0.85*** (-4.34)	6.54 (3.6)	5.83 (3.22)	-0.71*** (-3.46)	6.41 (3.68)	5.62 (2.98)	-0.79*** (-5.56)
Dep. Ratio	1.25	1.31	0.06	1.26	1.28	0.02	1.26	1.3	0.04

Variables	2010			2011			All Years		
	Participants (457)	Non- Participants (644)	Difference	Participants (488)	Non- Participants (613)	Difference	Participants (945)	Non- Participants (1257)	Difference
N. Literates	(0.69) 2.19 (3.0)	(0.75) 1.72 (2.1)	(1.41) -0.47*** (-3.04)	(0.74) 2.37 (2.50)	(0.71) 1.87 (2.05)	(0.42) -0.5*** (-3.57)	(0.71) 2.28 (2.76)	(0.73) 1.79 (2.08)	(1.31) -0.48*** (-4.69)
N. Trained	0.31 (0.65)	0.18 (0.54)	-0.13*** (-3.53)	0.27 (0.22)	0.16 (0.12)	-0.11 (-3.23)	0.29 (0.63)	0.17 (0.52)	-0.12*** (-4.75)
Population	1798.25 (2181.78)	1262.9 (1494.99)	-535.35*** (-4.83)	1923.95 (2114.1)	1371.78 (1498.49)	-552.17*** (-5.06)	1863.16 (2146.88)	1315.99 (1497.06)	-547.17*** (-7.04)
Dist. Road	38.75 (38.85)	39.08 (37.45)	0.34 (0.14)	38.08 (39.14)	39.87 (40.10)	1.78 (0.74)	38.4 (38.98)	39.46 (38.75)	1.06 (0.63)

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Notes: Participants are households which were engaged in any off-farm activity; Non-Participants are households which did only farming

Standard Deviations are in parentheses for column Participants and Non-Participants; t-statistic are in parentheses for columns reporting differences



4.2.9 Off-farm Labour Supply

Figures 4.1 to 4.3 present the distributions of off-farm labour supply for each category of off-farm work and the aggregated off-farm labour supply. For all years and for each work category, labour supply is distributed over few integers with majority of household have a zero-supply. Wage labour supply (Figure 4.1) is relatively small. More than 95 per cent of households which participated in wage labour employment supplied a single unit of labour while not more than one household supplied up to five or six units of labour. Non-farm business employment was the major employer in the rural off-farm sector. The number of people engaged by a household in non-farm business activities varies between zero and 24 in 2010, and up to 31 in 2011. About 96 per cent of households which had some non-farm activities employed less than 6 units of labour while non-farm labour of almost 99 per cent of them is limited to the first ten integers. The number of households that employed more than 20 people is one while the number of households that employed more than a dozen of people is not more than three. Off-farm labour supply sums, for each household, the number of people its engaged in either or both activities. Its distribution is similar those of its sub-sectors. Off-farm labour supply of almost 99 of off-farm participants lies between the interval [0;10]. These results show that count models are the most appropriate method of analysis for this data. The figures show that the distributions are positive and skewed to the right with a half bell-shape.



Figure 4. 1: Wage Labour Supply by Year

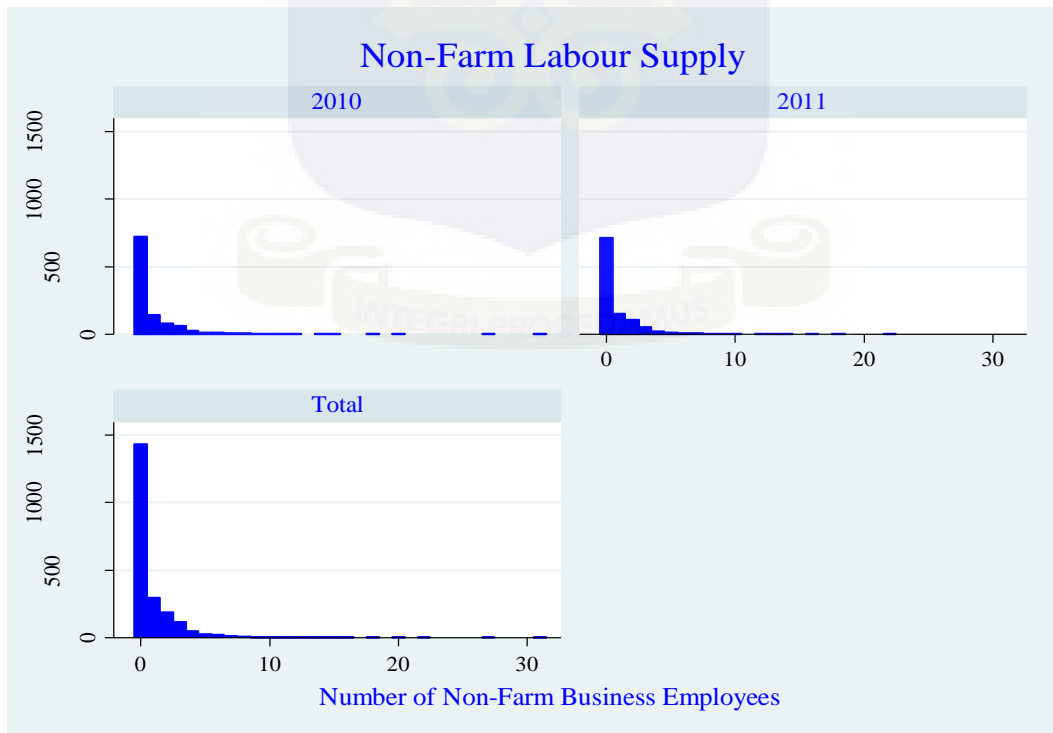


Figure 4. 2: Non-Farm Labour Supply by Year



Figure 4. 3: Total Off-Farm Labour Supply by Year

4.3 Empirical Results

4.3.1 Rainfall Variability and Households' Wealth Portfolio

Table 4.9 presents the econometric results for the share of households' total liquid assets in total wealth. Results are on the share Liquid Wealth1 (only small livestock, poultry and grain). Estimations with the share of Liquid Weath2, which is Liquid Wealth1 augmented by large livestock holdings give similar results (see Appendix 3, Model 5). For results presented in Table 4.9, the dependent variable is the logarithm of the share of liquid wealth. It would be therefore inaccurate to interpret coefficients directly as the percentage change in liquid wealth share induced by a marginal variation in covariates (Wooldridge, 2013).

Denoting x any explanatory variable and $\hat{\beta}$ the associated coefficient, the exact percentage change can be computed as $100 * (e^{\hat{\beta}} - 1)$, according to Wooldridge (2013).

In the first column, rainfall shock was excluded, but permanent income is included as a proxy of total wealth. Column 2 includes both rainfall shocks and the permanent income measure. In the third column, rainfall shock was kept while permanent income is excluded. The fourth column presents the estimation results that exclude both shocks and permanent income estimates (also see Appendix 4, Models 1 to 4 respectively). By doing so, the short-run response to weather outcome can be tested; as also, the portfolio may be readjusted as shocks change the relative profitability of each assets category. At the same time, total wealth reflects the household's ability to invest while allowing for the model specification to be checked.

For all equations, the model fitness is almost similar and moderately good (the overall R-Squared varies between 38.2 and 38.7 per cent according to specification). The Wald statistic of overall significance is also very high in all estimations (the Chi-Squared varies between 720 and 784). Estimates are approximately similar in all estimations except the constant which significance depends on whether the permanent income estimates are included in the regression.

Adding the rainfall shock in the regression (column 2) implies an overall gain of efficiency as compared to column 1, as most significant variables had their t-statistic increased. There is slight efficiency loss associated with the exclusion of the permanent income estimate compared to the first two specification but the significance level remains the same for all variables. Significant changes occur in the last specification where some variables (Marital

status of the head, the population size) that are not significant in the first three specifications have become significant but t-statistics decreased, suggesting loss of efficiency. The last specification appears to be less adequate.

The results show no significant effect of rainfall uncertainty on households' wealth portfolio in all specifications but the coefficient is positive as predicted. This implies that households' wealth portfolios are not affected by the rainfall risk, that is, households facing riskier distribution of the rainfall hold similar portfolio structure as households facing less risky rainfall patterns. Among plausible explanations for this result is that the uncertainty estimate is likely a lower bound of the rainfall uncertainty; that is, the risk faced by the household is underestimated. This is one of the drawbacks of studies of two-year panel; a lower variability is reflected by the data. Particularly, as shown in by figure 1.2, on average the rainfall did not vary much between the two years covered by this study. Using the data on rainfall over this period would therefore reflect the minimum variance faced by the households, even at the district level.

Another explanation may be one suggested by Jalan & Ravallion (2001) according to whom households are more sensitive to idiosyncratic income risk than the weather risk itself. However, empirical studies in the context of rural Burkina Faso have largely challenged the empirical ex-post response of liquid assets to rainfall induced households' income shocks, even over a period that spanned drought shock.

The most plausible explanation is that the households' wealth portfolio holdings respond to long-term rainfall condition. In terms of income risk, this may refer to the permanent income. The results indicate a negative and significant relationship between the share of

liquid assets in total wealth and the long-run rainfall mean. The coefficient, though small, is significant at 1 per cent level in all the regressions. In particular, a 10 millimetre increase of the long-run rainfall mean would reduce the proportion of wealth held in liquid unproductive form by about 3 per cent.

The rainfall deviation from its long-run mean also appears to have no significant effect on liquid asset holdings in any specification; rejecting the hypothesis of portfolio adjustment to short-run rainfall shock. This is in line with Fafchamps *et al.* (1998) and Kazianga & Udry (2006) who found that livestock sales are not significantly affected by transitory income shocks. The sign is however positive, tending to suggest that liquid wealth is accumulated in good time. But households' portfolios are less liquid in the second year as compared to the first; and may reflect the fact that households dissipated part of the liquid assets in response to the income drop observed during the immediate subsequent period. This is in line with the assumption that liquid assets may be accumulated to mediate farm income shocks.

The age of the head of the households indicates a relationship different from the inverted U-shape prediction of the lifecycle model but is not significant. The irrelevance of age in explaining the share of liquid assets in total wealth is however in accordance with the prediction of the buffer stock model according to which buffer assets are accumulated at relatively low levels and that the stock levels may exhibit a flatter trend over the lifecycle (Deaton, 1991).

Positive shocks on permanent income (see Appendix 2 for income regression) are negatively associated with the share of wealth held in liquid form. A marginal increase of

household permanent income reduces the intensity of liquid wealth in the portfolio by about more than 20.14 per cent. This result suggests that the portfolio structure depends on total wealth. Similar results are found by Rosenzweig & Binswanger (1993). As a proxy of total wealth, differences in permanent income reflect differences in ability to save and to invest amongst households. Also, permanent income may also reflect ability to overcome liquidity constraints. Permanent income is not only a proxy of a household's investment capacity, but also an indicator of its ability to cope with risk ex-post. In this perspective, the negative relationship is also an argument of the role of consumption in shaping the households' wealth portfolio. Low consumption level may have consequences on labour efficiency which in turn affects the return to farm capital. The risk of low consumption may therefore have high potential consequence as any other source of risk to the income generation process.

The negative relationship between permanent income and the share of wealth held in liquid form may also reflect the concern of liquidity constraints. Since households which are subject to farm income shock are restricted in borrowing to consume, this may imply a high demand for liquidity. Therefore, households with low permanent income may need to hold more liquid assets. Jalan & Ravallion (2001), however, have found that the relationship between portfolio liquidity and permanent income is not linear among households in rural China. Their finding suggests an inverted U-shaped relationship. The liquidity of households' portfolios first increases sharply with permanent income before decreasing slowly as permanent income increases. This relationship was tested with the squared of the permanent income estimate but the coefficient is not significant. Rosenzweig & Binswanger (1993) included interaction between the risk factor and households' total

wealth (current and inherited) and found that portfolio risk depends on weather risk but that such response varies with wealth level. Kazarosian (1997) also interacted income uncertainty with occupation and showed that the proportion of liquid wealth responds to shock but that such response varies with occupational choices. Interaction between the uncertainty measure and permanent income in this study however are not significant. Several estimations of the wealth portfolios, including estimations by wealth classes, have been carried out but results were not different from those presented in Table 4.9.

The role of liquidity constraints in shaping households' portfolios is particularly important. Portfolios of households which have access to formal credit tend to be less liquid than that of households which do not. Access to credit reduces portfolio liquidity by between 10.6 and 13.6 per cent. Moreover, the amount of remittance received on a regular basis has a negative and significant effect on portfolio liquidity. The effect varies between 6.4 and 6.5 per cent decrease for a 100 CFA increase in regularly received remittances. On the other hand, the amount of remittances received on non-regular base is positively associated with the portfolio liquidity though the coefficient is only significant at the 10 per cent level. Specifically, a 100 CFA increase in the amount of transfers received occasionally increases the liquidity of total wealth by between 2.7 and 3.2 per cent. The effect of remittances on the liquidity of the portfolio may emphasise the role ex-post consumption smoothing abilities; also related of liquidity constraints.

The use of fertilizers, manure and seed increase portfolio liquidity. These factors are expected to have a positive effect on the return to the productive assets base (land, farm equipment and draught animal holdings) and therefore enhance accumulation of those

assets instead of the liquid assets. For fertilizer consumption, the effect varies between 13.31 and 21.16 per cent increase for households that have access to fertilizer. The use of improved seed increases the portfolio liquidity by between 18.3 and 19.14 per cent while the use of manure increases liquidity by between 15.72 and 16.76 per cent. The effect of these factors on the productive asset base is measured in terms of grain produced which in turn feeds into the grain stock holdings. Therefore, these results do not necessarily imply that access to farm input enhance accumulation of non-productive liquid assets at the expense of farm capital.

Households' labour endowment is positively associated with liquidity but the effect is significant only in the first two regressions. A marginal increase in the household size (adult equivalent) increases the liquidity of wealth portfolio by about 2.7 per cent. A negative effect would have suggested that larger households tend to accumulate farm capital rather than non-farm liquid assets which would be in accordance with the hypothesis that labour increases return to farming and therefore makes farm capital more attractive. The argument above may be reported here as well in the sense that the effect of labour on farm capital investment is measured in terms of grain output, which positively affects the liquid component of the portfolio. But the transaction motive for holding liquidity as in the "Keynesian economy" seems more plausible for this positive relationship as argued by Jalan & Ravallion (2001). Indeed, larger households also have higher demand for liquidity for transaction motive regarding their higher demand of both agricultural and non-agricultural goods and services.

This transaction motive for holding liquidity is also suggested by the positive effect of the dependency ratio on the share of liquid wealth. A marginal increase in the proportion of dependents results in an increase of the liquid share by 6.7 to 7.73 per cent. This is as expected because inactive household members contribute less to the outcome from farming. While aged may have some human capital in terms of experience with farming, presence of children under the age of five may even affect the availability of farm labour as they require more care.

Other household level variables that significantly affect the wealth portfolio structure include the ethnic group and the marital status of the head of the household. Households belonging to ethnic groups that are traditionally involved in farming hold portfolios that are between 28.53 and 29.53 less liquid as compared to others. Households in which the head live in union (mono or poly-gamy), widowed or separated headed households, tend to hold less liquid portfolio compared to heads who are single.

With respect to community level variables, the results indicate that households in high populated villages tend to hold less liquid portfolio. While higher population may mean higher possibility to liquidate assets when it is needed, which may encourage livestock accumulation, the results suggest a different thing. First, high population may be potentially congestive, limiting the amount of assets such as livestock that can be held. Second, informal insurance (reciprocity, informal credit schemes) are likely to function, not necessarily to a large extent, in high populated villages. Third, high population may boost the development of seasonal non-farming activities which provide another source of access

to liquidity. Finally, the demand for liquid assets may be driven by exogenous factors that flow from urban cities than the local markets.

The results also show that distance to paved road have a negative effect on portfolio liquidity. A marginal decrease in the distance to a paved road linking two cities increases the portfolio liquidity by between 0.23 and 0.26 per cent. This result highlights the role of transaction cost in the asset holdings decisions. A large share of the liquid assets (livestock mainly and cereal stocks to a certain extent) are likely sold to outsiders. The longer the distance to buyers, the larger the associated transaction cost, reducing the profitability of livestock keeping for instance or storing grain. Indeed, the fact that a village is accessible by vehicle, a proxy for road quality, has a positive and significant effect on liquidity holdings, with the effect increasing the road quality in turn.

However, the existence of a market within a village does not affect the structure of dwellers' wealth holdings. This may imply that assets are traded out villages as tends to suggest the road quality. None of the variables included to control for public intervention (Sofitex, NGO, and Public Program) was significant. The results indicate that households which reside in low agricultural potential areas hold more liquid portfolio than others. The share of liquid assets is more than twice higher for households in the Soudano-Sahelian zone than households in the Sahelian zone. The share of liquid assets of households in the Soudano-Sahelian zone, the second best in terms of agricultural potential, is more than 10 times higher than households in the Soudanian zone, the highest agricultural zone. This is line with the effect of long-run weather outcomes in households' asset holdings.

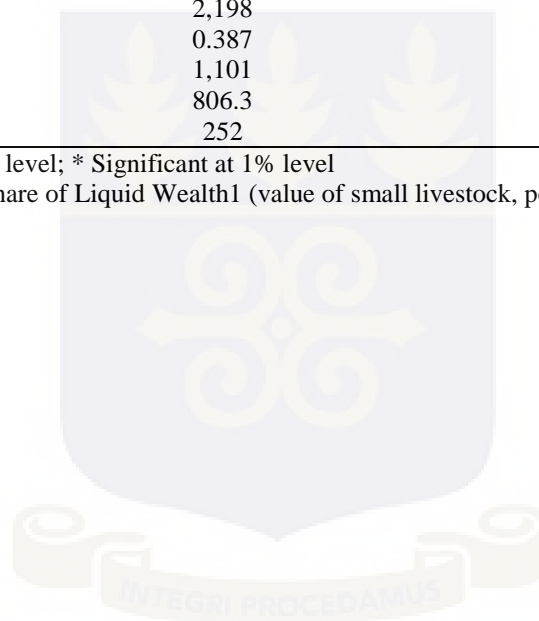
Table 4. 9: Results of the Regression of the Liquid Wealth Share

VARIABLES	Model 1	[t-stat]	Model 2	[t-stat]	Model 3	[t-stat]	Model 4	[t-stat]
Risk Factors								
Rainfall Risk (CV)	0.755	[1.187]	0.796	[1.244]	0.495	[0.775]	0.447	[0.706]
Mean Rainfall	-0.00296***	[-9.215]	-0.00295***	[-9.278]	-0.00290***	[-8.976]	-0.00290***	[-8.919]
Rainfall Shocks			0.000197	[0.866]	0.000207	[0.906]		
HOUSEHOLDS								
Age of the head	-0.00116	[-0.0967]	-0.00127	[-0.106]	0.00636	[0.546]	0.00646	[0.554]
Age of the head (squared)	7.86e-07	[0.00704]	1.51e-06	[0.0136]	-6.24e-05	[-0.571]	-6.30e-05	[-0.576]
Permanent Income	-0.225***	[-3.097]	-0.225***	[-3.108]				
Access to Credit	-0.112**	[-2.554]	-0.117***	[-2.650]	-0.136***	[-3.031]	-0.130***	[-2.926]
Net Regular Transfers	-0.000646***	[-5.223]	-0.000639***	[-5.193]	-0.000649***	[-5.432]	-0.000655***	[-5.450]
Net Occ. Transfers	0.000272*	[1.662]	0.000274*	[1.668]	0.000303*	[1.861]	0.000300*	[1.854]
Access to Fertilizer	0.190***	[3.620]	0.192***	[3.614]	0.141***	[2.639]	0.141***	[2.672]
Access to Seed	0.168*	[1.852]	0.175*	[1.914]	0.170*	[1.863]	0.163*	[1.799]
Use of Manure	0.155***	[2.983]	0.155***	[2.974]	0.154***	[2.948]	0.154***	[2.954]
Hhd Size (adlt equival)	0.0268**	[2.457]	0.0268**	[2.453]	0.00619	[0.777]	0.00620	[0.779]
Dependency Ratio	0.0656**	[2.065]	0.0664**	[2.091]	0.0679**	[2.151]	0.0671**	[2.121]
Ethnic Group	-0.336***	[-3.308]	-0.342***	[-3.406]	-0.350***	[-3.471]	-0.344***	[-3.369]
Marital Status								
Live in Union	-0.223	[-1.351]	-0.222	[-1.347]	-0.249	[-1.514]	-0.249	[-1.515]
Separated or Widow	-0.384*	[-1.725]	-0.384*	[-1.708]	-0.394*	[-1.775]	-0.394*	[-1.791]
Source of Energy	0.151	[0.871]	0.151	[0.875]	0.101	[0.589]	0.102	[0.591]
Gender of the Head	-0.166	[-0.770]	-0.162	[-0.747]	-0.218	[-1.000]	-0.223	[-1.025]
Education of the Head								
Primary Education	-0.404**	[-2.154]	-0.406**	[-2.171]	-0.424**	[-2.229]	-0.422**	[-2.213]
Secondary Education	-0.523***	[-3.166]	-0.543***	[-3.328]	-0.545***	[-3.167]	-0.524***	[-3.014]
Madrasa	0.143	[1.416]	0.140	[1.380]	0.126	[1.240]	0.130	[1.275]
VILLAGE								
Population Size	-0.0166	[-1.066]	-0.0152	[-0.976]	-0.0213	[-1.385]	-0.0227	[-1.472]
Distance to Paved Road	-0.00256***	[-3.034]	-0.00252***	[-2.998]	-0.00228***	[-2.637]	-0.00233***	[-2.680]
Sofitex	-0.158	[-1.224]	-0.150	[-1.123]	-0.136	[-1.008]	-0.145	[-1.117]
NGO	-0.0619	[-0.364]	-0.0578	[-0.365]	-0.125	[-0.813]	-0.127	[-0.771]
Public Program	0.0201	[0.133]	0.0302	[0.195]	0.0484	[0.305]	0.0368	[0.240]
Village Access								
All the Year	0.265***	[3.512]	0.270***	[3.546]	0.276***	[3.577]	0.270***	[3.540]

VARIABLES	Model 1	[t-stat]	Model 2	[t-stat]	Model 3	[t-stat]	Model 4	[t-stat]
During Dry Season Only	0.0364	[0.573]	0.0409	[0.637]	0.0487	[0.760]	0.0439	[0.691]
Market Dummy	0.0141	[0.0670]	0.00703	[0.0334]	-0.0159	[-0.0749]	-0.00743	[-0.0351]
Agricultural Potential								
Soudano Sahelian	0.772***	[8.255]	0.775***	[8.391]	0.819***	[8.705]	0.817***	[8.573]
Sahelian	0.411**	[2.217]	0.439**	[2.305]	0.445**	[2.289]	0.415**	[2.189]
yardum	-0.168***	[-3.908]	-0.188***	[-4.109]	-0.183***	[-4.024]	-0.162***	[-3.786]
Constant	-0.0474	[-0.0677]	-0.0686	[-0.0983]	-1.426***	[-2.685]	-1.407***	[-2.642]
Observations	2,198		2,198		2,198		2,198	
R-squared	0.386		0.387		0.384		0.382	
Number of Households	1,101		1,101		1,101		1,101	
Chi-Squared	784.2		806.3		741.4		719.9	
Number of Clusters	252		252		252		252	

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Notes: The dependent variable is the log of the share of Liquid Wealth1 (value of small livestock, poultry and grain) in the household total asset value. Cluster-robust estimates are presented



4.3.2 Rainfall Variability and Off-Farm Labour Supply

Three equations of off-farm labour supply are estimated using random effects model. Results are presented in Table 4.10. For the first regression, the dependent variable is the number of household member who for against payment, either in-kind or cash in both agricultural and non-agricultural activities. This is referred to as wage labour supply in the discussion. In the second regression, the dependent variable is the number of people that a household has engaged in for its non-farm activity; it therefore includes both labour from family as well as hired labour, and is referred to as non-farm labour. Finally, the total number of people a household has engaged for either or both categories of labour, referred to as aggregate off-farm labour supply, is regressed against the same set of covariates (also see Appendix 4, Models 1 to 3 respectively).

As random effects estimators are used, time invariant variables are allowed in all equations. The value of the Log-Likelihood indicates a good fit for all equations. The Wald statistic of joint significance indicates that all three models are appropriate.

The results indicate that rainfall variability positively affects off-farm labour supply. This confirms the presence of ex-ante response to rainfall risk. The coefficients are substantially high and significant for the two work equations and the aggregated off-farm labour equation as well. In particular, a one standard-deviation increase in the coefficient of variation of rainfall leads to an increase of 3.47 and 2.02 percent respectively in waged and non-farm labour supply. The aggregate off-farm labour would increase by 1.56 per cent. This therefore implies that households facing riskier rainfall distribution tend to work more in off-farm activities.

On the one hand, this is consistent with the predicted portfolio effect that households will adjust their activity portfolios away from the risky one. On the other hand, this result may reflect the presence of precautionary motive. Presence of precautionary motive may imply that households increase work time (maybe in both) at the expense of leisure to reduce the likelihood of getting low income (Rose, 2001). In the context of the present study, the latter is unlikely as it is the number of employees that is observed. Precaution in terms of forgone leisure is therefore not appropriately captured by this data. The precaution, in accordance with the theoretical framework, may also be expressed in terms of aversion to loss. This implies that risk averse households will tend to pursue a minimum income level through the riskless activities. As the risk of farm income collapse increases with volatility of rainfall, risk averse households will increase off-farm work in their attempt to reduce likelihood of lower farm outcomes.

For a model of labour market participation among households in rural India, Rose (2001) found similar results, although with much lower effect of rainfall uncertainty. The effect of a standard-deviation increase in the likelihood of participation were at most 1.5 percent, closer to what is found by Menon (2009) for occupational choice in rural Nepal. Results of the present study are relatively comparable to those of Ito & Kurosaki (2009) who found an effect that varies between 1.4 and 2.32 per cent for hours of wage labour supply.

This is not surprising under the assumption of risk aversion as households which seek to reduce labour income volatility would work more in the off-farm sector as rainfall volatility increases. Labour is therefore used as a means of ex-ante risk management.

There is also evidence of ex-post response as well. Though this seems to be limited to non-farm business employment, total off-farm labour supply is negatively and significantly affected by rainfall. With respect to non-farm business employment, this is reflected by the negative and significant effect of the rainfall shock (Rainfall Deviation) on non-farm labour supply. This implies that households reduce non-farm labour supply in the aftermath of a positive rainfall shock. In terms of the magnitude of the labour response, the results indicate that 100 millimetres of rainfall lower than the long-run mean increases non-farm labour supply and total off-farm labour supply respectively by 8.8 and 5 per cent.

The effect of rainfall shock is positive but not significant for the wage labour supply. This implies that households increase work in non-farm activities rather than salary employment when hit by negative rainfall shock. Where credit constraints are relevant (entry barriers), it would be expected that wage labour supply would be more responsive to shocks than non-farm business labour. However, this may not be suggestive that entry barriers are irrelevant to working off-farm. There are several possible explanations for this finding. First, this may be explained by the patterns of the non-farm activities. Non-farm activities are mainly small business activities which exhibit low start-up costs as revealed by the data. Therefore, households may be able to meet requirements for starting some of these activities. Second, non-farm business activities may be subject to seasonality but may be carried over time. Households that are subject to negative shocks may just need to increase labour to maximize outcome from previous activities. Finally, this result may reflect synergy between farming and off-farm work. When a positive shock affects the economy, there is a positive shock on the demand for non-farm goods which increase the demand for labour. However, part of the demand for wage labour comes from cropping activities which

will not be available after the shock realization. This may justify why the wage labour supply is not significant. That is, when a shock reduces farm income, households may use more family labour in their own business since they cannot sell it out.

The long-run mean of rainfall has the expected sign but is only significant in the estimation of non-farm labour supply and the total off-farm labour supply. The coefficient of the long-run mean of rainfall in the wage labour regression has the predicted sign but is not significant. This result shows that households' off-farm labour allocation responds also to anticipated long-run rainfall conditions. This means that where better weather outcomes are likely, households tend to work less in non-farm activities. More specifically, labour supply to non-farm activities would decrease by 7.22 per cent if the long-run rainfall mean were to increase by 100 millimeters while the overall labour supply would decrease by 6.54 per cent. The fact that only labour supply to non-farm activities respond to long-term conditions reflects the fact that non-farm activities are likely carried out over years unlike wage employment which will likely respond to seasonal changes in the rural environment. Participation in off-farm activities as a response to expected long-run weather outcome is also found by Mathenge & Tschirley (2015) among households in rural Kenya.

As expected, the results also show that experiencing negative health shock during the farming season increases off-farm labour supply. The coefficient is significant in the last two labour equations. A marginal increase in the number of household members who were inflicted by injuries, diseases or other kind of illness which prevented them from working, increases households non-farm labour supply by about 5.23 per cent against 6.15 per cent for aggregate labour. A plausible explanation of this result is that health shocks reduce the

farm labour force (given that other members might be mobilized for care) and consequently, available farm outcome. The households will therefore have to work more in off-farm activities to supplement farm outcome. This suggests that households do make use of labour in response to ex-post idiosyncratic shocks as well.

With respect to the household structure, the results show that the number of male adults and female adults in the household have positive and significant effect on wage employment but have no significant effect on non-farm labour supply. Specifically, a marginal increase in the number of male (respectively female) adults in the households increases its wage labour supply by 17 (respectively 13.43) percent. With respect to the aggregate off-farm labour supply, only number of male adults has a significant effect. The results suggest that a marginal increase in the number of male adults in the household increases its total off-farm labour supply by 3.86 per cent. The sign is as expected regarding non-farm and aggregate labour equations but is not significant. On the one hand, the result indicates that households' labour supply depends on their respective labour resource endowment; and probably that wage employment in the rural economy settings requires some physical skills. For instance, over the two years, activities such as masonry, agricultural labourer, herding and traditional mining account for about between three quarters and 80 per cent of the total wage employment. This physical skill requirement may be the explanation of why households with more young members (between the age of 6 and 14) tend to supply less labour in this category of off-farm work. On the other hand, the non-significant effect of households' labour endowment on non-farm labour implies that participants in this work category do not rely heavily on family labour; that is, they also hire labour.

The results also show a U-shaped relationship between age and wage labour employment but the coefficient is only significant at the 10 per cent level. Specifically, there is a 5.23 per cent decrease in wage labour for a marginal increase in the age of the head of household until the age of 53; then, wage labour supply starts decreasing at a rate of 0.05 per cent for a marginal increase in its age. This result therefore suggests that households headed by young tend to engage more labour in wage labour supply than households headed by older people. However, the pattern is far from symmetry as the rise of less sharply. This result is in line with the prediction of the life-cycle model. Older heads of household might have accumulated more wealth which enhances their ability to handle income risk (or increases the return from farming). After certain a point, accumulation slows down and (or) the household might start decumulating. Off-farm work might again become necessary to supplement the household income. The same U-shaped effect is observed in the non-farm labour equation but not significant. The relationship is hump-shape for the aggregate off-farm labour, though not significant.

According to the results, the presence of children under the age of five does not explain a household off-farm labour supply. On the one hand, it might be argued that higher number of children has a direct negative effect on the potential off-farm labour supply for the household; either in terms of fewer active members or through the need for care. However, this need for care may rather reduce the farm labour force and by this, the attainable farm outcome. Households may therefore need to work more in off-farm activities to supplement farm income. A significant effect is however rarely encountered in the empirical literature. An exception is Mishra & Goodwin (1997) who found a positive effect on hours of work

of both farmers and spouses. Similar expectations are made regarding the number of aged in the households. This is also the case regarding the number of aged.

Gender of the household head as well as their marital status has no effect on any labour equation. The former means that there is no evidence of gender bias in labour market participation while the latter rejects the hypothesis of differentiated labour allocation behaviour between single headed households and non-single ones.

With respect to the education of the head, the results suggest that only attainment of secondary education has a positive and significant effect on the aggregated off-farm labour supply. Though the sign is expected, school attendance does not explain labour supply in any specific labour model. The role of human capital is rather revealed by the effect of the number of household members having benefited from capacity building programs (number of trained) on all labour equations. A marginal increase of the number of trained members increases wage, non-farm and total labour supply by 31.65, 17 and 14.8 per cent respectively. These results reveal the kind of human capital required in the rural labour market; that is, improved work skills. This also points out the importance of the various capacity building programs for improving off-farm working capacities. The number of literate does not have significant effect in any labour supply model.

Unexpectedly, access to energy has no effect off-farm labour supply though the signs are in conformity with expectations. As a capacity variable, access to energy is expected to enhance small businesses but a deeper look at the pattern of non-farm activities suggests that most of the activities do not require energy. Access to information has a positive effect on the aggregate labour model.

Access to credit has significant and positive effect on non-farm employment and the aggregate off-farm employment (14.57 and 10.85 per cent respectively). The effect is not significant on waged employment. Indeed, credit may provide start-up cost or working capital but would not play any role in wage employment. Given that credit constrained household may be left with the option relating to wage employment, a negative effect may be expected.

If access to credit affects off-farm work by means of overcoming financial barriers, livestock holdings, landholdings and permanent income should have had similar effects as well. The results indicate that livestock income affects wage labour and non-farm employment labour in opposite direction. More livestock income implies lower wage labour supply and higher non-farm labour supply. The effect is not significant on the aggregate labour supply. This result may suggest that return to labour in non-farm businesses are higher than the return of labour allocated to wage employment while confirming the existence of financial entry constraints. This suggests that livestock sales serve both the purpose consumption smoothing and that of providing finances to pursue return opportunities.

This result regarding livestock income is observed for landholding and permanent income measure (see Appendix 2 for income regression). The effect of landholding exhibits a hump-shaped profile with respect to non-farm business labour and the aggregate off-farm labour supply. The effect on the wage labour is non-significant but rather U-shaped. This conforms to the expectation that the variable affects the two work categories in opposite ways. More landholdings implies lower labour supply to non-farm activities until about

between 26 and 28 hectares from which the reverse is observed. First, more landholdings may provide more farm outcome, provide less incentive to work increasingly in off-farm (the need to smooth income). Second, the use of land as collateral to access credit may be more feasible for higher landholdings, particularly for risk averse households; where the aversion to losing one main resource is high. Finally, this result may reflect the empirical inverse relationship between land size and yield as well. That is, farming is more efficient for lower landholdings, which will likely mean lower land per capita.

The effect of the permanent income measure also exhibits a humped-shaped pattern across all labour equations, with a turnaround point around 7.5; but the effect is not statistically significant on the wage employment. This means that the wealthier the household, the higher labour engaged in non-farm business activities. This may reflect the consideration of ex-post consumption smoothing ability.

The amount of remittances received by a household on a regular basis is negatively associated with off-farm labour supply but the effect is significant only regarding the wage labour supply. On the other hand, the amount of remittances received occasionally affects negatively all equations but non-significant with the wage employment. These results therefore emphasized the role of off-farm labour in supplementing household consumption.

Community-level factors include road quality, population size, distance to paved roads, access to market and public intervention. The results suggest that the number of inhabitants of a village has positive effect on non-farm labour supply. Population may therefore reflect the potential demand for non-farm goods and services. However, whether market exist within the village has no significant effect in any labour supply model. This may suggest a

weaker role of such institution in the exchange of non-farm goods and services. Also, produced non-farm good may be traded outside villages. This is likely as the coefficient of village road quality (Village Acc. By Vehicle) is highly significant and positive. However, distance to paved road is not significant.

The presence of an on-going public development program has no significant effect on off-farm labour supply. On the other hand, non-farm work employment, and the aggregate off-farm labour supply are larger in village where non-governmental organizations intervene.

The results also indicate that only off-farm labour supply in the Soudano-Guinean zone differs significantly from the labour supply in the Soudanian zone. Households in the Soudano-Sahelian zone supply less wage labour, and off-farm labour in general. With respect to the rainfall distribution, the Soudanian zone represents the highest agricultural potential zone. It is expected that off-farm labour in less potential agricultural zones be higher. Though the sign is as expected in the Sahelian zone, it is not significant. A plausible explanation is the potential synergy between the sectors of the rural economy, implying that the off-farm sector is more developed in more favourable agricultural areas. It is also possible that household income is more volatile in higher potential agricultural zone as households will tend to focus on farming.

Table 4. 10: Results of the Regression of Off-Farm Labour Supply

VARIABLES	Wage Labour Supply	[t-stat]	Non-Farm Labour Supply	[t-stat]	Aggregated Off-farm Labour Supply	[t-stat]
RISK FACTORS						
Rainfall (CV)	3.409**	[2.166]	2.003***	[2.942]	1.546***	[2.631]
Mean Rainfall	0.000656	[0.740]	-0.000876***	[-2.587]	-0.000495	[-1.640]
Rainfall Deviation	-0.000350	[-0.291]	-0.000722*	[-1.858]	-0.000654*	[-1.892]
HOUSEHOLD						
Number of Male Adults	0.157***	[2.585]	0.0302	[1.144]	0.0379*	[1.806]
Number of Female Adults	0.126**	[2.341]	-0.0241	[-0.910]	-0.0175	[-0.833]
Young Members	-0.0551	[-1.590]	0.0201	[1.200]	0.0213	[1.478]
Number of Literate	0.0356	[1.039]	0.00470	[0.382]	0.00169	[0.167]
Number of Trained	0.275***	[2.914]	0.157***	[4.245]	0.138***	[4.452]
Health Shock	0.100	[1.592]	0.0510*	[1.933]	0.0597***	[2.829]
Education of the Head						
Primary Education	-0.168	[-0.525]	0.129	[0.841]	0.0466	[0.323]
Secondary Education	0.605	[1.231]	0.194	[0.508]	0.475**	[2.407]
Madrassa	0.0598	[0.163]	0.102	[0.779]	0.0923	[0.810]
Gender of the Head						
Gender of the Head	1.257	[1.195]	-0.183	[-0.645]	0.129	[0.435]
Age of the head						
Age of the head	-0.0538*	[-1.760]	0.0108	[0.671]	-0.00167	[-0.131]
Age of the head (squared)	0.000503*	[1.778]	-0.000161	[-1.019]	-1.37e-05	[-0.111]
Marital Status of the Head						
Live in Union	-0.563	[-1.600]	-0.0607	[-0.219]	-0.210	[-1.047]
Separated or Widow	-0.234	[-0.408]	0.0919	[0.271]	-0.0775	[-0.310]
Children Under 5	-0.0654	[-1.294]	0.0112	[0.573]	-0.00167	[-0.102]
Number of Aged	0.0336	[0.247]	-0.0883	[-1.443]	-0.0660	[-1.259]
Source of Energy	-0.246	[-0.449]	0.209	[1.385]	0.153	[1.248]
Access to ICT	0.00930	[0.0384]	0.195	[1.446]	0.244**	[2.210]
Net Regular Transfers	-0.00106***	[-2.615]	-6.49e-05	[-0.502]	-1.31e-05	[-0.108]
Net Occ. Transfers	-0.00111	[-1.116]	-0.00110***	[-2.942]	-0.000888***	[-3.197]
Permanent Income	0.436	[0.322]	2.100***	[3.372]	1.822***	[3.561]
Permanent Income (Squared)	-0.0573	[-0.601]	-0.136***	[-3.079]	-0.121***	[-3.343]
Access to Credit	0.0494	[0.330]	0.136**	[2.199]	0.103**	[1.963]
Land Size	0.0326	[0.841]	-0.0372***	[-2.697]	-0.0294**	[-2.519]
Land Size (Squared)	-0.000943	[-0.870]	0.000661***	[3.485]	0.000557***	[3.549]
Transport Assets	-7.27e-05	[-0.239]	0.000127	[1.187]	1.92e-05	[0.194]
Livestock Income	-0.00241*	[-1.952]	0.000487**	[2.037]	8.67e-05	[0.272]

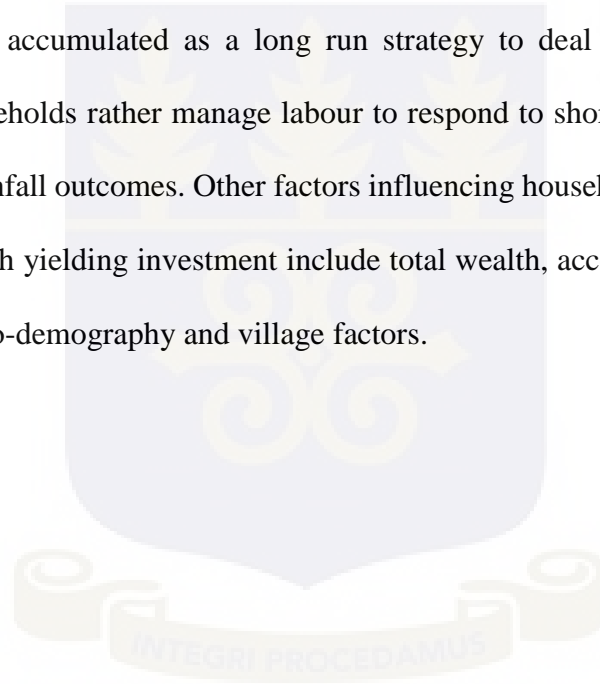
VARIABLES	Wage Labour Supply	[t-stat]	Non-Farm Labour Supply	[t-stat]	Aggregated Off-farm Labour Supply	[t-stat]
VILLAGE CHARACT.						
Population Size	0.0395	[0.971]	0.0460***	[2.873]	0.0415***	[3.668]
Village Acc. By Vehicle						
All the Year	0.327	[1.213]	0.167*	[1.691]	0.232***	[2.701]
During Dry Season Only	0.262	[1.253]	0.156*	[1.744]	0.190**	[2.487]
Distance to Paved Road	-0.000161	[-0.0549]	-0.00147	[-1.389]	-0.000450	[-0.517]
Market Dummy	-0.703	[-0.977]	0.506	[1.382]	0.398	[1.175]
Public Program	-0.734	[-1.247]	0.149	[1.122]	0.114	[1.115]
NGO	-0.201	[-0.261]	0.590***	[2.857]	0.435**	[2.431]
Agricultural Potential						
Soudano Sahelian	-0.666***	[-2.603]	-0.0959	[-0.986]	-0.195**	[-2.523]
Sahelian	0.250	[0.403]	0.245	[0.996]	0.133	[0.678]
Year Dummy	0.231	[1.189]	0.130	[1.622]	0.110	[1.536]
Constant	-2.536	[-0.498]	-9.158***	[-3.949]	-7.722***	[-4.117]
Constant Insig2u	0.0491	[0.0793]	-14.02	[-0.000319]	-14.22	[-0.000291]
Observations	2,200		2,200		2,200	
Number of men	1,101		1,101		1,101	
Log likelihood	-1002		-1495		-1672	
chi-squared	129.1		164.6		145.2	

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.

Notes: The dependents variables are respectively number of wage workers, labour in non-farm businesses and the sum of them
Cluster-robust estimates are presented

4.4 Conclusion

The data showed that land represents the main source of households' wealth while cropping represent their main sources of income. Holdings of liquid assets and income from off-farm activities are both decreasing with total wealth, suggesting that they are low yielding investment as compared to cropping. The results also indicate that there has been a sluggish inter-wealth quartile mobility as compared to inter-income quartile mobility; and for non-farm labour supply as compared to wage labour supply. Econometric results suggest that liquid assets are accumulated as a long run strategy to deal with anticipated rainfall conditions. Households rather manage labour to respond to short-run rainfall shocks and unanticipated rainfall outcomes. Other factors influencing households' resource allocation towards risky high yielding investment include total wealth, access to credit, remittances, households' socio-demography and village factors.



CHAPTER FIVE

CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Introduction

Despite continuous growth of the global economy, poverty remains very high in Burkina Faso, particularly in rural areas. Indeed, while there is still about 40 per cent of the population living below the national poverty line, more than 90 per cent of these poor are located in rural areas. Agriculture constitutes the main source of livelihood for the rural poor. For their livelihood, they accumulate various types of assets, mainly agricultural related, and engage their resources in different activities. To achieve the social development goal of reducing poverty, there is need to enable them to invest in high yielding assets and activities. However, assets and activities that have high rate of return in the rural environment are generally associated with important risk. The main source of risk affecting their assets and activities is weather related because agriculture is still essentially rainfed. The absence of risk markets and the low development of credit market push households to development endogenous mechanisms to deal with the potential effect of weather hazard. The costs of such self-insurance strategies are high as they often lead to increased investment in low yielding assets and activities in attempts to reduce disutility associated with volatile income processes; resulting in lower income on average which may hinder low income households' upward mobility. The main objective of this study was to analyse the effect of uninsured rainfall risk on resource allocation decisions by smallholder farm households in Burkina Faso. More specifically, the study analysed the

effect of the rainfall variability on smallholder farm households' asset holdings and on their labour supply to the off-farm sector.

5.2 Summary

Rainfall risk remains the main challenge to agricultural development in Burkina Faso. This study examined the effect of rainfall risk in resource allocation by smallholder farm households in this context, using a two-year panel data. The data were collected along with the implementation of the second phase of the Program National de Gestion des Terroirs (PNGT-II) by the LAQAD.

Using Stochastic Dynamic Programming Methods, the theoretical model showed that increased rainfall risk raises the relative desirability of liquid unproductive assets and leads to increased investment in such assets. This may result in a relatively flatter income path depending on the constant return to such assets. Combining stochastic dynamic programming methods and the real option approach, it is shown that increased volatility prompts shifts to riskless low yielding activity. In addition, increased volatility also raises the relative desirability of the low yielding activity, tending to support the likelihood of risk induced poverty.

The data has shown that land represents more than 95 per cent of households' total wealth. For the households in the highest wealth quartile, non-land assets represent less than one per cent of their total asset value. The results also indicate that the stock of non-land farm capital increases with households' total wealth, unlike the share of liquid assets. Households appeared also to hold important levels of non-farm assets. As income is

concerned, households derive between 54 and 85 per cent of their income from cropping against less than five per cent from livestock assets holdings. On average, off-farm activities contribute between 31 and 34 per cent to total income. Because wealthier households have more means to enable them to take advantage of high yielding investment, given prevailing risk, this seems to indicate that productive farm assets yield higher than other liquid assets, but also that return to farming is higher than return to off-farm work.

The results also indicate that there has been a sluggish inter-wealth quartile mobility over the two years as compared to what is observed with inter-income quartile mobility. With respect to off-farm participation, the results show a relative persistence for non-farm labour supply against a very low proportion (around 20 per cent) of households being involved in wage labour over the two consecutive periods. Off-farm participation increased in the second year despite an increase in rainfall, yield and farm income. This highlights the importance of inter-village variability but also that households may be affected differently by shocks, depending on their total wealth.

The econometric results indicate that rainfall variability has no significant effect on the share of liquid assets in the households' total asset value as well as rainfall shocks. Liquid asset holding is rather a long-term strategy in response to anticipated rainfall conditions. The direction of the effect of access to credit and permanent income suggests a role for liquidity constraints. The sign of permanent income measure is in accordance with the assumption of precaution, but may also reflect consideration for consumption smoothing as is revealed by the net inflow of remittances.

Access to farm inputs, as well as the structure of households, affect the share of liquid asset in total wealth. Village level variables that affect the liquidity of households' portfolios includes distance to paved roads and the quality of roads, suggesting the role of transaction costs in household portfolio structure. Finally, the results showed that households in the Sahelian and the Soudanian zones hold portfolios that are more liquid than households in the Soudanian zone. This highlights the importance of locational considerations for policy purpose.

Off-farm labour supply revealed the presence of both ex-ante and ex-post responses to rainfall shocks. As predicted, labour supply responds positively to increased rainfall risk and negatively to positive rainfall shocks. The estimated off-farm labour supply model also indicates the presence of response to anticipated long-term weather outcomes. In addition, off-farm labour rises with the magnitude of idiosyncratic shocks.

The effect of permanent income on off-farm labour supply is hump -shaped, while the effect of landholdings is u-shaped. Capacity variables, including access to credit and livestock income also affect labour supply positively. The amount of remittances received affects negatively the labour supply. Households socio-demographic characteristics appeared to influence significantly, household labour supply. The significant effect road quality on non-farm business labour supply suggests the role of transaction costs. As with the proportion of wealth held in the form of liquid assets, there are locational differences. Households in the Soudano-Sahelian zone tend to work less off-farm than the households in the other Soudanian and Sahelian zones.

5.3 Conclusions

Rainfall risk is a major concern for smallholder farm households. Rainfall risk may limit their ability or willingness to adopt high yielding technologies. It may push them to pursue costly risk reducing strategies by engaging increased resources in low return investments because they are low risk. This may result in lower return on average which may create but also perpetuate poverty.

This study has shown that anticipated rainfall outcomes affect significantly the liquidity of smallholder farm households' wealth portfolios. Rainfall variability and rainfall shocks add to these anticipated rainfall outcomes to determined labour allocation to low yielding low risk off-farm activities. These results show the role of rainfall in household wealth accumulation and income generation strategies. Households in the lowest quartiles derive more income from farm liquid assets (livestock, poultry and grain) and from off-farm activities. This tends to imply that productive farm assets, and farming in general, have better returns than non-productive liquid assets and off-farm activities. The tendency to accumulate high level of liquid unproductive assets or work more off-farm will therefore result in lower income paths which may lead to poverty. The study also reveals that labour resources are more responsive to rainfall distribution than assets. This implies that households recourse to labour supply in response to short-run aspects of the risk factor and that wealth structure is adapted to long-run risks. Enabling households to accumulate more farm productive assets and allocate more labour on the farm is necessary to boosting their income generation capacities. This implies addressing the weather challenge they face.

5.4 Policy Recommendations

The findings of this thesis suggest that households increasingly allocate resources to lower return production structure because they have less means to protect themselves from rainfall hazard. Where proper risk coping mechanisms are available, even risk averse households are shown to be able to abide risk and undertake high yielding and high risk investment. The role of liquidity constraints in their resource (wealth and labour) allocation is also emphasized. Policies should therefore focus on measures that either mitigate the risk and or reduce its impact on households' well-being.

One approach requires a structural transformation of the farming system that lowers the effect of the rainfall variability on the households' production structure. Development of irrigation schemes may be pursued to this end. Though, this may be viewed as part of the long-run agricultural development strategy, the promotion and diffusion of groundwater pump irrigation can be the focus of short and medium term policies. Groundwater pumping is an emerging technology that offers means to reduce the effects of low rainfall on cropping and livestock breeding as well.

Mitigating the effect of risk on households' well-being involves developing both ex-ante and ex-post risk management tools. With respect to ex-ante risk management strategies, insurance schemes remain the most adequate strategy identified in the literature. In the Programme d'Action National d'Adaptation aux changements climatiques (PANA), the development of an agricultural insurance scheme is considered as the long-run strategy to mitigating the effect of climate change on the agricultural sector. It is important here to emphasize the need to take into account the role of stakeholders' attitudes towards

insurance policies, as there is a high reluctance among smallholder farmers to pay for insurance policies that are not heavily subsidized around the developing world. This may be the case when they have access to low cost insurance mechanisms (informal risk-sharing), which is less likely regarding evidence from empirical research in the context of Burkina Faso, or when insurance cost is relatively too high to be affordable. It is worth noting that while agricultural insurance policies benefit from public subsidies, agricultural insurance policy premiums are subject to a taxation at 12% in Burkina Faso¹⁵. Despite, farmers showed an increasing interest in two agricultural insurance products (satellite based index maize drought insurance and yield risk insurance for cotton) introduced by PlaNet Guarantee Burkina, covering up to 3886 farmers within three farming seasons. This opens room for policy maker to reduce the cost of agricultural insurance by cutting (or reducing) this tax, for instance.

Adequate ex-post risk management tools must enable households to smooth consumption. This may be achieved through the development of affordable credit for consumption. Indeed, from the risk induced perspective, poverty results from the attempt to reduce the disutility of variable consumption by pursuing a low volatile income process. Development of credit markets related policies will also serve to reduce the role of liquidity constraints in the households' behaviour. On the one hand, liquidity constraints push households to invest in liquid assets for precaution; but liquidity constraints also result in the inability to take advantage of opportunities. Access to low cost credit will therefore contribute to reducing the effect of liquidity constraints on households' investment behaviour.

¹⁵ Press conference <http://lefaso.net/spip.php?article72072>

Regulatory policies that seek to improve returns to the liquid assets that the households accumulate can lower the bounds of the amount of assets required to face potential rainfall hazards. This suggests that current initiatives regarding popularisation of fodder-crops and veterinary care, must be emphasized. Efforts to reduce transaction costs through the development of rural infrastructure may be considered, particularly in low agricultural potential areas. This will contribute to create jobs and develop the rural labour market as well.

Finally, the results suggest that risk factors affect accumulation of liquid assets and off-farm work in the same directions. This implies that policies for improving either market will encourage farm investment, but that where both markets are functioning, households may achieve self-insurance at lower cost.

5.5 Suggestion for Further Research

A key suggestion of the conceptual framework which is only implicitly implied by the findings of this thesis is the potential synergies between off-farm work and liquid asset accumulation in enhancing farm capital accumulation and labour allocation on farm. The literature has, however, found only little evidence elsewhere in Asia and the middle-east (Ahituv & Kimhi, 2002). Whether off-farm work encourages on-farm investment therefore need to be empirically investigated in the context of Burkina Faso regarding the important implication that policy reforms in either sector may have on the other. There is also a need to analyse the role of off-farm labour income in insuring smallholder farm households' consumption against farm income shocks; as well as how it supplements livestock accumulation to this end. While the empirical literature has extensively provided evidence

against the use of livestock to offset consumption in the wake of rainfall shock, any other alternative has not been investigated yet. Regarding the potential of risk induced poverty, understanding how both risk management strategies may interact to mitigate it remains unexplored.



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APPENDIXES

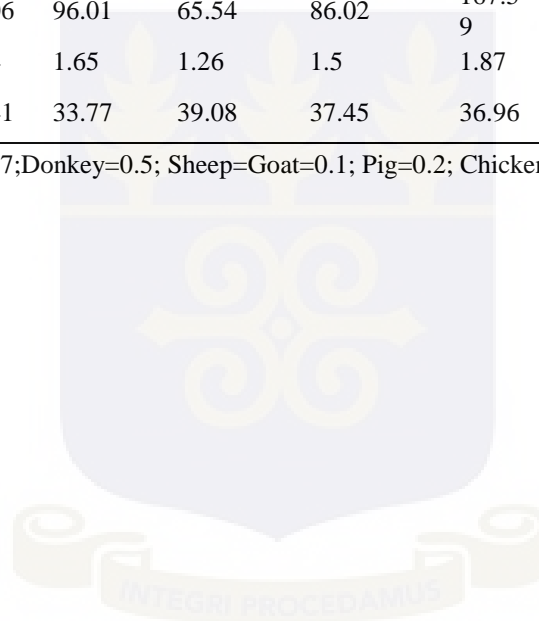


Appendix 1: Households' Characteristics by Off-Farm Work Category and by Year

	2010						2011					
	Wage Work (116)		Non-Farm Work (380)		Non-Participants (644)		Wage Work (152)		Non-Farm Work (388)		Non-Participants (613)	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Hhd Head Age	48.14	14.18	46.65	13	49.18	14.32	48.87	15.01	47.85	12.83	50.03	14.13
N. of literate	2.51	3.13	2.38	2.12	1.72	2.1	2.26	3.15	2.45	2.63	1.87	2.06
N. of Trained	0.36	0.76	0.37	0.78	0.18	0.54	0.31	0.64	0.3	0.63	0.16	0.5
Hhd Size	6.74	4.68	6.32	3.9	5.43	2.71	6.42	3.09	6.64	3.7	5.82	3.22
Dep. ratio	1.12	0.66	1.23	0.68	1.31	0.75	1.16	0.7	1.27	0.73	1.28	0.71
Farm Income	110.27	172.94	131.15	243.91	94.22	103.86	160.67	936.61	186.21	2367.6	101.27	579.55
Yield (MT/ha)	1.108	1.07	1.2	1.33	0.95	0.8	0.95	1.11	1.3	4.85	0.91	2.79
Remittance	-0.13	16.005	3.4	42.89	7.36	29.76	1.32	48.61	1.26	35.47	5.72	23.76
Val. Farm Eqp	18.65	64.74	24.01	145.37	20.41	55.24	24.57	124.04	20.88	109.40	23.45	57
Draught An. (N)	0.17	1.02	0.22	0.84	0.23	0.96	0.22	0.8	0.35	1.52	0.25	1.2
Livestock (TLU)	3.92	10.22	4.67	9.85	4.01	8.33	3.77	7.07	5.19	8.40	3.6	7.28
Poultry (TLU)	0.25	0.35	0.27	0.38	0.25	0.32	0.26	0.27	0.27	0.28	0.23	0.3
Val. Grain Stock	38.26	84.04	61.47	423.09	36.13	48.72	32.38	43.47	35.95	51.37	28.02	39.8
Food Exp.	535.09	478.46	565.65	460.07	467.67	373.31	194.19	193.50	196.23	189.92	157.63	130.94
Non-Food Exp.	45.22	74.71	46.34	58.51	33.46	24.82	315.88	401.05	382.94	509.53	286.38	454.62
Land (ha/adlt)	1.05	1.05	1.06	0.82	1.05	0.87	1.15	1.02	1.1	0.88	1	0.7
Fert per ha	15.83	36.74	18.83	34.74	7.88	13.52	25.61	220.88	46.003	313.46	10.7	26.52
Val. Trsp Ass.	24.17	30.92	31.61	43.74	27.57	38.41	31.94	38.61	39.45	67.05	29.21	37.14

	2010						2011					
	Wage Work (116)		Non-Farm Work (380)		Non-Participants (644)		Wage Work (152)		Non-Farm Work (388)		Non-Participants (613)	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Acc. credit (%)	51.72		52.37		0.37		42.76		43.81		0.31	0.46
Rainfall	0.86	0.14	0.85	0.15	0.9	0.14	1.03	0.18	0.98	0.2	0.96	0.18
Rainfall (CV)	0.12	0.08	0.1	0.06	0.12	0.07	0.14	0.08	0.13	0.07	0.1	0.06
Rain dev.	26.42	106.47	21.06	96.01	65.54	86.02	167.5 9	83.21	147.5 7	96.45	141.8	91.28
Population	1.68	2.07	1.84	1.65	1.26	1.5	1.87	2.25	1.97	2.22	1.39	1.48
Dist. Paved Road	46	42.05	34.41	33.77	39.08	37.45	36.96	37.7	37.89	39.53	39.86	40.1

Notes: TLU: Camel=1; Horse=0.8; Cattle=0.7; Donkey=0.5; Sheep=Goat=0.1; Pig=0.2; Chicken Birds & Fowls=0.01; Other Poultry=0.03



Appendix 2: Determinants of Households' Income

```
. xtreg lntotal_income lnreal_farm_capital lvstk_init tluinit_poul pumpset ///
> land_type1 land_type2 land_type3 land_type4 land_type5 child_under5 ///
> aged young_member male_adults female_adults ///
> lnhead_age c.lnhead_age#c.lnhead_age seed_use fert_use manure_use ///
> land_management pop lntrsp_asset ///
> hhead_sex hhead_educ credit_access ict_access zone_climat ///
> , re vce (cl vill)
```

```
Random-effects GLS regression           Number of obs   =   2168
Group variable: men                    Number of groups =   1101

R-sq:  within = 0.0678                  Obs per group:  min =    1
      between = 0.4273                      avg   =    2.0
      overall = 0.3218                      max   =    2

Wald chi2(27)   =   550.79
corr(u_i, X)    = 0 (assumed)           Prob > chi2     =   0.0000
```

(Std. Err. adjusted for 252 clusters in vill)

lntotal_income	Robust					[95% Conf. Interval]
	Coef.	Std. Err.	z	P> z		
lnreal_farm_capital	.0339243	.0138614	2.45	0.014	.0067565	.0610921
lvstk_init	.0071783	.0033997	2.11	0.035	.000515	.0138416
tluinit_poul	.3072011	.0705497	4.35	0.000	.1689262	.445476
pumpset	.5554326	.1936871	2.87	0.004	.1758128	.9350524
land_type1	.0607605	.0087442	6.95	0.000	.0436221	.0778988
land_type2	.0606847	.0097542	6.22	0.000	.0415669	.0798025
land_type3	.0593727	.0107484	5.52	0.000	.0383063	.0804392
land_type4	.0856778	.0301021	2.85	0.004	.0266788	.1446768
land_type5	.0494007	.0087461	5.65	0.000	.0322587	.0665428
child_under5	.0245457	.0153924	1.59	0.111	-.0056228	.0547142
aged	-.0424831	.0469596	-0.90	0.366	-.1345223	.0495561
young_member	-.0011398	.0134152	-0.08	0.932	-.0274332	.0251536
male_adults	.0313934	.0172971	1.81	0.070	-.0025083	.0652952
female_adults	.0211393	.0179033	1.18	0.238	-.0139505	.0562291
lnhead_age	-3.885906	1.639066	-2.37	0.018	-7.098416	-.6733969
c.lnhead_age#c.lnhead_age	.4986693	.2153359	2.32	0.021	.0766187	.9207199
seed_use	.0878866	.059432	1.48	0.139	-.028598	.2043711
fert_use	.2839511	.0472515	6.01	0.000	.1913397	.3765624
manure_use	-.0689225	.0433501	-1.59	0.112	-.1538872	.0160421
land_management	.0411338	.0572134	0.72	0.472	-.0710024	.15327
pop	.0291957	.0117826	2.48	0.013	.0061023	.0522891
lntrsp_asset	.0535843	.0111058	4.82	0.000	.0318174	.0753512
hhead_sex	.0242656	.1452592	0.17	0.867	-.2604373	.3089684
hhead_educ	.0056169	.0306534	0.18	0.855	-.0544626	.0656965
credit_access	.0591313	.0412049	1.44	0.151	-.0216288	.1398914
ict_access	.2287958	.0602608	3.80	0.000	.1106868	.3469048
zone_climat	-.0665309	.0479537	-1.39	0.165	-.1605185	.0274567
_cons	12.25609	3.091183	3.96	0.000	6.197482	18.3147
sigma_u	.39259227					
sigma_e	.75996677					
rho	.21065093	(fraction of variance due to u_i)				

Appendix 3: Determinants of the Share of Liquid Wealth

Model 1: Dependent variable is the log of the share of Liquid Wealth 1 (Inshareliquid1). Explanatory variables do not include rainfall deviation from its long-run mean

```
. xtreg lnshareliquid1 cv_rainfall rain_mean hhead_age c.hhead_age#c.hhead_age ///
> permanent_inc credit_access regultsfnct occtrsfnct fert_use seed_use manure_use ///
> hhd_size dep_ratio hhead_eth i.hhead_marstat e_type hhead_sex i.hhead_educ ///
> pop dispav sofitex_interv ngo_interv pub_devprog ///
> i.veh_access vill_market i.zone_climat yrdum , re vce(cl vill) 1(90)

Random-effects GLS regression              Number of obs   =    2198
Group variable: men                       Number of groups =    1101

R-sq:  within = 0.0367                    Obs per group:  min =     1
        between = 0.4779                  avg             =     2.0
        overall  = 0.3861                  max             =     2

Wald chi2(32) =    784.21
Prob > chi2   =    0.0000

corr(u_i, X) = 0 (assumed)

(Std. Err. adjusted for 252 clusters in vill)
```

lnshareliquid1	Robust				
	Coef.	Std. Err.	z	P> z	[90% Conf. Interval]
cv_rainfall	.7554078	.6365831	1.19	0.235	-.2916783 1.802494
rain_mean	-.0029569	.0003209	-9.22	0.000	-.0034846 -.0024291
hhead_age	-.0011567	.0119583	-0.10	0.923	-.0208263 .018513
c.hhead_age#c.hhead_age	7.86e-07	.0001117	0.01	0.994	-.000183 .0001846
permanent_inc	-.2252572	.0727246	-3.10	0.002	-.3448786 -.1056358
credit_access	-.1118199	.043784	-2.55	0.011	-.1838382 -.0398016
regultsfnct	-.0006458	.0001236	-5.22	0.000	-.0008491 -.0004424
occtrsfnct	.0002718	.0001636	1.66	0.097	2.78e-06 .0005408
fert_use	.1904569	.052611	3.62	0.000	.1039195 .2769944
seed_use	.1681218	.0907925	1.85	0.064	.0187815 .3174621
manure_use	.1551846	.0520252	2.98	0.003	.0696107 .2407584
hhd_size	.0268186	.0109141	2.46	0.014	.0088666 .0447707
dep_ratio	.0656274	.031777	2.07	0.039	.0133589 .117896
hhead_eth	-.3358416	.1015293	-3.31	0.001	-.5028424 -.1688407
hhead_marstat					
in union	-.2229987	.1650011	-1.35	0.177	-.4944013 .0484039
separ or widow	-.3843969	.2228219	-1.73	0.085	-.7509064 -.0178875
e_type	.1505447	.1728669	0.87	0.384	-.1337961 .4348855
hhead_sex	-.1660814	.215673	-0.77	0.441	-.520832 .1886692
hhead_educ					
prim educ	-.4036279	.1873502	-2.15	0.031	-.7117915 -.0954643
sec&tert educ	-.523369	.1652918	-3.17	0.002	-.7952498 -.2514883
medersa	.1432299	.1011742	1.42	0.157	-.0231868 .3096467
pop	-.0165803	.0155565	-1.07	0.287	-.0421685 .0090079
dispav	-.0025649	.0008455	-3.03	0.002	-.0039555 -.0011742
sofitex_interv	-.1577934	.1288872	-1.22	0.221	-.3697939 .0542072
ngo_interv	-.0619059	.1699952	-0.36	0.716	-.3415232 .2177114
pub_devprog	.0200526	.1507982	0.13	0.894	-.2279884 .2680936
veh_access					
good access all the year	.2645089	.0753161	3.51	0.000	.1406249 .388393
good access only on dry season	.036438	.0635817	0.57	0.567	-.0681446 .1410205
vill_market	.0140874	.2103596	0.07	0.947	-.3319234 .3600982
zone_climat					
soudano_sahelian	.7720322	.093524	8.25	0.000	.6181989 .9258655
sahelian	.4105061	.1851238	2.22	0.027	.1060046 .7150077
yrdum	-.1677854	.0429311	-3.91	0.000	-.2384008 -.0971699
_cons	-.0474489	.700935	-0.07	0.946	-1.200384 1.105487
sigma_u	.59611682				
sigma_e	.77167053				
rho	.37373139	(fraction of variance due to u_i)			

Model 3: Explanatory variables do not include household permanent income measure

```
. xtreg lnshareliquidl cv_rainfall rain_mean rain_dev hhead_age c.hhead_age#c.hhead_age ///
> credit_access regultrsfnet occtrsfnet fert_use seed_use manure_use ///
> hhd_size dep_ratio hhead_eth i.hhead_marstat hhead_sex e_type i.hhead_educ ///
> pop dispav sofitex_interv ngo_interv pub_devprog ///
> i.veh_access vill_market i.zone_climat yrdum, re vce(cl vill) 1(90)
```

```
Random-effects GLS regression          Number of obs   =    2198
Group variable: men                   Number of groups =    1101

R-sq:  within = 0.0347                 Obs per group: min =     1
      between = 0.4764                  avg       =     2.0
      overall  = 0.3837                  max       =     2

Wald chi2(32)   =   741.39
Prob > chi2     =   0.0000

corr(u_i, X)    = 0 (assumed)
```

(Std. Err. adjusted for 252 clusters in vill)

lnshareliquidl	Robust				
	Coef.	Std. Err.	z	P> z	[90% Conf. Interval]
cv_rainfall	.4948051	.6380892	0.78	0.438	- .5547582 1.544368
rain_mean	-.0029008	.0003232	-8.98	0.000	-.0034323 -.0023692
rain_dev	.0002067	.0002281	0.91	0.365	-.0001684 .0005819
hhead_age	.0063553	.0116343	0.55	0.585	-.0127814 .025492
c.hhead_age#c.hhead_age	-.0000624	.0001092	-0.57	0.568	-.000242 .0001172
credit_access	-.1359887	.044864	-3.03	0.002	-.2097834 -.062194
regultrsfnet	-.0006492	.0001195	-5.43	0.000	-.0008458 -.0004526
occtrsfnet	.0003025	.0001625	1.86	0.063	.0000352 .0005699
fert_use	.141212	.0535042	2.64	0.008	.0532055 .2292186
seed_use	.170207	.0913414	1.86	0.062	.0199637 .3204503
manure_use	.1539316	.0522094	2.95	0.003	.0680548 .2398085
hhd_size	.0061932	.0079673	0.78	0.437	-.0069119 .0192984
dep_ratio	.0679144	.0315705	2.15	0.031	.0159856 .1198432
hhead_eth	-.3495285	.1007139	-3.47	0.001	-.5151882 -.1838688
hhead_marstat					
in union	-.2487382	.1643215	-1.51	0.130	-.5190229 .0215466
separ or widow	-.3944486	.2222354	-1.77	0.076	-.7599933 -.0289039
hhead_sex	-.2181405	.2181953	-1.00	0.317	-.5770398 .1407587
e_type	.1010028	.1714994	0.59	0.556	-.1810885 .3830941
hhead_educ					
prim educ	-.4241284	.1902545	-2.23	0.026	-.7370692 -.1111877
sec&tert educ	-.5445465	.1719242	-3.17	0.002	-.8273367 -.2617564
medersa	.1262192	.1018263	1.24	0.215	-.0412701 .2937085
pop	-.02131	.0153808	-1.39	0.166	-.0466092 .0039891
dispav	-.0022778	.0008638	-2.64	0.008	-.0036986 -.0008569
sofitex_interv	-.1363197	.1352145	-1.01	0.313	-.3587278 .0860885
ngo_interv	-.1246811	.1533918	-0.81	0.416	-.3769881 .127626
pub_devprog	.0483536	.1584312	0.31	0.760	-.2122425 .3089496
veh_access					
good access all the year	.2761725	.0772141	3.58	0.000	.1491666 .4031784
good access only on dry season	.048708	.0641209	0.76	0.447	-.0567616 .1541776
vill_market	-.0158603	.2117578	-0.07	0.940	-.364171 .3324503
zone_climat					
soudano_sahelian	.8192133	.0941127	8.70	0.000	.6644116 .974015
sahelian	.4450733	.1944825	2.29	0.022	.1251781 .7649685
yrdum	-.1832292	.0455324	-4.02	0.000	-.2581233 -.1083351
_cons	-1.426241	.5312183	-2.68	0.007	-2.300018 -.552465
sigma_u	.56599157				
sigma_e	.771275				
rho	.35002448	(fraction of variance due to u_i)			

Model 4: Explanatory variable do not include household permanent income and rainfall deviation

```

.do "C:\Users\h\AppData\Local\Temp\STD08000000.tmp"

.xtreg lnshareliquidl cv_rainfall rain_mean hhead_age c.hhead_age#c.hhead_age ///
> credit_access regultrsfnet occtrsfnet fert_use seed_use manure_use ///
> hhd_size dep_ratio hhead_eth i.hhead_marstat e_type hhead_sex i.hhead_educ ///
> pop dispav sofitex_interv ngo_interv pub_devprog ///
> i.veh_access vill_market i.zone_climat yrdum, re vce(cl vill) 1(90)

Random-effects GLS regression              Number of obs   =    2198
Group variable: men                       Number of groups =    1101

R-sq:  within = 0.0371                    Obs per group: min =     1
      between = 0.4731                    avg           =     2.0
      overall = 0.3822                    max           =     2

                                           Wald chi2(31)   =    719.87
                                           Prob > chi2     =     0.0000

corr(u_i, X) = 0 (assumed)

(Std. Err. adjusted for 252 clusters in vill)

```

	Coef.	Robust Std. Err.	z	P> z	[90% Conf. Interval]	
lnshareliquidl						
cv_rainfall	.447204	.633807	0.71	0.480	-.5953157	1.489724
rain_mean	-.0029035	.0003256	-8.92	0.000	-.003439	-.002368
hhead_age	.0064558	.0116479	0.55	0.579	-.0127033	.0256149
c.hhead_age#c.hhead_age	-.000063	.0001093	-0.58	0.565	-.0002428	.0001169
credit_access	-.1303674	.0445515	-2.93	0.003	-.203648	-.0570867
regultrsfnet	-.000655	.0001202	-5.45	0.000	-.0008527	-.0004573
occtrsfnet	.0002995	.0001616	1.85	0.064	.0000337	.0005653
fert_use	.1413459	.0528962	2.67	0.008	.0543395	.2283524
seed_use	.1634286	.0908482	1.80	0.072	.0139966	.3128607
manure_use	.1537296	.0520379	2.95	0.003	.0681349	.2393244
hhd_size	.0061984	.0079564	0.78	0.436	-.0068887	.0192855
dep_ratio	.0670511	.0316173	2.12	0.034	.0150454	.1190569
hhead_eth	-.3435316	.1019574	-3.37	0.001	-.5112366	-.1758266
hhead_marstat						
in union	-.2490946	.1643864	-1.52	0.130	-.5194862	.021297
separ or widow	-.3941012	.2200896	-1.79	0.073	-.7561164	-.0320861
e_type	.1018189	.1722687	0.59	0.554	-.1815379	.3851756
hhead_sex	-.2225365	.217051	-1.03	0.305	-.5795536	.1344806
hhead_educ						
prim educ	-.4217476	.1906023	-2.21	0.027	-.7352606	-.1082347
sec&tert educ	-.524414	.1740158	-3.01	0.003	-.8106446	-.2381834
medersa	.129669	.1017376	1.27	0.202	-.0376746	.2970125
pop	-.0226628	.0153935	-1.47	0.141	-.0479828	.0026573
dispav	-.0023274	.0008683	-2.68	0.007	-.0037557	-.0008992
sofitex_interv	-.1445258	.1294064	-1.12	0.264	-.3573804	.0683287
ngo_interv	-.127475	.1652711	-0.77	0.441	-.3993217	.1443717
pub_devprog	.0368011	.1535406	0.24	0.811	-.2157508	.289353
veh_access						
good access all the year	.2699086	.0762457	3.54	0.000	.1444955	.3953217
good access only on dry season	.0439084	.0635247	0.69	0.489	-.0605805	.1483973
vill_market	-.0074251	.2113598	-0.04	0.972	-.3550811	.3402309
zone_climat						
soudano_sahelian	.8165111	.0952381	8.57	0.000	.6598584	.9731638
sahelian	.4147789	.189493	2.19	0.029	.1030907	.7264672
yrdum	-.1619816	.0427857	-3.79	0.000	-.2323578	-.0916055
_cons	-1.406837	.5324292	-2.64	0.008	-2.282605	-.5310691
sigma_u	.60066519					
sigma_e	.77167053					
rho	.3772963	(fraction of variance due to u_i)				

Model 5: Dependent variable is the log of the share of Liquid Wealth 2 (lnshareliquid2)

```
. xtreg lnshareliquid2 cv_rainfall rain_mean rain_dev hhead_age c.hhead_age#c.hhead_age ///
> permanent_inc credit_access regultrsfnet occtrsfnet fert_use seed_use manure_use ///
> hhd_size dep_ratio hhead_eth i.hhead_marstat e_type hhead_sex i.hhead_educ ///
> pop dispav sofitex_interv ngo_interv pub_devprog ///
> i.veh_access vill_market i.zone_climat yr dum , re vce(cl vill) 1(90)

Random-effects GLS regression                Number of obs   =    2196
Group variable: men                        Number of groups =    1101

R-sq:  within = 0.0354                      Obs per group:  min =     1
      between = 0.4716                          avg   =     2.0
      overall  = 0.3782                          max   =     2

Wald chi2(33) =    711.51
Prob > chi2   =    0.0000

corr(u_i, X) = 0 (assumed)

(Std. Err. adjusted for 252 clusters in vill)
```

lnshareliquid2	Coef.	Robust Std. Err.	z	P> z	[90% Conf. Interval]	
cv_rainfall	.7488534	.6431416	1.16	0.244	-.3090205	1.806727
rain_mean	-.0029018	.0003083	-9.41	0.000	-.003409	-.0023947
rain_dev	.0001684	.0002562	0.66	0.511	-.0002529	.0005898
hhead_age	-.0059132	.012279	-0.48	0.630	-.0261103	.0142839
c.hhead_age#c.hhead_age	.0000422	.0001134	0.37	0.710	-.0001444	.0002288
permanent_inc	-.2453063	.0730342	-3.36	0.001	-.3654369	-.1251756
credit_access	-.1238354	.0480823	-2.58	0.010	-.2029237	-.0447471
regultrsfnet	-.0005892	.0001357	-4.34	0.000	-.0008123	-.000366
occtrsfnet	.0003069	.0001548	1.98	0.047	.0000523	.0005616
fert_use	.2483361	.0569719	4.36	0.000	.1546256	.3420465
seed_use	.1740404	.0900297	1.93	0.053	.0259547	.322126
manure_use	.1422233	.0539065	2.64	0.008	.053555	.2308916
hhd_size	.0157928	.010667	1.48	0.139	-.0017528	.0333383
dep_ratio	.0448532	.0333884	1.34	0.179	-.0100658	.0997722
hhead_eth	-.2971602	.0988137	-3.01	0.003	-.4596944	-.1346261
hhead_marstat						
in union	-.2509385	.1710992	-1.47	0.142	-.5323716	.0304947
separ or widow	-.470462	.2010738	-2.34	0.019	-.8011989	-.1397251
e_type	.127314	.1524194	0.84	0.404	-.1233936	.3780215
hhead_sex	-.1769663	.1988927	-0.89	0.374	-.5041156	.150183
hhead_educ						
prim educ	-.3393106	.1914359	-1.77	0.076	-.6541946	-.0244265
sec&tert educ	-.5035787	.1890016	-2.66	0.008	-.8144587	-.1926987
medersa	.1032899	.1047014	0.99	0.324	-.0689285	.2755084
pop	-.0081134	.0171245	-0.47	0.636	-.0362806	.0200539
dispav	-.0024205	.0008713	-2.78	0.005	-.0038537	-.0009874
sofitex_interv	-.141768	.1399192	-1.01	0.311	-.3719147	.0883787
ngo_interv	-.0708208	.1674155	-0.42	0.672	-.3461947	.2045532
pub_devprog	-.1194856	.1622747	-0.74	0.462	-.3864037	.1474326
veh_access						
good access all the year	.2225921	.0777095	2.86	0.004	.0947714	.3504129
good access only on dry season	-.0032717	.0643957	-0.05	0.959	-.1091932	.1026498
vill_market	.0383756	.2325771	0.17	0.869	-.3441797	.4209309
zone_climat						
soudano_sahelian	.7791711	.0902541	8.63	0.000	.6307163	.9276259
sahelian	.2967577	.2180804	1.36	0.174	-.0619527	.655468
yr dum	-.1949309	.0465185	-4.19	0.000	-.271447	-.1184148
_cons	.1136449	.6989014	0.16	0.871	-1.035946	1.263235
sigma_u	.53798416					
sigma_e	.7774618					
rho	.3237895					(fraction of variance due to u_i)

Model 2: Dependent variable is the number of labour in non-farm business

```

Random-effects Poisson regression      Number of obs   =    2200
Group variable: men                   Number of groups =    1101

Random effects u_i ~ Gaussian          Obs per group:  min =     1
                                       avg   =    2.0
                                       max   =     2

Integration method: mvaghermite        Integration points =    12

                                       Wald chi2(40)    =    164.58
Log pseudolikelihood = -1495.2166      Prob > chi2     =    0.0000
    
```

(Std. Err. adjusted for 252 clusters in vill)

nonfarm_work	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]	
cv_rainfall	2.002641	.6807233	2.94	0.003	.6684474	3.336834
rain_dev	-.0008759	.0003386	-2.59	0.010	-.0015396	-.0002122
rain_mean	-.0007224	.0003887	-1.86	0.063	-.0014843	.0000395
male_adults	.0301627	.0263647	1.14	0.253	-.0215112	.0818365
female_adults	-.0240905	.0264722	-0.91	0.363	-.075975	.027794
young_member	.0201228	.0167749	1.20	0.230	-.0127554	.053001
literacy_n	.0046984	.0123119	0.38	0.703	-.0194324	.0288293
trained_n	.1570974	.037008	4.24	0.000	.0845632	.2296317
health_shock	.051003	.0263906	1.93	0.053	-.0007216	.1027276
hhead_educ						
prim_educ	.1286398	.1529253	0.84	0.400	-.1710883	.4283679
sec&tert_educ	.1937153	.3816056	0.51	0.612	-.554218	.9416486
medersa	.1016858	.1305428	0.78	0.436	-.1541734	.3575451
hhead_sex	-.1830813	.2840087	-0.64	0.519	-.7397281	.3735655
hhead_age	.0108108	.0161099	0.67	0.502	-.0207641	.0423857
c.hhead_age#c.hhead_age	-.0001614	.0001585	-1.02	0.308	-.000472	.0001492
hhead_marstat						
in union	-.0606566	.2773807	-0.22	0.827	-.6043127	.4829994
separ or widow	.0918607	.3390937	0.27	0.786	-.5727508	.7564722
child_under5	.011227	.0195885	0.57	0.567	-.0271658	.0496198
aged	-.088292	.0611868	-1.44	0.149	-.2082159	.0316319
e_type	.208746	.1507497	1.38	0.166	-.0867181	.50421
ict_access	.1949849	.1347991	1.45	0.148	-.0692165	.4591863
regultrsfnet	-.0000649	.0001291	-0.50	0.615	-.0003179	.0001882
occtrsfnet	-.0011026	.0003748	-2.94	0.003	-.0018373	-.000368
permanent_inc	2.099782	.6227954	3.37	0.001	.8791256	3.320439
c.permanent_inc#c.permanent_inc	-.1363495	.0442824	-3.08	0.002	-.2231413	-.0495576
credit_access	.1356335	.0616739	2.20	0.028	.014755	.2565121
land_size	-.037248	.0138104	-2.70	0.007	-.0643158	-.0101802
c.land_size#c.land_size	.0006614	.0001898	3.48	0.000	.0002894	.0010333
trsp_asset	.0001273	.0001073	1.19	0.235	-.0000829	.0003376
total_lvstk_income	.0004875	.0002393	2.04	0.042	.0000184	.0009566
pop	.0459613	.0160001	2.87	0.004	.0146016	.077321
veh_access						
good access all the year	.1672476	.0989075	1.69	0.091	-.0266075	.3611027
good access only on dry season	.1555336	.0891578	1.74	0.081	-.0192125	.3302798
dispav	-.0014728	.0010605	-1.39	0.165	-.0035512	.0006057
vill_market	.5058697	.3659869	1.38	0.167	-.2114514	1.223191
pub_devprog	.1487374	.1325911	1.12	0.262	-.1111364	.4086112
ngo_interv	.5901231	.206539	2.86	0.004	.1853141	.9949321
zone_climat						
soudano_sahelian	-.0959074	.0972709	-0.99	0.324	-.2865547	.09474
sahelian	.245054	.2461408	1.00	0.319	-.2373731	.7274811
yrdum	.1304225	.0804135	1.62	0.105	-.0271851	.2880301
_cons	-9.157522	2.318834	-3.95	0.000	-13.70235	-4.61269
/lnsig2u	-14.01696	43941.42	-0.00	1.000	-86137.61	86109.58
sigma_u	.0009042	19.86549			0	.

Model 3: Dependent variable is total off-farm labour (wage + non-farm labour)

```

Random-effects Poisson regression      Number of obs   =   2200
Group variable: men                   Number of groups =   1101

Random effects u_i ~ Gaussian         Obs per group: min =    1
                                       avg =    2.0
                                       max =    2

Integration method: mvaghermite       Integration points =    12

                                       Wald chi2(40)    =   164.58
                                       Prob > chi2      =    0.0000

Log pseudolikelihood = -1495.2166
    
```

(Std. Err. adjusted for 252 clusters in vill)

nonfarm_work	Robust				
	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
cv_rainfall	2.002641	.6807233	2.94	0.003	-.6684474 3.336834
rain_dev	-.0008759	.0003386	-2.59	0.010	-.0015396 -.0002122
rain_mean	-.0007224	.0003887	-1.86	0.063	-.0014843 .0000395
male_adults	.0301627	.0263647	1.14	0.253	-.0215112 .0818365
female_adults	-.0240905	.0264722	-0.91	0.363	-.075975 .027794
young_member	.0201228	.0167749	1.20	0.230	-.0127554 .053001
literacy_n	.0046984	.0123119	0.38	0.703	-.0194324 .0288293
trained_n	.1570974	.037008	4.24	0.000	.0845632 .2296317
health_shock	.051003	.0263906	1.93	0.053	-.0007216 .1027276
hhead_educ					
prim educ	.1286398	.1529253	0.84	0.400	-.1710883 .4283679
secstert educ	.1937153	.3816056	0.51	0.612	-.554218 .9416486
medersa	.1016858	.1305428	0.78	0.436	-.1541734 .3575451
hhead_sex	-.1830813	.2840087	-0.64	0.519	-.7397281 .3735655
hhead_age	.0108108	.0161099	0.67	0.502	-.0207641 .0423857
c.hhead_age#c.hhead_age	-.0001614	.0001585	-1.02	0.308	-.0004472 .0001492
hhead_marstat					
in union	-.0606566	.2773807	-0.22	0.827	-.6043127 .4829994
separ or widow	.0918607	.3390937	0.27	0.786	-.5727508 .7564722
child_under5	.011227	.0195885	0.57	0.567	-.0271658 .0496198
aged	-.088292	.0611868	-1.44	0.149	-.2082159 .0316319
e_type	.208746	.1507497	1.38	0.166	-.0867181 .50421
ict_access	.1949849	.1347991	1.45	0.148	-.0692165 .4591863
regultrsfnet	-.0000649	.0001291	-0.50	0.615	-.0003179 .0001882
occtrsfnet	-.0011026	.0003748	-2.94	0.003	-.0018373 -.000368
permanent_inc	2.099782	.6227954	3.37	0.001	.8791256 3.320439
c.permanent_inc#c.permanent_inc	-.1363495	.0442824	-3.08	0.002	-.2231413 -.0495576
credit_access	.1356335	.0616739	2.20	0.028	.014755 .2565121
land_size	-.037248	.0138104	-2.70	0.007	-.0643158 -.0101802
c.land_size#c.land_size	.0006614	.0001898	3.48	0.000	.0002894 .0010333
trsp_asset	.0001273	.0001073	1.19	0.235	-.0000829 .0003376
total_lvstk_income	.0004875	.0002393	2.04	0.042	.0000184 .0009566
pop	.0459613	.0160001	2.87	0.004	.0146016 .077321
veh_access					
good access all the year	.1672476	.0989075	1.69	0.091	-.0266075 .3611027
good access only on dry season	.1555336	.0891578	1.74	0.081	-.0192125 .3302798
dispav	-.0014728	.0010605	-1.39	0.165	-.0035512 .0006057
vill_market	.5058697	.3659869	1.38	0.167	-.2114514 1.223191
pub_devprog	.1487374	.1325911	1.12	0.262	-.1111364 .4086112
ngo_interv	.5901231	.206539	2.86	0.004	.1853141 .9949321
zone_climat					
soudano_sahelian	-.0959074	.0972709	-0.99	0.324	-.2865547 .09474
sahelian	.245054	.2461408	1.00	0.319	-.2373731 .7274811
yrddum	.1304225	.0804135	1.62	0.105	-.0271851 .2880301
_cons	-9.157522	2.318834	-3.95	0.000	-13.70235 -4.61269
/lnsig2u	-14.01696	43941.42	-0.00	1.000	-86137.61 86109.58
sigma_u	.0009042	19.86549			0 .