Essays on Household Demand and Agricultural Policy Implications in Developing Countries

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Abstract

This thesis comprises four papers that contribute to the economic literature in the area of food demand and agricultural policy related issues. Paper I examines the main forces driving farmers' decision to adopt modern agricultural inputs (MAI) in farming, and the effects on farm household welfare in Rwanda. Evidence from this study reveals that size of land endowment, access to farm credits and awareness of farm advisory services were the main driving factors behind MAI adoption. It was also found that adopting MAI significantly increased farm income, crop yield and household expenditure. This provides an indication that MAI adoption is the most consistent and potentially best pathway to reduce poverty among rural farmers. Paper II analyses the short and long-term effects of likely changes in rainfall on food crop prices in Rwanda. The results from this study identify that food crop prices are essentially vulnerable to rainfall shocks and that the effect is asymmetric in both the short and long-run. The analysis also revealed seasonal effects, with food prices falling significantly during the harvest season and rising thereafter. Further, the reliability of unit value (defined as expenditure by quantity) or community price (mostly gathered from local markets), both used to represent market prices when computing food demand elasticities, was investigated in Paper III using Tanzanian household data. A quadratic almost ideal demand system (QUAIDS) was created for nine food categories based on unit values and community prices. The results showed that expenditure elasticities from both prices appear to be almost similar. However, price elasticities from unit value and community prices displayed significant discrepancies. These findings suggest that, when opting to use these proxies for market prices, researchers should apply caution, particularly in accounting for quality variations and measurement errors in household reported prices and income. Finally, Paper IV presents the analysis of the food Engel curves and consumption patterns in Rwanda. The study results reveal that a large proportion of the average household food budget (more than 50%) is spent on cheap sources of calories (such as roots, tubers and cereals), resulting in unbalanced diets among members of Rwandan households. In particular, poor households, mostly in rural communities, appeared to spend almost nothing on protein food items (including meat). Overall, this thesis makes a series of novel contributions to the economic literature on food demand and agricultural policy for the under-explored continent of Africa. Improved understanding of rural and urban food consumption patterns can enable purposive and targeted food policies to be formulated.

Keywords: Modern agricultural inputs, Welfare effects, Food crop prices, Rainfall, Unit values, Community prices, Household demand, Food Engel Curves, Developing countries, Rwanda, Tanzania

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Dedication

To my wife Pétronille, children (Christelle, Chris and Kevin Aimable)
To the memory of my late father (Mr. Habimana Canisius)

Abbreviations and Acronyms

ATE	Average Treatment Effects
CPI	Consumer Price Index
EICV	Enquête Intégrale sur les Conditions de Vie des Ménages
ESR	Endogenous Switching Regression
FAO	United Nations Food and Agriculture Organization
FEC	Food Engel Curve
FIML	Full Information Maximum Likelihood
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
LSMS-ISA	Living Standards Measurement Study-Integrated Survey on Agriculture
MAI	Modern Agricultural Inputs
NARDL	Nonlinear Autoregressive Distributed Lag
NPS	National Panel Survey
OECD	Organisation for Economic Co-operation and Development

QUAIDS	Quadratic Almost Ideal Demand System
RBP	Recursive Bivariate Probability
SIDA	Swedish International Development Agency
SSA	Sub-Saharan Africa
TNBS	Tanzanian National Bureau of Statistics
WFP	United Nations World Food Program

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Nsabimana, A*. (2017). Is change worth it? The effect of adopting modern agricultural inputs on household welfare in Rwanda (Revised & resubmitted to Agricultural Economics).

II. Nsabimana, A*. and Habimana, O. (2017). Asymmetric effects of rainfall on food crop prices: Evidence from Rwanda. Environmental Economics (open-access) 8(3), 137-149.

III. Nsabimana, A*., Mensah. J.T and Surry, Y. (2018). Analysis of household demand patterns using household data: Re-thinking the use of unit values or community prices (manuscript).

IV. Nsabimana, A*., Bali Swain, R., Surry, Y. and Ngabitsinze, J.C. (2018). Income and food Engel Curves in Rwanda: A household microdata analysis (manuscript).

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1. Introduction

The use of modern agricultural inputs (including hybrid seeds, chemical fertilisers, pesticides etc.) in agriculture and the effects of predicted changes in the weather on crop food prices in Africa were investigated in this thesis. Characterisation of food demand and household consumption patterns was also examined. This introductory chapter describes the general context of the work, the research objectives, data sources and research methods.

1.1 Background and research objectives

Sub-Saharan Africa (SSA) is characterised by the highest proportion of under-nourished people in the world, with more than 30% of the rural population experiencing chronic hunger (FAO, 2008; Schlenker et al., 2010). Poverty is also a long-standing challenge, with uneven economic progress across the region. Despite a reduction in the rate of malnutrition in SSA from 33% in 1990-1992 to 23% in 2014-2015, the rate remains high compared with that in other developing regions (FAO, IFAD and WFP, 2015). The state of poverty and slow progress towards food security in the region have been mainly ascribed to low farm productivity, very high population growth rates and political instability (OECD, 2016). However, although there are vast regional differences, there are some successful countries with stable political conditions, a growing economy and expanding productivity in the farm sector. This suggests that effective governance, together with good quality institutions and structural macroeconomic policies, can all work together to eradicate poverty and eventually improve food security in the region in a long-lasting and sustainable manner.

Agriculture can undoubtedly play an important role in structural transformation leading to economic growth and food security in Africa. The sector is the largest employer, an important foreign exchange earner and has the greatest potential for poverty reduction. It plays a pivotal role in employment opportunities, providing jobs for more than 60% of the total workforce (Chauvin et al., 2012). Rural households in general benefit from agriculture, but it is also the main source of livelihood for 10-25% of urban households in SSA (Yeboah & Jayne, 2015). However the majority of households in SSA are located in rural areas,

and for these agriculture, mostly subsistence farming, constitutes their main source of income for daily household livelihood (Diao et al., 2010; Smale et al., 2016; Alia, 2017). This is an indication that in SSA, macroeconomic performance has not been inclusive for the agricultural sector in general and for rural areas in particular. In addition, the productivity of the agricultural sector in Africa is low. This has been attributed partly to climate change, as farming practices are largely based on weather-sensitive agro-pastoral production systems (Stige et al., 2006). Due to the low use of modern inputs in economies heavily dependent on agriculture, the SSA region is predicted to be particularly hard hit by global warming, as it is already facing high temperatures and high variability in rainfall. For instance, it has been shown that weather variability has severe consequences and that dryland crop and livestock farmers are especially vulnerable, with temperature elasticities of -1.9 and –5.4, respectively (Kurukulasuriya et al., 2006). Hence, considering the central role of the agriculture sector and the unprecedented variations in climate anticipated in Africa over the coming decades (Washington et al., 2006; Christensen et al., 2007; Schlenker & Lobell, 2010), there is a urgent need to provide further empirical economic evidence on possible responses of climate change on crop production in SSA and of food prices in the region.

Despite low farm productivity, Africa has experienced very high population and income growth rates, coupled with intensified urbanisation over the past two decades. This has led to sharp changes in food demand. Furthermore, given that the population in SSA is expected to double by 2050 (UNDP, 2015), feeding poor households will remain a critical challenge. In this respect, not only will food demand continue to rise with increasing incomes, but the composition of food demand will also change and continuing urbanisation will contribute substantially to changes in diets (Melo et al., 2015). There is also a very important gap between food production and food consumption in Africa and this is attributable to the fact that most countries in SSA are failing to provide sufficient food and nutrition for their growing population (Chauvin et al., 2012). Therefore, understanding the composition of people's food demand and analysing the relationships between household income and food demand is paramount for designing food policies aimed at addressing malnutrition and upgrading food security in the African context.

The main motives of the work described in this thesis were to: (i) provide new insights into increasing farm productivity by adopting consistently modern agricultural inputs with the aim of improving the welfare of smallholders in Africa and hence eradicating chronic poverty; (ii) evaluate the potential impacts of climate variability on farm activities in Africa, where rain-fed farm systems remain farmers' main option for agricultural activities; (iii) assess the reliability

of using community prices or unit values when estimating elasticities; and (iv) characterise household consumption patterns taking into consideration household location. Over long historical periods in Africa, farmers have mainly relied on traditional farming systems. Now, however, intensive family labour, land and weather conditions (exogenous temperature/rainfall) have reached their limits in increasing farm production (Alia, 2017). Therefore, this thesis sought to identify ways to redress this by examining the intensity of modern agricultural input (MAI) adoption, weather variability and farm household welfare in SSA countries. It also sought to shed light on the driving forces for household food consumption patterns and the design of food policies in an African context. The following research objectives were formulated for the work:

i) Examine the effects of modern agricultural input adoption on the welfare of farmers.

ii) Explore how the likely changes in weather (rainfall) will affect food prices in Rwanda.

iii) Assess the reliability of unit values or community prices when analysing food demand patterns.

iv) Characterise the Engel curves of food staples and identify potential Engel curve modelling issues.

This thesis covers two broad aspects of the literature, namely agricultural development and food demand. Specifically, Papers I and II deal with farm input technology adoption and climate change. Paper I examines the driving factors that affect farmers' decision to adopt modern inputs and how this influences farmers' livelihood in Rwanda. Issues of climate risk and shocks have been identified as potential threats to poor and vulnerable households in developing countries, particularly in SSA (Holden & Quiggin, 2017). The most recent global climate change trends with associated extreme weather events are likely to continue. Their adverse effects will most likely affect farm yields and this might jeopardise the food supply that is needed to meet the demand from excessive population growth rate and urbanisation (Alston et al., 2010). The future distribution of rainfall is particularly important, as stochastic events like drought or rainstorms can cause severe damage to food crops, hence inducing drastic food price variability at the market level. Given these preconditions, Paper II investigated the potential effects of likely rainfall shocks on agriculture and how these unexpected changes are transmitted into agricultural food market prices in Rwanda.

Papers III and IV deal with food demand. Analysis of household food demand has received considerable attention in the economic literature, both in the context

of developed countries (Banks et al., 1997; Abdulai, 2002; Aepli & Finger, 2013; Aepli, 2014) and low-income counties (Abdulai & Aubert, 2004a; Boysen, 2016). The empirical estimates produced in these studies have been extremely useful in household welfare, poverty and nutritional related policies (Borlizzi et al., 2017; Subramanian & Deaton, 1996). To add to this research, Paper III assesses the reliability of unit values or community prices when computing price and/or income elasticities, by controlling for quality variations using Tanzanian household data. Finally, in Paper IV a detailed analysis of driving forces of disaggregated food demand in Rwanda was conducted. In that study, demand (different food Engel curves) was explored and estimated for the following disaggregated food categories: cereals, roots and tubers, vegetables, meat products, beverages and other food (including eating away from home).

1.2 Context and scope

1.2.1 Agricultural technology adoption and farm household welfare

Agriculture is still the economic mainstay in most developing economies. In SSA, farming activities engage about 60% of the workforce and contribute over 30% to gross domestic product (GDP) (Thornton et al., 2011). However, the agricultural sector in SSA continues to underperform. Farm production is extremely low compared with that in other regions of the world and productivity growth continues to be slow (Sheahan & Barrett, 2017). For instance, between 1961 and 2000, cereal yields fluctuated around 0.8 ton/ha and only experienced modest increases thereafter, to reach 1.3 ton/ha in 2014 (FAOSTAT, 2017). This level of yield represents less than half the cereal yield achieved in other developing countries and less than one-quarter of the yield in high-income countries (Rodrik, 2016; Alia, 2017). Based on these facts, together with current high population growth rates (Djurfeldt & Jirström, 2013), SSA needs to constantly increase crop productivity through farm technology adoption in order to meet the growing demand for food. Paper I sought to add to the existing economic literature concerning agricultural technology adoption. A number of recent studies have demonstrated that adoption of modern agricultural inputs in developing countries contributes to raising farm yields and reduces the level of poverty among farm households (Zeng et al., 2015; Abdulai, 2016). However, others argue that the adoption of MAI should involve a bundle of innovations instead of a single technology (Becerril & Abdulai, 2010). This means that potential benefits from the use of modern agricultural inputs can be realised only

if the users integrate different farming practices (Abay et al., 2017). In addition, development policies in low-income countries in recent decades have sought to promote modern agricultural inputs use among small-scale farmers, in a bid to tackle poverty and its effects. This underscores the importance of technology diffusion for the agricultural revolution in the developing world.

In developing countries, farm yields are limited by a wide range of constraining forces. These include biophysical and agronomic constraints, and also socio-economic and institutional barriers (Diagne et al., 2013). Achieving optimal farm production under such constraints requires farmers to adopt modern agricultural technologies such as hybrid seeds, chemical fertilisers, herbicides, better ways of planting and weeding, and other improved soil and innovative watering techniques (Evenson & Gollin, 2003; Morris, 2007). Some of the shortfalls affecting smallholder agriculture, such as fundamental resource constraints (poverty), lack of market information among farmers, difficulties in market access and risk minimising attitudes of farmers, are often reported to be the major constraints to farm technology adoption (Kebede et al., 1990). In addition, adoption of agricultural technology innovation in developing countries is constrained by lack of appropriate agricultural credits, insufficient skilled human capital, inadequate incentives associated with farm tenure arrangements, a characteristically chaotic supply of complementary inputs (seeds, pesticides, chemicals and water) and inappropriate transportation infrastructure (Feder et al., 1985). The slow and low rate of agricultural innovation adoption is often linked with market failure and lack of adequate policy interventions (Feder & Umali, 1993). However, Conley and Udry (2010) claim that success requires fundamental changes in the ways in which innovations diffuse out to farmers.

From a farm productivity standpoint, there is a major difference between what smallholder farmers obtain in terms of yield and what is feasible under the optimal farm inputs available in SSA. The adoption of new technology would help maximise agricultural output. However, the only way smallholder farmers can benefit from new farming technologies is to apply them appropriately on farms (Muzari et al., 2012). Therefore, appropriate adoption of inputs in agriculture is considered to be the engine driving increases in farm productivity and farm income, and subsequently a reduction in poverty among rural household farmers. Moreover, the literature highlights the role of adoption of technology in poverty eradication. Agricultural technology in particular is regarded as a leading factor in reducing poverty and this can occur directly or indirectly. The direct effects of input use on poverty reduction are the productivity benefits gained by the farmers who directly adopt the technology (De Janvry & Sadoulet, 2002; Becerril & Abdulai, 2010). These benefits are manifested in the form of improvements in household food intake and health

status. When adopters reap the benefits from new technology, the resulting productivity provides additional indirect gains for others. These may include lower food prices, resulting in an increase in consumption for all households. Similarly, for poor people with limited land access, an increase in agricultural productivity will result in indirect gains. Moreover, the increased in productivity resulting from technology adoption could induce changes in cropping patterns and allocation of farmers' own resources to various other uses (Khanna, 2001; Kassie et al., 2011). Previous research in this area has focused mostly on the role of farm size, farm profitability, credit constraints, higher yield of seed varieties, modern breeding and dairy farming adoption (Abdulai & Huffman, 2005). However, some studies have emphasised the importance of farmers' capacity and decision making in learning how to use new techniques sustainably in farming (Ali & Abdulai, 2010; Conley & Udry, 2010; Asfaw et al., 2012; Abdulai, 2016). Abdulai (2016) assessed the potential factors and the impact of conservation agriculture technology adoption on farm household welfare in Zambia, while Asfaw et al. (2012) evaluated the effects of improved legume technology on rural household welfare in Ethiopia and Tanzania. Both studies report a substantial impact of adoption. Ali and Abdulai (2010) studied adoption of genetically modified cultivars in cotton farming on poverty reduction in Pakistan, while Conley and Udry (2010) analysed the role of social learning and agricultural production patterns for farm technology adoption in Ghana. These different empirical and theoretical studies have pointed out the positive impact of use of modern agricultural inputs on the wellbeing of rural poor farmers, but have also identified adoption behaviour and decisions by smallholder farmers on modern agricultural input use as a major research need. Paper I sought to meet this research need by deriving economic benefits of modern agricultural inputs for smallholder farmers and by examining whether adopting modern agricultural inputs is the most consistent and potentially best pathway to reduce poverty among rural farmers. The main findings from Paper I are described in detail in Section 3 of this thesis.

1.2.2 Climate change and crop food prices

While Paper I focused on household MAI adoption decisions, Paper II examined the links between predicted changes in rainfall and crop food prices in SSA. In general, agriculture in most developing countries depends heavily on seasonal weather, as greenhouse farming and large-scale irrigation systems have yet to be implemented. The economics of food production and price dynamics clearly

predict that food price will spike as a natural consequence of demand growth outpacing supply expansion and the unseen forces of climate change (Deaton & Laroque, 1992; Barrett, 2013). The latter is regarded as a major threat to global food production and is expected to exacerbate food insecurity in many parts of the world (Burke et al., 2015). Furthermore, it has been found that climate events played an important role in the surge in global food prices in 2008 (Ericksen et al., 2009).

In ongoing research on the relationship between climate change and agricultural development, there have been number of findings that reaffirm the direct causal relationship between climate change and farm yield distortions. The consequences of climate change, such as flooding, higher temperatures and unexpected frequent and extreme weather events, negatively affect food production, leading to a decrease in food supply and ultimately in higher prices. Moreover, it has been argued that climate change is linked to poverty traps in developing regions (Enfors & Gordon, 2008). Paper II presents an asymmetric investigation on how climate change, proxied by rainfall, explains crop food prices in Rwanda. In this context, using rainfall as a proxy for climate change is justified, especially in a landlocked country like Rwanda, where agriculture is mainly rain-fed and irrigation systems and farm mechanisation are almost non-existent.

According to Blanc (2012), the unexpected variability of temperature and rainfall in SSA has had substantial adverse effects on maize, millet, sorghum and cassava production in the region. A similar study investigating the effects of rainfall shocks on household welfare in Guatemala has shown that rainfall shocks increase poverty by 18% and reduce household food consumption by 10% (Baez et al., 2015). Moreover, the effects of climate change are likely to fall disproportionately on developing nations and on poorer, agrarian households within those nations (Jarvis et al., 2011; Wood et al., 2014). This implies that smallholder farmers who do not have any alternative income sources apart from subsistence farming are more likely to face adverse impacts of climate change.

Considering the ongoing threat of climate change and the evidence that its relative effect is greater in low-income countries (Tol, 2010), a clear understanding of the significance and magnitude of the effect of rainfall on food prices is of the utmost importance for policy making. However, there is limited empirical evidence in this regard. This leads to an important research question: How do food prices respond to precipitation changes? To examine this issue, the driving forces and vulnerability of food prices to weather shocks in Rwanda were explored in Paper II. The analysis examined the symmetric effects of rainfall on food crop prices, which is essential information, especially in a developing country context like Rwanda, where a high proportion of household income is

spent on food and where crop production relies heavily on rain-fed farming. More results discussions are provided in section 3 of the thesis.

1.2.3 Income and price elasticities: Use of unit values or community prices

Living conditions have changed dramatically in developing countries, thanks to the quantum leaps achieved in innovative production systems and in technology. In particular, food consumption has radically increased, at an unprecedented pace, a change driven by population, economic growth and rapid urbanisation[1]. However, in these low-income economies, poverty rates and prevalence of undernourishment are still considerable. For instance, the World Bank (2012) reported that inadequate access to food in SSA affects 47% of the population. This underscores the need for more extensive and accurate research, based on detailed and differentiated estimates of household food consumption patterns. Considering all these facts, and given that only a few studies on household food demand have been undertaken in context of SSA (e.g. Abdulai & Aubert, 2004b; Muhammad et al., 2011; Boysen, 2016), there is a need to provide more evidence for this diverse region.

Furthermore, in the design of comprehensive poverty and nutritional food policies, clear and consistent estimates of price and income elasticities, often derived from estimation of food demand systems, are required. The problem is that there are very few household surveys in developing countries reporting prices of goods and services at which the households purchase these items, thereby constraining their usefulness in demand analysis. To this end, Timmer and Alderman (1979) suggested the use of unit values (defined by dividing household expenditure by quantity) as a proxy for market prices. Since then, numerous empirical estimates have relied solely on unit values to derive price and income elasticities (Banks et al., 1997; Abdulai, 2002; Boysen, 2016). However, using unit values without any adjustments may lead to biased estimates, due to differences in commercial forms of commodities (e.g. cassava flour and roots, maize flour or grain). It is therefore possible that any differences detected could potentially result from diet composition, and diet composition

[1] According to FAO (2013, 2017), massive rural-urban migrations in developing countries, substantial increases in per capita food consumption (expressed in kcal/person/day), increases in income inequality and recurrent climate shocks across the globe all have led to enormous food shortfalls in most developing countries.

may vary across households and regions (Deaton & Dupriez, 2011; Boysen, 2016). Furthermore, household survey data are usually marred by errors in income and expenditure data (Deaton, 1997). Therefore, using unit values without accounting for the errors in reported household income and expenditure may further bias the estimates.

An alternative approach to gathering data on prices in household surveys is the use of community prices. Relying on the assumption of one price in local markets, prices of respective items within a given location (often the primary sampling units) are collected and referred to as community prices. This approach is seen as relatively more robust as price imputations based on unit values. However, using community prices might also induce a number of potential biases. First, the prices may not conform to the true prices encountered by sampled households in the community of interest. For instance, the household may purchase the good outside their residential cluster or not consume it at all. Thus unless carefully handled, use of community prices might lead to more severe errors than use of unit values. To investigate this issue, the reliability of community prices or unit values when analysing food demand patterns was assessed in Paper III. The analysis revisited the work of Gibson and Rozelle (2011), who evaluated the reliability of unit values and community prices when estimating consumer demand and how this can affect policy analysis. To my knowledge, Paper II is the first study to evaluate the use of unit values and community prices in an African context. The empirical material comprised household survey data from Tanzania where, as in other low-income countries, a large proportion of household income is spent on food consumption.

1.2.4 Household food Engel curves in the context of developing countries

The problems of food insecurity and malnutrition are common key issues in SSA. For instance, the United Nations Food and Agriculture Organization (FAO) reported in 2017 that SSA is one of the regions in the world with the largest number of hungry people (233 million). The World Bank (2012) found that over 47% of the total population in SSA lives on $1.90 a day or less, a driving factor in widespread hunger in the region, where one person in four is undernourished. The high malnutrition prevalence has been largely attributed to household income being too low to meet the required minimum calories and nutrient levels (Melo et al., 2015).

Besides these general common trends on food consumption patterns, it has also been shown that there are important differences in dietary composition and food supply structures across household locations in SSA (Fabiosa, 2011). These

differences often affect the relationship between household income and food demand, hence affecting alternative allocations of household income. Analysing the driving factors of food demand taking into account household location (rural or urban) is very useful, especially in light of intensive urbanisation, income and population growth, to reveal the impact of household location on food demand patterns and possible policy interventions for food insecurity and malnutrition. Such an analysis is described in Paper IV. The following section provides more details on the estimation procedures and methods used.

2. Methods

2.1 Data sources: Living Standard Measurement Surveys (LSMS)

Data from household surveys are extremely important to development economists seeking to measure consumer behaviour, welfare and poverty. Such data have been extensively used in testing theories about household behaviour and in discovering how people respond to changes in the economic environment in which they live. Specifically, the Living Standards Measurement Surveys (LSMS) conducted by the World Bank have been very valuable in collecting data on a wide range of household characteristics and activities, from household composition and distribution of resource endowments to all types of economic transactions (Deaton, 1997). Furthermore, these types of data have been highly important in the context of developing countries, due to lack of long-time data series, to cast light on a range of policy issues. More importantly, they have been used to analyse household consumption patterns and individual welfare (Deaton et al., 1992; Deaton, 1997; Abdulai & Aubert, 2004b; Boysen, 2016).

Three of the papers on which this thesis is based (Papers I, III and IV) involved household surveys in the context of SSA. The empirical analysis focused specifically on two countries in SSA, Rwanda and Tanzania. The dataset for Rwanda was mainly extracted from the Integrated Household Living Conditions surveys (Enquête Intégrale sur les Conditions de Vie des Ménages of Rwanda (EICV 3 and EICV 4 in French). The two surveys used in this thesis provide information on changes in household well-being such as poverty, inequality,

employment, education, health and housing conditions and household consumption patterns. These surveys have been implemented by the National Institute of Statistics of Rwanda (NISR) with the World Bank and EU providing financial and technical supports. Surveys EICV3 (2010/2011) and EICV4 (2013/2014) were chosen for analysis in this thesis work as they represent the most recent and fully cleaned data from NISR.

In examining the potential household welfare effects of modern farm technology adoption in Paper I, EICV3 data were used. That survey encompassed the entire country of Rwanda, divided into four provinces. The South, East and West provinces accounted for 31%, 28% and 21%, respectively, of sampled households used in the present study and the Northern province represented 19% of the sample[2]. The sample selected was restricted to households with farm activities, to ensure that all households in farm technology adopting and non-adopting groups had engaged in farming economic activities in the 12 months before the survey was conducted (see Paper I, Table 1). EICV3 provides information on household farm income, farm productivity and poverty level. The total sample size used in Paper I was 4090 households, with the proportion of adopters and non-adopters being 55% and 45%, respectively[3].

In Paper II, monthly average price data on beans, potatoes and cassava roots obtained from the NISR for the period 2000-2012 were used. These are nominal retail prices that prevail on the markets in the country. From these nominal prices, real prices were computed using the consumer price index (CPI), taking January 2005 as the base. To measure the impacts of the likely changes in rainfall on food crop market prices, food price data were merged with monthly data series on rainfall from the World Bank's climate change knowledge portal over the same period.

To assess the reliability of community prices or unit values when analysing food demand patterns, in Paper III data from the third wave of the Tanzanian National Panel Survey (NPS) were employed. The NPS is part of an ongoing Living Standards Measurement Study-Integrated Survey on Agriculture (LSMS-ISA) by the Tanzanian Bureau of Statistics (TNBS) with assistance from the World Bank. The data cover 4416 sampled households from all regions of the

[2] To minimise the bias, city dwellers were removed as the main focus was on farming, which is mainly undertaken by rural inhabitants.

[3] The final sample was decided after removing all farm households with incomplete information and data cleaning.

Tanzanian mainland. The sampled households were stratified into three broad regional categories. These were: the Dar-es-salaam area, represented by 770 households; other urban areas with 883 households; and rural areas represented by 2763 households. However, after data cleaning, data on a total of 1765 households remained for the analysis. This was mainly due to lack of basic information on household food expenditure. It is important to highlight that the main purpose of Paper III was to derive and compare price and expenditure responses using both unit values and community prices. Hence, the restriction of having households with sufficient information to compute the two set of prices was imposed.

Furthermore, to characterise household food consumption patterns and identify the heterogeneity of food demand between rural and urban households, EICV4 data (conducted 2013/2014) were used in Paper IV. A sample of 14,172 households was selected, comprising 11,660 rural and 2,512 urban households, representing 82.2% and 17.8% of the total sample, respectively. The data cover the entire country, including its four provinces and the city of Kigali. Southern province accounted for 27% of all sampled households, Eastern province for 24%, Western province 23%, Northern province 16% and the city of Kigali 10%. To account for the effects of differences in household composition, the following demographic and household variables were used: age of household head, household size, number of adult members in household, education level of both household head and spouse, proportions of household members aged below 6 years, between 7 and 16 years, between 17 and 59 years, and 60 years or more, a dummy of whether the household has non-farm business or not, and a dummy defining monogamous household head. These variables are known to have a potential influence on household preferences and food expenditure decisions.

2.2 Research methods

The empirical analyses reported in this thesis were conducted using different methods and econometric estimation techniques. Each of the methods used relies on economic principles and a quantitative framework and all were used to measure farm household welfare and agricultural policies in African countries, with particular emphasis on Rwanda and Tanzania.
Paper I sought to identify factors that affect farmers' decision to adopt modern agricultural inputs and how it influences household welfare by using endogenous

switching regression (ESR) and recursive bivariate probit (RBP) models to account simultaneously for self-selection and unobserved heterogeneity of adopters and non-adopters. The ESR approach makes it possible to control for farm household unobserved heterogeneity (unobservable farm and household characteristics that may be correlated with the outcome variables). To estimate the endogenous switching model, the full information maximum likelihood (FIML) estimation approach (Lokshin & Sajaia, 2004) was used to simultaneously fit the adoption decision and derive welfare effects. While the ESR approach can only be applied when the outcome is a continuous variable, the RBP model can be used in the case of a binary outcome. Thus in order to estimate jointly the effects of adoption decision and the impact of modern agricultural input use on farm household poverty level, both of which are binary outcomes, a recursive bivariate probit model was used.

Paper II investigated the transmission of rainfall changes to food crop prices, in particular whether there is an asymmetric knock-on effect of rainfall on food prices. For this, the Nonlinear Autoregressive Distributed Lag (NARDL) model was employed. This is a generalization of the Autoregressive Distributed Lag (ARDL) bounds testing approach (Pesaran et al., 2001), which incorporates an error correction mechanism and allows estimation of asymmetric long-run and short-run dynamic coefficients in a co-integration framework.

In Paper III, a theoretical framework based on standard consumer theory was applied to examine the differences and similarities between unit values and community prices. A quasi-concave utility function of the sampled household and fully choice behaviour of each household to gain utility from any demand at a given limited household income were assumed. It was also assumed that the amount of food consumed by each household and the quality choice are both functions of food market prices, household income and other economic factors. Quadratic Almost Ideal Demand Systems (QAIDS; Banks et al., 1997) were derived. Furthermore, to deal with the issue of censored household data, the Shonkwiler and Yen (1999) technique was applied. An additional assumption was that households make food expenditure decisions in a two-stage procedure. In the first stage, households decide on whether to purchase or not purchase each of the food items. In the second stage, they decide how much to spend on each item, conditional on a positive purchase decision from the first stage. In Paper III, the first stage was estimated using a probit model that describes consumption selection decisions. The predicted estimates from the first stage were used to generate the cumulative distribution function (cdf) and probability density function (pdf), and were augmented in the QUAIDS equation in the second stage.

The use of household data in analysing household demand raises the issue of quality effects. Using unit values to represent market prices has caused concern and debate among economists. The use of raw unit values may induce measurement errors and biased estimates. A number of studies have even revealed that expenditures and quantities, used to derive unit values, are usually contaminated by e.g. differences in forms of commodities (e.g. cassava flour and roots, maize flour or grain) or differences potentially resulting from diet composition, which may vary across households and regions (Deaton & Dupriez, 2011). To deal with these biases in unit values, two approaches have been proposed. First, Cox and Wohlgenant (1986) suggest that the quality effects and measurement error of unit values can be corrected by regressing proxies of quality variations (like household size, education of household head, ratio of household dependency members etc.) on the unit values. This makes it possible to have quality-adjusted prices that vary across households (Aepli, 2014). However, others have suggested that, in addition to the Cox and Wohlgenant (1986) correction, for households to face the same price they should be at least in the same region, and propose a new approach to find quality-adjusted prices at the regional level (Majumder et al., 2012; Aepli & Finger, 2013). Paper III followed the Cox and Wohlgenant approach, but extended it as suggested by Majumder et al. (2012).

In Paper IV, quadratic food Engel curves were estimated. The dependent variables were entirely expressed in terms of proportion spent on the goods in total household expenditure (food budget-share), to capture a range of functional forms. Therefore, the dependent variables were household expenditure on each of six food groups (cereals, roots and tubers, vegetables, meat, beverages, and other food) as a share of total household food consumption. To estimate the quadratic food Engel curves of food groups, three critical estimation issues were accounted for. These were: variable measurement errors, zero household expenditure and the presence of extreme values (outliers) in household expenditure. The approach of Hausman et al. (1995) was used to deal with variable measurement errors in the household expenditure data. The issue of zero household expenditure is another pitfall that could cause biased estimates if not accounted for. Several factors can lead to zero household expenditure, including infrequency of household purchases, data misreporting and variation in preferences across sampled households (Deaton & Irish, 1984; Keen, 1986). In Paper IV, it was assumed that the first two reasons for occurrence of zero expenditure are exogenous and therefore only the third motive was considered. It was thus assumed that zero expenditure arises only if the individual household does not purchase any of a particular food item. However, deriving food Engel

curves may induce endogeneity threats that arise when expenditure share on food is regressed on total household expenditure (Hausman et al., 1995). More specifically, a simultaneous decision on using household expenditure together with allocation to each food group can lead to the former becoming endogenous. One of the best solutions is to use an instrumental variable, but a major challenge is in obtaining good instruments. Household income was used in Paper IV, since it is considered an appropriate instrument for expenditure and has been used in a significant number of Engel curve studies (Banks et al., 1997; Bhalotra & Attfield, 1998; Blundell et al., 1998; Blundell et al., 2007; Hasan & Mozumder, 2017). In addition, another useful aspect of using income as the instrumental variable for household expenditure is that the two are highly correlated and, in two-stage budgeting, household income does not have a direct effect on expenditure shares, an indication of a valid instrument. Different statistical tests were carried out to examine the validity of the instrument. The following section gives a summary of Papers I-IV with more details on results discussion.

3. Summary of the Papers I-IV

3.1 Paper I: Is change worth it? The effect of adopting modern agricultural inputs on household welfare in Rwanda

Adoption of efficient farm practices has been proven to have a direct link to economic well-being in many developing countries, mostly in SSA, with existing evidence indicating that agricultural technology adoption increases farm yields and, importantly, is critical in achieving goals of food security and poverty alleviation in SSA (Ersado et al., 2004; Abdulai & Huffman, 2014). Using Rwandan farm household data from EICV3 (2010/2011), comparative average values between adopters and non-adopters for farm income, farm yield, per capita consumption and poverty index were derived in Paper I. Analysis of descriptive statistics revealed significant differences between farmers who adopted technology and those who did not. However, the differences obtained were not sufficient to conclude that adopters of modern agricultural inputs are better off than non-adopters, since the comparison did not account for unobserved characteristics and self-selection bias among farmers. Therefore, factors affecting farmers' adoption decisions and subsequent welfare implications were analysed using an endogenous switching regression model (for continuous outcomes) and recursive bivariate probit model (for the binary outcome) to simultaneously account for both the self-selection problem and unobserved heterogeneity forces.

Analysing factors that influence adoption of modern agricultural inputs revealed useful and interesting results. Specifically, household and farm characteristics, such as farm credits, farm size and land consolidation practices were found to have a significant positive effect in increasing the probability of a household adopting modern agricultural inputs. Access to agricultural credits made farmers less liquidity-constrained, hence increasing their likelihood to adopt modern agricultural inputs, which subsequently led to potential changes in farm income, yield and consumption levels. However, while modern agricultural input

adoption reduced poverty, the effect was not statistically different from zero. In general, the results showed that farm households that have adopted modern agricultural inputs are always better off from adopting than not adopting, and that non-adopters are still worse off when not adopting than adopting. Specifically, the estimates for average treatment effects showed that the impact of modern agricultural input adoption induces significant causal positive effects on farm income, farm yield and consumption per capita, by as much as 72%, 52% and 32%, respectively. These findings are consistent with the existing literature, which reports that new agricultural technology improves farm yield and farm income for smallholder farmers (see Minten & Barrett, 2008; Abdulai & Huffman, 2014).

3.2 Paper II: Asymmetric effects of rainfall on food crop prices: Evidence from Rwanda

The vast majority of households in developing countries are located in rural areas and still depend on agriculture as their main source of livelihood. However, agriculture in these countries is strongly dependent on climate variables such as temperature and precipitation. The consequences of climate change such as flooding, higher temperatures and unexpected frequent and extreme weather events will negatively affect food production, hence leading to a decrease in food supply and ultimately in higher prices. For instance, Baez et al. (2015) investigated the effects of rainfall shocks on household welfare and indicated that there is a substantial negative impact of shocks in precipitation, with the effect being particularly high among urban households. They also found that rainfall shocks increase poverty by 18% and reduce household food consumption by 10%. Similarly, in a study by Sassi and Cardaci (2013), who investigated the consequences of different rainfall scenarios on food availability in Sudan, a strong relationship was found between climate change and income variability, poverty and food shortage.

Despite these concerns about the effect of climate change on economic losses and social welfare impacts, few studies have been undertaken in the East African region and particularly in Rwanda. Therefore Paper II fills this gap and provides an empirical base that is potentially relevant for policy decisions. It investigated the dynamic and asymmetric effects of rainfall on food crop prices (beans, cassava roots and Irish potatoes) with an application to Rwanda, a landlocked country with rain-fed agriculture. The analysis revealed strong associations between rainfall shocks and asymmetric variations (positive or negative) in food

crop prices, with these effects being expressed in both the short and long run. The analysis also revealed that the negative shocks in rainfall are transmitted to crop prices with substantially greater intensity than positive shocks in rainfall. In particular, the negative long-run elasticity of rainfall shocks on cassava root prices was roughly 32 percentage points higher than that of positive rainfall shocks. There was also evidence of seasonality, whereby prices fall during the harvest season and rise thereafter. This highlights the necessity for crop storage systems in Rwanda to help smooth food prices across the agricultural year.

3.3 Paper III: Analysis of household demand patterns using household data: Re-thinking the use of unit values or community prices

In developing countries, where time series data are rarely compiled at household level, economists and other food policy-makers rely mostly on Living Standards Measurement Surveys (LSMS), usually conducted by the national statistical bureau in different countries together with technical and financial assistance from the World Bank, to derive price and income elasticities. The problem with this approach is that most household surveys rarely report prices of goods and services at which the household purchased the items in developing countries, hence constraining the usefulness of the data in demand analysis. To design effective food policy and assess household consumption behaviour, economists usually employ unit values or community prices, both considered as proxies for market prices, to estimate price elasticities. Although a significant number of studies on household consumption analysis have been undertaken using one of these two prices, little attention has been paid to the sources and reliability of the price data. Therefore Paper III examined similarities and discrepancies in income and price elasticities using unit values and community prices in the context of SSA, using the example of Tanzania where a large share of household income is still spent on food items.

The results from nine food groups (cereals, starches, sugar, nuts, vegetables, fruits, meat, milk and edible oil products) revealed that expenditure elasticities from both prices were similar in both size and sign. However, the estimates of price elasticities from both approaches showed significant discrepancies. These deviations may mainly result from community prices if survey enumerators do not consider the probability of consumers bargaining. In that case, community prices could be expected to be considerably higher than the unit values reported by households after bargaining with sellers. It is therefore suggested that, prior

to use of household data to compute price and income elasticities, analysts should carefully account for possible data noise that may lead to biased estimates.

3.4 Paper IV: Income and food Engel Curves in Rwanda: A household microdata analysis

Food demand in low-income countries has steadily increased over recent decades. Specifically, high population and income growth rates coupled with intensified urbanisation have significantly altered dietary habits, and this has caused rapid changes in food demand in SSA (Melo et al., 2015).

Sub-Saharan Africa is known as one of the poorest regions in the world, where the poverty rate and malnutrition prevalence are higher than in other developing countries. In fact, according to FAO (2017), SSA is the region in the world with the largest number (233 million) of hungry people. Moreover, World Bank (2012) reported that over 47% of the total population in SSA lived on $1.90 a day or less, a driving factor causing widespread hunger in the region. However, as in other developing countries, food demand has increased exponentially over recent years in SSA. In Paper IV, new evidence to improve understanding of household consumption trends in Rwanda was obtained by deriving the associations between household income, food expenditure and expenditures on specific food types (cereals, roots, tubers, vegetables, meat, beverages and other foods). The results revealed that unconditional expenditure elasticities are relatively higher for rural than urban households, indicating that Rwandan rural areas tend to have poorer households than urban areas. That is, as total expenditure increases, rural households raise their expenditure on food more proportionally than urban households and this increase in expenditure is mostly on low-value staples, starches and cereal products. The results also revealed that there are important differences in dietary composition and food supply structures across household locations in Rwanda. In addition, the study confirmed earlier findings that low-income countries spend a greater proportion on their budget on food, as necessity commodities (Muhammad et al., 2011). These findings are useful, especially in a developing country like Rwanda with emerging intense urbanisation, income and population growth rates. Importantly, they reveal the impact of household location on food demand patterns and the possible policy interventions on food insecurity and malnutrition. Hence, a good understanding of rural and urban food consumption patterns would provide more insights into purposive and targeted food policies in many SSA and other developing regions.

4. Contribution of the Thesis

The results presented in this thesis make novel contributions to the economic literature, particularly in the area of agricultural economics, climate change, development and food economics. In the area of agricultural economics, Paper I identified the driving forces that influence farmers' decision to adopt modern agricultural inputs, such as hybrid seeds, fertilisers and pesticides. It also revealed the underlying effects of using modern agricultural inputs on farm income, yield, household consumption per capita and poverty level of smallholder farmers in rural Rwanda. In addition, it uncovered heterogeneity effects between adopters and non-adopters of modern agricultural inputs, using endogenous switching regression and bivariate recursive probit models that compared estimates between two groups while accounting for both observed and unobserved farm and household characteristics.

In the area of climate change, Paper II identified asymmetric effects of rainfall on food crop prices, which is particularly useful information for poor countries, including Rwanda, where a high proportion of household income is still spent on food and crop products rely heavily on rain-fed farming. Unlike previous studies, Paper II determined the driving forces and vulnerability of food prices (cassava roots, beans and potatoes) to weather shocks by considering non-linear and asymmetric effects. The use of asymmetric non-linear autoregressive distributed lag (NARDL) to analyse the effects of likely changes in rainfall on food crop prices is a distinct novel contribution to the literature.

In the area of development economics, Paper III contributes in two ways to existing literature on deriving elasticities using surveyed prices. The study reassessed the reliability of using community prices or unit values when analysing food demand patterns, by revisiting earlier works (Gibson & Rozelle, 2005, 2011) and determining how selection can affect policy analysis. To my knowledge, this is the first study to evaluate the use of unit values or community

prices in an African (Tanzanian) context. Second, unlike Gibson and Rozelle (2011), who used a linear system of equations, a complete nonlinear demand system approach was applied in Paper III to estimate the demand for food commodities. In this context, a quadratic almost ideal demand system (QUAIDS) developed by Banks et al. (1997) was applied to determine non-linear Engel curves in household food demand analysis.

Paper IV makes a distinctive contribution in the area of food economics, by using nationwide household expenditure survey data to derive food Engel curves for major food expenditure categories in Rwanda. The underlying factors in household food demand were derived while taking into consideration the household location (rural or urban). The results revealed the impact of household location on food demand patterns and possible policy interventions to enhance food security and reverse malnutrition. This is very useful information, especially in developing countries like Rwanda with emerging intensive urbanisation, income and population growth. A good understanding of rural and urban food consumption patterns would enable purposive and targeted food policies to be formulated.

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