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The Determinants of Long-Term Growth in Smallholder Agriculture in Rwanda: An Intergenerational Analysis

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Zusammenfassung

Die vorliegende Studie untersucht die Ursachen des langfristigen Wachstums in der kleinbäuerlichen Landwirtschaft im ländlichen Ruanda, wobei der Schwerpunkt auf die Mobilität von Einkommen und Armut zwichen den Generationen über die vergangenen zweieinhalb Jahrzehnte gelegt wird. Die Analysen basieren auf einen einzigartigen Paneldatensatz, der sich über einen Zeitraum von 26 Jahren erstreckt und aus zwei Haushalterhebungen in Nyabihu besteht, des am dichtesten besiedelten Verwaltungsbezirkes in Ruanda. Die erste Datenerhebung umfasste 190 Haushalte und wurde im Jahr 1986 vom International Food Policy Research Institute (IFPRI) durchgeführt. In der zweiten Befragung im Jahr 2012 folgten wir den gleichen und weiteren Haushalten, die sich von den ursprünglichen Haushalten abgespalten hatten, um den Datensatz der Großfamilien, bestehend aus 164 ursprünglich existierenden Haushalten und 200 abgespaltenen Haushalten, zu konstruieren.

Die Analyse der Bevölkerungsstruktur im Studiengebiet zeigt einen Anstieg der Bevölkerung um 88 Prozent während der letzten zweieinhalb Jahrzehnte. Die ökonometrische Analyse zeigt, dass Fruchtbarkeit positiv mit ursprünglichem Haushaltseinkommen, Alter des Haushaltsvorstands, und negativ mit dem Alter der Mutter bei der Eheschließung und dem Bildungsstand der Mutter korreliert. In diesem Zusammenhang konnten wir Anzeichen für den Boserup-Effekt finden. Demnach besteht ein statistisch positiver Zusammenhang zwischen Haushaltsgröße und der Intensivierung der Landwirtschaft sowie der landwirtschaftlichen Produktivität. Allerdings verlangt die identifizierte umgekehrte Beziehung zwischen der Anzahl der Haushaltsmitglieder und den Pro-Kopf-Ausgaben des Haushaltes umgehend politische Maßnahmen, um das Bevölkerungswachstum in der Region einzudämmen.

Die Ergebnisse der Schätzung der Cobb-Douglas-Produktionsfunktion legen nahe, dass Produktionsfaktoren, wie Arbeit, Land und Bodenqualität die Hauptdeterminanten des Produktionswachstums sind. Die landwirtschaftliche Produktion in der Untersuchungsregion ist durch abnehmende Skalenerträge charakterisiert und durch hohe Produktionselastizitäten der Arbeit (0,48), gefolgt von der des Kapitals (0,17) und der Anbaufläche (0,13). Allerdings kann nicht davon ausgegangen werden, dass die Arbeitsproduktivität weiter ansteigt, wenn man das gegenwärtige Niveau des Bevölkerungswachstums betrachtet. Wege zu weniger arbeitsintensiver Landwirtschaft und eine Erhöhung nicht-landwirtschaftlicher Tätigkeiten sind wünschenswert.

Der Gebrauch von Mobiltelefonen durch Landwirte führte in den letzten Jahren zur gesteigerten Produktion und höheren Einkommen. Die Studie zeigt auf, dass die Höhe der landwirtschaftlichen Produktion für Handy-Nutzer 38 Prozent höher ist als für Nicht-Nutzer, während deren Einkommen um etwa 26 Prozent höher ist. Die Bereitstellung von Netzinfrastruktur und Elektrizität in der Untersuchungsregion kann eine positive Entwicklung des Agrarsektors durch die Adoption von Telekommunikationstechnologie von Kleinbauern verstärken.

Die Übertragungs-Matrizen und Regressionsergebnisse legen eine hohe Einkommensmobilität und eine relativ geringe Persistenz der Vermögenswerte über Generationen hinweg nahe, dies gilt insbesondere für Grund und Boden sowie Nutztierbestand. Unter sonst gleichen Bedingungen führt eine zehnprozentige Zunahme des elterlichen Grundbesitzes zu einer um drei Prozent höheren Verfügbarkeit von Land für deren Kinder. Ebenso führt eine zehnprozentige Zunahme des Nutztierbestands der Eltern zu einer 2,2-Prozent-Zunahme des Bestandes der Nachkommen. Zudem zeigen die Daten in der Untersuchungsregion einen relativ kleinen Grad der Armutspersistenz über Generationen hinweg. Aus diesem Grund sollten die zentralen Politikmaßnahmen nicht nur die Kontrolle des Bevölkerungswachstums anstreben, sondern auch die Gewährleistung einer fairen Wohlstandsverteilung zur Armutsbekämpfung und zur landwirtschaftlichen Entwicklung in Ruanda zum Ziel haben.

Abstract

The current study explores the determinants of long-term growth in small-scale agriculture in a rural area of Rwanda, with a special focus on intergenerational mobility of income and poverty over the past two and a half decades. We use a unique panel dataset that spans over a 26 year-period, constructed from two waves of household surveys conducted in Nyabihu, the most densely populated rural district in Rwanda. The first wave of data was collected by the International Food Policy Research Institute (IFPRI) from 190 respondents in 1986. While in the second survey done in 2012, we followed the same households and the households of family members who split off from them in order to construct a dataset of extended families that consists of 164 original households and 200 split-off households.

The analysis of the demographic structure shows that the sample population has increased by 88 percent over the past two and a half decades. Econometric results indicate that human fertility is positively associated with initial household income, and household head's age, but inversely correlated with mother's age at marriage and mother's education. In this context, we found evidence of Boserup effect in the study area. Accordingly, there is a positive and statistically significant correlation between household size and agricultural intensification as well as farm productivity. However, the obtained inverse association between the family size and per capita expenditure speaks for immediate policy to reduce the growth of population in the study area.

The findings from Cobb-Douglass function estimation suggest that factors such as labor, capital, land, and land quality are the key drivers of output growth. Agricultural production in the study area is characterized by decreasing returns to scale economies, with high output elasticities of labor (0.48), followed by lower elasticities of capital (0.17) and land (0.13). However, productivity of labor will not continue to grow at the pace of consumption demand, considering decreasing marginal returns of labor and the prevailing level of population growth. Pathways to less labor intensive agricultural and off-farm employment are highly desirable.

The use of cellular phones by farmers has significantly increased output level and income in recent years. The study finds that agricultural output of mobile phone users is at least 38 percent higher than output of non-users, whereas their income level is about 26 percent higher. The provision of network infrastructure and electricity in the study area can enhance agricultural development through increased adoptions of telecommunication technology by smallholder farmers.

The transmission matrices and regression results suggest strong income mobility and relatively small persistence of assets holding across generations, especially with regard to land and livestock which are considered as eminent assets in the study area. Everything else being equal, a ten percent increase in parental landholding is associated with a three percent increase in available land for the children. Similarly, an increase of ten percent in parent's livestock is associated with a two percent increase in livestock for their offspring. Besides, the data suggest a relatively small degree of persistence of poverty across generations in the study area. Therefore, key policy options should not only aim at controlling the population growth, but also ensuring a fair distribution of wealth to ensure poverty reduction and rural development in Rwanda.

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List of Abbreviations

2SLS	Two Stage Least Squares
AMIS	Agricultural Management Information System
ATT	Average Treatment of the Treated
AU	African Union
BGLW	Becketti-Gould-Lillard-Welch
CAADP	Comprehensive Africa Agriculture Development Programme
CF	Chemical Fertilizers
CIP	Crop Intensification Program
CPI	Consumer Price Index
DAAD	Deutscher Akademischer Austausch Dienst
DID	Difference in Difference
DRC	Democratic Republic of Congo
EDPRS	Economic Development and Poverty Reduction Strategy
EICV	Enquête Integral des Conditions de Vie de ménages
FEWSNET	Famine Early Warning System Network
FPI	Food Price Index
GDP	Gross Domestic Product
HYV	High Yield Variety
ICT	Information and Communication Technology
IFPRI	International Food Policy Research Institute
ILO	International Labor Organization
LFPI	Laspeyres Food Price Index
LR	Log Likelihood

MINAGRI	Ministry of Agriculture and Animal resources
MINECOFIN	Ministry of Finance and Economic Planning
NEPAD	New Partnership for Africa’s Development
NISR	National Institute of Statistics in Rwanda
NSP	National Seed Policy
OLS	Ordinary Least Squares
PRSP	Poverty Reduction Strategy Paper
PSM	Propensity Score Matching
PSTA	Plan Stratégique de Transformation Agricole
Re-SAKSS	Regional Strategic Analysis and Knowledge Support System
RITA	Rwanda Information and Technology Authority
RWF	Rwandan Francs
TFPG	Total Factor Productivity of Growth
USA	United States of America
USD	United States Dollar
VCM	Vicious Circle Model
ZEF	Zentrum für Entwicklungsforschung

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May God bless you all!

Chapter 1. INTRODUCTION

1.1. Problem statement and motivation

> *"Most of the people in the world are poor, so if we knew the economics of being poor, we would know much of the economics that really matters. Most of the world's poor people earn their living from agriculture, so if we knew the economics of agriculture, we would know much of the economics of being poor." (Schultz, 1980).*

The above statement from Shultz's Nobel Prize lecture has been widely cited by agricultural and poverty economics researchers over the last three decades, and stresses the key importance of agriculture in reducing rural poverty. The role of agriculture in economic growth has a number of aspects. It goes beyond the fundamental one of food and fiber provision to the growing population and the complexity of contribution increases with economic growth. According to Mackie (1964), the contributions are made to the growth process by increasing production above subsistence level to facilitate the non-farm economic growth, stimulating industries for both agricultural inputs and output processing, releasing labor to other sectors, a resource for investment or government activity, and by providing income to the population. From most of these perspectives, agriculture is seen as permissive or facilitating rather than as an engine of growth (Stern, 1996).

Alternatively, Mellor (1995) pointed out the predominant role of agriculture to pave the way to industrialization due to its important size in the early stages of development. As it is difficult for developing economies to rely on foreign demand for the majority of their incremental output, agricultural growth should focus on incremental domestic demand (Mellor, 1995). Therefore, agricultural growth needs to be accelerated in order to obtain growth in other sectors even though land expansion, as one of the key factors of agricultural growth, has reached its limit in most developing countries. However, under fixed land, the accumulated knowledge will enhance technological change in agriculture, increasing the level of output and national income (Mellor, 1995).

Over the last two decades, researchers examined the evolving and complex relationships between agricultural growth and overall economic growth, through its linkages to the nonfarm rural sector, urban sector, and the rest of the world. Most development policies focus on industrialization which in turn needs to be nurtured by resources from agriculture (Vasant, 1998). Hence, for development to take place, the accelerated agricultural growth that includes small farmers is required because other sectors of the economy expand as a result of changes in agriculture (Mellor, 1995).

Recent literature recognizes agriculture as an engine for growth and notes the special role of agricultural growth in poverty reduction through direct impacts on farm income and employment and indirect impact through growth linkages as well as its impact on food prices (Byerlee et al., 2005; Headey et al., 2005). The World Development Report (World Bank, 2007) pointed out the basic features of agriculture which make it a unique instrument for development. Agriculture contributes to development as an economic activity, as a livelihood source, and as a provider of environmental services, and can be a main source of growth for the agriculture-based countries through improving access to assets, diversification of income sources, and facilitating migration out of agriculture.

This is specifically the case in Rwanda where agriculture is the backbone of the economy. Rwanda's population of about 10.5 million lives in Africa's most densely populated country where the majority of people depend on small scale farming for their livelihoods. Agriculture constitutes the second biggest component of the country's GDP. Between 2001 and 2008 it constituted 36 percent of the economic output. As recently as 2005, agriculture was the biggest GDP contributor. The services sector has grown faster than agriculture so it has higher share now, whereas the industry sector stagnated at around 13.9 percent of GDP. However, agriculture remains the major source of jobs for poor rural households, and less educated segments of the population. Real agricultural growth averaged at 4.9 percent between 2006 and 2010, attained a record of 7.7 percent in 2009, and stood at 4.6 percent in 2010 (Hansl et al., 2011).

More than 60 percent of all farm households cultivate less than 0.7 ha of land (MINAGRI, 2009). This constraint is aggravated by the fact that most farms have multiple and scattered plots (MINAGRI, 2009). These small size plots, mainly maintained with a hand hoe, have to carry more than five crops a season. Indeed, their production is still regarded as a major source of food diet and exchange on local markets to feed non-farming households (MINAGRI, 2005, 2009).

Table 1.1 Selected development indicators for Rwanda

Indicator	1985	2000	2005	2012	2020 (2000 projections)
Population (million)	6.1	7.7	8.65	10.5	13
Population growth rate (%)	3.3	2.9	2.7	2.6	2.2
Rural population (% total)	-	90	82.2	80	70
Literacy (% population)	-	48	76.8	80	100
GDP (USD billion, current)	1.835	1.701	2.533	7.103	-
GDP (USD per capita, current)	300.8	212	280.3	681.5	875.8
Manufacture (% GDP)	-	-	18	16	26
Services (% GDP)	35	49	36	46	41
Agriculture (% GDP)	45	45	46	32	33
Agricultural population (%)	95	90	83.4	75	50
Calorie supply (Kcal per capita/ day)	1,665	1,612	-	2,000	2,200
Poverty (% < 1USD/day)	-	60.4	56.9	44.9	30
Infant mortality rate (per 1,000 children less than 1 year)	127	107	86	62.5	50
Life expectancy at birth	48	46.5	52.2	58.4	55

Sources: The Rwandan Central Bank at www.bnr.rw accessed on 21/11/2013; MINECOFIN (2000); MINAGRI (2009); NISR (2007, 2008, 2010, 2012a, 2012b); World Economic Outlook Database at www.imf.org accessed on 22/11/2013; Hernandez (2013); von Braun et. al (1991).

Table 1.1 reveals that agriculture occupies the largest part of the Rwandan population. The last column of the table shows the country projections according to the main policy document "Vision 2020", where some indicators have already reached the targets before the time horizon. The vision of Rwanda is to transform itself from subsistence agricultural to a knowledge-based economy by 2020 (MINECOFIN, 2000). The achievement of this vision requires an intensification and market-orientation of agriculture on the one hand, and a diversification of the economy through a proliferation of non-agricultural sectors on the other hand (Hansl et al., 2011). This also requires a change of 50 percent of farms into modern-type farms, an increase of 3 times the land productivity, and an increase of 4 to 5 times the work productivity (MINAGRI, 2005). Therefore, there is a compelling need for an empirical approach to understand the sources and determinants of agricultural growth, especially for smallholder farmers who constitute a large segment of the population, and for whom agriculture has been (and still is) the main source of household income and a way to get out of poverty.

The drivers of change in Rwandan agriculture are not only variations in agricultural practices, but also climatic, political, and institutional factors (Donovan et al., 2002). While exploring the Rwandan agricultural household income and nutritional outcome, McKay and Loveridge (2005) found that the struggle to income recovery of the period 1995-2000 was accompanied by an increase in population, and has resulted in a decrease in land per capita, accompanied by increase in inequality and rural poverty. Also, the extent of income mobility and poverty persistence are important social indicators to be placed alongside information about income distribution (Jenkins, 2000). Changes over time in smallholder agriculture may result subsequently in changes in household income, and changes in poverty among rural households. The latter may depend not only on the current economic factors, but also on socioeconomic features of the past generations (Blau, 1999; Jenkins, 2000; Lee and Solon, 2009; Peters, 1992; Shea, 2000). An analysis of intergenerational mobility of income and poverty is included in the current study in order to better comprehend the extent of wealth and poverty transmission across farmers' generations, as well as the impact of technology and economic change.

1.2. State of the Art

For nearly half a century, economists and politicians from all nations, rich and poor, capitalist, socialist and mixed, have examined the sources of economic growth where capital accumulation, human resources, and technological progress have been considered the three major factors of economic growth for any society (Todaro and Smith, 2012). While analyzing growth in poor economies, Stern (1996) suggests that one should go beyond capital, labor, and technology to consider three further groups of factors which are of great importance: management and organization, infrastructure, and the sectorial allocation of output.

The theory of agricultural growth, considered as an engine for overall growth for developing countries (Tiffin and Irz, 2006), has dominated growth literature over the past half century. Schultz (1944) pointed out the necessary conditions for economic progress in agriculture. He argued that policy should minimize the excess of labor in agriculture by labor-saving technology introduced into farming, and policy should increase the rate of expansion of labor force in non-agricultural industries. Recent literature has associated long-term agricultural growth with the productivity growth which itself is induced by investment in research, extension, human capital, and infrastructure, and emphasized on the magnitude and contribution of total factor productivity of growth (TFP) to total output growth (Rosegrant and Evenson, 1995). In a study on progress, performance, and determinants of agricultural development in India, Tripathi and Prasad (2009), using the Cobb-Douglas Production function and the time series data, found that land is the most important source of agricultural growth and that Indian agriculture is characterized by increasing returns to scale. Similar production function relating output to inputs (land, labor, fertilizers) and other conditioners such as land quality and household characteristics was used by Clay et al. (1996) when studying the determinants of farm productivity in Rwanda using cross sectional data. They found that land size and labor have positive and significant effects, while farmer age has significant negative effects on the agricultural output value. von Braun et al. (1991) identified the substantial role of farm size for crop production in a land scarce environment. Using cross sectional data from rural Rwanda, they found that the production elasticity of land was higher than the production elasticities of labor and capital.

Factors of agricultural growth include population growth (Boserup, 1965, 1981) and other factors affecting agricultural intensification, including changes in market prices, technology (whether or not induced by population growth). While numerous studies have shown a positive correlation between population growth and environmental degradation (Cropper and Griffiths, 1994; Hohm, 2002; Pat-Mbano, 2012), there are also many examples showing that high population growth and densities may be consistent with sustainable agricultural practices (Pender, 1998). Agricultural practices may result from technical change or technical progress through the invention of new cultivation techniques (Boserup, 1981). Since having a large population is not sufficient to generate growth (Romer, 1991), it is important to examine the mechanism by which population density influences innovation.

Models of agriculture development also emphasized the role of infrastructure (Lewis, 1955). It is believed that both physical and institutional infrastructure can boost the spread of technology that can accelerate the development of an economy (Mellor, 1976). Researchers indicated that the observed lags in agricultural production are not only due to input constraints, but also to the underutilization of modern agricultural technologies. According to Aker (2011), the determinants of agricultural technology adoption depend on a number of factors including education level, wealth, risk preference, complementarity of inputs and access to information. Mobile phones, for example, have proved to significantly reduce the costs of communication and information in rural areas (Kramer et al., 2007). This is because they provide new opportunities for farmers to obtain access to information on agricultural technologies, and to use information and communication technologies (ICTs) in agricultural extension systems. Berdegué and Escobar (2002) studied the effects of agricultural innovation policies and poverty reduction and found that technological innovations can make a direct contribution to a farm household's welfare, and can also have indirect benefits for the poor through effects on food prices, employment, and linkages to other parts of the economy. Key extension services functions vis-à-vis national agricultural development goals include technology transfer, especially for staple food crops, training farmers to use natural resources management practices, teaching farmers how to diversify their farming systems, and training farmers to organize into producers and community groups (Burton and Riikka, 2010) .

In most developing countries, resources allocations principally take place inside households, within families, and between members of kin (Stark, 1990). These altruistically motivated transfers between individuals are more valuable than transfers received in markets and shape the quality of life (DeScioli and Krishna, 2013; Haltiwanger and Waldman, 1993; Qi and Zhao, 2009; Stark, 1989, 1997). Since the household's wealth is mostly acquired firstly through direct transmission from parents, and secondly from the resources available to all members of the population (Mulder et al., 2009), shocks to economic fortunes of a household (due to disease, accident, luck in harvest, etc.) are likely to have important effects on the next generation. These effects will thus accumulate overtime and counteract or amplify poverty and inequality among the offspring: this is the essence of the intergenerational analysis debate on income mobility and poverty dynamics (Baulch and Hoddinott, 2000; Mulder et al., 2009; Peters, 1992; Shea, 2000).

In the study on determinants of income mobility and poverty dynamics in South Africa between 1993 and 1998, Woolard and Klasen (2005) found that demographic changes and employment changes are the most important drivers of mobility. They indicated that poverty traps hindering the progress of the poor are related to initial household size, initial education, initial assets, and initial participation in the labor market. Becker and Tomes (1979) pointed out that a full analysis of income distribution within a specific society or country should consider both inequality in income between different generations of the same family and inequality in income between different families in the same generation. Empirical data showed a significant degree of intergenerational continuities in earnings in Britain (Atkinson, 1980), in the United States (Solon, 1992), in Bangladesh (Asadullah, 2012), and among several agricultural and pastoral communities from developing countries (Mulder et al., 2009). The implications on lifetime household welfare may still need more attention today because they can have strong implications on poverty reduction efforts (Corak, 2014; Piketty, 2011; Piketty and Saez, 2014).

1.3. Research Objectives and Questions

Following the problem statement above, this study seeks to investigate the determinants of long-term socio-economic change in small farm households, and the extent of wealth transmission between parents and their offspring over time. So far, studies on this relevant topic are rare, particularly in Africa. Existing studies on agricultural productivity by Donovan et al. (2002) and McKay and Loveridge (2005) were rather descriptive to explore the forces driving changes of Rwandan smallholder agriculture and household income. Clay et al. (1996) studied the determinants of farm productivity in Rwanda but focused the analysis on the farm's ability to invest in conservation and fertility technologies. The study of von Braun et al. (1991) assessed the effects of agricultural commercialization on household production, income, employment, consumption, and nutrition in rural Rwanda. Recently, Ali and Deininger (2014) focused on the causes of the inverse relationship between farm size and productivity in Rwanda. All the above use single year datasets and can ascertain neither the long-run agricultural productivity behavior, nor the extent of intergenerational transmission among farm households.

Therefore, the proposed study is intended to answer the following research questions:

(i) What are the long-term drivers of socio-economic changes in the sample population, with special consideration to demographic changes?

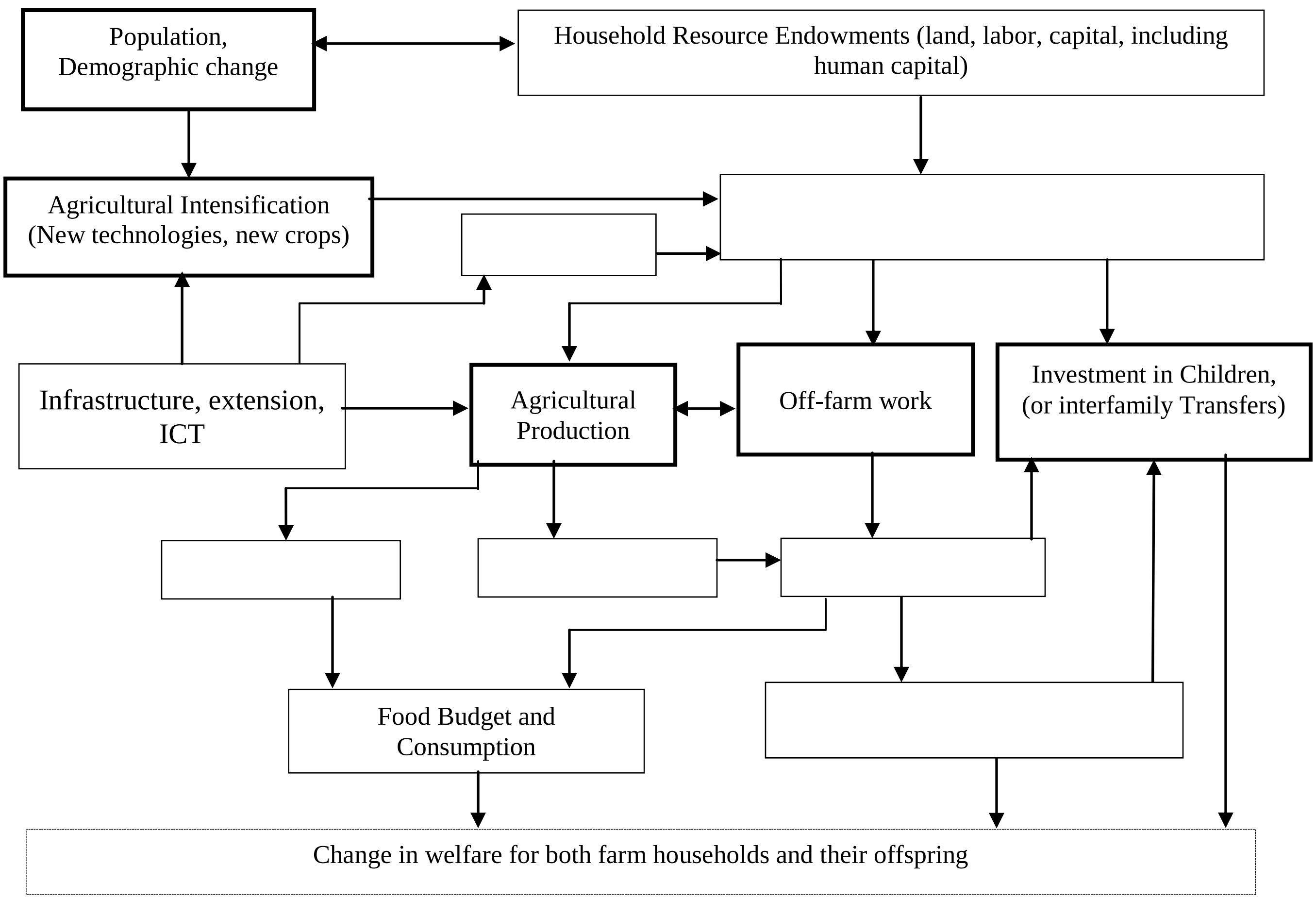
(ii) What are the determinants of changes in agricultural output over time? And in that context, what role did off-farm employment expansion as well as access to ICT play in agricultural growth?

(iii) What are the changes in well-being of households over the past two and a half decades, and to which extent are wealth and poverty transmitted across generations?

(iv) What are the policies that enhanced agriculture and rural development in the past, and what policy implications arise from the findings for the future?

The analyses carried out in this study rely on a unique dataset that spans 26 years, originating from two detailed household surveys conducted in 1986 (see von Braun et al., 1991) and 2012, respectively. The second round survey follows the original households and their offspring, allowing the construction of an extended families dataset, offering the chance to get useful insights on long-term changes among smallholders' agricultural production.

Figure 1.1 Conceptual framework of the study



Source: Adapted from von Braun et al. (1991) and modified by Author.

Figure 1.1 depicts the conceptual framework of the study. On one hand, the analysis focuses on demographic change and its impact on agricultural intensification. On the other hand, the study assesses how population changes contribute to resource endowments (land, labor, capital), which in turn are allocated into agricultural production, off-farm work, or passed to other family members through altruistically motivated transfers. The study also proposes to find out the role played by off-farm employment as well as Information and Communication Technologies (ICT) on agricultural production in the study area. Furthermore, the mechanism by which resources and income are transferred across generations will be analyzed. In resources allocation, households are not only driven by their own utility, but also include their children and extended families in the welfare function. The details on causal relationships on each component of the figure 1.1, and hence on each research question are explained in their respective chapters.

1.4. Outline of the Study

The rest of the study is organized as follows: the second chapter presents the background of the study from the country profile to the description of the study area and data used. The third chapter explores the patterns of demographic changes in the study area, and the effects of population growth on rural economic changes over time. It measures the drivers of fertility in the sample area on the one hand, and the relationship between population and agricultural intensification, farm productivity, and household welfare on the other. The fourth chapter is devoted to the empirical analysis of agricultural output over time; and assesses the drivers of off-farm employment expansion and the role of Information and Communication Technology (ICT) on agricultural productivity and income changes in the study area. The fifth chapter investigates the extent at which wealth and poverty are transmitted across generations over time. Finally, in chapter six, general conclusions and key policy implications derived from the study are presented.

Chapter 2 BACKGROUND OF THE STUDY

2.1. A brief Country Profile

Rwanda is a landlocked country located in the Great Lakes region of central-east Africa with an area of 28,338 square kilometers. The so called "land of thousand hills" has a mountainous relief in the western part, and the rest of the country is savanna grassland. The country is bordered by Burundi in the south, Uganda in the north, Tanzania in the east, and the Democratic Republic of Congo in the west. Its population of 10.5 million inhabitants and its population density of 416 inhabitants per square kilometer place Rwanda among the most densely populated countries in the world (Rwanda, 2012). The Rwandan population is predominantly rural. The median age is 19 years, and the country registered a high fertility rate of 2.6 percent according to the fourth population census held in August 2012. Significant efforts were made by the government of Rwanda to rebuild socio-economic structures after the 1994 war and genocide which devastated the country (more than 800 thousand people killed) and left others exiled outside the country. About 44.9 percent of population is classified as absolutely poor (48.7 percent in rural areas), and only 79 percent of the households have satisfactory food consumption (NISR, 2012).

After the 1994 genocide, the new government has embarked on its way to reconstruct the Rwandan economy through three broad areas: good governance, human resources development, and foreign and domestic investment. A number of institutions have been put in place to foster unity and reconciliation, to eliminate gender discrimination, transform judiciary system, and fight corruption. By 2005 the local governance was restructured, reducing the number of provinces (formerly *prefectures*) from 12 to five, and the number of districts (formerly *communes*) from 106 to 30. The institution of "*imihigo*" program or "performance contracts" was made to promote accountability of leaders of these decentralized institutions from the village to the district level. The vision 2020 and a series of medium-term policy documents such as "Poverty Reduction Strategy Paper (PRSP)" and "Economic Development and Poverty Reduction Strategy (EDPRS)" among others include ambitious goals and government strategies to transform Rwanda into a middle-income economy by the year 2020 (Porter et al., 2013). By 2009, Rwanda has achieved the highest primary school enrollment in Sub-Saharan Africa of 97 percent for boys and 98 percent for girls, and established a nine-year compulsory education program. Recently much effort is being put on science, technology, and entrepreneurship. A special program to reduce illiteracy among community members was launched in 2010.

Due to high growth rates registered in the service sector over the past half-decade (recently from 8.9 percent in 2011 to 12.2 percent in 2012), Rwanda achieved the highest national economic growth rate in the East African Community of 7.2 percent in 2010 and 8.2 percent in 2011. In 2012, the domestic economy remained robust with a growth rate of 8 percent (higher than the average Sub-Saharan Africa growth rate), despite existing uncertainties caused by a 20 percent reduction in Official Donor Assistance in the first half of the year 2012, following the intensifying conflict in Eastern Congo (Hernandez, 2013). The government of Rwanda continues to embark on pathways out of poverty through resilience and adoption of strategies to reduce aid dependency, but relatively lower growth rates of 7 percent and 7.5 percent are expected in 2013 and 2014, respectively, due to a projected reduction in government expenditures.

2.2. Overview of Agriculture Sector in Rwanda

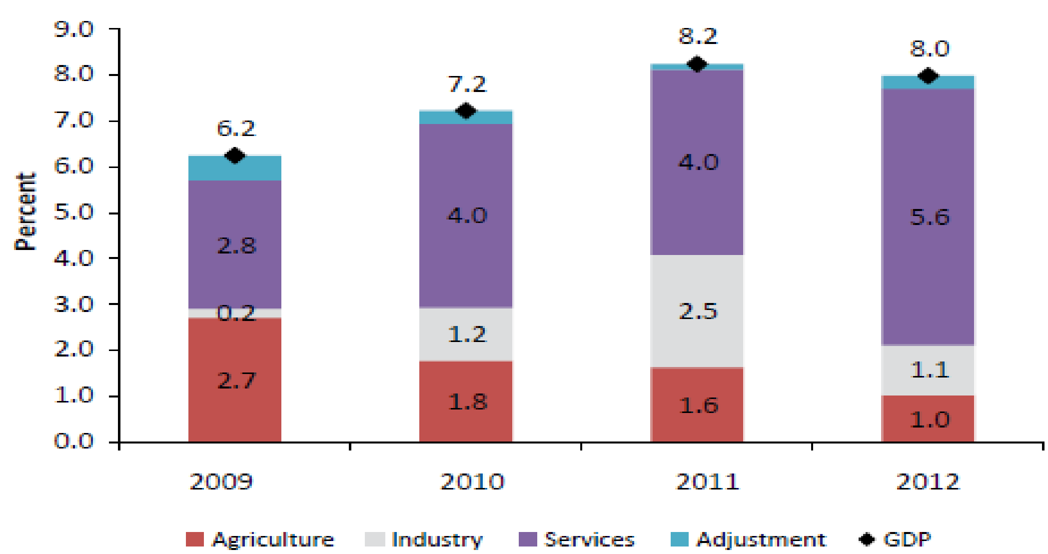
2.2.1. Context and Achievements

Agriculture is still widely regarded as the major catalyst to economic growth and poverty reduction in Rwanda, but the sector is very fragile. The livelihoods in rural areas are principally rooted on agricultural production characterized by small scale farming with mixed crops on less than one hectare of land. More than 77 percent of rural households own one-third of the total arable land in the country with an average of 0.37 hectare of land. The majority of grown food crops are devoted to home consumption (more than two thirds); the marketable high value crops (coffee and tea) are grown by a small number of farmers and occupy less than three percent of arable land. In their study on agriculture and development strategies in Rwanda, Diao et al. (2010) pointed out that more than 1.4 million rural households depend on it for their livelihoods. About 90 percent of the economically active Rwandans are engaged in agriculture but still 20-36 percent of domestic consumption in wheat, maize, and rice are imported from outside the country (Diao et al., 2010).

The most important crops in Rwanda are roots and tubers where Irish and sweet potatoes dominate agricultural production (more than 27 percent), followed by cassava (about 7 percent). Rwanda also produces sorghum, beans, maize, wheat, and rice, but the share of rice in grain production is still very low. Sorghum is the largest produced grain crop, while coffee and tea remain the major traditional export crops with relatively low share in agricultural production, accounting for 2.4 and 1.6 percent of total agricultural production, respectively (Diao et al., 2010; MINAGRI, 2009). More than 70 percent of Rwandan households own at least one head of livestock. The main livestock types owned in Rwanda are cattle, goats, and chicken at 53, 47, and 46 percent of livestock owning households, respectively (NISR, 2012).

Within its limited performance, however, agriculture generates more than 45 percent of the country's export revenues and it is still believed to assist the country to realize its vision of transforming economy by 2020(Ansoms and McKay, 2010; Diao et al., 2010; Hansl et al., 2011; MINAGRI, 2009).

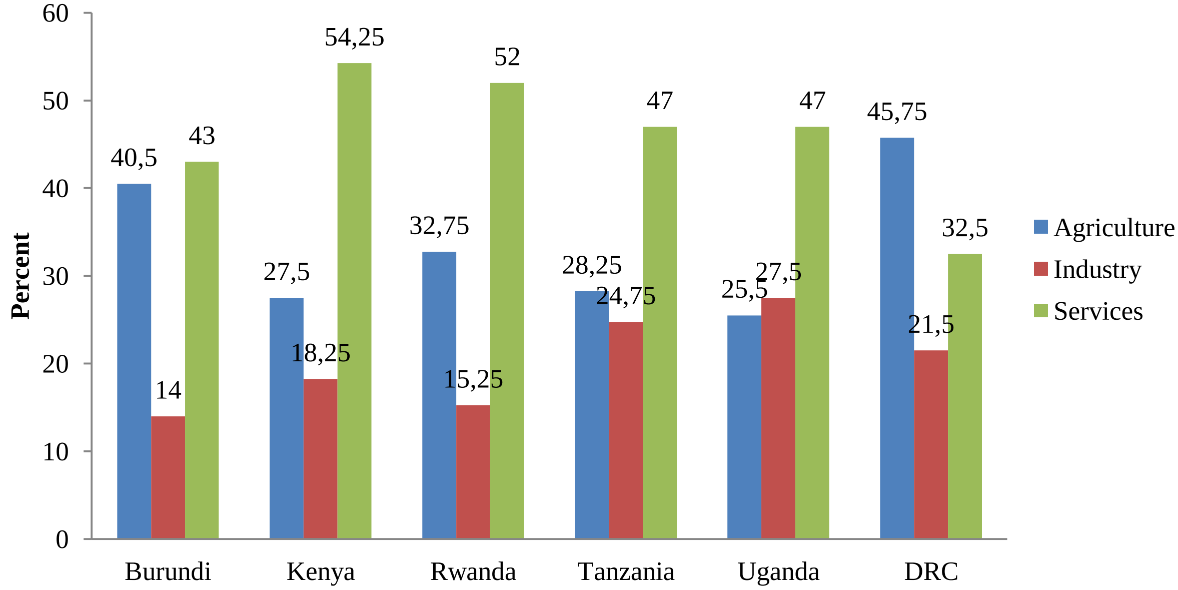
Figure 2.1 Contribution of different sectors to real GDP growth in Rwanda, percentage points



Source : Hernandez (2013)

Figure 2.1 shows a decrease in agricultural contribution on GDP growth over the past five years. In 2011 and 2012, the percentage points of agriculture sector to GDP growth are below the service sector and slightly below the industry sector. This may result from the frequent short-term weather shocks that occurred in Rwanda during the last decades. The development of transport and communication services is taking the lead of Rwandan economic growth, but the place of agriculture, as the major employer of active population should not be ignored.

Figure 2.2 Agricultural share of GDP in the region: average value added 2009-2013



Source: made by author based on African Development Indicators 2012/13 at www.data.worldbank.org/indicator accessed on 12/05/2014

Compared to neighboring countries, the Rwandan agricultural value added to the GDP is still higher over the past five years (33 percent). Excluding the Democratic Republic of Congo (DRC) and Uganda, the agricultural sector is the second contributor to GDP in the region, but its average contribution over 2009-2013 was lower for Kenya, Tanzania, and Uganda. Recently, the service sector is taking the lead in the East African countries.

Table 2.1 Comparison of major national crop yields in the region: tons/hectare

Major national Crops	Rwanda (2011)	Burundi (2010)	Kenya (2012)	Tanzania (2010)	Uganda (2010)
Banana	9.1	-	-	7.3	5.5
Irish potatoes	11.2	-	20.3	-	-
Sweet potatoes	8.1	2.7	12.8	-	67.1
Cassava	13.9	4.3	-	9.7	12.0
Beans	1.0	1.2	-	-	-
Maize	2.3	-	1.7	1,2	

Source: Food and Agriculture Data Network (2013) at www.countrystat.org accessed on 28/11/2013; Bizimana et al. (2012)

Despite the large share of agriculture to Rwandan GDP, the productivity of major national crops is lower compared to other countries (Table 2.1) especially in potatoes that constitute a substantial part in the diet for rural households. However, the country has a competitive advantage in banana, cassava, and maize over other countries in the region. Looking at the predominant role of the agricultural sector in providing employment to rural populations, a special focus on it is required. Particularly, the high population growth in Rwanda demands an immediate agricultural transformation in order to meet land scarcity challenges and food security in rural areas (von Braun et al., 1991; Hansl et al., 2011).

2.2.2. Major Agricultural Policies and Strategies in Rwanda

Agricultural policies are integral parts of the long-term national plan (Vision 2020). Beyond reconstruction and good governance, the vision 2020 targets the transformation of agriculture into a professional and market-oriented sector, private sector development, human resources capacity building, infrastructural development, and regional integration (MINECOFIN, 2000). The implementation of the vision is materialized by medium term (5 years) strategies compiled into the Economic Development and Poverty Reduction Strategy (EDPRS) document. The first EDPRS adopted in 2008 tremendously transformed the national economy, targeting in particular agriculture. On the other hand, the National Agricultural Policy adopted in 2004 had among the key strategies agricultural modernization, value chain development, competitive products, and promotion of entrepreneurship (Bizimana et al., 2012).

Table 2.2 Main agricultural policies in Rwanda

Policy/Strategy	**Year of adoption/Time-frame**	**Main objectives**
Vision 2020	2000	Transformation of Rwanda into a medium income country by the year 2020
EDPRS	Five year strategic plan (2008-2012; 2013-2018)	Increased agricultural productivity and sustainability, increased public and private advisory services to farmers, and scaling up agro-processing
National Agricultural Policy	2004	Agricultural modernization, value chain development, competitive products and entrepreneurship
Strategic Plan for Agricultural Transformation (PSTA)	Four year operational plan (2004-2008; 2009-2012; 2013-2017)	Agricultural intensification, sustainable production systems, and institutional development
Crop Intensification Program (CIP)	2007	To ensure the proper use and distribution of agriculture inputs, land use consolidation, extension service development, post-harvest management, capacity building, and marketing (Kathiresan, 2011)
National Seed Policy (NSP)	2007	Facilitate access to quality seeds by farmers through integrated activities related to production and distribution of improved seeds
Land Consolidation Program	2008	Individual landholding integration with a strong collaboration in types of crop grown in order to achieve a unified production
Comprehensive Africa Agriculture Development Program (CAADP)	2007	Overall sustainable agricultural growth and poverty reduction, through increased budget allocated to agricultural sector. This objective is common for NEPAD member states.

Sources: Author's conception based on Bizimana et al. (2012); Kathiresan (2011); MINECOFIN (2000, 2012); MINAGRI (2007, 2009, 2013).

Recently, the PSTA III (2013-2017) has been drafted and its strategic vision is to increase both staple crop production and livestock products with a greater involvement of the private sector where the Government role will move from provider to facilitator over time (MINAGRI, 2013). Since it was adopted, the land use consolidation policy allowed the highest GDP growth rate (11.4 percent) in 2008 (Bizimana et al., 2012). These policies are also aligned with the national investment and decentralization policies, and the Comprehensive Africa Agriculture Development Program (CAADP) which is the African Union (AU) and the New Partnership for Africa's Development

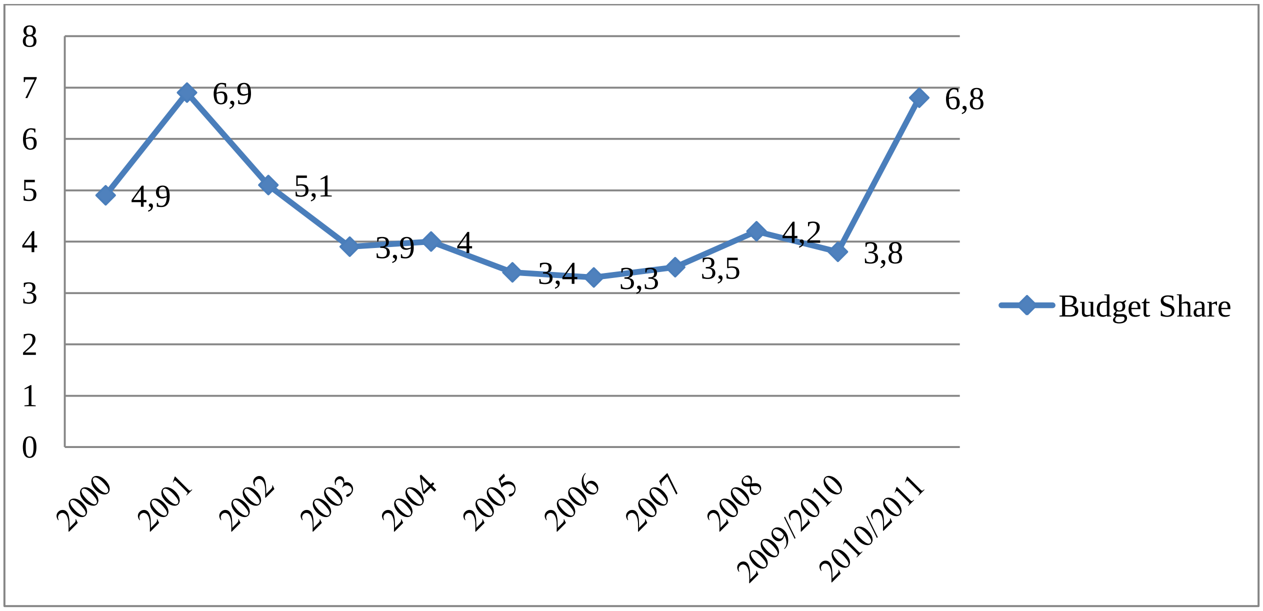
(NEPAD) effort to accelerate agricultural growth and sustainable poverty reduction among member states (CAADP, 2007).

2.2.3. Rwanda CAADP Compact and Related Impact

CAADP has been the most comprehensive answer to agricultural problems on the African continent. Initiated in 2001 by NEPAD member states and launched in 2003, CAADP is an Africa-led and-owned agenda and acts as an institutional architecture for improved and evidence-based policy formulation for the agricultural sector (Diao et al., 2013). The CAADP targets overall sustainable agricultural growth and poverty alleviation, by increasing government budgeting, donor and private sector investment in agriculture (Brüntrup, 2011). CAADP is built on wider principles of mutual dialogue, accountability and international (African) partnership. However, its agenda should be integrated into the national effort towards agricultural growth and economic development (CAADP, 2007). Countries whose plans are aligned with CAADP framework are offered political, technical and financial support. The latter also commit themselves to achieve agricultural growth rates of 6 percent per year, and to allocate at least 10 percent of the national budget to the sector. To achieve this growth rate requires adoption of sound public expenditure mechanisms that ensure detailed allocation, reliable tracking, and reporting of expenditures in agriculture at country level (Badiane et al., 2010). CAADP is now an integral part of the NEPAD's broad priority area, and henceforth reflects some of NEPAD's key principles of African ownership and stakeholders' participation, policies harmonization and regional integration, peer learning and review policymaking, and coordination of public and private investment (Brüntrup, 2011).

The Objectives of CAADP were set to embody more of the spirit of the compact that of its predecessors and was seen as an effort to build collective reputation and donors' perception of African countries regarding their commitment to agricultural development (Kolavalli et al., 2012). Although the CAADP country process was launched in 2006, the implementation evolved slower than expected and did not receive much support from member countries. Rwanda was the single country to sign the compact before mid-2009. Having signed the CAADP compact in March 2007, Rwanda served as pioneer of this AU/NEPAD effort. The CAADP agenda was devoted to supplement to the PSTA, an operational plan for the agricultural sector, under the EDPRS. In this regard, the Government of Rwanda committed, under the CAADP Compact, to stimulate long term economic and social development, reduce poverty, fight hunger and malnutrition (achieve food and nutrition security) as predefined in its vision 2020 and set out in the medium-term strategy (CAADP, 2007).Since the signing of the compact, the Rwandan budget share of agricultural has doubled (Figure 2.3) from 3.5 percent in 2007 to 6.8 percent in 2011(Badiane et al., 2010).

Figure 2.3 Changes in post-compact agricultural budget shares in Rwanda (%), 2000–2011



Source: Badiane, Odjo &Ulimwengu (2011)

The successes of the CAADP in Rwanda are threefold (NEPAD, 2011). First there is a clear engagement of stakeholders as required by the CAADP. The second phase of the Strategic Plan for Agricultural Transformation (PSTA II) was designed and is being implemented as a joint initiative involving the ministries of Agriculture, Local Government, Gender, Trade and Industry, and Finance. The annual Joint Sector review meeting brings together these five ministries, private sector, donors and other partners to check on implementation process and ensure a sound coordination of different activities by respective parties. Second, the CAADP contributed to the formulation and costing of investment plan needed for PSTA II implementation. The presentation of an well-thought out investment plan to key stakeholders in 2009 enabled the Government of Rwanda to secure substantial support to the program, up to USD 350 million over its five-year period, and the increased agriculture investment contributed to 9 percent growth in 2008 (Rwanda, 2009). Third, due to the well-coordinated CAADP-aligned PSTA II, agricultural production and productivity increases are evident. There has been large increase in land area under maize, wheat, and Irish potatoes cultivation from 2009 to 2010. There has also been a subsequent increase in the productivity of maize from less than 0.8 tons per hectare in 2007 to 2.5 tons per hectare in 2009, while wheat yields rose from one ton per hectare to 2.5 tons per hectare over the same period.

The successful implementation of CAADP compact in Rwanda was enhanced by the Africa Joint Peer Review Mechanism (APRM) which evaluates the performance of CAADP and checks whether countries are still on track with respect to both the plan and its implementation. Besides, the effective macroeconomic management has increased Rwanda's credibility and accountability, allowing the country to be among the best performers in 2010. Private sector involvement, decentralization, and gender mainstreaming have been important drivers for achieving economic development goals (Rwanda, 2009).

In summary, CAADP has had a tremendous influence not only for adopting nations, but also the effects are being felt at both regional and international levels so that positive changes are expected on administrations, politicians and donors' attitudes towards agriculture finance and development. Nevertheless, the evaluation of CAADP influence should not be overestimated since many countries still face implementation problems and their agricultural policies seem to be marginally improved (Brüntrup, 2011). To some extent however, there is a disappointing result by comparing the promise of CAADP and its available impacts. Despite the dramatic changes observed in African agriculture compared with 2002, there is an obvious attribution problem, and the role of CAADP vis-à-vis other initiatives cannot be fully isolated (Kolavalli et al., 2012). As a continental initiative, CAADP suffers a lack of capacities on behalf of individual countries to play a significant role in international dialogue and regional networking, peer learning, and review. Due to the complexity of the agricultural sector and the many actors involved, some important stakeholders such as farmers' organizations and the private sector are ignored (Kiriro, 2009; Randall, 2009), and the expected networking could not fully materialize. On the other hand, the heavy dependence on donor support for funding is a threat to national ownership. Tackling the existing governance issues in the agricultural sector should increase both political and private willingness to provide funds and hence, ensure the sustainability of such agricultural investments (Brüntrup, 2011).

2.3. Implications on Poverty and Inequality

Limited access to land is a key indicator explaining income inequality and poverty in Rwanda (Diao et al., 2010). The principal challenges confronting smallholder agriculture in Sub-Saharan Africa, and particularly in Rwanda, include the distribution of land patterns which prevent small-scale farmers from adopting required crop technologies and input intensification (Jayne et al., 2010). The scattered and tiny plots on hillsides, unequally distributed and highly exposed to soil erosion, are the main causes of persisting poverty in rural Rwanda because these small-scale farmers cannot produce beyond subsistence level, nor participate in commodity markets principally dominated by a small group of relatively large farmers. While agriculture is still believed to be a route out of poverty in Rwanda, trends show that access to land has been decreasing over the past three decades. Similarly to other African countries such as Kenya, Ethiopia, Mozambique, and Zambia, Jayne et al. (2003) found that access to land in Rwanda is negatively and significantly correlated to the household size, indicating that high population growth in this country has increased the already great pressure on available land.

The recent World Bank report on Rwanda (Hernandez, 2013) pointed out that there has been an improvement in the standards of living over the past decade, especially in the second half of the decade where the household consumption per adult equivalent grew at 2.5 percent per year, leading to a 14 percentage point decrease in poverty headcount in 2011. This was the result of increased agricultural productivity over the past decade, and especially of emerging non-farm activity, both self- employment and wage employment. Inequality decreased over the past decade but indicators still show unequal income distribution. The Gini index fell from 0.52 in 2006 to 0.49 in 2011 (NISR, 2012).

Table 2.3 reveals that poverty is a rural phenomenon in Rwanda. More than 85 percent of the total population lives in rural areas where more than 72 percent live with less than one hectare of land. This denotes that size of land plots matters even though it does not alone explain the prevalence of poverty in Rwanda. Over the past two decades, the poverty rate, which was always higher among rural farmers with limited or without access to land, has decreased from 60.3 percent in 2001 to 56.9 percent in 2006, and reached 44.9 percent in 2011. The poverty analysis in Rwanda is based on household consumption per adult equivalent, of which adjustments are made for price differences between regions and periods of survey rounds to make data properly comparable over time and by location (NISR, 2012).

Table 2.3 Distribution of population and the poor

Indicator	Rural	Total	Urban	National

	Holding less than 1 hectare	Holding more than 1 hectare	rural		
EICV1[ab] (2000/2001)					
Share of population (%)	65.0	24.6	89.5	10.5	100
Poverty rate (%)	71.1	51.4	65.7	14.3	60.3
EICV2[b] (2005/2006)					
Share of population (%)	61.1	22.3	83.4	16.6	100
Poverty rate (%)	68.2	46.7	62.5	28.7	56.9
EICV3[c] (2010/2011)					
Share of population (%)	72.7	12.4	85.2	14.8	100
Poverty rate (%)	48.2	27.3	48.7	22.1	44.9

Note: [a] EICV: Enquête Integral des Conditions de Vies de Ménages (integrated household living conditions survey). Source: [b]: Diao et al. (2010); [c]: Author's calculations based on EICV3 database from the National Institute of Statistics of Rwanda.

However, despite the impressive decrease in poverty head count observed in 2012, the absolute number of people in poverty almost stagnated due to high population growth. The off-farm movement did not benefit the rural poor. There has been a decrease in wage employment among the rural population. Since independent agriculture cannot absorb all excess labor available in rural households, the only alternative is venturing into an informal rural economy with unattractive earnings. Therefore, there are still opportunities to expand agricultural productivity on available land by a joint action of the government of Rwanda and its development partners since agriculture is still the main driver of poverty alleviation among Rwanda's poor. According to Hernandez (2013), scaling up agricultural intensification and commercialization followed by the creation of job opportunities outside the farm will be the quickest way to get significant numbers of people out of poverty.

2.4. Description of the Study Area and Data

2.4.1. The District Context

The area under study is located in Nyabihu,[1] a rural and densely populated district situated in the northwestern part of Rwanda. This particular area belongs to the agro-ecological zone of the central Congo-Nile Divide that passes through Rwanda from north to south, with high altitudes exceeding

[1] After 1994, the local administrative units in Rwanda have been modified and given new names for districts (former communes) and sectors (district sub-units). In this study current names are being used and the old mentioned where necessary.

2,000 meters and abundant precipitations averaging 1,300 millimeters a year (von Braun et al., 1991). Today Nyabihu district totalizes 295,580 inhabitants on 532 square kilometers surface; which makes a density of 556 inhabitants per square kilometer of land. With its 61,741 households grouped into 12 "*Secteurs*", the district is still among the most densely populated of Rwanda. According to the recent population and demographic census (Rwanda, 2012), the district population density is far above the province level (421 inhabitants per square kilometer in Western Province), and the country level (416 inhabitants per square kilometer). It is therefore ranked seventh out of 30 Districts of Rwanda and the most densely populated among rural districts.

2.4.2. The Study Area

The study was conducted in five selected sectors which belong to the former *commune* of Giciye[1] that was selected during the study on commercialization of agriculture under population pressure (von Braun et al., 1991) because of its high altitude, its large population, its level of agricultural commercialization and its proximity to Gishwati forest, a major source of commercialization.

The five sectors under study are Jomba, Muringa, Rambura, Rurembo, and Shyira. Today, the area is inhabited by 39 percent of the district population, and agriculture is still a major source of livelihood. Almost half of all arable land (49.32 percent) is located in these five sectors. Within the land consolidation context, climbing beans, maize, wheat, and peas are the top selected food crops recently grown in the study area, but later in the 1990s, sweet and Irish potatoes were among the most cultivated crops.

Table 2.4 Distribution of population in the study area

Sector name	Population	Agricultural land (km^2)	Density Population/km^2 of agricultural land
Jomba	20,647	45.25	457
Muringa	22,923	23.20	988
Rambura	28,477	25.37	1,122
Rurembo	23,774	25.40	936
Shyira	19,855	16.91	1,174
Study area	***115,676***	***136.13***	***850***
District	***295,580***	***276.02***	***1,071***

Source: Author calculation based on community survey data, 2012

Table 2.4 indicates the gravity of the population-land problem in the study area. Even though the area possesses most of the arable land in the district, the average population density per square kilometer of agricultural land is very high (850 persons per one square kilometer), and it is slightly below the district density of 1,071 inhabitants per one agricultural square kilometer of land. Livestock is an important source of income and agricultural productivity by providing organic fertilizers as input. Before 2000, the main livestock type grown in the area was goat, followed by sheep and pigs. Over the past decade, cattle have become the main livestock, followed by goats, sheep and pigs. Today, more than half of the population in the study area keeps at least one cow; the situation enhanced by the recent "*Girinka* Program": A Rwandan president's initiative to avail one cow per poor family in order to eradicate food insecurity and poverty in rural areas of Rwanda. It targets more than 700,000 poor households by 2035.

As stated earlier, most policy documents and existing research on Rwanda report the shortage of off-farm activities. Nevertheless, the current study shows an increase in off-farm employment opportunities. About 11 percent (against 2 percent in 1986) earn a wage labor on other farms, and 9 percent (practically zero in 1986) have off-farm paid employment in administration, medicine, teaching, and military services. Employment opportunities in tea factories shrank by nearly half from 30 percent in 1986 to 16 percent in 2012, principally due to closures. Today, the construction sector is the dominant employer (28 percent).

Generally, agriculture practices in the study area are not well developed. On average only 51.4 percent of the agriculturalists use improved seeds and only 42 percent use chemical fertilizers. Pest management is practiced at a very low frequency of 19.4 percent. In 1986, application of mineral fertilizers was limited to agricultural development projects. Only 3 percent of the sample population used mineral fertilizers, and the use of improved variety limited to potatoes (von Braun et al., 1991).

Agricultural mechanization is not yet known because only one agricultural cooperative in Jomba sector is using a tractor for cultivation, which makes an average of two percent of the population. On the other hand, agricultural extension and veterinary services have increased in the study area. About 74 percent have been visited by an extension agent, and 78 percent have received livestock related assistance during the past twelve months preceding the household survey in October 2012. This is the result of a Rwandan government effort to increase agricultural extension services at cell level, a cell being a smallest administrative sub-unit in Rwanda composed of 100 households.

Access to electricity is very limited. Apart from Rambura sector where a number of households (but far less than a half of the population) use electricity for home lighting, only 31 households use electricity in Muringa sector, and only three households in Shyira sector. No household used electricity for home lighting in 1986. More than 70 percent of the households have access to safe drinking water, but only 40 percent of the households have access to pit latrines, a major health constraint in the study area. Other facilities which should enhance agricultural growth and development are not well developed and unevenly distributed across five sectors under study.

Table 2.5 shows the availability of major social facilities and markets in the study area. The most relevant facilities to agricultural development are still missing, while the existing ones are concentrated only in Rambura and Shyira sectors (agricultural markets and financial institutions) limiting accessibility by a large number of farmers. The area under study is still generally constrained by insufficient health and education facilities, limited markets for agricultural produce, lack of post-harvest management and storage facilities, and the high level of unemployment. Besides, agriculture is constrained by persistent soils erosion, soil infertility, unpredicted weather variability, and household poverty which limit access to both input and output markets.

Table 2.5 Physical infrastructure in the study area

Facility	1986	2012
Education facilities		
Primary school	33	54
Secondary schools	4	20
Vocational training center	1	2
Health facilities		
Health center	2	6
Hospital	1	1
Pharmacy	0	1
Transport infrastructure		
Main Paved roads	0	1
Main unpaved roads	1	7
Markets		
Local periodic market	2	2
General market	2	2
Livestock trading center	0	0
Credit facilities		
Bank branch office	1	2
Micro-finance institution	0	3
Saving and credit cooperative	0	5

Source: Community survey & von Braun et al., 1991.

2.4.3. Methodology and Data

The dataset used in this study comes from two waves of household surveys carried out in the study area in 1986 and 2012, respectively. The first household survey was conducted by the International Food Policy Research Institute (IFPRI) during the study on commercialization of agriculture under population pressure, and targeted 190 households randomly selected across the five sectors. A structured questionnaire was used to collect the information on household demographics, household expenditures, health and nutrition, agricultural production, and crop use information. Due to the purpose of the current re-survey, the old questionnaire was expanded to capture more information on demographics, agricultural production, consumption, income, capital assets, credit, infrastructure, ICT, and others. The second wave of data comes from a revisit to the same area in 2012, and was conducted by the Center for Development Research (ZEF) of Bonn University, with the financial support of the foundation fiat panis and the German Academic Exchange Service (DAAD). The activities consisted of retracing and re-surveying the same households as surveyed in 1986, and their offspring. With a group of trained research assistants, and key informants from the area, 164 out of 190 original household (86%) have been retraced and re-surveyed, together with their 200 split-off households (offspring) who still reside in the district and in neighboring areas. The table 2.6 shows the numbers of interviewed households by year.

Table 2.6 Number of original and split-off households

Interviewed Households	1986	2012
Original sample	190	164
Split-off (offspring)	-	200
Total sample	**190**	**364**

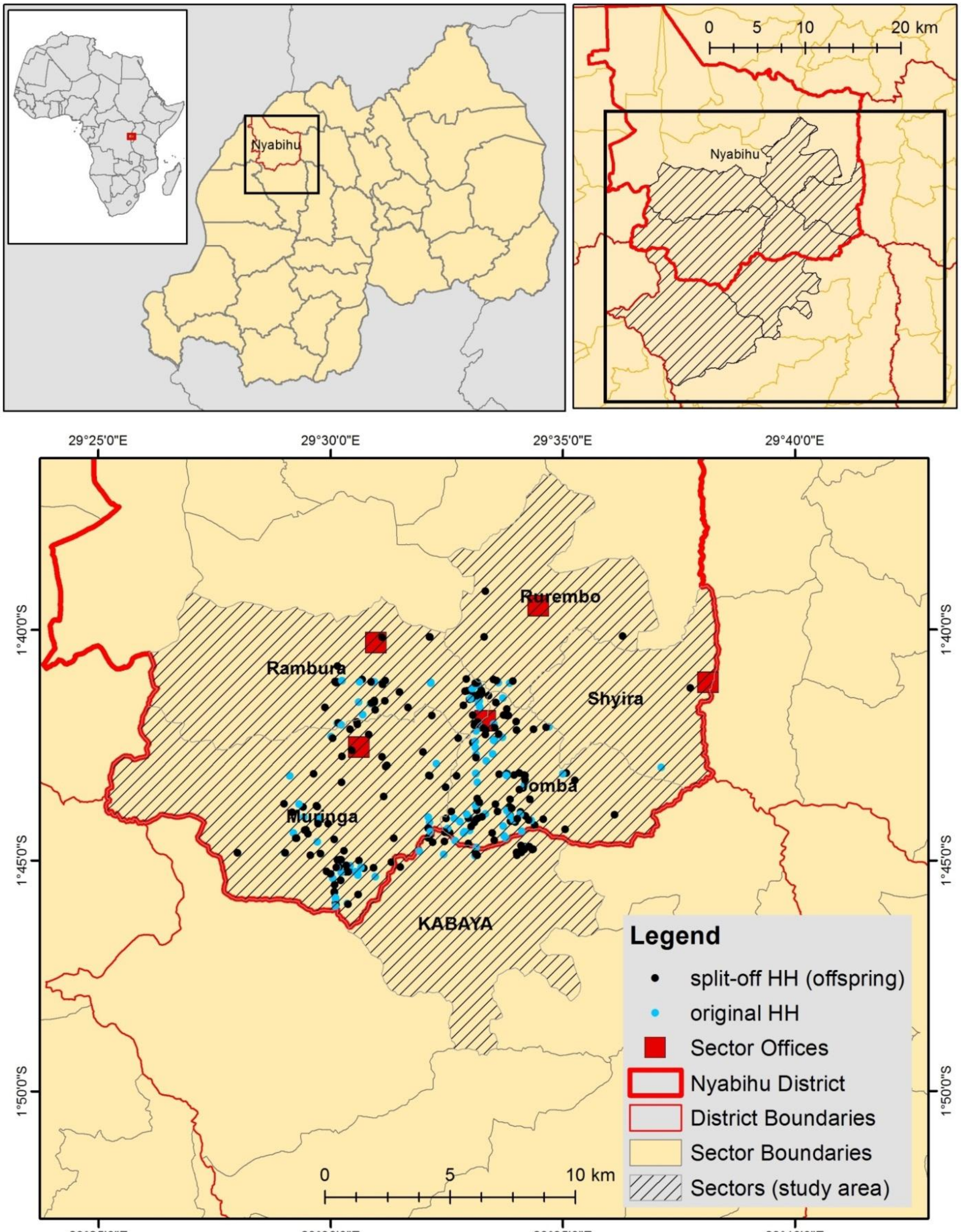
Source: Author conception based on survey data.

The tracing of original households and their offspring was easy using the household roster information from the 1986 survey. The roster contained necessary information about the household including the names of all members, their gender, age, and relationship with the household head. The identification code was useful to locate administrative sectors and cells inhabited. Once an original household was found, the existing head helped to locate individuals (on roster) who moved from the parent household to form their own since the previous survey. All split-off households residing in the study area and neighboring areas were traced and interviewed. In case the targeted households were not found (when destroyed, or completely moved of the area), we contacted their neighbors to help us locating them. The latter also informed us whether all members died, migrated to an unknown area, or exiled outside the country.

26 households (14% of the original sample) could not be traced. The annual attrition rate is 0.6[2] percent which is far below the attrition rates reviewed by Alderman et al. (2001) among developing countries household surveys and proved not to be a problem to obtain consistent estimates. Table 2.7 compares the basic statistics between the "stayers" households and the "leavers" (not found) households in the sample.

[2] Annual attrition rate=$1-(1-q)^{1/T}$ where q is the overall attrition rate, and T is the number of years covered by the panel (Alderman et.al., 2001)

Figure 2.4 Map of the study area identifying the surveyed households



Source: Author's conception

A quick look at the summary statistics would lead to believe that attrition in the sample is negatively correlated to the family size. The “leavers" are principally the less educated people with few capital assets, probably whose dwellings were located to the highest altitudes of the sample area. There is no significant difference between “leavers” and “stayers” on other relevant socio-economic features such as the age of the household head, the farm size, which is considered the main household asset in the study area, the level of expenditure (referred also to as income proxy) which mostly determines the level of household well-being, and the gross output considered as the major indicator of subsistence.

Table 2.7 Summary statistics by attrition status

Variable name	Means		Mean difference t-value
	Leavers (N=26)	Stayers (N=164)	
Family size	4	6	-4.634***
Sex ration (male/female)	1.12	1.16	-0.244
Head age	44	42	0.617
Head education	0.7	2.3	-2.863***
Farm size	0.55	0.76	-1.610
Number of off-farm jobs	3.61	4.09	-0.460
Capital stock value	637	1264	-2.084**
Expenditure/capita	13,151	11,140	1.552
Gross output	13,274	19,198	-1.712
Livestock	2.5	3.6	-1.212
Altitude of the house	2382	2313	2.344**

** $p<0.05$, *** $p<0.01$; the table compares the survey data of 1986 only.

The Probit results on determinants of attrition presented in table 2A (see appendix) suggest that only two variables are significantly and negatively correlated with attrition: the capital stock and the education level of the household head. The logarithm of capital stock value is statistically significant at 5 percent level, indicating that the “leavers” from the sample are mostly households with lower agricultural capital endowments; while the head education level is statistically significant at 1 percent to explain attrition.

Compared to the “stayers,” “leavers” are mostly households of which heads reported a low level of education during the 1986 survey. The pseudo R-square reported by Probit regression may be interpreted as the percentage of attrition explained by the covariates (Baulch, 2011). The baseline socio-economic variables explain about 31percent of sample attrition that occurred between 1986 and 2012. The Wald test was performed to verify whether all the covariates jointly predict attrition, and the resulting Chi-squared statistic of 40.62 shows that the included variables are jointly statistically different from zero (with p-value: 0.001). Thus, the null hypothesis that all coefficients equal to zero was rejected with high confidence level.

The 26 households may have left the sample due to a number of reasons including natural death, war, exile out of the country, or in-county migrations. None of the remaining socio-economic variables explains attrition, especially the gross output value and the number of calories taken per day per adult equivalent, which were the major outcomes of interest in the 1985-6 study. Even though the survey was not designed for panel at the beginning, the outcome of interest (gross output value) will be our main focus in the current study as it was partly in the baseline study. The behavior of agricultural output as a dependent variable was assessed using the Becketti-Gould-Lillard-Welch (BGLW) test developed and applied by Becketti et al. (1988). It was used by researchers to assess panel attrition impact in USA, and in developing countries (Alderman et al., 2001; Duncan and Hill, 1989; Fitzgerald et al., 1998).

The rationale of the BGLW test is to compare the total sample and the "stayers" sample in order to check how different parameter estimates would be from those in total sample if only a "stayers" sample is used in the analysis (Fitzgerald, Gottschalk et al. 1998). Table 2.8 shows the regression results of the log output for the full sample and for the non-attriting sample (stayers), together with the test for difference in coefficients.

The specification (1) refers to the production function estimation of the complete 1986 sample (see von Braun et.al, 1991), while the specification (2) reports estimates from non-attriting sample only. Even though the specification (2) shows a higher explanatory power than the original one, the respective joint tests conducted are all significant. The F-statistic is 49.22 for original sample and 44.96 for non-attriting sample. The null hypothesis that all coefficients equal to zero is rejected with high probability of significance (0.0000) for both samples. It is also easy to observe that for each specification; almost all statistically significant variables on original sample regressions are also statistically significant on non-attrited sample regressions. The last column of the table 2.8 reports the differences in coefficients obtained from original 1986 sample and non-attrited (or continuing) sample. The probability of significance is therein written in brackets, using the chi-square test. The non-significant difference between the coefficients from two regressions is a good indicator that, if only the non-attrited sample is used for the panel data analysis, there is no evidence that biased and inconsistent estimates will be obtained (Alderman et al., 2001; Becketti et al., 1988; Duncan and Hill, 1989; Fitzgerald et al., 1998), especially when the purpose is to estimate the production function.

Table 2.8 Comparison of output elasticities between original and stayers in the sample

Explanatory Variables (in Log)	(1) Original Sample	(2) Non-attriting Sample	(3) Difference Prob>chi2 in (.)
Farm size	0.513***	0.529***	-0.016
	(8.699)	(8.446)	(0.658)
Labor	0.227**	0.197 *	0.03
	(2.217)	(1.757)	(0.556)
Capital	0.201***	0.191** *	0.01
	(3.365)	(3.259)	(0.636)
Land quality	-0.181**	-0.164**	-0.017
	(-2.329)	(-2.064)	(0.708)
Constant	7.458***	7.694***	-0.236
	(10.695)	(10.007)	(0.543)
Adjusted R-squared	0.508	0.522	
Number of observation	190	164	

* p<0.10, ** p<0.05, *** p<0.01; Reported are Cobb-Douglas output elasticities and t-values between brackets. The 1986 dataset is used here.

To stop from getting inconsistent and biased estimates from the outcomes of which the BGLW test is not significant, the attrition issue is normally addressed by the application of the inverse probability weighting (IPW) proposed by Moffit et al. (1999). The procedure to compute IPW consists of estimation of the probability to stay in the sample in the second round, then use the inverse of the predicted probabilities to weight the second round data of responders (Kazianga, 2012). The reasoning behind this procedure is to reconstruct a random sample by giving more weights to subjects (households) who are less likely to remain in the sample, and hence not to be observed in the second round (Baulch, 2011; Kazianga, 2012; Vandecasteele and Debels, 2007; Vansteelandt et al., 2010), conditional on observables (Fitzgerald et al., 1998). For all regressions reported in this study, the BGLW test shows no strong evidence for inconsistent estimates.

2.4.4. Extended Family as Unit of Analysis

The unique feature of the study dataset is that it followed both the original and split-off households during the second wave. This allowed constructing an extended families dataset, and using for the current wave, the extended family, as the unit of analysis in panel regressions. The purpose is to analyze the household evolution and observe how a nuclear family in 1986 came up in terms of production, income, and population in 2012.

The motivation of this procedure comes from a current debate on how much the economic decisions are made at the levels of families or extended dynasties. Cox and Fafchamps (2007) argued that, due to several reasons, including the lack of economic/financial safety nets in developing countries, households may rely on parents, friends, and other relatives for their livelihoods and their survivals. This social arrangement may also originate from the absence or shortage of financial and insurance markets in rural areas (Ling et al., 1997). Therefore extended families play a key role in risk sharing by pooling their income and other resources to support their relatives, especially in agricultural-depending societies where production and income variations are very frequent. If this is the case, it would be inappropriate to drop split-off households and base the analyses only on original households' panel.

In his study on risk sharing within the extended family in Indonesia, Witoelar (2013) suggested that researchers should consider extended families as the unit of analysis while analyzing consumption growth and decisions. Even though the extended family does not fully act as a unitary household, some important allocations are made at extended family level. Therefore, when analyzing households' production, income, and consumption over time, using a panel of extended families is preferable to using a panel of original households only. In this view, our study links the split-off households (offspring) to their original parent households and takes advantage of this featured dataset to assess the determinants of long-term growth in agricultural production in rural Rwanda.

In the subsequent analyses that involve panel data regression, a comparison is made between different specifications and datasets. An *extended family* is hereby defined as a set of households that originate from the same 1986 nuclear household. An *extended family dataset* (or *balanced panel*) is therefore constructed, consisting of 164 original households (stayers) for the first wave, and 164 extended families (that is 164 stayers merged with their respective 200 offspring households) in the second wave. On the other hand, a *full sample* (or *unbalanced panel*) is referred to as a panel dataset made of 164 original households for the 1986 wave, and 364 households for the 2012 wave (164 stayers and 200 split-offs considered individually). Despite the possible shortcomings associated to each specification, it is assumed that the true parameters lay in between.

2.4.5. Note on Deflator

Nominal values in 2012 have been converted into real terms using our own calculated Food Price Index taking 1986 as a base year. The Fixed Basket Approach (or Laspeyres Approach) has been used where the same food basket for median household has been priced in each period. The following modified Laspeyres formula has been used (FEWSNET, 2009; Turvey, 2004):

$$LFPI = 100 * (\sum W_n \,\mathrm{Pr}) / \sum W_n \tag{2.1}$$

Where:

LFPI= Laspeyres Food Price Index

Wn= is the budget share of different commodities that form the food basket

Pr= Are the relative prices (a relative price is a ratio of a good or service in one period to the price of that same good or service in the reference period).

This is motivated by the fact that household spending on food commodities in the study area accounts for more than 80 percent of total expenditure. Then farmers will be affected more by price variations in food than non-food items, making the FPI the best deflator for output, expenditure and income values in rural areas. Besides, the existing dataset lacks some information on non-food item prices necessary to calculate the Consumer Price Index (CPI) in the sample area. The resulting FPI in 2012 taking 1986 as base year is 914.51 percent, which does not much differ from the national CPI of 950.80 percent.

Chapter 3. THE ECONOMICS OF DEMOGRAPHIC AND AGRICULTURAL CHANGE

3.1. Introduction

Over the last two and a half decades Rwanda has faced a number of economic shocks including the genocide which left over 800 thousand inhabitants dead in late 1994 (Des Forges, 1999; Prunier, 1995; Verpoorten, 2005, 2009). As an agricultural based country, this has had a significant impact on agricultural production and economic growth in general. Today, the overall image of Rwandan post-war economic recovery is judged to be quite positive (Ansoms and McKay, 2010). Nevertheless, despite considerable efforts by the government of Rwanda and the ongoing economic and political recovery from the devastating war and genocide, the rate of poverty is still higher and the gross domestic product is lower compared to the ones of before genocide (Diao et al., 2010). Little is known on the household responses to adverse income and demographic shocks stemming from the conflict in Rwanda (Verpoorten, 2009). But in order to paint an overall picture of household economic change, one must consider the households' behavior before and after the shock. McKay and Loveridge (2005) found that the struggle to income recovery during the period 1995-2000 was accompanied by an increase in population, and has resulted in a decrease in land per capita, increase in inequality, and rural poverty.

Rather than exploring just the effect of the conflict, this chapter traces the changes in demographic patterns in the sample population over the past 26 years on one hand, and their impact on agricultural change, particularly on agricultural intensification, farm productivity and household welfare on the other hand. Over the last three decades, the population of Rwanda has increased progressively from 6.3 million in 1986 to 7.1 million in 1991, and fell to 5 million in 1994 due to war and the genocide. After the 1994 genocide, the population recovered rapidly to achieve 8.1 million inhabitants in 2002, and 10.5 million inhabitants in 2012 with a growth rate of 2.6 percent (Rwanda, 2012). The 2010 Rwandan Demographic and Health Survey showed a fertility rate decline over the last 2 decades, from 6.2 in 1990 to 4.6 children per woman in 2010. Nevertheless, the rural fertility rate (4.8 children) is still higher than the rate in urban areas (3.8 children) (Rwanda, 2010). The national population density evolved gradually from 191 inhabitants per square kilometer in 1978 to 416 inhabitants per square kilometer in 2012 (Rwanda, 2012).

The rapid population growth in Rwanda has brought considerable changes in the agricultural systems such as a decrease and fragmentation in land holding, cultivation pushed on lands previously under pastures and forests, increased cultivation on rented land, and shortened periods of fallow (Clay et al., 1998). Farmers living in the areas subject to growing pressure on available land as a result of population growth (such as in Rwanda) need to adopt new appropriate land use and institutional arrangements that aim at economizing the scarce resources (Andre and Platteau, 1998). The 1993 sample from Rwanda showed that very few inputs were used, and that most farmers were relying on traditional techniques of cultivation and soil conservation, with simple tools like hoes and machetes (Andre and Platteau, 1998; Fenske, 2011).

From this perspective, the purpose of this study is to assess the patterns of demographic, agricultural, as well as economic changes over the past 26 years among smallholder farmers. First, patterns of demographic changes will be described by tables and age pyramid, and then the determinants of population growth in the study area will be empirically investigated. Finally, the chapter will assess the mechanisms by which demographic changes in rural Rwanda have affected agricultural practices and household welfare over the same study period. The next sections are sequentially devoted to the theoretical background, conceptual framework, empirical strategy, data description, empirical results, and discussion.

3.2. Theoretical Background

From a macroeconomic point of view, the neoclassical growth theory (Solow, 1956) finds a negative correlation between population growth and per capita income. The model is built on fixed assumptions such that the rate of population growth, the rate of saving, and the rate of technological progress are constant and exogenously determined. Even though this was rejected by the endogenous growth theory which shows a strong positive correlation between population growth rate and per capita income (Romer, 1991), the evidence from 105 countries supported the neoclassical growth theory, and it is believed that a high growth rate in population leads to lower levels of income per capita in the long run (Todo, 2001). On the other hand, the theory of demographic transition (Caldwell, 1976; Kirk, 1996) attempted to explain the determinants of fertility and population growth. Traditionally, factors such as moral codes, religious doctrines, education, cultural habits and customs were conducive to high fertility. In modern society, however, fertility is decreasing and this is being viewed as a rational choice, just as how high fertility was accepted as rational behavior in pre-modern society (Kirk, 1996).

In his early economic analysis of fertility, Becker (1960) attributed the demand for children to the levels of income, tastes, and costs of raising children. Parents determine the number of children they want, having in mind the amount to be spent on them and the quality of children they desire. The increase in family income will allow more children to survive at childhood; and hence a decrease in mortality. However in the long run, the decline in child mortality is likely to affect fertility decisions because families are mostly interested in the number of survivors rather than births. The same conclusions that income is the major determinant of fertility have been reached by Adelman (1963); Easterlin (1975) and Birdsall (1988). Tadesse and Asefa (2002) indicated that the age at marriage, prices, employment outside agriculture, education index, and population density are the key determinants of fertility.

Fertility decline in modern society is in response to mortality decline (Lutz and Qiang, 2002). This view assumes that modernization of society is a driving force in the mortality and fertility decline. Evidence to support this idea was found in Europe, North America and Japan, where mortality rates have dramatically declined as a result of reduced variability of food supply, better housing, improved sanitation, and progress in preventive and curative medicine. de Sherbinin et al. (2008) pointed out that poverty leads to high fertility through mechanisms such as demand for farm labor or any other benefits such as cultural and social security.

A number of studies have also found a positive relationship between fertility and farm size, and other family titles such as cattle or any other physical capital. They postulate that a larger farm size creates demand for children as labor to keep land in production (de Sherbinin et al., 2008). Results in Rwanda suggest that farm size increases marital fertility of farmer couples but the possibility of a reciprocal effect is rejected (Clay and Johnson, 1992). Moreover, in the research on Rwanda and Madagascar, it has been found that it is economically rational for households' heads to create a large pool of household labor through high fertility (Clay and Reardon, 1998).

Trendle (2009) found that high levels of income act to mitigate population increases. However, some unobserved factors such as parents' preferences and their productive capabilities are important in influencing fertility decisions, and may be associated with being poor or rich (Schultz, 2005).

This makes the fertility effect of household income (or expenditure) to vary with respect to different sources of growth and by country. Benefo and Schultz (1996) found that income and fertility were negatively associated in Ghana and positively associated in Côte d'Ivoire. There was a positive association between fertility and income in rural areas of both countries, and negative association in urban areas. Alternatively, Schultz (2005) found the household consumption per adult to be positively correlated with fertility in Kenya using income from land ownership, and the receipt of both farm and non-farm rents. But fertility was negatively associated with household income from sources other than physical capital, land, and natural resources.

Dartanto (2009) explored the factors affecting high fertility rates observed in south Asian countries with panel data approach and found that people prefer a large number of births to compensate deaths; the high mortality rate being the major determinant of fertility. Besides, fertility decisions are highly influenced by the lagged values of per capita income and consumer price index in Asian countries; which means that the demand for children follows the same demand for normal goods. As families demand more children to increase utility on one hand, there is a positive correlation between income and fertility. On the other hand, the increase in the cost of raising children (as for normal good) limit the consumption (demand) for children; and the negative relationship between fertility and consumer price index is expected.

A recent study on population density and fertility in farm households in Ghana (Ahiadeke and Der, 2012) found that for agricultural households, fertility may be affected by population density. High density areas were associated with lower average birth rates and the empirical analysis confirmed a negative and significant correlation between population density and children born, controlling for female education, age and agricultural production. In the long run, fertility was found to be associated growth if income per capita which implies that changes in fertility are viewed as consequences of economic development (Herzer et al., 2012).

Vosti et al. (1994) and Witcover et al. (2006) showed the multifaceted fertility effects of agricultural technology in India. The latter are susceptible to reduce fertility through increasing income for the educated, and to increase fertility by increasing the demand for labor including unskilled labor, and to ambiguously affect fertility when they alter the demand for women's work. They found that agricultural change leads to higher income by farmers allowing access to contraception and health services. Even though nutritional gains derived from agricultural change may raise fertility among the poor, the evidence showed that mechanization, adoption of HYV technologies for wheat and rice, and the use of fertilizers have affected fertility decline in India through their effects via real wage growth (Witcover et al., 2006).

Since the time of Malthus, there has been a long debate on how population growth affects land scarcity as well as the well-being of agrarian societies. The opposite arguments showed that high population growth will, in the long run, give rise to higher standards of living through agricultural intensification and improved productivity (Boserup, 1965, 1981), also referred to as "demographically induced change." Under the Boserupian optimistic view on the impact of population growth, a beneficial density-intensity development is expected regardless of possible diminishing well-being and environmental deterioration (Turner et al., 1993). von Braun et al. (1991) tested for Boserup effects in Rwanda and found significant support for it: productivity in agriculture increased with population growth, but less so than population growth. Similarly, evidence showed that farmers adapted to population growth by adoption of agricultural technologies such as fertilizer use and new crops in Nigeria (Goldman, 1993). Population growth was also found to increase the intensity of agricultural land use in Kenya and stimulate non-farm enterprises(Okoth-Ogendo and Oucho, 1993), and hence increase well-being.

However, the adoption of agricultural technology is also influenced by both a farm or a farmer's characteristics (Waithaka et al., 2007) and the institutional environment the farmers operates (Clay et al., 1998; Fenske, 2011; Tosakana et al., 2010). Literature also recognizes the role of institutional factors (Mazvimavi and Twomlow, 2009) and farmers organizations (Abebaw and Haile, 2013) to influence adoption of fertilizer and pesticides.

The issue of Rwandan population growth and agricultural technological change as explained and of which was alerted about in the last two and a half decades is still alarming today:

> *"With a population growth of 3.3 percent a year in the 1980s, the already very limited land base becomes more and more a constraint to agricultural growth and income generation. The obvious way out of this dilemma appears to be a combination of policies that will lead to reduced population growth, increased land productivity through technological change in agriculture, conservation and land resources (…). Investments in rural infrastructure, education, and technological change in agriculture should be the key inputs."* (von Braun et al., 1991, p. 17)

Over the recent decades, this population pressure and land scarcity has contributed to several changes in the landholding structure, and it is believed that these landholding changes have also affected the adoption of land use and land management practices by farmers, and hence, the agricultural productivity (Clay et al., 1996).

The research presented above on this issue presents one important limitation of relying on one year "snapshots" of rural livelihoods (de Sherbinin et al., 2008) even though the socio-economic household characteristics are controlled for. Little was done to assess the relationship between population growth, and agriculture technical change with longitudinal data, which provide a great foundation for an assessment of economic changes over time. Doss (2006) criticized researchers in agricultural technology adoption to use cross-sectional data to address issues that are fundamentally dynamic, and they are unable to account for the role of institutions, policy and infrastructure on technology adoption. Even though cross-sectional analyses can provide useful description of farmers' practices and explain factors influencing their decision, she recommended the use of panel data as one of the sound methodologies in order to control for heterogeneity across households. In this study, we analyze the role of demographic composition among others factors affecting land intensification and agricultural productivity in Rwanda in line with the above criticism, and contribute to addressing the existing methodological gap using panel data approach.

3.3. Conceptual Framework

The economic analysis of fertility originated in the work of Becker (1960) and Easterlin (1975) where children are treated as a source of satisfaction or psychic income to parents. In Rwanda, for example, parents choose a number of children to continue the household in the future, to secure money income until they reach adult age and labor services from their adult children. Using a Becker's framework, it is assumed that the household faces a constraint of total time devoted to child-raising and labor market participation while deciding on the number of children and work.

3.3.1. Household Preferences and Optimization

Assume that in each period t there is a generation of identical individuals who join the labor force. Members of generation t live for two periods, where in the first period (childhood), $t-1$, they consume a fraction of their parents' income, and in the second (parenthood), t, individuals are endowed with one unit of time, which they rationally allocate between labor-market activities and child-rearing (Galor and Weil, 2000). Therefore, households choose the optimal combination of children quantity and quality, and devote the remaining time in labor market. This preference behavior can be represented by the utility function of the form:

$$u^t = (c_t)^{1-\delta}(w_{t+1}n_t h_{t+1})^{\delta} \tag{3.1}$$

Where u^t is utility function, c_t is own consumption, n_t is the number of children, w_{t+1} is the wage per unit of labor of each child, and h_{t+1} is the level of human capital of each child at time *t*+1. Let $T^q + T^e e_{t+1}$ be the time cost for raising a child with a level of education (quality) e_{t+1} . Hence, members of generation *t* choose the number and quality of children, and their own consumption so as to maximize the intertemporal utility function as follow:

$$Max\ u^t = (c_t)^{1-\delta}(w_{t+1}n_t h_{t+1})^{\delta}$$

Subject to (3.2)

$$w_t h_t[1 - n_t(T^q + T^e e_{t+1})] \geq \tilde{c} \quad ;$$

$$(n_t, e_{t+1}) \geq 0$$

Members of generation *t* define their consumption preferences above the subsistence level $\tilde{c} > 0$, as well as over the potential total income of their children. The optimization with respect to n_t implies that the time spent to children rising is δ, whereas the time $1 - \delta$ is devoted for labor force participation. Therefore, as rising household income is supposed to increase on average the expenses on normal goods, it will also increase the amount spent on children. Both quality and quantity of children will improve, but the children quantity will increase with a small elasticity compared to the increase of children quality (Becker, 1960; Birdsall, 1988; Willis, 1973).

Becker's model shows that child services are just normal goods, and increase in income is expected to have a *ceteris paribus* increase in the quantity of children desired. However, this association is not always as expected, especially in advanced economies where the increase in income has resulted in fertility decline. This frequent phenomenon is due to two reasons (Birdsall, 1988) which do not prevent the validity of the model: First in higher income societies the opportunity cost associated with childbearing is very high because children are more time intensive. Second, parents should be interested in children quality rather than quantity and would prefer few and well educated children to many who are not well educated. This is also motivated by the reduction in the price of children quality, decline in mortality and increase in life expectancy which enable children to survive at childhood.

3.3.2. Human Capital and Technological Progress

It is hypothesized that farmers adapt to population growth in order to avoid food shortages in the future (Boserup, 1965, 1975, 1981; Hayami and Ruttan, 1971). The possible options include labor intensification in traditional agriculture (technology change) and labor migration. With little mechanization in developing countries, cultivators increase their productive capacities through larger inputs of labor in different farming activities. Traditionally, the increased labor force and intensity of land use and husbandry were the major channels of adaptation to population growth. Today, the traditional techniques are supplemented by industrial inputs (such as chemical fertilizers, pesticides and insecticides), improved seeds, tractors, irrigation, extension services, etc. (Boserup, 1975). The latter allow the use of all types of available land and higher yields to be obtained from the population-constrained agriculture.

According to Galor and Weil (2000), the level of human capital of children of members of generation *t*, h_{t+1}, is an increasing, strict concave function of their education e_{t+1}, and a decreasing strictly convex function of the rate of technology progress (*A*) from period *t* to period *t+1*, $g_{t+1} \equiv (A_{t+1} - A_t)/A_t$. This implies that, the higher the quality of children, the lower the adverse effect of technological progress, for instance the land degradation caused by the overuse of fertilizers. Hence,

$$h_{t+1} = h(e_{t+1}, g_{t+1}) \tag{3.3}$$

Where $h(e_{t+1}, g_{t+1}) > 0$, $h_e(e_{t+1}, g_{t+1}) > 0$, $h_{ee}(e_{t+1}, g_{t+1}) < 0$, $h_g(e_{t+1}, g_{t+1}) < 0$, and $h_{gg}(e_{t+1}, g_{t+1}) > 0$. If the rate of technological progress between the two periods depends on the education per capita e_t of the working generation in period *t*, L_t, then

$$g_{t+1} \equiv \frac{A_{t+1} - A_t}{A_t} = g(e_t, L_t) \tag{3.4}$$

Where for $e_t \geq 0$ and $L_t > 0$, $g(0, L_t) > 0$, $g_i(e_{t,} L_t) > 0$, $g_{ii}(e_{t,} L_t) < 0$, $i = e_t, L_t$

Hence, for large population size, the rate of technological progress between two times *t* and *t+1* is a positive and increasing function of the size of working generation and its level of education. The rate of technological progress remains positive even if the quality of labor is zero.

Smallholder farmers, like any other human being, are driven by rational behavior in adoption of new agricultural technologies. Being so, farmers drop traditional technology and adopt a new one if they expect additional output from it or anticipate the possibility of making gain (Barungi and Maonga, 2011). Both farmers' attributes and access to financial, social and biophysical capital enhance farmers' perception about new agricultural technology. Guided by the rational behavior of profit maximization, the farmer decides to invest or not in one or more available agricultural technologies, subject to cost constraints. The expected outcomes from any adoption are principally increase in crop yields, hence increase in agricultural returns, and capital and labor savings when the adopted technology is capital-saving and labor-saving, respectively.

3.4. Empirical Strategy

As stated earlier, the purpose of this study is to depict the demographic changes in the sample population over the past 26 years and identify the potential drivers on one hand, and assess the relationships between population growth and agricultural intensification, farm productivity and household welfare on the other hand. First patterns of the sample population are described by simple tables and pyramids of ages. Thereafter, the attempt is made for an empirical model of population growth in the sample area and subsequent relationships with rural economic change.

To analyze fertility, we shall consider as dependent variable the total number of children born per woman after two and half decades. The number of children is discrete and takes nonnegative numbers only. There exist several ways to account for such type of data using Ordinary Least Squares regression, Tobit model, and the Probability models (Logistic, Probit, binomial Logit). However, due to the special nature of this dependent variable, the Poisson model which restricts the conditional mean to be positive, is more appropriate and has been acknowledged to fit well the count nature of demographic data (Cameron and Trivedi, 2010; Wang and Famoye, 1997; Winkelmann and Zimmermann, 1994). For a unit period and for individual i, the Poisson distribution has the probability function of the form:

$$P(Y_i = y_i) = f(y_i) = \frac{\mu_i^{y_i} e^{-\mu_i}}{y_i!}, \quad \mu_i \epsilon R^+, \quad y_i = 0, 1, 2, \dots \tag{3.5}$$

Where μ_i is the predicted mean of count response ($\mu_i > 0$); and the variation is introduced as:

$$\mu_i = E(Y_i \mid x_i) \quad = \exp(x_i' \beta) \;\; i = 1, \dots, n \tag{3.6}$$

Where x_i is a vector of linearly independent covariates including the constant, β is a vector of coefficients, and Y_i is the outcome count variable. The estimation of the equation 3.6 with maximum likelihood is straightforward (Winkelmann and Zimmermann, 1994), and the Poisson model is theoretically correctly specified making the estimator $\hat{\beta}$ consistent (Cameron and Trivedi, 2010). It offers the advantages to capture the discreteness and non-negative nature of data, solves the heteroscedasticity and skewing problems, and it is simple to apply (Winkelmann and Zimmermann, 1994). Despite the recorded weakness of the Poisson model to impose the equality of conditional mean and variance of the dependent variable which may result in violation of equidispersion assumption, its estimates remains consistent. When evidence shows the presence of overdispersion or underdispersion, this can be easily solved by the Generalized Poisson Regression (Cameron and Trivedi, 2013; Hardin and Hilbe, 2007; Wang and Famoye, 1997; Winkelmann, 2008).

To assess the population effects on rural economic change over time, the following panel fixed effect model was selected to account for unobserved household heterogeneity:

$$Y_{it} = \beta D_{it} + \delta X_{it} + a_i + \mu_{it} \tag{3.7}$$

Where Y_{it} is a dependent variable, D_{it} a vector of household demographic composition, X_{it} is a vector of other socio-economic household characteristics, whereas β and δ, are parameters to be estimated, respectively. The term a_i is the household fixed effect, and μ_{it} is the idiosyncratic error term. The robustness check is carried out distinctively on intensification, farm productivity, and household welfare models, respectively.

3.5. Data

The data used in this chapter comes from the two-wave household survey as described in section 2.4.3 of the previous chapter. The first wave of data collected in 1986 contains demographic information and other socio-economic characteristics which are used to predict fertility. Fertility analysis was conducted using 164 continuing households only. The 2012 data is also comprehensive and is used together in panel with the 1986 dataset to explain the impact of demographic change on technical change, farm productivity change and household welfare.

3.6. Empirical Results and Discussions

The findings are presented in three different subsections. First, the patterns of the sample population over time are described. Secondly, the empirical results of fertility model (equation 3.6) will be presented and discussed. The third subsection is devoted on econometric results on population growth and economic change and the subsequent interpretations.

3.6.1. Patterns of the Sample Population

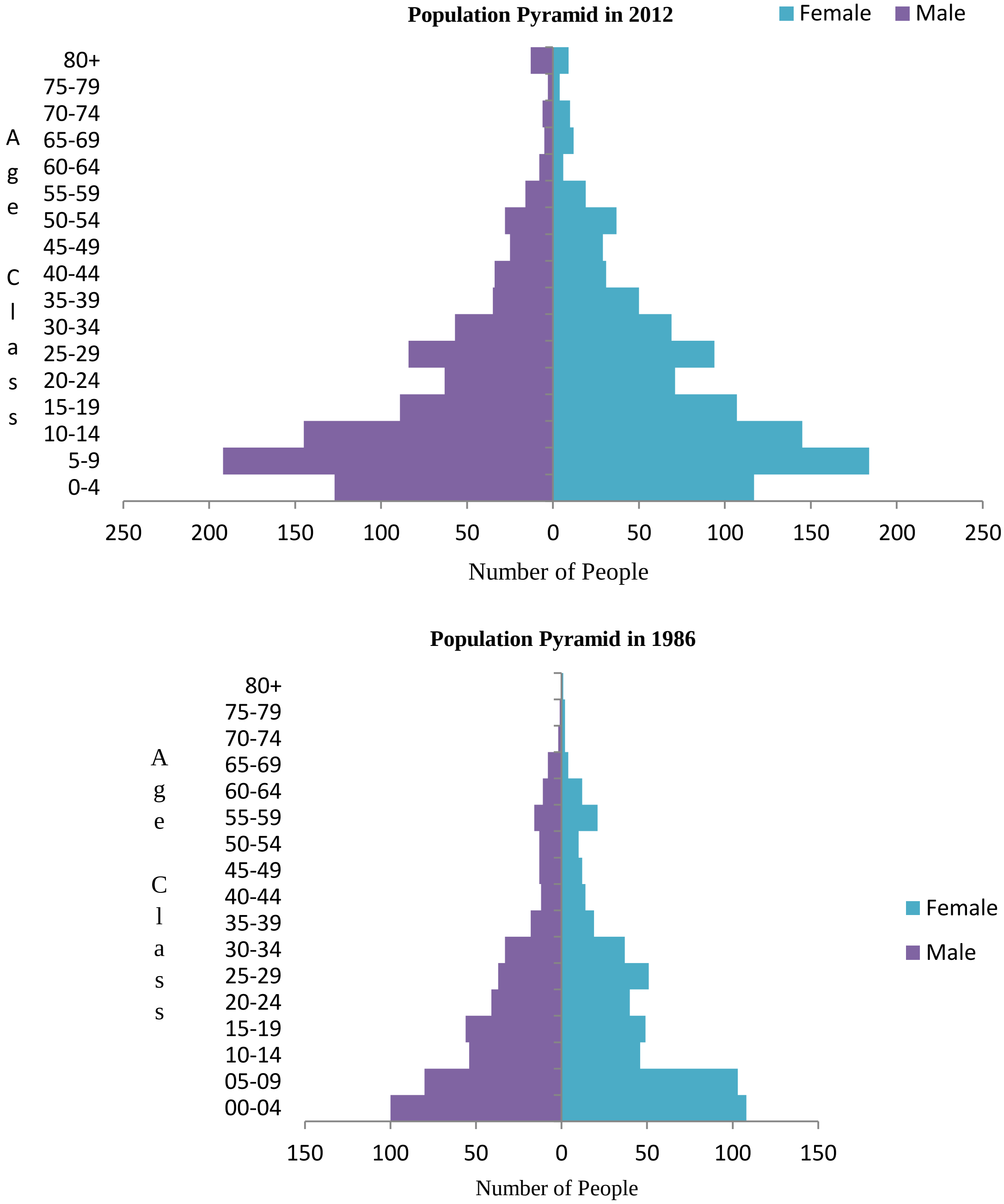
The total population in the 5 sample sectors is 115,646 inhabitants (that is around 40 percent of the district population). According to the 2012 Rwandan population census, their respective population densities vary from 336 inhabitants per square kilometer (Muringa) to 598 inhabitants per square kilometer (Rurembo) which make an average of 512 inhabitants per square kilometer, slightly below the district density of 556 inhabitants per square kilometer. Coming to the sample households, the population has increased from 1,026 people (of which 51.75 percent were females) in 1986 to 1,924 people (of which 51.66 percent are females) in 2012. This makes an 88 percent increase in the sample population over the past two and a half decades. The number of households almost doubled from 190 households in 1986 to 364 households in 2012. If the leavers are not considered, the number of households multiplied 2.2-fold between the two periods. Despite the slight decrease over time, the family size is still far bigger than the average country level of 4.6 people in a household.

After the 1994 genocide, the new population policy was not only oriented in curbing demographic growth and reducing fertility, but also increase the quality of life. Effort was made to create a favorable environment to behavioral change that would result in lower fertility rates. The new policy aims at increasing production, public health improvements, land use planning, promotion of school enrollment, environmental sustainability, good governance, and at providing equal opportunity to men as well as women to participate in the country's development (NISR, 2012; Rwanda, 2010). Despite small success in the urban areas where the fertility rate has decreased to 3.6 children per woman, the rural fertility of 4.8 children is still above the national average (Rwanda, 2010). This explains partly the high population growth observed in rural areas.

In figure 3.1, the population pyramids in 1986 and 2012 are compared. The common feature of the two distributions is that both are dominated by children and infants under 15 who occupy 48 percent in 1986, and 47 percent of the sample population in 2012. A cohort analysis of children under five showed that there has been a 14 percent decrease in the group (from 208 children in 1986 to 178 young adults between 25-29 years on 2012 pyramid). The group of children and infants under 15 years registered a 21 percent decrease (491 people in 1986 against 389 between 25 and 39 years on the 2012 pyramid) over the past two and a half decades.

The overall picture shows a tremendous increase in the sample population, particularly an increase in infant and children under 15 with a consequent increase in the dependency rate among households, putting more pressure on available land for crop production. Table 3.1 shows that the number of adult people (aged between 21 and 76) in the initial sample shrank by half between the two periods. The original total sample population decreased by 33.5 percent from 1986 to 2012, and male loss (37 percent) was found to be higher than female loss (30 percent). The loss in people is principally attributed to natural death. However, adjusting for natural death over the past 26 years, the observed number of people in 2012 is higher than expected with appreciations to health practice improvements over the past one and a half decade. The dispatching of health workers who volunteer to do community sensitization on immunization programs, water and sanitation, and on basic preventive measures has improved health conditions in the study area. Health workers may also carry out some basic medical treatment to prevent imminent death before the affected people reach the nearest health center.

Figure 3.1 Population pyramids of the sample area in 2012 and 1986



Source: Author's conception based on survey information

Table 3.1 Population changes by age cohort 1986-2012

Age Group 1986 (years)	Number 1986 (A)	Age Group 2012 (years)	Observed Number 2012 (B)	Percent change 1986-2012	Natural death[3] (C)	Expected number 2012 (D=A-C)	Unexpected loss (%) E*
Children under 5	208	25-30	178	-14%	84	124	-26
Children under 15	491	25-40	389	-21%	198	293	-20
Active Population: 15-64	521	40-80+	295	-43.4%	210	311	**3**
Adults: 21-76	434	45-80+	230	-47%	175	259	**7**
Total sample : 0-80+	1026	25-80+	684	-33.5%	413	613	-7

Source: Author's calculation based on survey data. * E=100*[(D-B)/A]

The unexpected loss observed in the cohort of active population may result from different causes: first, it is likely attributed to the 1994 war and genocide which also caused others to emigrate from the country. Second, the study area was exposed to frequent natural calamities over the past decade. Several times, heavy rain, and soil erosion was the cause of many deaths. However, the sample population was less affected by war and natural calamities.

The next section empirically investigates the extent at which parents' initial socio-demographic conditions influenced human fertility over the past 26 years. Table 3.2 indicates the probable relationships between fertility (children born per woman), household income, and woman characteristics such as age and the age at the first cohabitation.

Table 3.2 Demographic statistics by income quartiles

Income Quartiles 1986	Average Family size 1986	Children ever born per woman 1986-2012	Average mother's age 1986	Average age of mother at marriage
Bottom quartile	4.1	3.8	35.8	23.7
Second quartile	5.6	5.8	39.0	23.6
Third quartile	6.2	6.5	38.7	24.0
Top quartile	7.0	7.5	40.5	24.1

Source: Author's calculation based on survey data

[3] The number of people lost subsequent to natural death was obtained by applying continually the national annual crude death rates for total population over the past 25 years: 1987-2011. The data are retrieved from: http://data.worldbank.org/indicator/SP.DYN.CDRT.IN on 24/02/2014.

It is obvious that initial high family income is associated with high family size and mother's age. The same families have, after 26 years, reached the highest fertility. One should expect a positive correlation between initial family income, mother age and fertility in the study area.

3.6.2. Determinants of Fertility: Poisson Regression Results

For fertility analysis, the number of children ever born per woman was retained as dependent variable. It takes the total number of children born between 1986 and 2012, regardless of age. The independent variables are drawn from the 1986 survey in order to assess at which extent the initial socio-economic conditions affect fertility during the parents' lifetime. The regressions controls for the mother, husband, other socio-economic, and community characteristics. However, like other demographic data, the dataset lacks some information on prices and cost of child bearing as well as the cost of child quality investment. Table 3.3 indicates the description of variables used to fit the fertility model.

Table 3.3 Variable definition and descriptive statistics: fertility model

Variable name	Variable description	Mean	Std. Dev.
Dependent variable			
Children ever born	Number of children ever born per woman: 1986-2012	5.91	3.13
Independent variables (all for 1986)			
Household income	Total household income (expenditure) in RWF	62,159	39,449
Woman education	Education level of the woman in years	1.97	1.65
Mother age	Age of the woman (mother) in years	38.51	13.12
Death experience	A dummy variable indicating if the woman had a death experience in the past (child death, miscarriage, or stillbirth)	0.06	0.24
Cohabitation age	Age of the woman at first cohabitation (marriage) in years	23.82	6.17
Mother height	The height of the mother in meters	1.58	0.06
Health incident	A dummy variable indicating if the woman had a health incident during 12 months before the survey	0.52	0.50
First born girl	A dummy indicating if the first child is girl	0.46	0.50
Head education	Education level of the household head in years	2.28	2.68
Head age	Age of the household head in years	42.37	13.61
Father height	The height of the husband in meters	1.67	0.05
Child immunization	A dummy indicating if children are immunized	0.79	0.41
Distance to health center	The distance to the nearest health center in kilometers	5.44	4.10
Distance to market	The distance to the nearest product market in kilometers	5.40	5.16

Source: Author's computation based on survey data. All independent variables are drawn from the 1986 survey. Std. Dev: Standard deviation.

The average number of children ever born per woman is 5.9 children. Initially, the average mother's cohabitation age is 24 years, and average age is 38.5 years. The education level, one of the important factors of women's fertility was lower compared to men: 1.97 years against 2.28 years of schooling.

Table 3.4 reports the regression results on determinants of children born per woman. For purposes of robustness, a distinction is made by (1) including woman characteristics only, (2) woman, husband and other household characteristics, and (3) by adding community characteristics into regression. The robust Poisson estimates show the expected signs on most woman, husband, household, and community-specific variables.

Results are robust across different specifications and their respective likelihood chi-squared statistics and corresponding probabilities confirm the rejection of the null hypothesis that all regression coefficients equal to zero. Goodness of model fit is measured by the squared coefficient of correlation {r (rho) ^2} between the fitted and observed values of the dependent variable (Cameron and Trivedi, 2010, 2013). The coefficients of correlation of 0.40 in (1), 0.46 in (2), and 0.48 in (3) indicate that 40 to 48 percent of total variation in the number of children born per woman is explained by the included explanatory variables. The coefficient of correlation is higher in specification (3) that includes more variables, and it is subject to most of our interpretations. Family income, age of the woman, her education, mother's age at marriage, and the husband's (or head age) are showing a high level of significance to explain fertility in the study area. Alternative specification was showing a strong correlation between the farm size and fertility, but this variable is omitted due to its high correlation with household income.

All other things being equal, one percent increase in family income increases fertility by 0.32 percent. The correlation is highly significant at 1 percent level. In other words, children are viewed as normal goods, of which consumed quantities increase with positive shift in income. The sign obtained on woman's education variables are as expected. To clearly measure the education effect, four categories of education level have been created: illiterate or primary incomplete (0-3 years of schooling completed), primary level (4-6 years completed), post-primary or nine years basic education (6-9 years completed), and secondary level (more than 10 years completed). The omitted level being illiterate or primary incomplete, our results show that fertility decreases with women's education level. Compared to mothers without education, mothers with primary or post-primary level of education in 1986 have fewer children in 2012.

Table 3.4 Poisson regression results on the determinants of children ever born 1986-2012

	(1)		(2)		(3)	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Household income (log)	0.317***	0.072	0.277***	0.075	0.266***	0.079
Woman education (base: illiterate)						
Primary: 4-6	-0.534***	0.193	-0.484***	0.178	-0.483***	0.186
Post primary: 6-9	-0.503*	0.291	-0.333*	0.179	-0.407**	0.178
Secondary: 10+	0.010	0.105	0.011	0.093	0.009	0.091
Mother age(base: 15-24)						
25-34	0.968***	0.177	0.721***	0.204	0.733***	0.211
35-44	1.244***	0.175	0.795***	0.227	0.816***	0.232
45+	1.249***	0.196	0.776***	0.256	0.803***	0.259
Cohabitation age (Base: 15-24)						
25-29	-0.241**	0.099	-0.230**	0.098	-0.228**	0.096
30-34	-0.136	0.129	-0.137	0.143	-0.127	0.141
35+	-0.327*	0.176	-0.322*	0.169	-0.343**	0.161
Mother height	0.452	0.643	0.433	0.589	0.395	0.593
Health incident	-0.040	0.067	-0.032	0.066	-0.047	0.066
Death experience			0.036	0.104	0.054	0.103
First born girl			0.028	0.064	0.002	0.066
Head education						
Primary: 4-6			-0.038	0.074	-0.027	0.072
Post primary: 4-9			-0.132	0.105	-0.156	0.107
Head age			0.086***	0.028	0.088***	0.028
Head age squared			-0.001***	0.000	-0.001***	0.000
Father height			-0.174	0.722	-0.187	0.740
Child immunization			-0.104	0.085	-0.131	0.086
Distance to health center					-0.008	0.010
Distance to market					-0.008	0.005
Constant	-3.371***	1.236	-4.203**	1.765	-3.932**	1.796
Observations	163		162		162	
Chi-squared	127.6***		163.73***		162.93***	
Squared correlation: r(rho)^2	0.40		0.46		0.48	

*, **, and *** indicate the significance level at 10, 5 and 1 percent respectively. Poisson coefficients and robust standard errors are reported. Model (1) includes the mother characteristics only, model (2) adds on both the husband and household characteristics; while model (3) completes the list by including some community characteristics.

Fertility also increases with mother's age and decreases with the age at the first cohabitation. Mother's age has been a very important factor to higher demographic changes observed in the study area during the past 26 years because during the first survey 67 percent of all mothers were aged between 18 and 40, which corresponds to a high fecundity period. Both coefficients on mother's age groups are statistically significant at 1 percent level. The omitted is the group of women aged between 15 and 24. On the other hand, delaying age at marriage can have strong implications on fertility in the study area, as shown by the negative and statistically significant coefficients on age at first cohabitation.

Among husband’s characteristics, only age is statistically significant to explain fertility. Estimates show that fertility increase by husband’s (or mostly household head) age. The expected signs were obtained on community characteristics but they are not statistically significant. However, their introduction brings slight improvement in the coefficient correlation to the estimated model.

3.6.3. Population Growth and Intensification Impacts

The impact of population growth on agricultural intensification, farm productivity, and rural economic change has been assessed with data collected in both surveys. Significant changes occurred in the input intensity, net returns per hectare, and the value of household assets and expenditure. The role of population at micro-level is principally measured by the family size (or the number of household members), and other demographic characteristics that are susceptible to impact agricultural practices (Codjoe and Bilsborrow, 2011). Table 3.5 indicates definitions and summary statistics of key variables by year.

Table 3.5 Variables definition and summary statistics by year

Variable	Description	1986		2012	
		Mean	Std. dev.	Mean	Std. dev.
Input intensity	The total cost of agricultural inputs per hectare in RWF: fertilizers, seeds, hired labor, and land preparation	5,427	11,340	27,508	34,124
Fertilizers/ha	Value (in Rwf) of fertilizers used per hectare,	1,878	7,109	10,767	20,963
Labor units /ha	The total person-days per hectare	941	642	438	1,368
Net farm income/ ha	Total net farm returns per unit of land	24,099	18,814	67,595	168,913
Total Assets/ca	Total value of household assets per capita in Rwf	4,321	8,636	5,294	6,822
Household expenditure /ca	Value of household expenditure per capita in Rwf	11,421	5,522	17,767	14,632
Household size	The family size (number of persons)	5.7	2.14	5.3	2.09
Women share	Share of adult females within a household	0.27	0.13	0.29	0.17
Male share	Share of adult males in a household	0.26	0.16	0.23	0.16
Head education	Average education level of the head in years	2.28	2.68	3.86	3.36
Head age	Age of the household's head in years	42.37	13.61	44.38	16.28
Farm size	The size of landholding in hectares	0.76	0.46	0.43	0.61
Land quality	The subjective land quality measure: percentage households with good quality land	96%	-	60%	-
Extension services	Access to extension services: percentage of households visited by extension agent in a year	6%	23%	62%	49%

Note: All monetary values are expressed in constant prices, base: 1986. Std. Dev: Standard deviation. The full sample is used for 2012.

Table 3.6 reports panel fixed effects results on agricultural intensification. For robustness check, two dependent variables are selected to measure intensification: inputs intensity per hectare (models 1-2) and labor units per hectare (models 3-4). The results suggest positive correlation between population variables (household size, and the proportion of adult males) on input use intensity and labor units per hectare. Over time, the population pressure has motivated agricultural intensification in the study area, which is consistent with Boserupian intensification theory. One additional member to the family results in 9 percent increase in input intensity per hectare. However, all other things being equal, the overall units of labor used per hectare decreased a lot over the last 26 years. The latter may due to the increasing land scarcity and more involvement in off-farm activities in 2012.

Table 3.6 Population growth and agricultural intensification: fixed effects results

	Input intensity		Labor units/ha	
	Extended Family (Balanced) (1)	Full sample (Unbalanced) (2)	Extended Family (Balanced) (3)	Full sample (Unbalanced) (4)
Household size	**0.089*** **	**0.066***	**0.111*** **	**-0.002**
	(0.021)	(0.038)	**(0.015)**	(0.029)
Women share	-0.575	-1.094***	1.627***	0.680***
	(0.497)	(0.417)	(0.466)	(0.252)
Males share	0.374	-0.046	1.899***	0.924***
	(0.474)	(0.418)	(0.509)	(0.282)
Head education (base: 0-3)				
Primary: 4-6	-0.037	-0.431*	-0.043	0.292**
	(0.190)	(0.256)	(0.156)	(0.144)
Post primary: 6-9	-0.421	-0.373	-0.048	0.325*
	(0.335)	(0.352)	(0.238)	(0.195)
Secondary: 10+	-0.457	-0.559	-0.163	1.131***
	(0.447)	(0.515)	(0.384)	(0.303)
Head age	-0.014*	-0.010	-0.012*	0.006
	(0.007)	(0.007)	(0.007)	(0.004)
Farm size (log)	-0.358**	-0.550***	-0.551***	-0.799***
	(0.138)	(0.116)	(0.100)	(0.063)
Land quality (Base: Good)				
Medium	0.042	-0.123	-0.015	-0.109
	(0.263)	(0.248)	(0.212)	(0.148)
Bad	-0.016	-0.071	0.022	-0.241
	(0.323)	(0.304)	(0.265)	(0.190)
Asset value (log)	0.156**	0.191***	0.074	0.058
	(0.069)	(0.059)	(0.058)	(0.035)
Extension services	0.353	0.282	0.053	0.114
	(0.256)	(0.242)	(0.198)	(0.132)
Year dummy 2012	1.695***	1.200***	-1.268***	-2.198***
	(0.296)	(0.238)	(0.224)	(0.159)
Constant	6.564***	6.514***	4.655***	5.100***
	(0.832)	(0.711)	(0.694)	(0.423)
Observations	303	473	321	492
F-statistic	62.27***	20.19***	17.29***	74.16***
R_squared	0.816	0.657	0.530	0.823

*, **, and *** denote a significance level at 10, 5 and 1 percent respectively. The reported are regression coefficients and the robust standard errors between brackets. All the dependent variables are expressed in log.

The negative effect on farm size and head age is also as expected. All other things being equal, a ten percent increase in the size of available land will have a subsequent decrease of at least 3.5 and 5.5 in input intensity and labor units per hectare, respectively. Agricultural intensification is found to be an affair of young farmers, who are more motivated, more innovative, and less risk averse than their counterpart old farmers. This is indicated by a negative correlation between head age and input intensity. It is also evident that input intensity increases with the household's assets such livestock and other important durable equipment. The correlation is highly significant; this may also reveal the positive impact of household income on land intensification. The 2012 year dummy coefficient suggests substantial positive changes in the study area over time with respect to input use intensity.

Changes in agricultural intensification may also be attributed to agricultural reforms introduced by the government of Rwanda during the past one and a half decades like the Crop Intensification Program (CIP), the *Girinka* Program, the Information Gateway of Agriculture and Livestock Sector in Rwanda (AMIS), and numerous government projects and agricultural research-oriented institutions, which aim at transformation of agricultural sector from subsistence to professional agriculture, and self-sustained food security among households. They impacted the intensity of adoption of agricultural technologies by rural smallholders. Besides, recent developments in the Information and Communication Technologies in Rwanda (particularly the expansion of mobile phones among rural farmers) are believed to be major factors to facilitate the flow of agricultural information on the existence and availability of new cultivars and fertilizers.

These policies are in line with The Montpelier Panel Report (2013) that recommended African and governments to adopt policies and plans that will enhance sustainable intensification and address the people's food security needs. It was observed that more than 75 percent of arable land in Sub-Saharan Africa is degraded, where farmers loose about eight million tons of soil nutrients each year(Toenniessen et al., 2008). Under such circumstances, the intensification policy options are highly required; otherwise African systems will be able to meet only 13 percent of the continent's food needs by 2050 (Global Harvest Initiative, 2012). It is only through sustainable land intensification that farmers will efficiently increase their levels of production, income, and nutrition and at the same time increase environment services. Therefore, such policies should be strengthened by creating enabling environment to agricultural intensification, building social capital through dissemination of market information to smallholders, enabling access to technical advice and credit, and creating sustainable livelihoods through improved food security, access to education, and increasing off-farm income (The Montpelier Panel, 2013).

3.6.4. Productivity and Welfare Effect of Population Growth

Technical change is a precondition to productivity increases and household welfare. The relationships between population and farm productivity and household welfare are analyzed, and panel fixed effects regression results are reported in table 3.7. Agricultural productivity is measured by net farm income per hectare (models 1-2) which includes, in addition to the net crop returns, the income from livestock (product) sales. The household welfare effect is captured by the annual household consumption expenditure per capita (models 3-4). For robustness check both results from balanced and unbalanced data are presented.

The results suggest that demographic variables are positively correlated with agricultural productivity, as would Boserup expect. A ceteris paribus one unit increase in household size is associated with a 10 percent increase in net farm income per hectare. Besides, farm productivity is inversely correlated with the landholding and the age of the household head, which was also a priori expected. A ten percent increase in land size has a consequent decrease of 7.2 percent in net farm return per hectare. This inverse relationship is attributed to the labor market imperfections in rural area. Relatively small farms are more likely to optimally absorb the amount of labor per hectare than large farms. In addition, there is reduced cost in labor supervision and organizational activities associated with small farms (Ali and Deininger, 2014) . This result seems to be controversial regarding the recent land consolidation policy that is against any landholdings subdivision as a means towards agricultural development and food security.

On the other hand, the findings suggest a negative impact of population growth on household welfare but the effect is low. All other things being equal, one additional member in a family would result in 0.2 percent decrease in total expenditure per capita. Beyond the demographic component, welfare is also a function of head education, the size of landholding, and family assets. Compared to farmers without education, those with secondary education have at least 53 percent higher income (expenditure).

Table 3.7 Population growth, farm productivity and household welfare: fixed effects results

	Net farm income/ha		Household Expenditure per capita	
	Extended Family (Balanced) (1)	Full sample (Unbalanced) (2)	Extended Family (Balanced) (3)	Full sample (Unbalanced) (4)
Household size	**0.101*** **	**0.009**	**-0.021** **	**-0.094*** **
	(0.023)	(0.038)	**(0.009)**	(0.021)
Women share	0.829	0.057	0.870***	0.626**
	(0.571)	(0.398)	(0.308)	(0.258)
Males share	0.437	0.104	0.650**	0.112
	(0.496)	(0.355)	(0.294)	(0.256)
Head education				
Primary: 4-6	-0.236	-0.149	0.026	0.149
	(0.213)	(0.260)	(0.082)	(0.104)
Post primary: 6-9	-0.414	0.223	0.106	-0.012
	(0.345)	(0.299)	(0.127)	(0.163)
Secondary: 10+	0.194	1.956**	0.525**	0.692**
	(0.578)	(0.775)	(0.211)	(0.299)
Head age	-0.008	0.012*	-0.006*	-0.006*
	(0.007)	(0.006)	(0.003)	(0.003)
Farm size (log)	-0.728***	-0.809***	0.131**	0.078
	(0.128)	(0.099)	(0.064)	(0.064)
Land quality				
Medium quality	-0.103	-0.171	-0.139	-0.087
	(0.275)	(0.260)	(0.167)	(0.156)
Bad quality	-0.348	-0.443	-0.221	-0.119
	(0.328)	(0.324)	(0.206)	(0.192)
Asset value (log)	0.186**	0.238***	0.064**	0.062*
	(0.074)	(0.058)	(0.031)	(0.032)
Year dummy 2012	0.605***	-0.389*	0.436***	0.355***
	(0.218)	(0.220)	(0.125)	(0.115)
Constant	7.374***	6.923***	8.794***	9.320***
	(0.772)	(0.677)	(0.346)	(0.339)
Observations	304	452	321	493
F-statistic t	20.43***	8.95***	7.77***	5.75***
R_squared	0.57	0.456	0.39	0.314

*, **, and *** denote a significance level at 10, 5 and 1 percent respectively. The reported are regression coefficients, and all dependent variables are expressed in log. The community variables (access to market and road) are controlled for across all specifications, though they are not significant.

This shows the dominant role of education in boosting household (family) income in the study area. Alternatively, one unit increase in family assets is associated with 6 percent increase in total expenditure per capita, other things being equal. The positive and statistically significant coefficient of the year dummy is again an indicator of positive change in household welfare over time.

3.7. Conclusion to Chapter Three

The chapter assessed the patterns of demographic change, as well as agricultural and economic changes among smallholder farmers in rural Rwanda. Over the past 26 years, the sample population registered an 88 percent increase, putting very high pressure on the arable land. The number of households doubled, and the average farm size per household shrank by half. The Poisson regression results showed that fertility in the area (measured by the number of children ever born per woman from 1986 to 2012) is positively correlated to initial family income, both mother and husband's ages, and mother's age at first cohabitation. Fertility was found to be negatively correlated with a woman's education level, and the mother's age at marriage. Children are viewed as normal goods in the study area, whose demand increases by 3 percent on average as a result of ten percent increase in income, other things being equal. These results are much consistent with previous findings in Ethiopia (Tadesse and Asefa, 2002), Côte d'Ivoire and Ghana (Benefo and Schultz, 1996). Similarly to the evidence from Kenya by Schultz (2005) and Muyanga and Jayne (2012), human fertility remains high in Rwanda because children's labor and land are still viewed as complementary factors to agricultural growth.

Regarding the impact of population change on agricultural intensification, productivity, and household welfare, the Boserupian land intensification hypothesis cannot be rejected in the study area. The results suggest that, demographic variables such as household size, proportion of adult females and adult males are highly associated with input intensity, labor units per hectare, and agricultural productivity (net farm income per hectare). Other things remaining constant, one additional household member will increase input intensity and net farm income per hectare by 9 and 10 percent, respectively. These results are consistent with those recently obtained in Ghana by Codjoe and Bilsborrow (2011) while assessing the role of population and agricultural practices in the dry and derived savannah zones. Nevertheless, the inverse correlation between family size and annual expenditure per capita calls for a sound population policy in the near future.

Finally, our results suggest an inverse relationship between farm size and input intensity and productivity in the study area. Ten percent increase in land size has a consequent decrease of at least 3.5 and 7.3 percent in net land intensification and net farm returns per hectare, respectively. This is in line with Ali and Deininger (2014) who found a robust negative relationship between farm size and per hectare gross output in Rwanda, and consistent with many similar studies on farm size and productivity in India (Chand et al., 2011), China (Chen et al., 2005), Nepal (Thapa, 2007), Bangladesh (Toufique, 2005), and Malawi (Matchaya, 2007). The intensive labor use by small farmers and high amount of fertilizers and other inputs required on large farms may be considered as the main underlying reasons on the inverse relationship between farm size and productivity in Rwanda.

In this regard, policies for agricultural and rural development in Rwanda should tackle the problems of market imperfections that prevent optimal gains on large farms. In addition, the Boserupian population effect on land intensification and productivity may fail in the long run if the pace of population keeps growing without possibility of land extension. The introduction of appropriate technologies will help but a sound population policy is urgently required. Efforts should be made to revisit the age of first cohabitation and promote women education. The latter, combined with employment opportunities outside the farm, will enhance rural women participation and raise the opportunity cost of rearing children in Rwanda.

Chapter 4. AGRICULTURAL OUTPUT, OFF-FARM EMPLOYMENT EXPANSION, AND ICT ADOPTION

4.1. Introduction

This chapter reviews the production theories of farm households, and presents the empirical models of agricultural output, and off-farm employment expansion as drivers of change in agricultural production in the study area. The descriptive statistics providing insights on the long-term change are also presented, while the discussion is closed by an assessment of the impact of ICT (with a focus on the recent mobile phone technology) as new driver of agricultural production in the study area.

Agricultural growth has long been recognized as an engine for economic growth and poverty reduction in developing countries (Byerlee et al., 2005; Headey et al., 2005). Agriculture is also the backbone of the economy in Rwanda, being the second largest contributor to Gross Domestic Product (31 percent in 2010/2011), after the service sector. Existing literature on agricultural research in Rwanda by Diao et al. (2010) Donovan et al. (2002), McKay and Loveridge (2005), Clay et al. (1996) and von Braun et al. (1991) do not capture the farm productivity in the long term because they had used single-year data in their analyses. Thus, the research question on the long-term drivers of agricultural growth in Rwanda remains unanswered so far.

This chapter assesses the drivers of agricultural growth over time among smallholder farmers in rural Rwanda. First, the Cobb-Douglass production function is estimated. Secondly, an analysis of the factors driving non-farm employment expansion is carried out and the simultaneity between off-farm work and agricultural output is tested. Finally, the impact of mobile phone technology adoption by rural farmers on agricultural growth and household welfare is assessed using the propensity score matching technique.

4.2. Drivers of Agricultural Output over Time

4.2.1. Relevant Literature on Production Theory

Since the seminal work of Cobb and Douglas (1928) the concept of “production function” has undergone a long debate among economists. The first attempt of a common definition is attributed to the school of early marginalists and neoclassical economists who found the production function to be purely technical relationship that is void of economic content (Chambers, 1988). As the fundamental concern of economists is to study economic phenomena, the technical aspects of production are also interesting to them because they impact the economic agents’ behavior. Originally, it is assumed that there is a relationship between inputs and output that can be represented in the mathematical equation, $y = f(x)$, separating output and inputs (ibid). This means that, a single output level is obtained by a unique combination of inputs x, where the economic agent is supposed to choose among different output levels, and select the highest. Therefore, a production function represents the maximum output that can be achieved using an arbitrary input vector $x = (x_1, \ldots, x_n)$, and it is used by economists to carry out different sensitivity analyses and to compute measures of technical efficiency (Hackman, 2008). It is also defined as the amount of output that can be produced with a given amount of inputs through the use of a given production technology (Rasmussen, 2011).

The use of capital and other intermediate inputs in traditional agriculture is thought to be very limited and the volume of agricultural output is mostly determined by land and labor (Cornia, 1985). Over time, agriculture has become more input intensive, but the evolution of input shares depends on the degree of technical substitution between land, labor and capital. Labor and capital are substitutable in long run, but mechanization is very limited in rural areas of low income countries and there is little evidence about its effects on yields (Cornia, 1985).

This has been the cause of high output elasticities of land obtained from production function estimation in Asian countries in the 1970s (Lau and Yotopoulos, 1971; ÍOkawa, 1972) with the former’s tendency to decrease over time in favor of labor and capital elasticities. In the study on factor demand and agricultural development in rural areas of Uganda, Deininger and Okidi (1999) estimated a production function and found that farm size and the use of seeds and fertilizers are important factors of agricultural output growth. Besides, households’ characteristics such as head age, head sex, education level, and farmer's experience were found to be relevant to agricultural productivity. Tripathi and Prasad (2009) studied the performance and determinants of agricultural growth in India since its independence and estimated a Cobb-Douglas production function using country level data. Their results confirmed that land, labor, and capital significantly explain the changes in agricultural output over time.

Mundlak et al. (2012) used country panel data to estimate agricultural production function with heterogeneous technology and found agricultural inputs to be relevant to agricultural output across countries. The sum of elasticities of capital and land were higher (0.90) leaving a little scope for labor and fertilizers; qualifying agriculture to be mostly capital-cost intensive in both within time and between countries. The inclusion of state variables such as technology, institutions, prices, and environmental variables in the production function improve its explanatory power.

However, the estimation of agricultural production functions is done differently depending on the type and nature of available data, specification approach used, and on the purpose of the study (Mundlak et al., 2012). Using Cobb-Douglas specification, agriculture productivity relationships have been empirically tested in Rwanda by von Braun et al. (1991), Clay et al. (1996), and Ali and Deininger (2014) and found that farm size and labor exhibits superior contribution to agricultural output variations.

4.2.2. Theoretical Framework

In their production and consumption activities, farm households respond to price incentives, changes in technology, and to change in factor prices. According to Sadoulet and De Janvry (1995), two elements determine the producer's response: the technological relation between any combination of factor inputs and the level of output, and the producer behavior on the choice of alternative inputs, given the level of market prices and input availability. Using the profit maximization theory (Chapoto and Ragasa, 2013; Kim, 2003), a household i is assumed to maximize the expected discounted value of future profits $E(\pi)$ by choosing the amount of inputs X_i (such as capital and labor) and output Y_i over the period T, subject to its production constraint. The intertemporal profit maximization problem facing the farm household is formulated as follows:

$$Max_{X_{it},Y_{it}} E_{it}(\pi) = \sum_{t=1}^{T} P_{y_{it}} E(Y_{it}) - \sum_{i=1}^{n} w_{it} X_{it}$$

$$s.t \sum_{t=1}^{T} F_{it}(Y_{it}, X_{1t}, \dots, X_{nt}) = 0$$

(4.1)

Where π is profit, E_{it} is the expectation conditional to the information available to the household at time *t*, $P_{y_{it}}$ is the price of output at time *t*, Y_{it} is the crop production (output) of a farm household at time *t*, X_{it} is a vector of variable inputs, and w_{it} is the price of input *i* at time *t*. Therefore, under intertemporal separability assumption, a farm household's optimization problem is decomposed into two steps. First, the household optimally selects input quantities to minimize the production cost given the level of output; while in the second step the farmer chooses the output level over time to maximize the expected discounted sum of profits.

Given the cost function:

$$C_{it}(Y_{it}, X_{1t}, \dots, X_{nt})$$

(4.2)

The application of Shephard's lemma to the cost function gives the input demand functions

$$\frac{\partial C_{it}}{\partial w_{it}} = X_{it}(Y_{it}, X_{1t}, \dots, X_{nt})$$

(4.3)

For the profit maximization, the first-order conditions imply that, under perfect markets, the solution of demand function of inputs results in the farmer to equate the intertemporal marginal rate of substitution of output supply to the discounted marginal costs of output in two successive periods, independent of household or farmer characteristics. Thus,

$$\frac{\partial C_{it}}{\partial y_{it}} = -\frac{dy_{it}}{dy_{it+1}} = \frac{\partial F_{it+1}/\partial Y_{it+1}}{\partial F_{it}/\partial Y_{it}}$$

(4.4)

However, for the above theory to be valid, markets are supposed to exist and to be working perfectly for both labor and factor inputs (Sadoulet and De Janvry, 1995). Theoretically, the farm household is at the same time a producer and a consumer of the same good, is assumed to take decisions based on exogenous prices, and maximizes profits as a producer, based on exogenous output and input prices, resource endowments, and relevant household characteristics (Baibagysh, 2010). Therefore, market failures render these decisions non-separable (Kuiper and Van, 2005).

When markets are imperfect or missing (which is the rule rather than the exception in most rural areas of low income countries), rural households are not able to make recursive decisions in production and consumption activities. If they view the sale (purchase) prices for inputs and produced output to differ from the household shadow prices, then the solution to the household problem cannot be derived recursively. When consumption decisions influence the prices of inputs used in production function, then the production and consumption decisions are a simultaneous outcome of each other and become non-separable (Baibagysh, 2010).

4.2.3. Empirical Strategy

From a practical point of view, there is no standard mathematical form to express a production function. Different forms are used in various applications to describe production (Rasmussen, 2011). The most famous functional form of production function used in many applications is the Cobb-Douglas function that satisfies a large number of properties and is also used in this study. Basically the production relationships have been evaluated using the equation of the form:

$$\ln Output = \ln A_i + \beta_1 \ln Land_i + \beta_2 \ln Labor_i + \beta_3 \ln Capital_i + \varepsilon_i \qquad (4.5)$$

However, deriving conclusions from the above standard specification is problematic. von Braun et al. (1991) pointed out that some unobserved variables may affect both inputs and output levels. These may be household or location specific and need to be kept in mind while interpreting estimates from equation 4.5. Even though we have controlled for education level of the head (as a proxy of farmer's ability) and the land quality, a number of latent variables might not have been measured and their effect is not possible to capture with cross section estimation.

To tackle this issue, the panel model is used in this study. The fixed effect model is specified as follows:

$$\ln Y_{it} = \ln A_{it} + \beta_1 \ln L_{it} + \beta_2 \ln M_{it} + \beta_3 \ln K_{it} + \beta_4 LQ_{it} + \alpha_i + \varepsilon_{it} \; ; \; i = 1,2,\dots n \; ; t = 1,..T \tag{4.6}$$

Where A_{it} is an index that measures the household's total factor productivity, Y_{it} is the household's gross agricultural output value, L_{it} is the household's land endowment, M_{it} is the total household labor, K_{it} is agricultural capital endowment, LQ_{it} is the land quality, α_i is the household specific fixed effect, and ε_{it} is the idiosyncratic error term. The β_i's are technology parameters to be estimated (elasticities of production) and are assumed to be constant across households. It is assumed that the total factor productivity index A_i of farm household is affected by education, farmer's experience, wealth, and other household and community characteristics (Deininger and Okidi, 1999) which need to be controlled for.

4.2.4. Data Description and Agricultural System in the Study Area

The unique dataset used for the current study contains relevant information on agricultural production, size of landholdings, quantity and value of agricultural inputs and cultivars, agricultural capital, and other farm and farmer's characteristics that will enhance estimation of production function. Agriculture is still the backbone of subsistence in the area under study. The land is the major factor of agricultural production, and the major source of access to land is through inheritances (64 percent), followed by purchasing land (33 percent). The remaining 3 percent are obtained through gifts through family linkages, free land, or rented out lands. This major asset (land) has registered a slight increase over time, from 0.76 hectares per household in 1986 to 0.43 hectares in 2012.

The land scarcity is mainly attributed to population pressure, and to the loss of land which was used before in Gishwati forest, but inaccessible today due to conservation measures. Additionally, the area has been exposed to severe soil erosion which removed a large amount of fertile soil. Agriculture is mainly subsistence-oriented and, the application of modern inputs, chemical fertilizers by households has recently increased, while it was previously found only in big agricultural development projects and tea plantations. Table 4.1 summarizes, for each survey and by farm size quartiles, the land ownership among the sample households.

Table 4.1 Household size, land holdings and age of the household head 1986/2012

Farm size group	Average Total Land, ha[a]		Average Household Size		Average Age of the Household Head	
	1986	2012	1986	2012	1986	2012
Bottom Quartile	0.24	0.06	4.5	4.8	35	41
Second Quartile	0.49	0.16	5.7	5.2	40	41
Third Quartile	0.77	0.37	6.2	5.3	46	49
Top Quartile	1.54	1.12	6.5	5.8	48	47
Average	0.76	0.43	5.7	5.3	42	44

[a] The total land owned include available land in Gishwati forest

The table 4.2 represents the transition matrix of land ownership between 1986 and 2012; the figures are the percentage of households. Among 100 households who were in the second quartile of land in 1986, for example, 12.5 percent lost a large part of their land over the past 26 years and found themselves in the first quartile of the landless or the families with less than 0.1 hectare of land. Of 100 households in the third quartile of land holding before, about 34 percent lost portions of their land and now belong to the first (17 percent) and second (17 percent) quartiles. More than 40 percent of the top landowners in the first 1986 survey are also found among the smallholders (1st and 2nd quartiles), and only 27 percent are still in the top quartile of land in 2012.

Table 4.2 Transition matrix of land holdings (percentage of households)

Quartiles of land/ Year		Percent, 2012				Total 1986
		Bottom	Second	Third	Top	
Percent, 1986	Bottom	33.3	16.7	38.1	11.9	100
	Second	12.5	22.5	37.5	27.5	100
	Third	17.1	17.1	26.8	39.0	100
	Top	14.6	29.3	29.3	26.8	100

Source: Author calculation based on survey data.

The existing farming system in the study area is still based on small holder agriculture with family labor as a major source of total labor input. Through the intercrop system, which is the most common in the area, the major crops grown include maize, sorghum, sweet potatoes, Irish potatoes, climbing and bush beans, wheat, peas, and a variety of vegetables. In many households they grow perennials such as fuel wood, banana trees, and/or plantains. Coffee and tea are nowadays not frequently grown on the household plots, due to increasing land scarcity environment and subsistence purposes.

Alongside mineral fertilizers introduced by the government through the extension services, land fertilization is facilitated by livestock keeping. Most households rear cows, goats, sheep, and pigs. Over the past 26 years, there has been a big decrease in the average number of goats and sheep per household. The average number of goats was 1.8 in 1986 (owned by 62 percent of households), but it has fallen to 1.7 goats per extended family in 2012 (grown by only by 45 percent of the sample extended families). The number of sheep averaged at 1 in the first survey (animals kept by 45 percent of the households), and rose to 1.5 sheep by household, kept by 42 percent of families. However, the decline in goat and sheep keeping observed in the area has been compensated by a considerable increase in the number of cattle which rose from 0.7 cows per household (cows only kept by 19 percent of households in 1986) to an average of 3 cows per family, kept by 76 percent of the extended families in 2012. As mentioned previously in this work, this is a result of the government initiative called "*Girinka* program" that intends to give one cow per every poor family in order to eradicate food insecurity and poverty in rural Rwanda by the year 2025.

4.2.5. Empirical Results and Discussions

The inclusion of profit maximization objectives and the long term expectations related to crop and labor markets in the production decision make the production relationship in the rural agricultural system very complex. According to von Braun et al. (1991), it is not very easy to capture the interactions between agricultural system, especially the complementarity between capital, labor, and land as the major factors of production and how they relate to aggregate output, using crop-specific analysis. An attempt is made to compare the cross sectional results from a Cobb-Douglass production function and, thereafter, a remedy to the above mentioned constraint is attempted through panel data analysis.

Table 4.3 shows the mean statistics per year. The statistics show that the levels agricultural output and the two factor inputs (farm size and labor) are significantly lower in 2012 compared to 1986. However, the value of agricultural capital has substantially increased over time, from 1,264 Rwf in 1986 to 6,671 Rwf in 2012. It is obvious that agriculture in the study area is becoming more capital intensive and much less labor intensive, while the landholding shrank by half over the past three decades.

The dependent variable (gross output value) is calculated as total market value of all crops produced within a household/family, evaluated at constant prices (1986). Agricultural capital is hereby referred to as the market value of all agricultural tools and equipment. Farm size (land) is evaluated in hectares while labor is captured by the number of person-days used in agriculture within a year. The land quality variable comes from a subjective judgment of farmers on their own land quality. Land quality takes values of one, two, and three for good, medium, and poor land quality, respectively. The positive relationship is expected between the three factors and agricultural output. The poor quality of land is believed to lower production.

Table 4.3 Summary statistics of regression variables per year

Variable name	Variable definition	1986		2012	
		Mean	Sdt. Dev.	Mean	Std. Dev.
Output	The gross output value for all crops in Rwandan francs	19,199	16,991	18,242	32,381
Land	Total farm size per household in hectare	0.76	0.67	0.43	0.61
Labor	Total labor units (person-days) used per household per year	493	218	73	100
Capital	Total value in Rwandan francs of agricultural tools and equipment	1,264	1,530	6,671	15,571
Land Quality	Subjective judgment on land quality: 1=very good 2=medium 3=bad (here: percent of households with at least good land quality)	96%	-	60%	-

Source: Author calculation based on survey data. Std. Dev: Standard deviation.

Table 4.4 reports OLS regression results for independent cross sectional data of 1986 and 2012. There is a tremendous increase in the elasticity of labor from 0.20 in 1986 to 0.68 in 2012 and a decrease in elasticities of land and capital from 0.53 and 0.19 in 1986 to 0.18 and 0.11 in 2012, respectively. The quality of land also matters for crop output growth in the study area.

Table 4.4 OLS results on determinants of agricultural output 1986 & 2012

Independent variables	(1) OLS 1986	(2) OLS 2012 Extended Family	(3) OLS 2012 Full Sample
Constant	7.524***	6.090***	6.288***
	(0.743)	(0.546)	(0.493)
Land (log)	0.527***	0.181***	0.176***
	(0.062)	(0.063)	(0.054)
Labor (log)	0.196*	0.679***	0.595***
	(0.112)	(0.068)	(0.090)
Capital (log)	0.191***	0.107*	0.096**
	(0.049)	(0.064)	(0.045)
Land quality (base: good)			
2. Medium	-0.149	0.084	0.202
	(0.110)	(0.149)	(0.283)
3. Bad	-0.375**	-0.078	-0.069
	(0.167)	(0.151)	(0.289)
Observations	162	161	337
R_squared	0.53	0.65	0.43
F-statistic	51.80***	77.90***	42.54***

*, **, and *** denote a significance level at 10, 5 and 1 percent respectively. The reported are regression coefficients and the robust standard errors between brackets. The dependent variable is the logarithm of gross output value for both specifications.

Nevertheless, as noted earlier, the interpretation of the above cross section model should be done with caution due to unobserved household heterogeneity. To control for the hidden bias that may arise, panel data models that allow interpreting the changes in agricultural output over time are estimated and presented in table 4.5. Columns (1) and (2) report pooled OLS or Difference in Difference, while columns (3) and (4) report fixed effects results as per equation 4.6. The results confirm the predominant role of labor, capital, and land quality to output growth in the study area.

The Difference in Difference coefficients obtained on labor, land, and capital do not very much differ from the independent cross sectional elasticities for 1986 as presented in table above. However, the elasticities of land are slightly higher for both extended families dataset (1) and full sample dataset (2), even though the labor force still shows a high contribution to agricultural output. The sum of output elasticities is 0.99 in (1) and 0.90 in (2) respectively, indicating the decreasing returns to scale economies.

Table 4.5 Panel model results for production function: pooled OLS and fixed effects

Independent variables	(1) Pooled OLS Extended Family	(2) Pooled OLS Full Sample	(3) FE Extended Family/Balanced	(4) FE Full Sample/ Unbalanced
Constant	5.506***	5.605***	5.731***	4.745***
	(0.431)	(0.554)	(0.531)	(0.756)
Land (log)	0.293***	0.230***	0.125**	0.128**
	(0.049)	(0.048)	(0.059)	(0.065)
Labor (log)	0.569***	0.556***	0.488***	0.652***
	(0.057)	(0.082)	(0.076)	(0.088)
Capital (log)	0.130***	0.110***	0.168***	0.142**
	(0.048)	(0.040)	(0.064)	(0.067)
Land quality (Base: Good)				
2.Medium	-0.122	-0.010	-0.228	-0.026
	(0.096)	(0.121)	(0.162)	(0.174)
3.Bad	-0.316**	-0.264*	-0.418**	-0.167
	(0.126)	(0.148)	(0.175)	(0.192)
Year dummy 2012	1.170***	1.011***	1.056***	1.071***
	(0.131)	(0.180)	(0.174)	(0.194)
Observations	323	499	323	499
R_squared	0.62	0.45	0.56	0.46
F-statistic	87.75***	54.10***	32.12***	17.50***

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. Robust Standard Errors are reported in brackets. The dependent variable is the logarithm of agricultural output value. All continuous explanatory variables are expressed in logarithmic terms.

Similarly, the fixed effects results in (2) and (4) suggest that output elasticity of labor is higher than the combined elasticities of land and capital. Over the period of the study, holding the capital and labor inputs constant, a 10 percent increase in land ownership leads on average to about 1.3 percent increase in agricultural output. Similarly, holding land and capital constant, a 10 percent increase in labor input leads on average to a 5 to 6.5 percent increase in output. The decrease in land productivity may be attributed to the reduction of fallow periods accompanied by losses in soil fertility over the past decades. The continuing demographic growth has resulted in a very high pressure on land and high agricultural intensity for subsistence purposes.

Furthermore, the productivity of capital is laying between 0.142 and 0.168 indicating that, holding labor and land inputs constant, a ten percent increase in agricultural capital increases output by almost 1.5 percent on average. The results also show that the poor quality of land significantly decreases agricultural output. Adding the three output elasticities, we obtain 0.63 in (3) and 0.92 in (4) respectively. Similarly to the independent cross section and pooled OLS results, it is obvious that agriculture in the sample area is characterized by decreasing returns to scale economies over the study period. The total factor productivity (indicated by the constant term in production function) is statistically significant at one percent. It suggests the role of technological progress and other farm specific variables to increase agricultural output. The significant coefficient obtained on year dummy suggests that, compared to 1986, the agricultural productivity is higher in 2012. The growth observed in 2012 may be attributed to increased productivity of major crops, government green revolution, conductive climatic change, and intensity of fertilizer use (Bizimana et al., 2012). From the statistical point of view, the R-squared obtained for various specifications above indicate a good fit, meaning that more than 50 percent of the variation in the log of output are explained by the log of land, labor, capital, and land quality.

The above results differ from with those obtained in productivity analyses in Rwanda (Ali and Deininger, 2014; Clay et al., 1996) with respect output elasticities and economies of scale. Table 4.6 summarizes the major findings on output elasticities in microeconometric studies in Rwanda over the past two and a half decades. Most studies show decreasing returns to scale, and suggest application and substitution of farm inputs with caution. As these results rely on different approaches, study purposes, datasets, study areas, and different units of analyses, they show different patterns of Rwandan smallholding agriculture.

The production elasticities of land and labor from Pooled OLS estimation in this study slightly differ from those obtained by D.A. Ali &Deininger (2014) and Clay et al. (1996), but they are dramatically divergent from the estimates obtained by von Braun et al. (1991) in the same study area. The differences may be attributed to the omission of important variables in production function estimation (for example capital) on one hand, or the underestimation of the included variables (such as labor). Since OLS estimation cannot fully ascertain the production relationships at household level, the alternative results by panel fixed effects that correct for unobserved heterogeneity are assumed to provide appropriate output elasticities in Rwandan agriculture.

Table 4.6 Output elasticities for selected microeconometric studies in Rwanda

Author and year	Method Used	Land	Labor	Capital	Other Conditioners	Economies of scale
von Braun et al. (1991)	OLS	0.526	0.22	0.192	-	Decreasing
Clay et al. (1996)	OLS	0.38	0.54	-		Decreasing
Ali & Deininger (2014)	OLS	0.308	0.410	-	0.313	Constant
Our findings (2014)	**OLS**	**0.293**	**0.569**	**0.13**	**-**	**Decreasing**
	Fixed Effects	**0.125**	**0.488**	**0.168**		**Decreasing**

Source: von Braun et al. (1991), Clay et al (1996), and D. A. Ali & Deininger (2014)

Due to the nature of the dataset used in this study, the decreasing returns to scale economies are confirmed for rural small holding agriculture. Our findings also show a very small relative contribution of farm size to agricultural growth and stress the relative importance of the labor input in the study area. Investment in both land and agricultural capital are important to boost agricultural growth in the study area. However, the increasing productivity of labor over time does not mean that agricultural output will continue to grow, considering the law of marginal productivity of labor in the long run. Within decreasing return to scale economies, pathways to less labor intensive agricultural innovations and off-farm employment are required in the study area, accompanied by sound population policy to check on the prevailing population growth.

4.3. Analysis of Off-Farm Employment Expansion

4.3.1. Introduction

The rationale of this section is to analyze the factors that determine off-farm work hours in the study area, and how farmers' off-farm employment affects agricultural output over time. Since production efficiency may depend on off-farm work and off-farm work depend on production efficiency (Lien et al., 2010), both production and off-farm work are endogenous. We investigate in this particular section the simultaneous relationship between off-farm work and agricultural production. Agriculture is not only the pillar of subsistence in the rural areas of Rwanda, but it is also a major source of income to the households. Through the sales to markets of the production surplus, they always get money income to purchase nonagricultural goods and services that they need. The statistics carried out on the 20 percent of the sample in 1986 survey showed that income from agriculture was 42.5 percent of the total income, while the off-farm income comprised 57.5 percent of the total income. Table 4.7 shows the income sources reported in the 2012 household survey. Still below the off-farm income level, the share of agricultural income has decreased over time (36 percent of the total income), while the off-farm income (which remains the major source of household income in the study area) increased to 64 percent.

We should however note that the information on income is very difficult to collect because it is a very sensitive subject to many respondents in Rwanda, and hence, is a reason why one cannot rely on income data for estimation purposes. In the study, the total expenditure is used as a proxy of income. Off-farm employment can have a significant impact in sustaining livelihoods in a land scarcity situation. It was argued that off-farm employment opportunities coupled with positive changes in agricultural technology is the precondition for pro-poor food security in a densely populated region (von Braun et al., 1991). The recent increase in the share of off-farm income in the total household is due to a slight increase in the number of days devoted to outside jobs between two survey periods; from 56 days per year in 1986 to 96 days on average per household per year in 2012.

Table 4.7 Household income composition, 2012

Income source	Percent
Livestock sales and other animal products	7.5
Farm rent revenues	0.4
Wages for labor on other farms	18.4
Crop sales	9.6
Total farm income	***36.0***
Wages and salaries from off-farm work	41.9
Nonagricultural business revenues	17.6
Remittances from family members	0.5
Non conditional cash transfers	0.4
Conditional cash transfers	1.4
Gifts from various sources	2.2
Total off-farm income	***64.0***
TOTAL INCOME	**100.0**

Source: Author's conception based on survey data

The money income earned as wages for labor undertaken on other farms other than the family farm is considered as on-farm income in the table because the work is categorized as agricultural work. If this is included in off-farm income, the contribution of agriculture to household income remains small (26.3 percent); which stresses the predominant role of non-agricultural employment to increase the rural household income. Today off-farm employment offers large diversity despite high unemployment rate between the two survey periods, mostly due to the phase out of some governmental and non-governmental projects which employed a large number of people in 1986. Table 4.8 illustrates the types of off-farm work in the study area in 1986 and 2012.

Table 4.8 Off-farm work by type of employment in1986 and 2012

1986		2012	
Type of employment	Total Percent	Type of employment	Total percent
Paid agricultural daily work	2.3	Paid agricultural daily work	10.5
Public projects	20.9	Public services (soldiers, teachers)	9.3
Tea Factory	30.2	Construction	28
Handicrafts	11.6	Drivers	0.1
Others	34.9	Guardian/House girls (boys)	6.3
		Mining	2
		Tea factory and other agro-industries	16.3
		Others	27.5
Total	**100**	**Total**	**100**

Source: Source: Author's conception based on survey data

The phase out of some important projects in the study area such as GBK (a World Bank project in Gishwati Forest), IPV (German Agricultural Development Project), and MINITRAPE (a public project of the former Rwandan Ministry of Transport) has limited off-farm employment opportunities. The tea factory is still operating in the study area, but under private authority, which decreased the number of people employed. Few household members with at least a secondary level of education are employed in civil service. There are seven primary teachers and nine soldiers in the sample population. The majority of people who reported to have an off-farm job are employed in construction (28 percent) and the "other" services include small commerce, handicraft, and others.

In the following, we review the relevant literature to off-farm employment and its relation to agricultural output; present the conceptual model and econometric strategy to off-farm employment and output relationships; and close the section with empirical results and subsequent discussion.

4.3.2. Relevant Literature

In their study on commercialization of agriculture under population pressure in Rwanda, von Braun et al. (1991) explained the allocation of time to off-farm work in an ordinary least square regression model. Under the hypothesis that, increase in labor productivity decreased the venture in off-farm employment, evidence from the same study area failed to reject it. They found a significant correlation between labor productivity and the time spent on off-farm work per household, which allowed ascertaining that any technology that aim at increasing labor productivity in the study area, will consequently reduce pressure on off-farm opportunities available in the region, allowing a favorable wage rate for the landless population. The same study found that women are less likely to participate in off-farm work.

Similarly, Lanjouw and Stern (1998) examined the determinants of off-farm employment in an Indian village using the Probit model and found that the likelihood of having at least one household member employed off the farm increases with the number of males in a family and decreases with the land owned. Besides, the probability of having off-farm employment significantly increases with the number of years of schooling of individuals in Panalpur. In the same period, a number of studies on off-farm employment (Abdulai and Delgado, 1999; Benjamin and Guyomard, 1994; de Janvry and Sadoulet, 2001; Jacoby, 1993; Reardon et al., 1996; Skoufias, 1994) have identified factors such as education, age, number of younger children, experience, and sex as important to explain off-farm participation decisions.

Beyene (2008) analyzed the determinants of off-farm participation decision of both males and female members of farm households in Ethiopia using a bivariate Probit model that takes into account the simultaneity of both male and female decisions to participate in off-farm work. He found that participation in off-farm activities is negatively correlated to the household age and positively correlated to the male headship. Men are more likely to participate in off-farm activities than women. The study also confirmed a negative relationship between the farm size and off-farm participation decision for both male and female and the positive effects of credit access on off-farm work while education do not have any significant evidence. However, the probability of working outside farm increases with training in off-farm activities and with proximity to the market. Babatunde et al. (2010) examined the determinants of off-farm employment in Kwara State of Nigeria using a multivariate probit technique. Evidence from household surveys showed that participation in off-farm employment is significantly correlated with household characteristics such as age, gender, and education level, with farm size, household income, and household assets, and with the access to local markets. The same effects were obtained when off-farm participation was disaggregated into agricultural wage employment, non-agricultural wage employment, and off-farm self-employment.

Muhammad et al. (2012) investigated the determinants of off-farm employment in North West Pakistan where a large number of farmers are engaged in daily paid labor, trade, and commerce jobs. Contrary to other research in this area, they used an ordinary least square technique to fit the off-farm employment model taking the hours spent per day by a farmer in off-farm jobs. His results did not much differ from his predecessors in the context that landholding and income from other sources are negatively correlated with off-farm employment in the area. The family size and income showed also strong positive effects to motivate households' members to venture in off-farm jobs in Pakistan. Barbieri and Pan (2012) used a multi-level analysis in analyzing the drivers of off-farm employment in Ecuador's Amazon region. Their model takes into account not only the decision to participate in off-farm employment but also the place of off-farm employment, either the in local community, other rural areas, or other urban areas. Controlling for individual level, farm household level, and community level characteristics, they came up with the conclusions that younger people are likely to move outside the community for jobs, while the married and adults tend to engage in off-farm employment locally. In all cases, the number of off-farm jobs is higher for landless households and large families.

VanWey and Vithayathil (2013) stressed the importance of social capital as the social context and kinship networks in a multinomial regression model to explain its impact on off-farm work in the Brazilian Amazon. They found that, beyond individual and household characteristics, having a close relative or friend working outside the farm increases the chances that an individual will participate in off-farm work.

Although the above analyses are mostly based on probability models to explain off-farm employment participation in developing countries, they provide useful insights on the direction and magnitude on the impact of different factors. However they are principally based on cross-sectional information and ignore some unobserved characteristics that may affect participation in off-farm employment. Additionally, little is known on the effects of off-farm work on farm performance and vice versa. Goodwin and Mishra (2004) analyzed the relationship between farming efficiency and off-farm labor supply and found a negative relationship between them, resulting in the fact that farmers who are more efficient on their farm are likely to supply less labor outside the farm.

On the other hand, more intensive participation in off-farm jobs reduces farming efficiency and farm output. Pfeiffer et al. (2009) explored the effects of off-farm work in agricultural production activities in Mexico using a national representative rural household survey. Their results suggested that off-farm income has a negative effect on crop production through a direct negative effect on labor supply on farm. However, off-farm work may increase the use of purchased inputs, resulting in slight effect on total factor productivity. Within the same perspective, the current study seeks to assess the determinants of off-farm employment and its impact on agricultural output in the context of a rural area of a developing country.

4.3.3. Conceptual Framework

The conceptual model for labor supply by farm households is essentially the one suggested by Singh et al. (1986), and then by Hallberg et al. (1991), where farm households are expected to allocate available time to both off-farm and on-farm work. For the purpose of this study, we follow Owusu et al. (2011); Phimister and Roberts (2006); Goodwin and Mishra (2004), and Nehring et al. (2013) to illustrate the conceptual framework of the farm household's labor allocation. As a rational consumer, the farm household maximizes utility function (*U)* subject to consumption of goods (*C*), budget (*Y*) and time (*T*) constraints. A single individual household must decide on the balance between on-farm work and off-farm work (L_o) in order to maximize utility. He may also decide not to work on both on- and off-farm and enjoy leisure moment (L_h). Therefore, the farmer's problem may be written as:

$$\text{Max } U(C, L_h) \tag{4.7}$$

Subject to

$$C=P_y Y+w_oL_o - w_fL_f - P_x X +R \tag{4.8}$$

$$Y=f(X, L_f) \tag{4.9}$$

$$L_h+L_o+L_f =T \tag{4.10}$$

Where, C - consumption, L_h – leisure, P - the price for market goods, P_y – the price for farm output, Y - farm output, w_o and w_f are wages for off-farm and on-farm labor, respectively, L_o and L_f are endowment of labor off- and on-farm, respectively, X stands for other inputs, R represents other exogenous income, and T denotes the total time endowment. The optimal allocation for farm work, off-farm work and leisure can be easily derived by setting the first order conditions from a Lagrangian equation. Thus, the supply function for farm work can be given by:

$$L_f = L_f(w_o, w_f, P_y, P_x, Z) \quad (4.11)$$

Likewise, the supply function for off-farm work is given by:

$$L_o = L_o(w_o, w_f, P_y, P_x, R, Z) \quad (4.12)$$

Where Z represents a vector of household and location characteristics that affect farm and off-farm labor supply.

4.3.4. Econometric Strategy

The purpose of this study is to explore the determinants of off-farm employment in the study area on one hand, and assess its impact on agricultural output on the other hand. First, we use panel data to estimate Eq. (4.12); thereafter, attempts will be made to account for the impact of off-farm work to agricultural output using Eq. (4.6) of which off-farm work appears among explanatory variables. Pfeiffer et al. (2009) noted that under the perfect market household model the impact of off-farm income will be only on the consumption side, and farm households would make production decisions independently from consumption decisions as well as a labor supply plan. However, imperfect markets in rural areas are the rule rather than the exception, and it is hypothesized that production and technical efficiency may depend on off-farm work, and off-farm work depends on agricultural production (Lien et al., 2010).

It is assumed that consumption and production decisions among the sample households are not separable in the study area. Therefore, the effect of off-farm work will not only affect consumption side, but also the production component as by earning more off-farm, farmers may increase their production capacity by paying more on hired labor. This makes agricultural production and off-farm work to be simultaneously determined in a non-separability case. The empirical strategy suggested here will tackle the problem of endogeneity that may occur between off-farm employment and agricultural output. Besides, there exists agricultural production and off-farm work heterogeneity that must be dealt with. As noted earlier in this chapter, there are a number of unobserved variables that affect agricultural production such as soil type, weather, pride of being a farmer, luck, and others.

Similarly, attitudes towards off-farm work and the preference for off-farm jobs are not observable and cannot be captured as explanatory variables. The use of panel data for both models is believed to correct this heterogeneity problem. The method used here is similar to one adopted by Lien et al. (2010), and consists of a system of equations to describe both agricultural production and off-farm employment as follow:

$$y_{1it} = f(x_{it}, y_{2it}, z_{it}^{p}; \beta) + a_i + \mu_{it} \tag{4.13}$$

$$y_{2it} = h(z_{it}, y_{1it}; \delta) + c_i + v_{it} \tag{4.14}$$

Where y_{1it} is output for farm i at time t, x_{it} is a vector of inputs, y_{2it} is off-farm work hours, z_{it}^{p} is a vector of control variables that affect agricultural output, and β is a vector of both technology and control variable parameters to be estimated; a_i is the unobserved heterogeneity and μ_{it} is the error term or exogenous production shocks that can increase or decrease output. In Eq. (4.14), y_{2it} stands for off-farm work as for Eq. (4.13), z_{it} is a vector of farm and farmer characteristics that affect off-farm labor supply, y_{1it} is agricultural output as for Eq.(4.13), δ denotes a vector of parameters to be estimated, c_i and v_{it} represent the unobserved heterogeneity and the error term respectively.

Being exactly identified, the above system of equation might be estimated by "two-stage procedure." Coming on off-farm equation 4.14, there is a truncation problem because not all farmers participated in off-farm work. The Random effects Tobit model will be estimated to account for the nature of data truncated at zero when no member from the household participated in off-farm work, while equation 4.13 will be estimated by fixed effects. For the first stage, we estimated the reduced form obtained from equations 4.13 and 4.14 using panel model accounting for household heterogeneity. In the second stage the predicted values of output (and of off-farm work) will be used to estimate the structural relationships in equations 4.14 (and 4.13) (Lien et al., 2010).

4.3.5. Data

The data used in this section comes from the farm household surveys in the study area in 1986 and 2012, respectively. Important descriptive statistics on the agricultural output model are presented in the previous section. The table 4.9 presents the mean statistics of the variables used for the off-farm employment model. The dependent variable is the number of hours worked in non-farm activities by all members of the family. The statistics show that the time devoted to off-farm employment is significantly higher in 2012. It rose from 58 hours per household per year in 1986 to 96 hours per household per year in 2012.

Other statistical differences are observed in the wage rates, the number of active household members, and the maximum education level of the head. The variable "wage" is included in the model because it is believed that increased wages outside the farm make off-farm employment more attractive, and a positive relationship is expected. However, a possible negative correlation is also expected in case the prevailing wage in the given area is affecting off-farm labor demand negatively, reducing participation in off-farm employment by the household members.

Table 4.9 Summary statistics by year for off-farm employment model

Variable	1986		2012	
	Mean	Std. Dev.	Mean	Std. Dev.
Total work hours per household per year	57.90	79.02	96.23	148.12
Daily wage rate	184.13	180.47	630	358
Active members	2.84	1.23	2.62	1.28
Adult females	1.45	0.79	1.41	0.87
Maximum education level	2.28	2.68	3.86	3.36
Farmer's experience	12.82	9.91	23.16	18.18
Gender of the head (1=male)	0.91	0.29	0.79	0.41

Source: author's calculation based on survey data

In our context, the daily wage increased from 184 Rwf per day in 1986 to 630 Rwf per day. The same positive correlations are expected from the number of active members, adult males, and from the education level of the head. However, the number of hours worked outside the farm will decrease with the large land holdings which necessitate more labor force from home. Besides, off-farm work requires a perfect mobility, and is likely to be correlated with male headship, and inversely correlated with age of the household head, and other things being equal.

4.3.6. Results and Interpretations

The random effects Tobit (two stages) results are reported in table 4.10, following the equation 4.14. The coefficients obtained on both models are statistically significant with expected signs. The results indicate that off-farm work in the study area over the past two and half decades is positively associated with the number of active population per family, education level, and the gender of the household head.

The population growth observed between the two periods of study has motivated the venture in off-farm employment; especially the rise in the active members per household significantly increased the supply of labor outside the farm. The same positive effects are observed on male headship. This may due to the fact that the off-farm labor market is more mobile in the study area, and men are more likely to participate than women. Most available employment opportunities in the study area such as help in construction, tea factories, or small commerce require at least basic literacy skills. This is confirmed by a positive correlation between off-farm work hours and the maximum years of education achieved by the household head.

On the other hand the number of adult females, farmer's experience, and minimum wage show significant negative correlations with off-farm hours worked. The result of women participation in off-farm work is consistent with the findings obtained by von Braun et al. (1991) during the study on commercialization of agriculture under population pressure in the same study area.

Table 4.10 Long-term determinants of off-farm work: panel model results

Independent variable	Tobit Random Effects		Two-Step Tobit	
	Extended (Balanced) (1)	Full sample (Unbalanced) (2)	Extended (Balanced) (3)	Full sample (Unbalanced) (4)
Constant	-183.013***	-242.766***	-1270.191***	-683.210***
	(62.944)	(49.259)	(325.843)	(166.517)
Wage	-0.145**	0.102	-0.144**	0.074
	(0.067)	(0.084)	(0.065)	(0.083)
Active members	55.122***	47.967***	43.166***	34.593***
	(11.314)	(12.281)	(11.492)	(12.296)
Adult females	-35.203*	-19.400	-43.135**	-15.580
	(18.816)	(18.769)	(18.488)	(18.420)
Maximum education level	8.292*	10.361***	5.795	9.053***
	(4.738)	(3.362)	(4.730)	(3.430)
Farmer's experience	-4.424***	-3.486***	-3.447**	-3.227***
	(1.414)	(0.796)	(1.397)	(0.787)
Gender of the head (1=male)	112.023**	114.052***	118.412**	98.224***
	(52.955)	(34.695)	(52.197)	(34.815)
Year dummy 2012	163.240***	76.388***	151.310***	84.806***
	(46.761)	(25.736)	(45.767)	(25.635)
Predicted values of log output	**-**	**-**	**116.883*** **	**51.978*** **
			(34.118)	(17.987)
Observations	325	525	322	499
Wald chi2	163.79	81.51	181.54	85.09
Prob>chi2	0.000	0.000	0.000	0.000

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. The dependent variable is the total off-farm work hours performed by all household members per year.

The negative and significant impact of the women's (minimal) share on off-farm work may be explained by the fact that women in the study area spend most of their time on childcare and housework, limiting their participation in off-farm work. The higher the farmer's experience, the less the number of hours worked outside the farm. All other things being equal, the most experienced farmers are more likely to stay on the farm. Treating farmer's experience as a proxy for farmer's age, this is also expected since employers in off-farm business would prefer younger people to old ones, and the same younger people (with little or no farming experience) are more likely to venture into their own business outside farming.

Table 4.11 Off-farm work and farm output: panel fixed effect results

Independent variables	Fixed Effects	2-Step Fixed Effects

	Extended (Balanced) (1)	Full sample (Unbalanced) (2)	Extended (Balanced) (3)	Full sample (Unbalanced) (4)
Constant	5.731***	4.745***	5.927***	5.625***
	(0.531)	(0.756)	(0.758)	(0.773)
Farm size (log)	0.125**	0.128**	0.118**	0.126*
	(0.059)	(0.065)	(0.060)	(0.065)
Labor (log)	0.488***	0.652***	0.483***	0.620***
	(0.076)	(0.088)	(0.081)	(0.084)
Capital (log)	0.168***	0.142**	0.144*	0.036
	(0.064)	(0.067)	(0.085)	(0.080)
Land quality				
2.Medium	-0.228	-0.026	-0.227	-0.012
	(0.162)	(0.174)	(0.163)	(0.165)
3.Poor	-0.418**	-0.167	-0.376**	-0.024
	(0.175)	(0.192)	(0.187)	(0.202)
Year dummy 2012	1.056***	1.071***	1.029***	1.100***
	(0.174)	(0.194)	(0.186)	(0.190)
Predicted values of off-farm hours	**-**	**-**	**0.0002**	**0.001****
			(0.000)	(0.001)
Number of observations	323	499	322	498
R-squared	0.562	0.461	0.569	0.477
F-statistic	32.12	17.50	31.20	15.75
Prob>F	0.000	0.000	0.000	0.000

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. The dependent variable is the logarithm of agricultural output value, reported are coefficients, and robust standards errors.

The daily wage is negatively correlated with off-farm work hours. Two reasons may explain this negative association: first, the increase in the daily wage paid to casual or permanent workers in the study area may demotivate farmers and off-farm employers to hire additional workers, thus reducing the demand for labor. Second, the increase in the minimum wage may increase leisure time because workers may still achieve their level of utility by working fewer hours outside their own farm.

The predicted values of output show a positive and significant contribution of farm output on off farm work in the study area. We could not find a convincing explanation of this phenomenon at the moment, but as the dependent variable “hours of off-farm work” does not distinguish between the types of off-farm employment, one may think that this causality occurs in cases when farmers intend to create their own business outside the farm, like small commerce, construction, and other such operations which require some preliminary investment. The latter are only possible through the revenues generated from agriculture. This assumption may be reasonable because, in the study area, there is a possibility of perfect substitution between hired and own labor on farm. Besides, the abundance of household labor may facilitate participation in off-farm jobs, without compromising agricultural production. This result contrasts with similar previous findings (Lien et al., 2010) and can be viewed as a special case in a densely populated rural area.

The results presented in Table 4.11 (Model 3&4) suggest a positive correlation between off-farm work and agricultural output with the expected sign. The result in (4) shows a significant impact of off-farm employment on agricultural output. Though there is still little off-farm employment opportunities in the study area, they are likely to generate income to boost agricultural production through the purchase of additional inputs. Labor, land and capital are still viewed as the main factors of agricultural production in the study area characterized by decreasing returns to scale. However, there is much evidence that off-farm employment and agricultural production evolve in the same direction in the study area.

4.4. Impact of ICT Adoption on Agricultural Output

4.4.1. Introduction

The rationale of this section is to investigate the impact ICT on agricultural output and income levels. Nowadays, ICTs are meant to include equipment that facilitate capturing, processing, display, and transmission of information such as computers (and their accessories), telecommunication equipment (and related services), and audio visual equipment and services. In the context of this study, we consider telephony (the use of cellular phones by farm households) as a proxy of ICT adoptions due to its outstanding role to facilitate improved access to information and communication on one hand, and to play as prerequisite to advanced technologies use such as internet on the other (Torero and von Braun, 2006).

Studies have stressed the leading role of ICTs in economic growth and development at both micro and macro levels. ICT has become a foundation of every sector of every economy, everywhere (Kramer et al., 2007) because of its multifaceted role in expanding economic opportunities such as reducing transaction costs and increasing productivity, enhancing the flow of information, increasing choice in market place and widening the geographical scope among other benefits. Goyal

(2013) proved that ICTs can make a difference by closing information gaps, and by empowering smallholders and improving market opportunities for farmers. According to von Braun (2010), ICTs may positively impact the poor's livelihoods by increasing their access to markets, improving the quality of public goods and services provision, improving human resources quality, and facilitating effective utilization of social networks. More specifically, cellular telephone technologies are believed to boost economic growth through job creation, increased agricultural and industrial productivity, and diffusion of innovation among farmers. However, much more skeptical views in respect to the benefits of ICTs to the poor have emerged. They postulate that access to (or adoption of) ICTs is itself driven by a number of factors such as education, income, and wealth. Consequently, the shortage or lack of the above resources may prevent the poor from ICTs adoptions, widening the information gap and increasing income disparities within and between countries (Torero and von Braun, 2006; von Braun, 2010).

Recent statistics show that more than 45 percent of Rwandan households use mobile phone technology in their daily activities (NISR, 2012). The Government of Rwanda believes that ICTs can open doors to more economic opportunities for rural poor; efforts have been put in ICT investments over the past decade. The e-Rwanda Project funded by the World Bank and implemented by the Rwanda Information Technology Authority intends to empower rural farmers and enable full access to information about market prices and successful farming. With a network coverage of about 80 percent of the whole territory, even farers from very remote areas can use their mobile phone devices to check on agricultural commodity prices and can take better price decisions concerning their produce. In the study area, more than 42 percent of district households own a mobile phone and 32.7 percent walk less than 20 minutes to reach the nearest public phone. However, though much is said about the role that mobile phones can play in agricultural development in Rwanda, no attempt has been taken to measure the extent at which this technology has impacted the level of output, fertilizer use, and household income among smallholders. This study will refer to current survey data to measure these impacts. In the following subsections we consecutively present the ICT strategies in Rwanda, the relevant literature, empirical strategy, data description, results, and subsequent interpretations.

4.4.2. Rwandan ICT strategies

The institutions and mechanisms to create an enabling environment for ICT development in Rwanda were established in 2000. Today, the most prevalent technologies in Rwanda are internet services, mobile applications, outsourcing, information security, clouds computing, and green ICT that aims at creating awareness of increasing environmental regulation. The National ICT strategies are adopted and implemented in five-year phases under the "National Information and Communication Infrastructure (NICI)" designation and coincide with the main policy document "Vision 2020." The NICI I (or NICI-2005 Plan) was adopted in 2001 and its main focus was to create an enabling environment to the growth of ICT sector in Rwanda through establishment of sound institutional and legal framework. The second phase of ICT strategy (NICI II or NICI-2010) was adopted in 2006 and aimed at providing outstanding infrastructures that will support the future of ICT requirements (Rwanda, 2011).

The current phase of the strategy (NICI III or NICI-2015 plan) was adopted in 2011 and is being implemented with a special emphasis to improve ICT service delivery to the citizens. More specifically, as a pre-final phase of the ICT strategy that will drive the country towards its vision 2020, the NICI III targets high skill and knowledge based-ICT, ICT-enabled private sector development, e-Government, and cyber security.

In order to accomplish these missions, the government of Rwanda has set a number of attainable objectives that include capacity building in ICT and enabling improved access to education and training, fostering innovation through research and development, developing a private-led competitive ICT sector, creating ICT awareness in communities, and increasing citizen participation and access to services through ICT-enhanced systems. In addition, through the NICI-2015 plan, the government intends to increase transparency and accountability through ICT, to establish a legal environment enabling easy adaptation to emerging technologies, and to ensure total protection of Rwanda's ICT infrastructures and systems against cyber-attacks. From these missions and objectives, a number of implementable projects have been designed and some are in their execution phases (Rwanda, 2011).

The NICI-2015 is being implemented under a strong multi-stakeholder framework where the Rwanda Development Board (RDB) is designated as the coordinating and implementing agency of all ICT-related initiatives. The strategic directions are provided by the National Steering Committee chaired by the Ministry in charge of ICT (MINICT). Through this partnership, Rwanda believes to obtain important and quantifiable measures of ICT contributions to the GDP.

4.4.3. Relevant Literature

A number of studies have emerged over the last decade on the relevance of mobile phone usage on economic welfare in developing countries. Aker (2010) found that the expansion of network coverage accompanied by the intensive use of mobile phones by local traders in Niger have significantly reduced market disparities and improved market performance. It is believed that mobile phone adoption in Sub-Saharan countries have had a positive impact on agriculture and labor market efficiency even though empirical evidences on this matter are still thin (Aker, 2008; Aker and Mbiti, 2010).

Mittal et al. (2010) found that farmers use mobile phones as a means of communication to check on the availability of inputs and market prices, resulting in higher crop yields because of better adjustment of supply to market demand. Similar effects have been observed with fishermen who registered a decrease in losses due to full market information. Mwakaje (2010) analyzes the impact of access to ICT, including radios, telephone, internet, and newspapers by rural farmers from Rungwe village in Tanzania and found that farmers who used mobile phones in their activities have sold more quantities and at better prices than others. However, the same study pointed out that access to ICT facilities is constrained by a lack of money income and electricity.

Evidence from Uganda confirmed that the mobile network expansion enhanced market participation for producers of perishable products such as bananas (Muto and Yamano, 2009). Regarding the determinants of mobile phone adoption, Muto and Yamano (2009) found that the household head age, the level of education of both males and females adults, and farm asset values are the most important determinants of mobile phone acquisition in Uganda. Younger household heads are likely to adopt the mobile phone technology, and this also increases with the level of education and household assets. Evidence from Rwanda showed that mobile phone ownership is associated with wealth, education, and gender (Blumenstock and Eagle, 2010).

Okello et al. (2011) analyzed the drivers of ICT use by smallholder farmers in Kenya, and found that mobile phone adoption is driven by farm and farmer characteristics, capital endowment and regional characteristics. All other things being equal, the use of mobile phone is positively correlated to male headship, education, income and assets and negatively correlated with the family size and age of the household head. Kirui et al. (2012a) found that the use of mobile phone-based money transfer services in Kenya has impacted agricultural production among smallholder farmers because farmers use the remitted funds to purchase inputs, equipment and to pay hired labor.

Houghton (2009) analyzed the impact of mobile phone use on agricultural productivity in selected developing nations using a two-stage regression model. The micro-data results showed that mobile phone ownership significantly increase agricultural productivity at household level in Swaziland, Cambodia and Honduras. In their study on mobile phone and economic development in rural Peru, Beuermann et al. (2012) found that the use of mobile phone has significantly contributed to household income consumption, and reduced extreme poverty by five percent in the area during the study period. The use of mobile phone by smallholder farmers in Oyo State in Nigeria (Bolarinwa and Oyeyinka, 2011) have enhanced a full-time access to extension services and increased agricultural output more than non-mobile phone users. Chong et al. (2009) also confirmed that the level of income per capita was higher for households with access to telephone services.

4.4.4. Theoretical issues on ICT economy

The markets for information technologies such as cellular phones, fixed telephone lines, and internet are distinguished from markets for other products by their so called "ICT-specific features." They include complementarities, lock-in and switching costs, network externalities and important scales of production (Shy, 2001).

First, the complementarity feature of information technologies means that consumers in these markets are supposed to shop systems instead of a single product. For example, access to the internet requires a computer, a telephone line, and an internet provider; that is a complementarity of products that must operate under the same standards. Major problems may arise from coordination of different actors to confirm the product standards. Second, new technologies are linked with a locked-in effect. Once a given technology is adopted, consumers are reluctant to shift to a new technology due to associated transaction costs. Switching costs include new contracts negotiations, training and learning a new technology, data conversion costs, etc. Then consumers are locked-in using a specific product and this reduces the competition among ICT markets. Third, consumption or network externalities emerge as a special feature of ICT-related products because utility derived from their consumption is a function of the number of other people using the same products. Unlike other simple consumable products, ICT products such as internet, telephone services are only adopted if consumers have full information about other people who have subscribed to them. Similarly, other ICT equipment is purchased if consumers are aware of other people using the same equipment. Fourth, information products exhibit significant economies of scales. The cost of production of the first copy is substantial, but the following copies are very cheap. The declining tendency of the average cost function with the number additional copies sold results in non-existent competitive equilibrium in ICT-related products markets.

The rational market equilibriums depend on the nature of the market outcome and consumers' expectations (Shy, 2001; Torero and von Braun, 2006). Due to the non-existent competitive equilibrium in network product and services markets (market failure), natural monopolies prevail. Most governments used to license telecommunication services, such as telephony, that require huge initial investments, to a single company for the entire country (or within a region in some cases). Nevertheless, due to asymmetric information, telecommunication companies' lobbying inflationary behaviors, government regulation failed to observe the true production costs, and the services were relatively poor. Henceforth, the efficient use of infrastructure is obtained by providing access to the available infrastructure to all competitors at a reasonable access price. However, this is still a threat for poor countries with very low initial infrastructure and low penetration rate, making it more likely for a natural monopoly to persist (Noam, 2001; Torero and von Braun, 2006).

Therefore, government intervention is still needed for developing countries to address community isolation in rural and remote areas and ensure access to information at the community level at least (Shy, 2001). At the national level, people will benefit from advanced ICT technologies with information on employment and investment opportunity. At the local level, ICT provides people with relevant information about market prices, education, health, and other social services. Directly, the use of technology (like cellular phone) by farmers may help them reduce their intermediary costs and increase profits when they use it for example to obtain daily market prices. The same benefit may still be enjoyed if the technology exists in a nearby community or district where the data can be transmitted to village by hard copy or by word of mouth. Indirectly, the poor can benefit from ICT use by their relatives working in the capital city while sending money to the village.

Finally, ICT is used in poverty-reduction programs from which the poor benefit (Torero and von Braun, 2006).

4.4.5. Empirical Strategy

Measuring the impacts of ICTs on rural households' welfare can be done through different methodologies. The frequently used techniques are compensating variations, willingness to pay, consumption functions, and matching (von Braun, 2010). To analyze the impact of mobile phone on outcomes such as agricultural output, fertilizer use, and household income, we start from a linear function:

$$Y_i=\beta_0+\beta_1X_i'+\beta_2M_i+\varepsilon_i \qquad (4.15)$$

Where Y_i is agricultural output, X_i is vector of inputs, M_i is a binary variable (M=1 if the household owned a mobile phone during the past 12 months preceding the survey), and βi are unknown parameters to be estimated. Even though mobile ownership from the equation (4.15) is treated as exogenous, it may also happen that households with higher agricultural output and income are likely to own a mobile phone. Then mobile phone ownership is not random and an estimation of this equation by simple OLS will yield biased estimates. As pointed out by Owusu et al. (2011) the Heckman two-step procedure has been used in many applications to correct the selectivity bias but it relies on restrictive normality assumptions. The instrumental variable (IV) technique as a second alternative is more demanding when it comes to finding a good instrument and revealing itself difficult to apply.

To solve the selectivity bias associated with mobile phone ownership, we employ the propensity score matching (PSM) developed by Rosenbaum and Rubin (1983). Compared to the techniques described above, the PSM requires no assumptions about the functional form in specifying the relationship between outcome and outcome predictors (Ali and Abdulai, 2010; Owusu et al., 2011). As a non-experimental method, the PSM is judged suitable to a non-randomness of mobile phone adoption in our sample (Abebaw and Haile, 2013; Spreeuwenberg et al., 2010) and we will employ statistical matches to address the self-selection problem. The idea behind the PSM is to identify non-adopters who are similar to adopters in their observed characteristics. The first step is to estimate by Logit model, the propensity score or the predicted probability that a farm household own a mobile phone such that:

$P(Z_i) = Prob(M_i=1 | Z_i),$ (4.16)

Where M_i=1 if the household own a mobile phone, and M_i=0 otherwise; Z_i is a vector of observed personal, household and farm characteristics susceptible to influence mobile phone adoption. The next step of the PSM consists of selecting the best matching estimator which does not eliminate too many of the original observations in the final matching and tries to provide equal covariate means for households in the treatment and control groups (Austin, 2009; Caliendo and Kopeinig, 2008).

Our principal concern is to answer the following question: What would be the level of agricultural output, and household income in case the households had adopted mobile phone technology? To answer this question, we will use the predicted propensity score from equation (4.16) to estimate the treatment effects. Following Ali and Abdulai (2010), Abebaw and Haile (2013); Owusu et al. (2011), the average treatment of the treated (ATT), which is in our case the average impact of mobile phone adoption on agricultural output, fertilizer use and income, is given by:

$$ATT = E\left(Y_{1i}^{k} - Y_{0i}^{k} \mid M_i = 1 \right) = E\left[E\left\{ Y_{1i}^{k} - Y_{0i}^{k} \mid M_i = 1, P(Z_i) \right\}\right]$$

$$= E[E\left\{ Y_{1i}^{k} \mid M_i = 1, P(Z_i) \right\} - E\left\{ Y_{0i}^{k} \mid M_i = 0, P(Z_i) \right\}] \quad (4.17)$$

Where Y_1 and Y_0 are the values of treatment variables of mobile phone adopters and non-adopters respectively; *i* stands for household; *k* refers to outcome variables being analyzed such as output, and household income.

The PSM is hereby employed as a probability that a farmer adopts mobile phone technology given pre-adoption socio-economic characteristics. In the absence of experimental data, the PSM technique uses the conditional independence assumption (Burke et al.) to create the conditions of randomized experiment (Ali and Abdulai, 2010). This means that mobile phone technology adoption is random and uncorrelated with the outcome variables if Zi are controlled for (Imbens and J.M., 2009). The literature suggests a number of algorithms that the adopters and non-adopters of mobile phone technology with similar propensity score. The most widely used include the nearest neighbor matching which tries to match close adopters with the most close non-adopter with similar characteristics, caliper matching which uses the nearest neighbor within each maximum propensity score and the kernel matching method which tries to use more non-adopters for each adopter in order to reduce variance (Kirui et al., 2012b; Owusu et al., 2011). However, a hidden bias may arise when the matching estimator is not robust (Rosenbaum, 2002). This problem is solved by controlling a large number of covariates to minimize the omitted variable bias. The sensitivity analysis is carried out in order to check how robust our estimates to hidden bias are.

4.4.6. Data Description

The data used in this section come from the 2012 survey carried out in 364 households from Nyabihu district. Table 4.12 compares means of key characteristics of mobile phone adopters and non-adopters.

Table 4.12 Descriptive statistics of sample households by mobile phone adoption

Variable	Non adopters (51 percent)	Adopters (49 percent)	t-value for mean difference
Age of the head	46.72	41.73	3.07***
Gender (% male)	75	82	-1.57
Off-farm job (1=yes)	43.5	56.2	-2.42**
Institutional membership (1=yes)	68.8	71.3	-0.52
Farm size in hectares	0.40	0.46	-0.95
Assets in Rwandan francs (current)	193,836	289,610	-2.95***
Education	4.2	5.5	-4.46***
Output value (current Rwf)	125,578	207,916	-2.69***
Household income (expenditure)	289,207	409,808	-4.01***

* p<0.10, ** p<0.05, *** p<0.01

We use only wave of data from 2012 because mobile phone technology use is recent in Rwanda. No farm household used mobile phone in 1986. About 49 percent were using mobile phones at least 12 months before our visit in 2012 and they were principally households with relatively younger heads. Mobile phone adopters work more outside the farm than non-adopters on average, and are relatively richer.

The levels of household asset, income, and output of mobile phone users are significantly higher than those of non-users. In addition, the summary statistics show that mobile phone users are more educated (5.5 years of schooling) than non-users (4.2 years). This may be due to the fact that the manipulation of mobile phone devices requires basic knowledge of at least one foreign language (English or French). This limits less educated people from adopting such technologies in rural areas. The latter prefer to use public phone services where dealers operate the devices on their behalf.

Statistics also show that male-headed households are more likely to use mobile phone technology in agriculture than female-headed households.

4.4.7. Empirical Results and Discussion

As mentioned earlier, the point of departure to implement the propensity score technique is to calculate the propensity scores through a Probit or a Logit estimation of the treatment variable on control variables. Table 4.13 reports Logit results on the determinants of mobile phone adoption on household level.

Table 4.13 Logit results of household level determinants of mobile phone adoption

Variable	Coefficients	Robust Standard Errors
Age of the head	-0.017**	0.008**
Gender (% male)	-0.139	0.313
Off-farm job (1=yes)	0.096	0.244
Institutional membership (1=yes)	0.034	0.251
Farm size in hectares (log)	0.048	0.116
Assets in Rwandan francs(log)	0.215**	0.101**
Education	0.105**	0.042**
Constant	-2.199*	1.294*
Number of observations	332	
Wald chi2	24.80	Prob>chi2: 0.0008
Pseudo R-squared	0.0613	LR=-215.97

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. The dependent variable is binary and equals 1 if a household has a mobile phone and equals zero otherwise.

The age of household head, household assets, and the head level of education are important factors to enhance mobile phone use in the study area. All other things being equal, old household heads will reduce the log odds of adoption of mobile phone use by 0.017. However, there is a positive correlation between asset value and mobile phone use on the one hand, and a significant positive relationship between education level of the head and the probability of mobile phone adoption on the other.

Table 4.14 shows the matching statistics. The results indicate that mobile phone services have a positive and significant impact on agricultural output value and household income (here household expenditure stands as income proxy). Both Kernel-based and radius or caliper matching algorithms indicate that the level of agricultural output value is 38-42 percent higher for mobile phone users than their counterparts, while the level of household income is 26-27 percent higher for mobile phone users. These results are those expected since farmers who use mobile phones are likely to have access to information and stay informed on the availability of inputs and markets prices or both inputs and output. They can also get easier access to extension services than non-users, which enable smoothness in production activities. With full information on prices, farmers know the best options to sell their produce and maximize profits from their agricultural crops. Hence, their agricultural income is higher.

Table 4.14 Impact of mobile phone use on output and income

Matching algorithm	Outcome indicator	Treated (N=163)	Control (N=169)	ATT T-statistics (.)	ATT (%)	Critical value of hidden bias
Kernel-based matching	Output value	201,348	145,919	55,429* (1.66)	38	1.52-1.53
	Household income	419,680	333,801	85,878***(2.70)	25.7	1.16-1.17
Radius matching	Output value	201,348	141,680	60,135* (1.80)	42.4	1.41-1.42
	Household income	419,680	329,251	90,429***(2.86)	27.4	1.22-2.23

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. T-values are indicated between brackets, ATT is the average treatment effect of the treated.

We tested the conditional independence assumption (CA) after propensity score matching. Table 4.15 indicates a substantial reduction bias in propensity score covariates after matching (more than 50 percent in each). Except the education level of the head, the mean differences on covariates between the mobile phone users (treated) and non-users (control) after matching were not statistically different. The figure 4.2 shows that the mobile phone users and non-users were within the region of common support, indicating that all treated households (mobile phone users) have got corresponding untreated households (non-mobile phone users) with similar characteristics. The quality of matching is judged good as all individuals could be successfully matched and the bias reduction is far above the threshold of 20 percent (Rosenbaum and Rubin, 1983).

The sensitivity analysis results also presented in the last column of table 4.14 indicate that our propensity score matching results on output value are more robust to hidden bias than household income. The critical level of gamma (Γ), at which the causal inference of significant impact of use of mobile phone may be questionable is comprised between 1.52 and 1.53 meaning that, the significance of average treatment effect for output would be questionable only if the odds of mobile phone adoption for two households with similar characteristics differ by the factor of 53 percent. Likewise the significance of average treatment effect on household income will be questionable if the odds of mobile phone use between two households with the same vector of characteristics differ by the factor of 23 percent. Across two different matching algorithms, the lowest critical value on output ATT is 1.41 and the highest is 1.53 while for household income ATT, the small critical value is 1.16 and the highest is 1.23.

Table 4.15 Test of matching quality of covariates

Variable	Unmatched/ Matched	Mean Treated	Mean Control	%bias	% reduction bias	t-test
Head age	Unmatched	42.12	47.91	-35.5		-3.23***
	Matched	42.12	43.01	-5.2	85.3	1.46
Gender	Unmatched	0.82	0.75	18.6		1.69*
	Matched	0.82	0.80	4.2	77.6	-0.88
Off-farm job	Unmatched	0.56	0.45	23.0		2.10**
	Matched	0.56	0.53	6.3	72.8	-1.13
Institutional membership	Unmatched	0.72	0.67	10.7		0.98
	Matched	0.72	0.73	-1.8	83.2	-0.38
Log asset	Unmatched	11.94	11.43	38.7		3.52***
	Matched	11.94	11.79	11.4	70.5	-1.43
Log land	Unmatched	-1.34	-1.49	13.6		1.24
	Matched	-1.34	-1.41	6.7	50.9	-0.48
Education	Unmatched	5.41	4.09	45.4		4.14 ***
	Matched	5.41	5.06	12.3	73.0	-1.97**

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. Results presented in this table are based on Kernel-based matching algorithm

The results suggest that large amount of hidden heterogeneity will not alter the inference about the estimated treatment effects on output, while the treatment effects on household income are sensible to large amounts of hidden bias. However, Ali and Abdulai (2010) pointed out that the main purpose of propensity score matching is to balance the distribution of relevant variables between the groups (here mobile phone uses and non-users) rather than obtaining a precise prediction of selection into treatment. In this regard, the overall indicators of matching before and after matching presented in table 4.16 confirmed the results presented in table 4.15 above that the large absolute mean reduction was obtained after matching indicating the balancing power of our estimates.

Figure 4.2 Distribution of propensity score

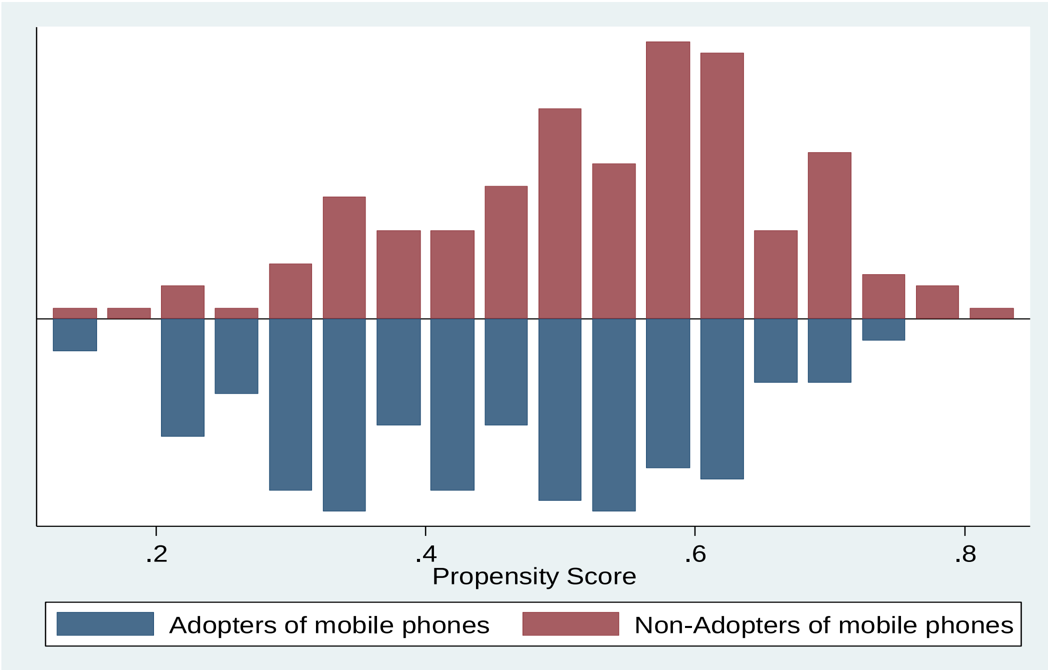


Table 4.16 Indicators of matching quality before matching and after matching

Matching algorithm	Outcome	Mean absolute bias (unmatched)	Mean absolute bias (matched)	Absolute bias reduction (%)	Pseudo R2 (unmatched)	PseudoR2 (matched)	LR p-value (unmatched)	LR p-value (matched)
KBM	Output	26.2	8.3	68.3	0.061	0.015	0.000	0.454
	Income	28.2	9.8	65.2	0.074	0.027	0.000	0.134
RM	Output	26.2	10.9	58.4	0.064	0.007	0.000	0.924
	Income	28.2	12.4	56	0.074	0.016	0.000	0.521

KBM: Kernel-based matching; RM: Radius matching

The pseudo R-squared is lower after matching and the likelihood ratio tests before and after matching indicate that the joint significance of regressors is always rejected after matching, while it couldn't be rejected before. We conclude that for the two outcomes of interest (output value and household income) there were no systematic differences in the distribution of covariates between mobile phone users and non-users after matching.

4.5. Conclusion to Chapter Four

In this chapter the drivers of agricultural output growth over time have been assessed in the study area. The findings from Cobb-Douglass function estimation suggest that factors such as labor, capital, land, and land quality are the key drivers of output growth in the study area. The respective 10 percent increase in land, labor and capital results in respective 1.3, 5, and 2 percent increase in gross output, all other things being equal. This result contrasts other previous findings on agricultural production relationships in Rwanda (Ali and Deininger, 2014; Clay et al., 1996; von Braun et al., 1991) and other developing countries (Cornia, 1985; Deininger and Okidi, 1999; Koffi-Tessio, 2004; Mundlak et al., 2012; Rasmussen, 2011; Tripathi and Prasad, 2009). However, over the past two and a half decades, agriculture has been characterized by decreasing return to scales, with a substantial decrease in land and capital elasticities, whereas the elasticity of labor has multiplied threefold over the same study period. This effect is attributed to high population growth in the sample area (88 percent increase) and continuing land scarcity.

The persistent land scarcity coupled by high population growth has resulted in off-farm employment expansion which has shifted the hours worked outside the farm from 58 hours in 1986 to 96 hours on average per household in 2012. The Tobit regression results suggest that the prevailing daily wage, the number of adult females and farmer's experience (farmer's age) are negatively associated with off-farm hours, whereas the total active members, maximum education level achieved and male headship are positively correlated with off-farm work. The simultaneous behavior between off-farm work and agricultural output is also evident. The two stages Tobit estimation indicates that off-farm hours increase by the level of agricultural output, probably because off-farm businesses themselves need to be established from crop sales revenues. Hence, agricultural production may not be substituted to off-farm employment expansion, but policies must target them simultaneously.

Finally, the findings suggest substantial impact of cellular phone technology adoption by farm households. Using propensity score matching, we find that agricultural output for mobile phone users is at least 38 percent higher than non-users, whereas their income levels are 26 percent higher on average. The provision of network infrastructure and electricity at community level will enhance agricultural and rural development through increased adoptions of tele-communication technology by smallholder farmers.

Chapter 5: INTERGENERATIONAL MOVEMENT OF WEALTH AND POVERTY

5.1. Introduction

The concept of wealth mobility, commonly known as "income mobility", is still unsettled because it connotes different things to different people. Disagreement between different researchers arise from the fact that there exist at least 20 mobility measures that have been used in literature and a distinction needs to be made between time independence, positional movement, directional movement of income, and mobility as an equalizer of longer-term incomes (Fields, 2008). Many empirical studies measure income mobility into quintiles, some estimate correlation coefficients between base-year and final year income (Atkinson et al., 1992), while others prefer to calculate intergenerational elasticities when the interest is on the intergenerational mobility (Solon, 1999). Studies on income mobility generally depart from a set of question such as: which country, society or group of people is more or less mobile than the other? Has mobility been raising or falling over time within a country? The answer to these questions depend on which mobility concept is used (Fields, 2008).

For their most informative interpretation, two concepts of income mobility are retained for this study: the positional movement which is about the movement of individuals among various quintiles of income (or wealth) distribution, and the time independence concept, which is about the calculation of intergenerational elasticities measuring how the current income (wealth) is dependent on the past income. The latter is materialized through regression of the log-income and wealth of the child on the log-income and wealth of parents (Fields, 2008, 2010). The discussion will also be brought about the extent of intergenerational transmission of poverty between parents and adult children, using the recent national poverty line based on annual household expenditure per adult equivalent.

5.2. Relevant Literature

Inheritance and own work are two major channels to become rich (Piketty, 2011). In the past, the transferability of wealth from parents to children through inheritance contributed to the persistent inequality across generations. More altruist parents were supposed to make more savings in order to secure their children's future consumption and welfare (Piketty, 2000). Since the nineteenth century, evidences show a pronounced U-shape pattern in the aggregate inheritance flow in most developed countries. This implies that, though labor income and hard work play a substantial role in people's wellbeing, patrimonial-based wealth still has much to play in the coming century (Piketty, 2011; Piketty and Saez, 2014).

Academic pursuits on intergenerational transmission of income and poverty among people dates back to Harrington (1962) statement:

"*… the real explanation of why the poor are and where they are is that they made the mistake of being born to wrong parents, in the wrong section of the country, in the wrong industry, or in the wrong racial or ethnic group*" (Harrington, 1962, p.21).

However, the question of whether adult children attain the same status as their parents remains not fully answered (Corak, 2014). Empirical evidences show that intergenerational transmission of earnings varies across parents, income groups or societies, with the level of economic development and changes in policies and institutions (Corak, 2014; Peters, 1992).

In the study on intergenerational mobility in income and earnings in the United States, Peters (1992) found that parents' higher income are associated with children's higher income, for both sons and daughters. Solon (1992) used intergenerational data from the Panel Study of Income Dynamics to analyze the extent of income mobility in the United States and has found an intergenerational income correlation of at least 0.4 portraying a much less mobile society. Chadwick and Solon (2002) used the same data set to investigate the extent of intergenerational income mobility among daughters with a special attention to the role of assortative mating. Their results showed a positive and quite substantial correlation between daughters' earnings and parents' earnings; but the intergenerational elasticities were slightly lower for daughters than the elasticities obtained for sons by other researchers.

Using the first seven waves of the British Household Panel Study and the retrospective family history, Ermisch and Francesconi (2001) found a very strong association between parental education and adult child educational attainments. Besides, educational attainments of children from poor families or who experienced a single parenthood in the past were found to be lower than those whose parents were in the top income quartile and home owners at some extent. Similar studies have found significant impact of parents' income on children outcomes such as college enrollment (Acemoglu and Pischke, 2001), educational attainment and high school graduation (Akee et al., 2008), and on completed schooling (Duncan et al., 2010). Compared to rich parents, poor parents are unable to make better investments for their children. Consequently, children of poor parents are subject to lower scores in schools, behavior problems, drop out, and poverty when they are adults (Mayer, 2010). Therefore, new born health and postnatal investments are crucial to children outcomes because life at birth deteriorates along with socio-economic conditions of people at the bottom of income distribution (Aizer and Currie, 2014).

Mulder et al. (2009) analyzed the intergenerational wealth transmission comparing the degree of transmission of different types of wealth (material, embodied and relational) among small-scale societies of hunter-gatherers, horticulturalists, pastoralists and agriculturalists. Their results indicated substantial differences in intergenerational transmission among economic systems and the types of wealth. They argue that material wealth, which is importantly higher in agricultural and pastoral societies, is more heritable than embodied and relational wealth. This results in a substantial inequality among agriculturalists and pastoralists, which roots from the ancient time (Pringle, 2014). The study also found a complementarity of technology and institutions effects in determining the intergenerational transmission of wealth among small scale societies (Mulder et al., 2009).

In the study on intergenerational wealth mobility in rural Bangladesh, Asadullah (2012) found the father-son wealth elasticity to be higher than the intergenerational elasticities obtained in developed countries, confirming very low mobility and persistence of poverty and inequalities in developing countries. Using data from retrospective records on households, and controlling for individual's age, employment, education, religion and sex, it was also indicated that differential schooling is an important source of substantial persistence of wealth across generations of the same family in rural Bangladesh.

Beyond parental transmission, Abebaw and Admassie (2014) found that extreme poverty based on household expenditure, calorie intake, and household assets is positively correlated with household size, and inversely associated with the household head's education, livestock ownership, and other farm assets. They also indicate that poverty may persist if people keep staying far away from community infrastructure such as roads, health and education facilities.

Studies on intergenerational income mobility and poverty have been relevant for policy making in the last three decades, but much still needs to be done to explain the differences obtained in intergenerational associations at different times and in different countries (Lee and Solon, 2009). Besides, most of the studies relied on incomplete data without enough information on each individual across generations, suggesting imprecise estimates. Although research on intergenerational mobility have been carried out in many developed countries of North America and Europe, and in some developing countries, these are not enough evidence to ascertain the extent of intergenerational movement of wealth and poverty in Rwanda, where such studies are still very rare.

The study on transient poverty in Rwanda by Muller (1997) was limited to the estimation of transient chronic poverty indices and showed the extent at which standards of living of peasants are impacted by seasonal fluctuations in agricultural production. De Walque (2009) suggested the importance of nurturing female human capital for better educational outcome of children, while recent studies on Rwandan economic mobility (Justino and Verwimp, 2012; Verpoorten and Berlage, 2007) focused on poverty impact of the violent conflict and economic convergence of rural households over time, without tackling the dimension of intergenerational mobility. With a unique data set spanning for a 26-year period following the same parents and their offspring, this study is intended to go beyond simple poverty and inequality measurements and sort out the degree of transmission of wealth and poverty across generations in rural Rwanda.

5.3. Conceptual Framework

The work of Gary Becker (1976, 1988) has provided new tools for microeconomic analysis and modeling of economic family, drawing economists into areas which were formerly reserved to sociologists and demographers. For years, a number of studies have been conducted by sociologists and economists on economic mobility and income distribution; but Becker's analysis was quite distinctive by integrating the utility maximizing behavior in resources allocation among families (Goldberger, 1989). The economic approach to social interactions views individuals as members of large families whose members span several generations (Becker, 1976; Becker and Tomes, 1979). Under such circumstances, members are expected to contribute to the family income and care of children supposed to continue the family in the future. As rational utility maximizers, parents allocate optimally their resources between consumer goods and investment in human and nonhuman capital of children and other family members. The theory of human capital approach to inequality also recognizes that, when children grow up, their income will depend not only on that investment, but also on their natural endowment and on their luck in market.

The conceptual framework of this study follows the model developed by Becker and Tomes (1979), and revisited by Goldberger (1989) and Solon (2004) on intergenerational mobility. It is assumed that the utility function of a parent (U_i) depends on his own consumption ($C_{i,t-1}$) and investment ($I_{i,t+1}$) in his child. The parent's income constraint can be formulated as:

$$Y_{i,t-1} = C_{i,t-1} + I_{i,t+1} \tag{5.1}$$

Where, $Y_{i,t-1}$ is the parent's income, and the equation 5.1 referred to as the parent's budget constraint. The investment in human and nonhuman capital of a child will produce a child's income Y_{it} with a rate of return r. After including the luck component L_i in child's income (wealth);

$$Y_{it} = (1+r)\, I_{i,t+1} + L_i \tag{5.2}$$

The equation 5.2 shows that parents can change the wealth of their children by investing more in their human and nonhuman capital, and Y_{it} is considered as the sum of total amount invested in children measured in physical units, plus the amount from their endowed capital, plus the capital gain due to luck in the market (Becker and Tomes, 1979). When a parent has full knowledge of the future child's luck in the market, he maximizes his own Cobb-Douglas utility function (Goldberger, 1989; Solon, 2004) of the type:

$$U_i = \alpha \log Y_{it} + (1-\alpha) \log C_{i,t-1} \quad ; 0<\alpha<1 \tag{5.3}$$

The altruism parameter α measures the parent's taste for child's investment related to his own consumption. If the parent is cognizant of equations 5.1 and 5.2, the utility function can be reformulated as:

$$U_i = \alpha \log((1+r)\, I_{i,t+1} + L_i) + (1-\alpha) \log (Y_{i,t-1} - I_{i,t+1}) \tag{5.4}$$

The first order condition to maximize utility is

$$\frac{\partial U_i}{\partial I_{i,t+1}} = \frac{\alpha(1+r)}{(1+r)I_{i,t+1}} - \frac{(1-\alpha)}{Y_{i,t-1} - I_{i,t+1}} = 0 \tag{5.5}$$

Solving for the optimal choice if $I_{i,t+1}$yields

$$I_{i,t+1} = \alpha Y_{i,t-1} - \frac{(1-\alpha)}{(1+r)} L_i \qquad (5.6)$$

Substituting equation 5.6 into 5.1 and solving for optimal parent's consumption yields

$$C_{i,t+1} = (1-\alpha) Y_{i,t-1} - \frac{(1-\alpha)}{(1+r)} L_i \qquad (5.7)$$

The intuitive implication behind the above results is that, holding public investment constant and with no distinction between before and after tax income, parents with higher income invest more in their children human capital, which in turn increases with parental altruism α (Solon, 2004). By substituting equation 5.6 into 5.2, we obtain the income transmission rule:

$$Y_{i,t} = (1+r)\alpha Y_{i,t-1} + \alpha L_i \qquad (5.8)$$

Setting $(1+r)\alpha = \beta$; we get the intergenerational income regression frequently estimated by empirical researchers:

$$Y_{i,t} = \beta Y_{i,t-1} + \alpha L_i \qquad (5.8b)$$

Where β is the propensity to invest in children or commonly "intergenerational elasticity". It increases with higher heritability, more productive human capital investment, and with higher earnings return to human capital. It measures the percentage change in child's income with respect to a marginal percentage change in the income of the parent (Björklund and Jäntti, 2009).

5.4. Econometric Strategy

The model presented above (eq. 5.8b) has been applied in most of the existing studies on intergenerational transmission of wealth, and it mainly measures the association of child's status and his/her father. Therefore, following Asadullah (2012); Chadwick and Solon (2002); Moonen and Van den Brakel (2011); Mulder et al. (2009); Peters (1992); Solon (1992), and Zimmerman (1992), we estimate the following regression:

$$\textit{Child's wealth}_t = \beta_0 + \beta_1(\textit{Parent's wealth}_{t-1}) + \varepsilon_t \qquad (5.9)$$

Where ε_t is the random error term which could reflect the child's luck from market or choice of a marriage partner and any other environmental disturbance; β_0 captures the growth in income that is independent of parents' income; β_1 measures the systematic relationship between parents' and children's income; t denotes the children's generation while the parents' generation is denoted by $t-1$. When both children's and parents' wealth is measured in logarithm terms, the ordinary least squares (OLS) estimate β_1 indicates the transmission elasticity, while it indicated only the degree of generational persistence in wealth across generations (Asadullah, 2012), but it gives no clues about the mechanisms underlying the persistence of wealth. The smaller β_1 is, the greater the mobility in the society (Peters, 1992).

It is important to note that other various factors such as government expenditures and family background characteristics may determine the intergenerational link in economic status between parents and children. Wealth and income are function of human capital investment in children, and wealthier parents are most likely to invest more in their children schooling, enhancing their future wealth, while children from poor parents stay relatively poor as a result of low education. Asadullah (2012) and Mulder et al. (2009) mentioned the importance of demographic characteristics such as age and household size, which determine the intergenerational division of some important assets in rural areas like land holdings. On estimation of intergenerational elasticity as per equation 5.9, the errors-in-variables bias may lead to inconsistency when data on parents' income or wealth are collected for many repeated waves. This errors-in-variable bias is reduced by measuring parental status through averaging parents' log income (log wealth) over the years (Chadwick and Solon, 2002). An alternative strategy suggested by Solon (1992) is the instrumental variable estimation where parent's education serves as an instrument to parent's income, even though a debate is still ongoing on the validity of this instrument among intergenerational mobility researchers.

The unique dataset used in this study is free from the above-mentioned problem, because it only consists of two waves. To avoid potential endogeneity in our estimation, we control for a number of observable variables for both children and parents. Therefore, the following equation has been estimated by OLS:

$$ChildW_t = \beta_0 + \beta_1 ParentW_{t-1} + \beta_2 child'sAge_t + \beta_3 child'seduc_t + \beta_4 otherchild'scharact_t + \beta_5 otherparent'scharact_{t-1} + Errorterm_t \qquad (5.10)$$

Where $ChildW_t$ and $ParentW_{t-1}$ are child's and parent's wealth, respectively. The distinction is made between income and wealth regressions on one hand and between landholding and livestock regressions as major components of household assets (wealth) in the study area on the other hand.

Likewise a Probit model of poverty transmission was estimated following Björklund and Jäntti (2009); Ermisch et al. (2001); Ermisch et al. (2004); Jenkins and Siedler (2007) as follows:

$$Child's\,poverty_t = \alpha_0 + \alpha_1 Parent'spoverty_{t-1} + \alpha_2 otherchild'scharact_t + \alpha_3 otherparent'scharact_{t-1} + Errorterm_t \quad (5.11)$$

The child's and parent's poverty status is a dichotomous variable taking the value of one if a child (parent) household is poor and of zero otherwise. The Rwandan poverty line of 118,000 RWF calculated in 2012 (NISR, 2012) using adult equivalent expenditure and expressed in constant prices (base: 1986) was used to identify poor and non-poor households in the study area.

However, the estimates of children-parents correlations do not provide a measure of mobility as positional change. In this regards, the intergenerational transition matrices technique which yields the probability of son reaching a particular wealth status for a given status of the father (Asadullah, 2012) is used here and intergenerational matrices showing the rank mobility of income (expenditure), landholding, livestock and total assets are presented early before the regression results. As matrix approach is only descriptive, accompanying statistics or indices were also computed in order to measure mobility in terms of time dependence. The indices computed are the Prais index, Atkinson et al. immobility ratio, determinant index, and average jump index. The first three indices are referred to as "aggregate measures of mobility". The Prais index is defined as (n-trace of M)/(n-1), where M is the transition matrix and n is the number of rows (columns). Atkinson immobility ratio focuses only on the principal diagonal and adjacent entries and is insensitive to the movement outside the principal diagonal when people go to the third or fourth quartiles (Atkinson et al., 1992). Prais index and Atkinson immobility ratio vary with the number of quintiles and the time period. The immobility ratio is higher for the short time period (Asadullah, 2012). The determinant index is defined as $1-|M|^{1/(n-1)}$. Both Prais and determinant indices converge to unity when there is perfect mobility in a given society. The average jump index is an individual cell-related measure and calculates the mean number of quintiles moved in absolute values. It is defined as: $AJ = \frac{1}{q}\sum_{i=1}^{q}\sum_{j=1}^{q}|i-j|P_{ij}$ where AJ is Average Jump, q is the number of quintiles, P_{ij} is the transition rate on row i and column j.

5.5. Data

As for the previous chapters, the data set used in this chapter is the unique panel data that spans for a 26-year period. Particularly in this chapter, we link 200 offspring to their 164 original households for intergenerational mobility analysis in order to apprehend the degree of association between children's wealth (poverty) and their initial (parents') wealth (poverty). Table 5.1 indicates the summary statistics of key variables used in the regression, focusing on 200 split-off households and initial 164 households. It is important to recall that offspring households under consideration in this study are those separated from original households to form their own families.

Table 5.1 Summary statistics of key variables on parents (1986) and their offspring (2012)

Variable	Parents (1986) N=164		Offspring(2012) N=200	
	Mean	Std. Dev.	Mean	Std. Dev.
Total annual expenditure in (Rwf , constant)	62, 159	39,449	80,948	62,304
Farm size in hectares	0.76	0.67	0.37	0.54
Total livestock units	0.73	2.43	0.71	0.83
Livestock value in Rwf (constant)	22,687	55,784	16,972	24,137
Household asset value (Rwf, constant)	23,956	56,514	28,105	33,667
Household size	5.71	2.14	5.25	1.90
Poverty head count (percent)	58	50	41	49
Off-farm job (percent)	54	50	54	50
Head age	42.37	13.61	34.42	7.10
Years of schooling	2.28	2.68	4.34	3.17
Gender of the head (percent of male)	91	0.29	89	0.32
Marital status (percent of married)	-	-	92	28

Source: Author computation based on survey data.

The summary statistics show smaller landholdings and livestock ownership for offspring (2012) than their parents (1986). However, adult children exhibit higher consumption expenditure (income), household asset values, education level (years of schooling), and hence, lower poverty rate. All split-off households in the study area resulted from marriages.

5.6. Empirical Results and Discussions

As mentioned earlier in this chapter, intergenerational elasticities cannot alone explain the mechanisms underlying the transmission of wealth and poverty across generations. I start with some basic statistics measuring poverty and inequality in the sample population over time. Second, the intergenerational mobility will be explained through transition matrices and indices before I present the OLS regression results from equations 5.10 and 5.11.

5.6.1. Basic Poverty and Inequality Indicators

The extent of poverty and inequality is indicated by classical index. For the sake of simplicity , we calculated the poverty headcount index and the Gini coefficient of inequality for adult equivalent expenditure, landholding, livestock and total assets values.

Table 5.2 Key poverty and inequality measures

Measure	Old sample 1986 (N=164)	Full sample 2012 (N=364)	Continuing households 2012 (N=164)	Offspring only 2012 (N=200)
Poverty rate (adult equivalent expenditure)	57.9	40.1	39.0	41.0
Extreme poverty rate	0.61	7.11	6.11	7.50
Gini coefficient (adult equivalent expenditure)	0.24	0.39	0.40	0.38
Gini coefficient (consumption expenditure)	0.27	0.37	0.38	0.36
Gini coefficient (land)	0.38	0.56	0.54	0.56
Gini coefficient (Tropical Livestock Unit)	0.67	0.43	0.46	0.39
Gini coefficient (household asset)	0.65	0.56	0.57	0.54

Source: Author computations based on household data.

Following the national poverty line defined by the National Institute of Statistics of Rwanda (NISR, 2012), extremely poor are referred to as households whose annual consumption expenditure per adult equivalent is less than 45,000 Rwf (or 4,950 Rwf in constant 1986 prices). Poor households are those whose annual household expenditure per adult equivalent is less than 118,000 Rwf (or 12,980 Rwf in constant terms). Despite the tremendous increase of population in the sample area over the past two and a half decades, there has been a decrease in the proportion of poor households from 58 percent in 1986 to 40 percent in 2012, a rate which is relatively closer to the national absolute poverty rate of 44.9 percent. The rate of poverty is smaller in 2012 if only continuing households are considered (39 percent). Continuing households are hereby defined as original households that stayed in the sample until the 2012 survey. However, the increase in extreme poverty (from less than one percent in 1986 to 6 percent for continuing households and 7 percent for the full sample in 2012) has resulted in increase in income inequality over time. The Gini index rose from 0.24 in 1986 (a relatively fair income distribution) to 0.40 in 2012 (an unequal distribution of income or expenditure). Similarly, the increased inequality in land distribution which is the principal source of wealth and livelihoods will result in the persistence of poverty in the area, because most land is obtained through inheritance.

5.6.2. Intergenerational Transition Matrices

Intergenerational transition matrices are helpful to understand the overall relationship between children's and parents' wealth (Black and Devereux, 2011). As noted earlier, they indicate the probability of a child to be in a given wealth quintile given the initial parent's quintile. A careful look on matrices presented in Table 5.3 on household expenditure, landholdings and other assets without land provides basic insights on extent of intergenerational mobility. We should recall that the sum of probabilities within each row must sum up to one.

The upper matrix shows the intergenerational mobility of income (expenditure) across two generations. The probability for adult children to be in any income quartile given the initial income (expenditure) quartile for the last 26 years is comprised between 13 and 35 percent (and principally converge in the neighborhood of 25 percent); a good indicator of the potential mobility of income (expenditure) across generations in the study area. The probability for a child from a poor parent to stay poor in the next generation is 35 percent, while 22 percent of cases are likely to stay relatively rich.

The next matrix is about intergenerational transition in landholdings, the most important inherited asset in the study area. The results indicate that 46 percent of offspring are meant to be landless (bottom land quartile) mainly if their parents were also landless in 1986. About 58 percent fall in the first and second quartiles (less than 0.4 hectare) when their parents were in the second quartiles, and about 26 percent of children who own more than 1 hectare of land originate from parents who were also in the top quartiles in 1986. Persistence in land ownership is evident. Similarly, the bottom matrix shows intergenerational transition of assets other than land. One may also suspect the persistence of wealth across generations, especially for the richest households since 41 percent of children originating from poor households remain poor. About 70 percent of offspring whose parents were in the top asset quartiles in 1986 are also positioned in the top asset quartiles in 2012.

Table 5.3 Intergenerational (father-child) transition matrices

Parent's Expenditure, 1986	Offspring's expenditure, 2012				Total
	Bottom quartile	Second quartile	Third quartile	Top quartile	
Bottom quartile	0.35	0.26	0.22	0.17	1
Second quartile	0.22	0.32	0.25	0.20	1
Third quartile	0.13	0.28	0.26	0.32	1
Top quartile	0.29	0.24	0.25	0.22	1
Parent's land, 1986	**Offspring's land ownership, 2012**				**Total**
	Bottom quartile	Second quartile	Third quartile	Top quartile	
Bottom quartile	0.46	0.29	0.20	0.05	1
Second quartile	0.35	0.23	0.12	0.30	1
Third quartile	0.24	0.31	0.16	0.28	1
Top quartile	0.24	0.28	0.22	0.26	1
Parent's assets, 1986	**Offspring's assets, 2012**				**Total**
	Bottom quartile	Second quartile	Third quartile	Top quartile	
Bottom quartile	0.41	0.25	0.19	0.15	1
Second quartile	0.16	0.31	0.24	0.29	1
Third quartile	0.21	0.32	0.28	0.19	1
Top quartile	0.14	0.16	0.35	0.35	1

Source: Author calculations based on survey data. Figures are the percentage of households being in a given quartile

The accompanying indices presented in Table 5.4 indicate the overall mobility measures. As mentioned earlier, the Prais and Determinant indices converge to unity when there is a perfect mobile society. From the Table 5.4 below, the intergenerational indices are close to unity, portraying the existence of substantial mobility in landholding and other assets across households in the study area. Income (expenditure) mobility is also evident. The results from Atkinson et al. immobility ratio need be compared to the mobility ratio obtained under perfect mobility where the probability of being in given range is independent of initial status (Atkinson et al., 1992). For the current case study where income and wealth are subdivided into quartiles, the probability of a child to be in a given quartile must be 25 percent in order to add up to one or 100 percent in each row.

Table 5.4 Intergenerational transmission indices

Index	Consumption Expenditure	Land ownership	Household Assets
Prais index	0.95	0.96	0.88
Determinant index	0.93	0.88	0.86
Atkinson immobility ratio	0.68	0.67	0.72
Average jump index	1.14	1.12	1.02

Source: Author calculations based on survey data.

Therefore, the Atkinson et al. immobility ratio under perfect mobility, taking the average of cases on principal diagonal and adjacent cases, would equal to 62.5 percent. Comparing this result with the Atkinson at al. immobility ratio obtained in table 5.4, one can foresee the apparent mobility of wealth and income across generations in the study area.

5.6.3. OLS Results on Intergenerational Transmission of Wealth and Income

Table 5.5 reports the OLS regression results on intergenerational wealth and income mobility. Estimates are robust to heteroscedasticity and misspecification. Of each of the five models, the null hypothesis that all the regression coefficients equal zero is rejected at 1 percent level. The signs obtained on different transmission elasticities and other control variables are as expected and our results confirm the previous findings on intergenerational transition matrices on the small degree of parent-child's wealth and income associations.

Model (1) relates the log of child's income (expenditure) as a dependent variable to the log parental initial income (expenditure). After controlling for other family characteristics for both children and parents, we find little evidence of income (expenditure) persistence across generations in the study area.

Table 5.5 OLS results on intergenerational transmission of income and wealth

Independent variables	(1) Expenditure	(2) Land	(3) Livestock	(4) Total assets	(5) Farm assets
Parent's expenditure (log)	**0.175***				

	(0.106)				
Parent's land (log)		**0.290****			
		(0.124)			
Parent's livestock value (log)			**0.201****		
			(0.100)		
Parent' total assets (log)				**0.231*****	
				(0.062)	
Parent's farm assets (log)					**0.085**
					(0.085)
Household size	0.009	0.104**	0.194***	0.067	0.047
	(0.025)	(0.048)	(0.068)	(0.065)	(0.048)
Farm size	0.358***	-	0.316**	0.490***	0.407***
	(0.090)	-	(0.157)	(0.174)	(0.101)
Head education	0.017	0.047	-0.026	0.041	0.068***
	(0.015)	(0.031)	(0.037)	(0.028)	(0.025)
Off-farm job	0.097	0.060	0.239	0.408**	0.343**
	(0.094)	(0.169)	(0.232)	(0.180)	(0.156)
Head age	0.079	0.093	0.056	0.130	0.028
	(0.058)	(0.112)	(0.151)	(0.105)	(0.084)
Head age squared	-0.001	-0.001	-0.001	-0.001	-0.000
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Head gender	0.280*	0.745*	0.142	1.086*	1.038**
	(0.145)	(0.431)	(1.160)	(0.581)	(0.410)
Marital status	0.027	-0.668	0.389	-0.298	-0.446
	(0.180)	(0.493)	(1.291)	(0.598)	(0.487)
Parent's age	-0.008**	-0.010	-0.029***	-0.035***	-0.019***
	(0.004)	(0.008)	(0.010)	(0.009)	(0.007)
Constant	7.274***	-3.895**	5.930**	4.449**	6.829***
	(1.451)	(1.958)	(2.634)	(1.915)	(1.641)
Observations	200	196	131	175	176
R-Squared	0.192	0.141	0.175	0.306	0.276
F-Statistic	5.59***	3.33***	3.85***	6.43***	5.69***

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. The dependent variables in all models (1-5) and their corresponding lagged or parents' variables are expressed in logarithms. Robust t-statistics are reported between brackets.

The transmission elasticity of income (expenditure) is small (0.175) and marginally significant. Children income is more likely determined by the size of landholding than their parents' income. The results in model (2) suggest a degree of persistence in farm size across generations, but the transmission elasticity of land is very small. Ten percent increase in the parent's landholding is associated with 3 percent increase in the child's land. Despite the high degree of inheritability associated with land, and its substantial role in agricultural production and livelihoods sustainability in the study area, children cannot obtain sufficient land from their parents due to large families.

Model (3) indicates the results on intergenerational transmission of livestock, using the logarithm of livestock values for both children and parents. As a major component of household assets, its transmission across generations is also evident but at low degree. The transmission elasticity of livestock from parents to children is statistically significant at five percent level, indicating that 10 percent increase in parent's livestock is associated with 2 percent increase in child's livestock. Both farm size and family size indicate positive and statistically significant correlation with livestock value.

Similarly, model (4) considers the parent-child's total assets (without land) relationship. The intergenerational transmission elasticity is also relatively low (0.231) indicating that about 2.3 percent of children's asset variation come from the initial parent's assets. Moreover, evidence of perfect mobility is obtained on farm assets only (model 5), excluding both land and livestock. The transmission elasticity is very small (0.085) and lacks statistical significance. The high mobility in farm assets is due to the fact that most household's farm assets are mainly agricultural tools and equipment, households furniture and other durable equipment which are less likely to be inherited by adult children. Variations in child's farm assets are significantly attributed to the size of landholding, educational level of the head, participation in off-farm employment, and male headship of the household.

5.6.4. Probit Results on Intergenerational Transmission of Poverty

Table 5.6 reports probit estimations on intergenerational poverty transmission based on household consumption expenditure. Model (1) reports the correlates of absolute income (expenditure) poverty. The household is qualified to be absolutely poor (poverty=1) if its adult equivalent expenditure is below 118, 000 Rwf (the national poverty line set by the National Institute of Statistics in 2012). Parent's expenditure-based poverty in 1986 is positively and significantly associated with child's poverty in 2012. This means that children born from poor parents or suffering from poverty during their childhood have a high probability of staying poor in their adult age. Absolute poverty in the study area is also positively associated with large families or population growth, and negatively correlated with the size of landholding, and the number of livestock units available to the family.

Table 5.6 Probit estimations based on household consumption expenditure poverty

Variables	Model (1) Absolute poverty		Model (2) Relative poverty	
	Probit Coeff	Marginal effect	Probit Coeff	Marginal

	& SE		& SE	effect
Parent's absolute poverty	**0.625****	**0.165*****		
	(0.249)	(0.0636)		
Parent' relative poverty			**0.505****	**0.1413****
			(0.222)	(0.0610)
Household size	0.450***	0.1185***	0.457***	0.1279***
	(0.082)	(0.1629)	(0.079)	(0.0161)
Farm size	-1.027**	-0.271***	-1.016***	-0.2845***
	(0.429)	(0.1047)	(0.375)	(0.0994)
Head education	-0.003	-0.0007	-0.040	-0.0111
	(0.040)	(0.0105)	(0.037)	(0.0103)
Head age	0.041	0.0109	0.099	0.0278
	(0.173)	(0.0457)	(0.159)	(0.0443)
Head age squared	-0.001	-0.0002	-0.001	-0.0003
	(0.002)	(0.0006)	(0.002)	(0.0006)
Head gender	-0.878	-0.2419	-0.521	-0.1460
	(0.553)	(0.1503)	(0.561)	(0.1534)
Total livestock units	-0.514***	-0.1355***	-0.300	-0.0839
	(0.169)	(0.0418)	(0.211)	(0.0569)
Agricultural equipment (log)	-0.183*	-0.0483**	-0.249***	-0.0696***
	(0.094)	(0.0237)	(0.091)	(0.0243)
Marital status	0.367	0.0918	0.186	0.0515
	(0.662)	(0.1554)	(0.664)	(0.1820)
Distance to market in km	-0.009	-0.0023	-0.016	-0.0045
	(0.031)	(0.0083)	(0.030)	(0.0085)
Constant	-1.248		-1.663	
	(3.136)		(2.868)	
Observation	182		182	
Wald-chi2	46.98***		55.76***	
Pseudo R-Squared	0.290		0.284	

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. Reported are probit coefficients, marginal effects, and their corresponding robust standards errors.

Model (2) reports the correlates of household consumption expenditure-based relative poverty. In contrast to absolute poverty, relatively poor are households which fall in the two bottom quartiles of adult equivalent expenditure. The purpose is to compare poverty status between the sample households only, instead of taking a national representative indicator. Probit results confirm intergenerational transmission of expenditure-based poverty among farmers in the study area. The large family size increases offspring's probability of being poor. Expenditure-based poverty decreases significantly with increase in landownership and farm assets.

Table 5.7 Probit estimations based on household asset poverty

Variables	(1) Total asset-based poverty		(2) Farm asset-based poverty	
	Probit Coeff & SE	Marginal effect	Probit Coeff & SE	Marginal effect

Parent's poverty (total assets)	**0.620*** **	**0.2123*** **		
	(0.194)	(0.0609)		
Parent's poverty (farm asset)			**0.344***	**0.1095***
			(0.200)	(0.0628)
Household size	0.048	0.0163	0.151**	0.0488**
	(0.060)	(0.0203)	(0.062)	(0.01897)
Farm size	-0.809**	-0.277***	-0.735**	-0.2342**
	(0.322)	(0.1043)	(0.318)	(0.0969)
Head education	-0.050	-0.0172	-0.087***	-0.0277***
	(0.033)	(0.0112)	(0.032)	(0.0099)
Head age	0.002	0.0008	0.005	0.0015
	(0.133)	(0.0456)	(0.140)	(0.0445)
Head age squared	-0.000	-0.00003	0.000	0.0001
	(0.002)	(0.0006)	(0.002)	(0.0006)
Head gender	-0.445	-0.1562	-1.425**	-0.4189***
	(0.405)	(0.1422)	(0.562)	(0.1171)
Marital status	0.193	0.0647	1.473**	0.3451***
	(0.509)	(0.1654)	(0.646)	(0.0848)
Distance to market in km	0.014	0.0048	0.105***	0.0336***
	(0.030)	(0.0101)	(0.032)	(0.0092
Constant	-0.182		-1.950	
	(2.351)		(2.468)	
Observation	200		200	
Wald-chi2	23.67***		38.21***	
Pseudo R-Squared	0.109		0.179	

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. Reported are probit coefficients, marginal effects, and their corresponding robust standards errors. The limited dependent variable is poverty=1 if the offspring household is poor, and zero otherwise.

Similarly, Table 5.7 reports probit estimations of poverty transmission based on household assets. Compared to their neighbors in the sample, asset-based poor households are those whose asset values fall into the first and second asset quartiles. Model (1) is based on total asset-based poverty and model (2) on farm asset-based poverty.

The results in Model (1) suggest that total asset-based poverty is transmitted across generations. The coefficient of poverty transmission is highly significant at 1 percent level. On the other hand, results in Model (2) confirm the findings obtained previously on farm assets transmission in the study area. The coefficient (marginal effect) of parent's farm assets is marginally significant to explain variation in offspring's farm asset-based poverty. Asset poverty is negatively associated with household size, head educational level, and gender of the household head. The incidence of asset-based poverty is aggravated by large household size, and lack of easy access to local markets.

5.7. Conclusion to Chapter Five

In this chapter we assessed the extent of intergenerational mobility of wealth and poverty among rural households in Rwanda using a unique panel data set linking adult children families and their parents after 26 years. The transmission matrices and OLS regression results suggest strong income (expenditure) mobility and a relatively small persistence of assets across generations, especially on land and livestock considered as superior assets in the study area. Holding other factors constant, a 10 percent increase in parental landholding is associated with 3 percent increase in adult child's available land. Similarly, ten percent increase in the parent's livestock is associated with 2 percent in child's livestock. Compared to the findings from similar studies in other countries, the Rwandan community appears to be much less immobile in terms of assets (wealth) transmission. Table 5.8 compares our transmission elasticities with those obtained in other countries.

Evidences from probit regression show further a relatively small degree of persistence of poverty across generations. Despite the decrease in absolute poverty rate between the two periods of study, the increase in extreme poverty has resulted in high inequality among households and hence about 41 percent of all offspring families are also poor in 2012. Both parent's expenditure and asset-based poverty are likely to be transmitted to the children at adult age. However, the probability to inherit poverty is not very high in the sample area. The same results suggest that absolute poverty increases with household size and decreases with landholding, household head's education, and family assets and livestock. This result is consistent with previous findings by Abebaw and Admassie (2014) who found extreme poverty to be positively correlated with family size and inversely correlated with gender, education, livestock and farm materials in Ethiopia. The latter also suggested positive association of poverty with distance to infrastructure; which is again consistent with our findings on asset-related poverty.

Table 5.8 Comparison of income (wealth) transmission across countries

Author (year)	Country of study	Transmission elasticities			
		Income	Livestock	Land	Assets
Solon (1992)	US	0.41	-	-	-
Chadwick & Solon (2002)	US	0.35-0.49	-	-	-
Mulder et.al (2009)	Kenya	-	0.635	0.357	
	Tanzania	-	0.622		
	England	-	-	610	-

	Germany	-	-	0.642	-
	Turkmenistan	-	-	0.528	-
Asadullah (2012)	Bangladesh	-	-	-	0.535
Our findings (2014)	**Rwanda**	**0.175**	**0.201**	**0.290**	**0.231**

Source: Author compilation based on various authors.

These results have strong implications on poverty reduction and development strategies. Initial wealth distribution (especially land and livestock) is a key determinant of the wellbeing of future generations. Increasing access and providing equal opportunities to education and income generating programs will avoid the persistence of wealth across generations, which may result in poverty trap. Increased access to local infrastructure such as roads, education and health facilities will reduce people's marginality (and hence poverty) in the study area.

Chapter 6: GENERAL CONCLUSIONS AND POLICY IMPLICATIONS

The fight against poverty in Rwanda requires a special focus on agriculture which still remains a key sector for employment, food security, and growth. Currently, the sector has a relatively large share of the gross domestic product. However, little knowledge has been generated regarding the potential of agricultural production in Rwanda. The objective of this study was to analyze the long-term drivers of agricultural growth over the past two and a half decades in one North West and densely populated area of Rwanda.

The analysis of population patterns over time indicated that the sample population increased by 88 percent despite the substantial losses (33 percent). However, this loss is far below the expected natural loss of 40 percent, considering the prevailing death rates between two periods. Thanks to progresses made by Rwandan Government in health practices, water and sanitation, immunization programs at community level over the past one and a half decades. The pyramids of ages show larger bases, indicating the dominant share of children less than 15 years. This results in a very high dependence ratio, one of the major constraints to agriculture in the study area. The econometric analysis of fertility suggested that high population increase in the study area is positively correlated with household income and women age, and inversely correlated with women's education and age at first cohabitation. Children are viewed as normal goods in the study area, for whom demand increases by 3 percent on average as a result of ten percent increase in income, other things being equal. Since incomes from farm are likely to keep high the level of fertility, efforts should be made to revisit the age of first cohabitation, and promote women education in order to enhance rural women participation in labor force, and raise the cost of rearing children in Rwanda.

The impact of population growth on agricultural intensification, farm productivity and household welfare has also been investigated. Both cross section and panel regression results indicated that farm productivity and household welfare increase with family size and other demographic characteristics. Similarly to other findings, the study supports the Boserupian hypothesis on population-induced agricultural intensification in the study area. Other things remaining constant, one additional household member will increase input intensity and net farm income per hectare by 9 and 10 percent respectively. Nevertheless, all other things being equal, one additional member in the family would result in 0.2 percent decrease in total expenditure per capita. This negative impact of population growth on household welfare calls for a sound population policy in the study area.

Besides, the same results indicate an inverse relationship between farm size and productivity in the study area. This is due to the intensive labor use by small farmers and high amounts on inputs (fertilizers, labor and supervision costs, etc.) required on large farms. Ten percent increase in land size is associated with 7.3 percent decrease in net farm returns per hectare. In this regard, policies for agricultural and rural development in Rwanda should tackle the problems of land inequality and market imperfections that prevent optimal gains on large farms. The Boserupian population effect on land intensification and productivity may not prevail in the long run, if the pace of population keeps growing, without the possibility of land extension. Alternatively farmers should be helped to increase their productivity and incomes per hectare much faster than population growth.

The assessment of agricultural production relationships brought about the dominant role of labor, capital, land, and land quality in raising output in Rwanda. The panel model results have shown a decreasing returns to scale economies with substantial output elasticities of labor (0.48), followed by elasticities of capital (0.17) and land (0.13). The OLS results indicated that, compared to 1986, the output elasticity of labor has dramatically increased over the past two and a half decades, while the output elasticities of land and agricultural capital decreased. This result is not surprising considering land scarcity and population pressure constraint. However, the decrease in elasticities of land and capital is an indicator that population will not keep relying on agriculture in the near future. Even though labor force is the main determinant of agricultural output over time, the law of diminishing returns to labor may reveal that output will not continue to grow. To ensure the labor quality is necessary, but not sufficient to maintain food security in the long run. Within a continuing land scarcity environment, an off-farm exile is highly recommended in the possible medium run. The sustainability of rural life will rely more on vocational training programs at local level and other measures to increase household income, as a driver of agricultural intensification.

The factors leading to the expansion of non-farm employment in the area were evaluated. It was found that the higher daily wage, the high number of adult females, and high farming experience decrease the hours worked outside the farm. More employment opportunities are mainly accessed by males and most educated people. The simultaneous behavior between off-farm work and agricultural output was also evident. The two stages Tobit estimation indicated that off-farm hours increase by the level of agricultural output and vice versa. Hence agricultural production may not be substituted to off-farm employment expansion, but policies must target them simultaneously.

The final driver of agricultural output analyzed was Information and Communication Technology adoption, with a focus on recently cellular phone adoption by smallholder farmers. The analysis has shown that farmers who use mobile phones have reached higher levels of output and income than non-users. Cellular phone adopters achieved 38 and 26 percent more of agricultural output and household income respectively. However, access to mobile phone is itself driven by education level of the household head and household wealth. Relatively richer households are likely to acquire and use mobile phone, other things remaining unchanged. The maximum from ICT will be obtained if not only necessary ICT infrastructure is expanded in rural areas, but also if community illiteracy is carefully addressed. More importantly, facilitating access to credit markets will enhance asset acquisition at household level and, hence provide means to ICT adoption in rural areas.

Over the past 26 years, the rate of absolute poverty has decreased in the sample population. From 58 percent in 1986 to 40 percent in 2012, it is slightly below the national level of 44.9 percent. However, there has been substantial increase in inequality between these two periods. The Gini coefficient computed using adult equivalent expenditure rose from 0.24 in 1986 to 0.39 in 2012. Likewise, the Gini index for land inequality that was initially 0.38 shifted to 0.56 in 2012. This has strong negative impacts on agricultural production and poverty reduction. The only indicators that improved over time are livestock ownership and other assets in general. Their respective Gini coefficients have fallen from 0.67 and 0.65 in 1986 to 0.43 and 0.47 in 2012; thanks to the recent program to provide “one cow per poor family” in Rwanda, which needs to be strengthened and accelerated.

The results on intergenerational transmission on poverty and income among rural farmers in Rwanda are mixed. Both transition matrices and OLS results suggest a strong mobility in household income and a relatively small degree of persistence of land, livestock, and assets across generations. The reason is that income (or expenditure) is not as easily inherited as land and livestock. The latter has a high degree of inheritability by adult children from their parents. Hence, the initial parents’ land ownership and livestock matter for adult children’s land and livestock attainment in the study area. The intergenerational transmission elasticities of income, land, livestock, and assets are 0.17, 0.29, 0.20, and 0.23 respectively. The intergenerational transmission of poverty is also evident. The transition matrices indicated that about 35 percent of offspring originating from poor households in 1986 remain also expenditure-based poor in 2012. The persistence in land and asset-based poverty is substantial. About 70 and 65 percent of offspring fall in the first and second quartiles of land and asset respectively as their parents were initially found in bottom quartiles. Moreover 70 percent of offspring are located in the third and top asset quartiles in 2012 following their parents' location in the top quartile in 1986. Econometric results (Probit) confirmed intergenerational transmission of both expenditure and asset-based poverty in the study area, but their respective marginal effects are low. However, offspring's poverty in 2012 is also attributed to the increasing family size, and the lack of access to community infrastructure. Land, livestock, and assets ownership, as well as increased educational level of the household's head reduce significantly the probability of being poor.

Policy options should not only aim at controlling population growth, but also ensuring equal distribution of wealth for poverty reduction and rural development. Initial wealth distribution is a key determinant of the wellbeing of the future generations. Providing equal opportunities to education, increasing access to basic infrastructure and income generating programs will avoid the persistence of poverty across generations which may result in a poverty trap.

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APPENDIX

1. Determinants of Attrition

Table 2A Probit results on determinants of attrition

ATTRITION (1=Leavers, 0=Stayers)	Coefficients	z-values
Family Size	-0.061	-0.487
Head Age (years)	-0.028	-0.436
Head Age squared	0.000	0.595
Farm Size (hectares)	0.038	0.107
Log Capital Stock Value	-0.495**	-1.965
Log Gross Output Value	-0.061	-0.204
Log Total Expenditure per Capita	-0.817	-1.483
Calories per adult equivalent	0.000	1.229
Altitude of the House	0.001	1.148
Head education level	-0.177***	-2.748
Number of adult females	-0.198	-0.744
Cattle	-0.034	-0.423
Goats	-0.064	-0.764
Sheep	-0.064	-0.608
Number of off-farm jobs	0.026	1.034
Gender of the head	0.310	0.660
Land Tenure (1=own land)	-0.434	-1.465
Constant	8.815	1.641
Log likelihood	-52.01	Prob > chi2=0.001
LR chi2	40.62	Pseudo R2= 0.312
Number of observations	188	

* p<0.10, ** p<0.05, *** p<0.01

2. Research Questionnaire

DETERMINANTS OF LONG-TERM GROWTH IN AGRICULTURE IN RWANDA

Sept-Oct 2012

Questionnaire Number:		

Objective: The purpose of this survey is to make a long term analysis on household economic growth and development

Use of data: The data collected as part of this survey are for research purposes ONLY.

Household ID number:			

Old househoud Details, 1986

Name Former Head

Name of household head		
Name of respondent		
Location of house		Code:
Province	**WESTERN**	
District	**NYABIHU**	
Sector		
Cell		
Village		

	Latitude	Longitude	Altitude
Coord. House.			

Did you find and interviewed the hh ? 1. yes ; 2. no

Details :

Other Codes:

Not Applicable: -77 Would Not Say: -88 Don't Know: -99

	Date			Signature	Code
	Day	Month	Year		
Interview: Visit 1					
Interview: Visit 2					
Field check					
Data entry					
Enumerator Name					
Supervisor Name:					
Data Verifier Name:					
Data Entrant Name:					

SECTION 1: HOUSEHOLD INFORMATION ROSTER

HH ID | | | | |

Interested in all members of the household whose food (or other necessities) are supplied by the household head for at least 6 months a year.

A1	A2		A3	A4	A5	A6	A7	A8	A9a	A9b	A10a	A10b
Household Member ID	**Household Member Name** **Last Name**	**First Name**	**Relationship to HH head** *(use codes below)*	**Sex** **1 =Male** **2 =Female**	**Age** *(record 0 months if <1 year)* **Years**	**Marital Status** 1= Married 2= Single 3= Divorced/ Separated 4= Widowed	**Principal Occupation** *(use codes below)*	**Secondary Occupation** *(use codes below)*	**Number of years of school successfully completed**	**Education Level**	**Literacy** 1 Read only 2 Write only 3 Read & Write 4 Can't Read	**Literacy in which Language?** 1 =Kinyarwanda 2= French 3= English 4=Swahili 5=2 or more
1- HH												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

Relationship to HH

1 = Self (HH)
2 =Wife or Husband
3= Son/Daughter
4= Father/Mother
5 =Sister/Brother
6 =Grandchildren
7= Grandparents
8=Mother inlaw/ father inlaw
9= Daughter inlaw/son inlaw
10= Adopted Child
11 =Not Related
12= Other Relative (specify)________________

Occupation

1=Farmer
2=Farm home help (unpaid)
3=Non farm home help (unpaid)
4=Agricultural wage labor
5=Non agriculture wage labor
6=Self-employment outside farm
7=Student
8= Civil servant (government)
9= Unemployed /idle
10= Too young for school (6 yrs & below)
11= Other (specify)____________

Education 9b

1=Never been to school
2=Primary Incomplete
3=Primary complete
4= Pre-primary Vocational
5=Post-primary Vocational
6=Secondary incomplete
7=Secondary. complete
8=Higher education incomplete
9=Higher education complete
10= Adult literacy

SECTION 2: HOUSEHOLD CHANGES FROM 1986-2012 **Page 3**

HH ID | | | | |

Interested in all members of the household who moved away since 1986

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
when was your hh founded **Since …[Year]**	**Are there members of your hh who moved away since 1986?** 1=Yes 0= No	**If yes list their names**	**Year of departure**	**Location** *(District if in Rwanda, Country if abroad)*	**reason for Departure** 1= Empoyment 2= Marriage 3= Exile 4= Jailed 5= other (specify)	**Relationship to HH head** *(use codes below)*	**Sex** **1 =Male** **2 =Female**	**Is s/he still alive?** 1=Yes 0= No	**Marital Status** 1= Married 2= Single 3= Divorced/ Separated 4= Widowed	**Principal Occupation if stll alive** *(use codes below)*	**Number of years of school successfully completed**	**Education Level** *(use codes below)*	**was/is s/he sending money to the family of helping in other activities?** 1=Yes 0= No

Relationship to HH

1 = Self (HH)
2 =Wife or Husband
3= Son/Daughter
4= Father/Mother
5 =Sister/Brother
6 =Grandchildren
7= Grandparents
8=Mother inlaw/ father inlaw
9= Daughter inlaw/son inlaw
10= Adopted Child
11 =Not Related
12= Other Relative (specify)________________

Occupation

1=Farmer
2=Farm home help (unpaid)
3=Non farm home help (unpaid)
4=Agricultural wage labor
5=Non agriculture wage labor
6=Self-employment outside farm
7=Student
8= Civil servant (government)
9= Unemployed /idle
10= Too young for school (6 yrs & below)
11= Other (specify)____________

Education 9b

1=Never been to school
2=Primary Incomplete
3=Primary complete
4= Pre-primary Vocational
5=Post-primary Vocational
6=Secondary incomplete
7=Secondary. complete
8=Higher education incomplete
9=Higher education complete

SECTION 3 - AGRICULTURAL PRODUCTION **SEASON A/B**

PART A: CROP OUTPUTS AND INPUTS

HH ID				

1. We are interested in land operated and rented by your household.

	Area in square meters (m^2)	Total Rent for Season (RWF)
A1	A2	A3
1.a. How much land do you own including all plots?		
1.b. How much of your own land did you use for this season's agricultural production?		
1.c. How much land did you rent in/sharecrop in/borrow for this season's agricultural production?		
1.d. How much land did you rent out/sharecrop out/ lend for this season's agricultural production?		

2. What crops were grown on each plot in SEASON A?

Plot ID	What is the total area of this plot?	How much area of this plot was irrigated?	Cropping system in plot 1=Pure stand 2=Intercrop	What crops were planted on this plot during SEASON A? *see crop codes below*		What percentage of the plot area was under this crop? (%)	How much was harvested from this plot during the season? UNIT CODES: KILO...1 GRAM...2 SACK...3 BASKET.4 LITER..5 CUP....6 GALLON.7 BUNCH..8 BUNDLE.9 PIECES..10 DOZENS..11 BOTTLES.12 BAGS....13 BOXES...14 JUG.....15 DISH....16 OTHER...17			What was the Seed Type for this crop? 1=Local/ traditional 2=Improved	For the crop grown in this plot, how much did this household spend on SEED during this season? [estimate value of seed used] (RWF)	Did you apply manure to this crop? 1=Yes 0= No	For the crop grown in this plot, how much did this household spend on MANURE during this season? (RWF)	Did you apply chemical fertilizer to this crop? 1=Yes 0= No	For the crop grown in this plot, how much did this household spend on chemical fertilizer during this season?(RWF)	Did you apply any pesticides, herbicides or fungicides to this crop? 1=Yes 0= No	For the crop grown in this plot, how much did this household spend on pesticides, etc during this season? (RWF)	How many person-days of *household labor* were used in this plot during this season (account for weeding and ALL activities)?	How many person-days of *hired or shared labor* were used in this plot during the [season] *(account for weeding and ALL activities)*?	How were hired laborers paid ? 1= cash 2= in kind 3= other (specify)	What was the average daily wage paid to these hired laborers? *[estimate value if in kind]*	Where do most of your hired laborers for this crop come from?	how far is the plot from the household ? (min)
	Area in square meters (m^2)	Area in square meters (m^2)		Crop Name	Crop Code	(%)	Quantity	unit (see codes)	Equivalent in KG for ONE Unit Measure	[SEED]		[MANURE]		[CHEMICAL FERTILIZER]		[pesticides, herbicides or fungicides]		Number Days	Number Days		RWF (per day)	1 Same village 2 Same cell 3 Same Sector 4 Other (specify)	minutes
A1	A2	A3	A4	A5a	A5b	A6	A7a	A7b	A7c	A8a	A8b	A9a	A9b	A10a	A10b	A11a	A11b	A12	A13	A14a	A14b	A14c	A15

Crop Codes

1.Bush beans
2.Climbing beans
3.Runner beans
4.Peas
5.Groundnuts
6.Soybean
7.Sorghum
8. Maize
9. Sunflower
10.Wheat
11.Rice
12 Soft cassava
13 Bitter cassava
14.Sweet potato
15.Irish potato
16Taro
17.Banana for cooking/plantain
18.Banana for wine
19.Apple banana Kamara
20.Other apple banana
21.Eleusine
22.Yam
23.Cauliflower
24.Cabbage
25.Tomato
26. Carrot
27. Cucumber
28. Beetroot
29. Lettuce
30. Spinach
31. Garlic
32. Eggplant
33. Squash
34. Onion
35. Okra
36. Leek
37. Pepper
38. Celery
39. Parsley
40. Dwarf pepper
41. Pilipili pepper
42. Orange
43. Lemon
44. Mango
45. Guava
46. Passion fruit
47. Mushrooms
48. Pineapple
49. Strawberry
50. Papaya
51. Avocado ordinary
52. Avocado Hass
53. Japanese plum
54. Coffee
55. Tea
56. Pyrethrum
57. Tobacco
58. Sugarcane
59. Vanilla
60. Geranium
61. Macadamia
62. Morus sp.
63. Patchouli
64. Flowers
65. Ornamental trees
66. Currants
67. Vegetables dodo
68. Sombe (Cassava leaves)
69. Moringa
70. Pastures
71. Afforestation
72. Fallow
73. Land preparation
74. Other ___________

Note: **Person-days** are calculated by multiplying the number of workers by the number of days worked.

3. In addition to the temporary labor documented above, how many permanent farm workers did you have over the last 12 months (i.e. last 3 seasons) and what was their wage? (this excludes household members)

Payment	Number of Permanent workers	How many months did they work?	What was the average Monthly Salary per worker (RWF)
A1	A2	A3	A4
Cash			
In-Kind			

SECTION 4 (a) - AGRICULTURAL PERMANENT LABOR

Interseted in households members who did agricultural labor outside the family in the last 12 months

HH ID				

Household Member ID	**Specify the Type of Agricultural labor** ***(see codes on the right)***	**Where was the work done?** 1 Same village 2 Same cell 3 Same Sector 4 Other (specify)	**For who?** 1= another peasant 2= civil servant 3= trader 4=coops/ass 5=NGO 6=Government 7=other (specify)	**how many days was the work done during the last 12 months?**	**was the labor paid?** 1=Yes 0= No	**If Yes, How was the labor paid ?** 1=cash 2= in kind 3= other (specify)	**What was the average daily wage paid to this labor in RWF?** *[estimate value if in kind]*	**was the person doing the same work in 1986?** 1=Yes 0= No	**In the last 5 years, the time allocated to this labor:** 1=Increased 2= Remained the same 3= Decreased
A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**

Codes for A2, B2 and C1

Agricultural Permanent labor (on farm)

1= Agricultural saisonal labor
2= Agricultural permanent labor
3= agricultural occasional labor
4= Exchange of labor (par exemple *kuguzanya*)
5= Livestock keeping

Non Agricultural Wage labor (off-farm)

1= construction
2= Guardian or houseboy/girl
3= Driver
4=Mining
5= Teacher

(b) NON AGRICULTURAL WAGE LABOR Interseted in households members who did off-farm labor outside the family in the last 12 months

Household Member ID	**Specify the Type of labor** ***(see codes on the right)***	**Where was the work done?** 1 Same village 2 Same cell 3 Same Sector 4 Other (specify)	**For who?** 1= another peasant 2= civil servant 3= trader 4=coops/ass 5=NGO 6=Government 7=other (specify)	**how many days was the work done during the last 12 months?**	**was the labor paid?** 1=Yes 0= No	**If Yes, How was the labor paid ?** 1=cash 2= in kind 3= other (specify)	**What was the average daily wage paid to this labor in RWF?** *[estimate value if in kind]*	**was the person doing the same work in 1986?** 1=Yes	**In the last 5 years, the time allocated to this labor:** 1=Increased 2=Remained the same
B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**

(c) LAND TENURE & LAND MANAGEMENT

Interested in land tenure by households AND investment in land management over time: 1990-2012

C1	Do you have your own land (legally?) 1. yes 2.no	
C2	What is the major source of your land? 1. inherited 2. Purchassed 3. Gifted 4. other source	
C3	What amount of land have you purchased over the last 25 years (m2)	
C4	What amount of land have you sold over the last 25 years? (m2)	
C5	(If C4 applied), Why did you sold your own land? 1. subsistance consumption 2. social expenditure (baptism, funerals, weedings) 3. Debt repayment 4. Bad location of the land 5. wealth reallocation (house costruction, schooling expenditure, etc) 6 Bad quality of land 7. Old age and lack of manpower 8. Good market conditions 9. other reason	
C6	How do you judge the quality of your cultivated land (all plots in general) 1. Best quality 2. Medium quality 3. Worst quality	
C7	Have you utilized any technique if land conservation over the last 25 years? 1. yes 2.no	
C8	If yes, which technique of land conservation have you utilized?	
C9	From where did you get support for this practice?	
C10	How do you estimate the value of the technique (s) used (RWF)?	
C11	If you parterned with government or NGO, what is the percentage (%) of your own contribution?	

C8 Codes: 1. Radical terraces 2. Grass stips 3. Antierosion ditches 4. Hedgerows 5. fallow 6.

C9 Codes: 1. Self-support 2. Government 3. independent project or NGO 4. Myself and

(d) USE OF LAND IN GISHWATI FOREST

Interested in land OWNED or USED by households in Gishwati over time: 1990-2012

D1. Do you own (or use) land in Gishwati Forest today? 1. yes 2.no	
D2. If YES How big is the land owned (or used) in Gishwati Forest (m2)?	
D3. (if NO in D1), have you ever (or your relatives) used the land in Gishwati before? 1. yes 2.no	
D4. (if YES in D3), How big WAS the land owned (or used) in Gishwati Forest (m2)?	
D5. (if YES in D3), why don't you own (or use) the land in Gishwati today? 1. Bad quality 2. sold or given to others 3. Reforestation of Gishwati 4. I rented it out 5. My lease conract expired 6. other reason (specify)	

SECTION 5 - AGRICULTURAL PRODUCTION

PART A. AGRICULTURAL EQUIPMENT

HH ID				

1. What special agricultural equipment do you have and what is its value?

Equipment or tool	Do you own a […]? 1= Yes 0 =No	Total Value (RWF)	Equipment or tool	Do own a […]? 1= Yes 0=No	Total Value (RWF)	Equipment or tool	Do own a […]? 1= Yes 0=No	Total Value (RWF)
A1	A2a	A2b	A1	A2a	A2b	A1	A2a	A2b
1. Water pump			11. Animal Plough			21. Barn		
2. Borehole			12. Hand Hoe			22. Flour Mill		
3. Water tank			13. Harvester			23. Mobile phone		
4. Drip irrigation system			14. Processing Machines			24. Axes & Knifes		
5. Special pipes			15. Machete, sickel, mower			25. Rakes		
6. Sprinkler			16. Ox cart			26.Pics, shovels		
7. Watering can			17. Wheelbarrows			27.radios		
8. Truck			18. Sprayer for Pesticides			28.sewing machine		
9. Thresher			19. Bicycles			29. watches		
10. Tractor			20. Motorcycles			30. Others durable goods		

PART B: LIVESTOCK

1. Iinterested in total numbers of livestock available and ther monetary value

B1	B2	B3	B4	B5	B6	B7
Type of Livestock	Do you own a […]? 1= Yes 0 =No	Quantity in stock now (currently)	Value (how much would you sell them today?) RWF	Quantity bought in the last 3 seasons	Quantity sold in the last 3 seasons	Total Value: Amount received for sale (RWF)
1. Cattle						
2.Goats						
3. Sheep						
4. Chickens						
5. Pigs						
6. Rabbits						
7. Donkeys						
8. Ducks						
9. Geese						
10. Fish						
11. Bees						
12. Other (specify)						

C. OTHER ASSETS (and Liabilities)

C1	C2
Asset name	Asset value (RWF)
1. Buildings	
2. Furniture	
3. Land	
4. Food Stocks	
5. Debts	
6. Banana Plantation	
7. coffee trees	
8. Tea Plantation	
9. Forests	
10. urubingo	
11. ibisheke	
12.others (specify)	

SECTION 6 - CROP SALES AND ACCESS TO FACILITIES

HH ID Number				

PART A. CROP SALES

1. List all crops sold over the last 3 seasons.

Season	What crops were sold during SEASON […]?		How much of this crop was sold during this season ?			
		Crop code *(see codes below)*	Quantity	UNIT CODES: KILO...1 GRAM...2 SACK...3 BASKET.4 LITER..5 CUP....6 GALLON.7 BUNCH..8 BUNDLE.9 PIECES..10 DOZENS..11 BOTTLES.12 BAGS....13 BOXES...14 JUG.....15 DISH....16 OTHER...17	Equivalent in KG for ONE Unit Measure	**Total Value** (How much did you sell crop for?) (RWF)
	Crop Name	Crop Code				
A1	**A2a**	**A2b**	**A3a**	**A3b**	**A3c**	**A3d**
Season A						
Season B						
Season C						

CROP CODES

1.Bush beans
2.Climbing beans
3.Runner beans
4.Peas
5.Groundnuts
6.Soybean
7.Sorghum
8. Maize
9. Sunflower
10.Wheat
11.Rice
12 Soft cassava
13 Bitter cassava
14.Sweet potato
15.Irish potato
16Taro
17.Banana for cooking/plantain
18.Banana for wine
19.Apple banana Kamara
20.Other apple banana
21.Eleusine
22.Yam
23.Cauliflower
24.Cabbage
25.Tomato
26. Carrot
27. Cucumber
28. Beetroot
29. Lettuce
30. Spinach
31. Garlic
32. Eggplant
33. Squash
34. Onion
35. Okra
36. Leek
37. Pepper
38. Celery
39. Parsley
40. Dwarf pepper
41. Pilipili pepper
42. Orange
43. Lemon
44. Mango
45. Guava
46. Passion fruit
47. Mushrooms
48. Pineapple
49. Strawberry
50. Papaya
51. Avocado ordinary
52. Avocado Hass
53. Japanese plum
54. Coffee
55. Tea
56. Pyrethrum
57. Tobacco
58. Sugarcane
59. Vanilla
60. Geranium
61. Macadamia
62. Morus sp.
63. Patchouli
64. Flowers
65. Ornamental trees
66. Currants
67. Vegetables dodo
68. Sombe
69. Moringa
70. Pastures
71. Afforestation
72. Fallow
73. Land preparation
74. Other

PART B: ACCESS TO FACILITIES

1. Please indicate whether the following facilities are available in your Sector.

Facility	Is a [….] available in this Sector? 1= Yes 0= No	How long does it take you to get to the nearest [….] facility?	
		Distance (in km)	**Time** (in minutes)
B1	**B2**	**B3**	**B4**
1. Agricultural products market			
2. Agricultural input market			
3. Livestock market			
4. Source of pure water			
5. paved road			
6. Unpaved but allweather road			
7. Primary school			
8. Secondary school			
9. Health center			
10. Hospital			
11. Car/Bus/taxi park			
12. other			

SECTION 7. (A) HEALTH INCIDENTS AND OFF-FARM LABOR

HH ID Number | | | | |

1. Please document health incidents that have affected your family in the last 12 months (i.e. last 3 seasons).*ask about all household*
When documenting care for a sick child, document child's illness and any loss of labor due to caregiver's response

Household Member ID	Have you had a health incident in the last 3 seasons? 1= Yes 0= No	Which main health Incident? *(use codes below, **main** refers to health incident that affected agriculture the most)*	How many days of agricultural labor did you lose due to the illness?	How did you deal with this loss of labor? (see codes	Where did you go for treatment?	How much did you spend on treatment ? RWF
A1	A2	A3	A4	A5	A6	A7
1-HH						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Codes for Question A2
01 Malaria
02 Diarrhea
03 Cough
04 Headache without Malaria
05 Measles
06 Parasitic disease/ Intestinal Worms
07 Sexually Transmitted Disease
08 Tetanus
09 Hypertension (Blood pressure)
10 Typhoid
11 Dysentery
12 Cholera
13 Ulcers/ Other intestinal
14 River Blindness
15 Trachoma
16 Other Vision disease
17 Meningitis
18 Asthma
19 Respiratory Problem
20 Dental Problem
21 Skin Problem/Scabies (Simama)
22 Wounds
23 Anemia
24 Severe malnutrition
25 Pregnancy/childbirth complications
26 Taking care of someone sick
27 AIDS
28. Others (specify) ______________

Codes for Question A5
01 Did Nothing
02 Hired someone to help
03 Credit from family /friend/neighbor
04 Credit from formal sources
05 Government transfer
06 Ask household member to help
07 Other (specify)

Codes for Question A6
1. Did not go anywhere
2. Govt Clinic /health center
3. Government Hospital
4. Private Clinic/ Hospital
5. NGO Health Clinic/ Hospital
6. Village Health Worker
7. Dispensary
8. Pharmacy
9. Traditional Doctor
10. Traditional birth attendant
11. Other ________

(B). MAIN HOUSING STATUS

B1	since when your familie live in this house?		
B2	When was the house built?		
B3	Who build this house?	1= the hh itself 2 = another hh 3= government 4=NGO 5= other (specify)	
B4	what is your occupying status?	1= owned 2 = Hired 3= free lodge 4= other (specify)	
B5	By what the roofing is made of?	1= Concrete/cement 2 = iron sheets 3= tiles 4= Metal 5= straw 6= other (specofy)	
B6	By what the walls are made of?	1= Brick/stone/concrete/cement 2 = Fiberglass 3= Wood 4= Adobe 5= Straw 6= Other (specify)	
B7	Is the ground cemented?	1= Yes 0= No	

SECTION 8: CREDIT AND AGRICULTURAL TECHNICAL ASSISTANCE, SOCIAL NETWORKS

PART A: CREDIT ACCESS

HH ID Number

1. Did you apply for a loan or credit in the last 12 months (i.e. last 3 seasons)? _________ (1= Yes, 0= No) *if Yes, go to question 3*

2. If no, why didn't you apply?_______________

1 No need
2 Lack of guarantee
3 Too risky
4 Too expensive
5 Not available
6 No loan information
7 Other (specify)

3. How many loan applications did you make in the last 12 months (i.e. last 3 seasons)?_________________

4. Document loan applications for the last 12 months (i.e. last 3 seasons) and for what purpose they were used. If no applications, go to Part ***B.***

List your loan applications	**Did you receive a loan? (if no go to A7)** 1 Yes 0 No	**If yes, what did you use it for?**	**If yes, what was the source of the loan?** (use codes below)	**Total Amount (RWF)** estimate of credit amount given	**If no loan was received, why not?** (use codes below)
A1	**A2**	**A3**	**A4**	**A5**	**A6**
		Uses of credit (A3): 1 Pay agricultural inputs 2 Pay education expenses 3 Pay health expenses 4 Other (specify)	**Credit Source (A4):** 1 Input Salesmen 2 Buyer of Harvest 3 Bank 4 SACCOS 5 Microfinance Institution 6 NGO 7 Family/friend 8 Govt 9 Other (specify)	**Reasons for Denial (A6):** 1 Lack of collateral or guarantee 2 Did not have necessary documents 3 Prior debt 4 Lack of ability to repay 5 Other (specify)	

HH ID Number | | | | |

PART B: AGRICULTURAL TECHNICAL ASSISTANCE (i.e. Agricultural advisory, training, and extension services)

1. Have you received technical farm assistance in the last 12 months (i.e. last 3 seasons)? 1= Yes; 0= No __________

2. If yes, how many times? ____________ (If none received, go to question 4).

3. Describe the source and cost of your technical assistance over the last 12 months (i.e. last 3 seasons).

What type of services were received from provider? (see codes below)	**What was the source of the assistance?** (see codes below)	**Who was responsible for the technical assistance?** (use codes below)	**How much did you spend on technical assistance in the last 12 months?(RWF)**
B1	**B2a**	**B2b**	**B3**
Services Received: 1= New Crop Introduction 2= Soil Analysis 3= Seeds (not new) 4= Pest and Disease Control 5= Harvesting Techniques 6= Farm Management 7= Marketing Techniques 8= Packing/Selection 9= Other (specify)	**Source:** 1= Extension agent 2= Livestock center 3= Veterinary clinic 4= Family member/ friend 5= Other farmer 6= Other (specify)	**Responsible Party:** 1= Ministry of Agriculture 2= District Government Office 3= NGO 4= Producers Committee/Farmers Organization 5= University 6= Independent 7= Private Company 8= Other (specify)	

4. If you did not receive any technical assistance, why do you think this is *(use codes below)*? _________

1= Not offered 3=Too expensive 5= Not needed

2=Not suitable 4=Don't trust providers 6=Other (specify)

SECTION 9: SOCIAL NETWORKS AND INFRASTRUCTURE

PART A: SOCIAL NETWORKS

HH ID Number | | | | |

1. Are you a member of any group or an association? ___ (Yes =1; No= 0) *If no, please skip question 2*

2. To what type of group do you belong?

To which groups do you belong? (use codes)	**How long have you been a member?** (months)	**Did you receive any services from group?** 1= Yes 0= No	**If yes, what services did your household receive from group?** (see codes below)
A1	**A2**	**A3**	**A4**
Group: 1= Producer Group 2= Farmers Cooperative 3= Women's Group/Youth Group 4= Community Welfare Group 5= Church Association 6= Other (specify)			Services: 1=Credit 2= Inputs 3= Training 4= Marketing 5= Welfare/Social Support 6= Other (specify)

PART B. INFRASTRUCTURE

1. Does your household have an electricity connection? _________ (1 Yes; 0 No)
2. Does your household own a telephone (fixed land/cell phone)? _________ (1 Yes; 0 No)
3. If your household does not own a phone, how many minutes would it take you to reach the closest public phone? (in minutes)____________

4. Does your household have an internet connection? ________(1 Yes; 0 No)
5. If your household does not own internet, how many minutes would it take you to reach the closest public internet? (in minutes)____________

HH ID Number

1. Document income earned in your household by each income earner from Non-agricultural & Off-farm income

ID	Total Income from Non-Agricultural & Off-farm income sources (RWF) in the last 3 seasons	Has this income changed in the last 25 years? 1= Yes 0=No	Reasons for these changes *(use codes below)*
A1	A2	A3	A4

Reason for Change in Income (A4)
1 =Working more off-farm in business
2=Increased employment opportunities
3=Increase in salary and wages
4 =Change in health or disability
5= Change in family size
6= Other (specify) _____________

2. What was your household's income from the following sources during the last 12 months (i.e. last 3 seasons)? *(include income of all household members)*

Income source	**Total value (RWF) in the past 12 months (i.e. last 3 seasons)**
B1	**B2**
1. Income from livestock sales, and other animal products (milk, eggs, skins, manure, etc)	
2. Income from own **non-agricultural** businesses	
3. Wages for labor on other farms	
4. Wages and salaries for **non-agricultural** employment	
5. Pensions	
6. Remittances from family members/friends who do not live in the household	
7. Revenues from leasing out land	
8. Non-conditional Cash transfers from government or other group	
9. Conditional cash transfers (specify conditions)	
10. values of foods, non food items, and other durable goods received as gift	
11. Other sources (specify)____	

SECTION 11: HOUSEHOLD CONSUMPTION

A. FOOD AND FUEL

HH ID Number

In the following questions, I want to ask about all purchases made for your household, regardless of which person made them. Please exclude from your answer any [ITEM] purchased for processing or resale in a household enterprise.

consumption			PURCHASES SINCE LAST 12 MONTHS				PURCHASES TYPICAL MONTH		HOME PRODUCTION					GIFTS
A1	A2	A3	A4	A5		A6	A7	A8	A9	A10		A11	A12	A13
	Has your household consumed [FOOD] during the past 12 months?	YES.1	How much did you pay in total?	How much did you buy?			How many months in the past 12 months did your household consume purchased [FOOD]?	How much do you usually spend on [FOOD] in one of the months that you purchase [FOOD]?	How many months in the past 12 months did your household consume [FOOD] that you grew or produced at home?	How much did you consume in a typical month?			What was the value of the [FOOD] you consumed in a typical month from your own production?	What is the total value of the [FOOD] consumed that you received as a gift over the past 12 months?
CODE	food item		RWF	QTY	UNIT	equiv (Kg)	MONTHS	RWF	MONTHS	QTY	UNIT	equiv (Kg)	RWF	RWF
1	Beans													
2	Wheat (flour or grain)													
3	Maize (flour or grain)													
4	Rice													
5	Peas													
6	sorghum (flour or grain)													
7	Cassava (imyumbati)													
8	Irish potatoes													
9	Sweet potatoes													
10	Other roots and tubes													
11	Groundnuts													
12	Soybeans													
13	Plantain (ibitoki)													
14	Liquid vegetable oils (dalda)													
15	Sugar (refined)													
16	Beef/Mutton/lamb/goat (meat)													
17	other animal products (milk, eggs, etc)													
18	Fish													
19	Vegetables													
20	Fruits													
21	Beverages													
24	Chapatti, Nan, other breads													
25	Tea & Tea													
26	Cooking stuff (Firewood, charcoal)													
27	Other food expenditure													

UNIT CODES:

KILO...1
GRAM...2
SACK...3
BASKET.4
LITER..5
CUP....6
GALLON.7
BUNCH..8
BUNDLE.9
PIECES..10
DOZENS..11
BOTTLES.12
BAGS....13
BOXES...14
JUG.....15
PLATE...16
DISH...17

SECTION 12 HOUSEHOLD CONSUMPTION

B. NON-FOOD

HH ID Number

Has your household bought, spent money on any [ITEM] during the past 12 months?

	Article	Value [RWF] in past 30 DAYS	value in the past 12 months
B1	B2	B3	B4
1	Personal care items (soap, shampoo, toothpaste, etc.)		
2	Cosmetics		
3	Women's clothing		
4	Men's clothing		
5	Children's clothing		
6	Women's footwear		
7	Men's footwear		
8	Children's footwear		
9	Cloth and sewing supplies		
10	Tailoring expenses		
11	Laundry and dry cleaning		
12	Personal services (haircuts, shaving, manicures, etc.)		
13	Traditional remedies and over the counter remedies		
14	Modern medicines and health services (doctor fees, hospital charges, etc.)		
15	Books, stationery (excluding textbooks)		
16	Postal expenses, telegrams,		
17	Entertainment (cinema, cassette rentals, cultural and sporting events, etc.)		
18	Household cleaning articles (soap, washing powder, bleach, etc.)		
19	Kitchen supplies (napkins, matches, garbage bags, etc.)		
20	Toilet supplies (toilet paper, cleanser, etc.)		
21	Electrical items (light bulbs, cords, plugs, batteries, etc.)		
22	Repair and maintenance of household articles		
23	Household linens (sheets. blankets, towels, etc.)		
24	Small kitchen appliances (blender, mixer, etc.)		
25	Dishes (crockery, cutlery, glassware, etc.)		
26	Kitchen utensils (pots, pans, buckets, tools, etc.)		
27	Small electrical items (radio, walkman, watch, clock, etc.)		

	Article	Value [RWF] in past 30 DAYS	value in the past 12 months
B1	B2	B3	B4
28	Household tools		
29	Sports and hobby equipment		
30	Toys		
31	Musical instruments		
32	Vehicle repair, maintenance, parts and licenses (do not include gasoline)		
33	Repair and maintenance of the house		
34	Home improvements and additions		
35	Insurance (auto, property)		
36	Health insurance		
37	Membership fees		
38	Excursion, holiday (including travel and lodging)		
39	Charity, donations		
40	Income tax		
41	Land tax		
42	Housing and property taxes		
43	Gambling losses		
44	Cash losses		
45	Contributions to ROSCAs, tontins, Christmas clubs, etc.		
46	Deposits to savings accounts		
47	Legal or notary services		
48	Marriages, births, and other ceremonies		
49	Dowry or bride price		
50	Funeral expenses		
51	transport (Bus, taxi, moto, bicycle)		
52	phone services		
53	other lighthening items (torch, pertol lamp, agatadowa, etc)		
54	cigarettes and tobacco		

	How much did you spend on the durable goods in the past 12 months?	Value [RWF] in past 30 DAYS	value in the past 12 months
C1	C2	C3	C4
1	Sewing/knitting machine		
2	Radio		
3	Television		
4	Video player		
5	Tape player/CD player		
6	Camera, video camera		
7	Bicycle		
8	Motorcycle		
9	Car or truck		

SECTION 13. CONSTRAINTS TO HOUSEHOLD INCOME

What is the biggest constraint to your household income? *(Rank the following with 1 being the biggest concern):atmost five constraints*

Constraint	Rank
A1	A2
1. Health Incidences	
2. Lack of Professional Education	
3. Lack of Market Access	
4. Inadequate Medical Care	
5. Rapid Price Changes for Agricultural Products	
6. Outmigration of youth	
7. Unpredictability of Weather	
8. Lack of Storage Facilities	
9. Lack of Farmer Training	
10. Land problems	
11. unemployment	
12. Death of family members	

Thank you for your time and patience!