An Empirical Analysis of Aspects of Food Security in Zimbabwe

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Statement of Authorship

I certify that the thesis contains no material which has been submitted for the award of any degree or diploma in any university or other institution, and to the best of my knowledge the thesis contains no material previously published or written by any other person, except where due reference is made in the text of the thesis.

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Abstract

At the World Food Summit held in Rome in 1996, world leaders reaffirmed the right of each and every individual to have access to safe and nutritious food and to be free from hunger. The quest since then has been to halve the hungry population by 2015. To this effect, various measures aimed at improving food availability, accessibility, utilisation and stability at individual, national and global levels have been taken. Currently, capacity building interventions are being promoted as a more sustainable way of improving food security. Capacity building projects encourage the beneficiaries to utilise locally available resources to improve their food security. Whilst progress has been evident in other regions, regions like South-East Asia and Sub-Saharan Africa are still lagging behind. A challenge thus remains of alleviating hunger in these two regions as the deadline for the attainment of the goal of halving the hungry population is fast approaching.

This thesis analyses various aspects of food security in Zimbabwe, a country in Sub-Saharan Africa. Firstly, the relationship between short-term (BMI-for-age) and long-term (height-for-age) child health is assessed for children below the age of five years. Secondly, the contribution of maternal nutrition (denoted by the mother's BMI) towards a child's short-term nutrition (denoted by the child's BMI z-score) is explored. Thirdly, this thesis assesses the merits of a capacity building project, the Smallholder Drip Irrigation Project, in alleviating household food insecurity in Mutasa and Mutoko districts of Zimbabwe. Two areas are examined; the determinants of dropout rates from and the duration a beneficiary lasts in smallholder drip irrigation projects and whether the project's main goal of improving household food security was achieved.

This thesis adds to existing literature on the relationship between short-term and long-term child health by using the Demographic and Health Survey data to assess this relationship for a poor country, Zimbabwe. Zimbabwe's main challenge is that of underweight children as opposed to overweight children who have been the focus of most of the studies on the relationship between BMI and height. The results show that there is a robust negative relationship between BMI-for-age and height-for-age for children below the age of 5 years. This means that taller children (better long-term health) are more likely to be underweight (poor short-term health). In terms of policy, this result implies that targeting food insecure children using the BMI-for-age measure, as is the current practice will result in the selection of children with better long-term health. For Zimbabwe, the prevalence of stunting (low-height-for-age) compared to being underweight (low BMI-for-age) is higher. Thus if BMI-for-age is used, some children with poor long-term health may be left out. Policies aimed at targeting the food insecure should therefore consider incorporating the height-for-age measure as part of their targeting criteria.

Existing literature on the impact of maternal BMI on a child's BMI mostly incorporates maternal BMI as an explanatory variable for child health. This thesis adds to the existing literature by modelling this relationship for using a nationally representative dataset from the Demographic and Health Survey. In addition, potential endogeneity or simultaneity bias arising from unobservable household factors that affect both the mother and the child's BMI is accounted for. The results reveal that maternal BMI has both a direct and indirect positive influence on a child's BMI. This implies that programs aimed at improving maternal nutrition for mothers who are not pregnant or lactating will also directly improve the child's nutrition. So in addition to existing programs targeting the nutrition of pregnant and lactating mothers, nutrition based programs for other mothers with children below the age of 5 will be beneficial to both the mother and the child.

Very little literature is available on the merits of capacity building projects in improving food security. For the smallholder drip irrigation project implemented on a large scale in Zimbabwe, available literature points out that dropout rates were quite high. This thesis adds to the literature by using data from the Smallholder Drip Irrigation Survey (conducted by the author) to examine why beneficiaries dropped out of the project. In addition the thesis also explores the factors that influence the duration a beneficiary lasts in the drip irrigation project. The results obtained indicate that timing of receipt of the drip kit, yield increases in vegetables and better socio-economic status significantly reduce chances of dropping out of the project and increase the time the beneficiary remains in the project. On the other hand, yield increases, experiencing water problems and the beneficiary's age increase chances of dropping out of projects and have a negative impact on the duration a beneficiary lasts in the project. These results can be incorporated in improving the implementation of smallholder drip irrigation projects as well as other capacity building projects in Zimbabwe.

The results of this thesis also suggest that the main impact of the smallholder drip irrigation program on household food security in Mutasa and Mutoko districts was through a reduction in the number of coping strategies used by the household. Dropping out had no significant impact on a household's dietary diversity score, in spite of the project aiming to increase household food diversity.

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And you will say in that day: "Give thanks to the Lord, call upon his name, make known his deeds among the peoples, proclaim that his name is exalted. "Sing praises to the Lord, for he has done gloriously; let this be made known in all the earth (Isaiah 12:4-5)

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List of Abbreviations

AIDS	Acquire Immune Deficiency Syndrome
AusAID	Australian Agency for International Development
BMI	Body mass index
CAADP	Comprehensive African Agricultural Development Program
CAPSA	Centre for Alleviation of Poverty Through Sustainable Agriculture
CIA	Central Intelligence Agency
CRS	Catholic Relief Services
CSO	Central Statistics Office
DAI	Development Alternatives Incorporated
DHS	Demographic and Health Surveys
FACT	Family Aids Counselling Trust
FAO	Food and Agricultural Organisation
FEWS NET	Famine and Early Warning Systems Network
FSN	Food Security News
FSNWG	Food Security and Nutrition Working Group
HIV	Human Immunodeficiency Virus
IDE	International Development Enterprise
IFAD	International Fund for Agricultural Development
IPC	Integrated Food Security Phase Classification
IPS	Inter Press Service News Agency
IRIN	Integrated Regional Information Networks
IV	Instrumental variable
IWMI	International Water Management Institute
LEAD	Linkages for the Advancement of the Disadvantaged
LSAC	Longitudinal Survey for Australian Children
LSCFA	Large scale commercial farming areas
LSMS	Living Standards Measurement Survey
MDG	Millennium Development Goal
MUAC	Mid-upper arm circumference
NICE	National Institute for Health and Clinical Excellence
NGO	Non-governmental Organisation
NNP	National Nutrition Plan

OCHA	United Nations Office for the Coordination of Humanitarian Affairs
ORAP	Organisation of Rural Associations for Progress
PSNP	Product Safety Net Programs
RCSD	Resource Centre for Sustainable Development
SD	Standard deviation
SSCFA	Small scale commercial farming areas
STI	Sexually Transmitted Infection
UCLA	University of California Los Angeles
UN	United Nations
UNICEF	United Nations Children's Fund
USAID	United Nations Agency for International Development
USDA	United States Department of Agriculture
WASH	Water, Sanitation and Hygiene
WFP	World Food Program
WHO	World Health Organisation
ZNHCSD	Zimbabwe National Household Survey Capability Program

CHAPTER 1: Introduction

"Freedom from hunger remains a long-cherished goal; alongside peace, hunger is the most pressing of all issues"

Jacques Diouf
Director-General FAO (1994-2011)

1.0 Introduction

Food security is a major concern worldwide. World leaders at the World Food Summit held in Rome in 1996 all reaffirmed the right of each and every individual to have access to safe and nutritious food and to be free from hunger. They pledged to reduce the number of food insecure people by half the current figure by 2015 (Food and Agricultural Organisation (FAO), 1997).

In the last two years (2011 to 2013), approximately 842 million people worldwide were suffering from chronic hunger. An estimated 98.2% of these people reside in developing countries (United Nations (UN), 2014). In spite of the progress that has been made in reducing the hungry population, sub-Saharan Africa is still lagging behind and according to the UN (2014), continues to be the region with the highest incidence of undernourishment. It is thus important that efforts to reduce the hungry population continue in sub-Saharan Africa and the world at large.

According to FAO (2008), the concept of food security can be categorised into four basic elements namely: physical availability, economic and physical access to food, utilisation and stability. Availability refers to having a constant supply of quality food for all people at all times and has been the main focus of food policy and food related studies up to the 1970's.

Accessibility, on the other hand, deals with the means of getting food, which is mainly summed up by the entitlements proposed by Sen (1981), namely: production based, trade-based, own-labour, inheritance and transfer entitlements. Upon realising that people can still be hungry despite there being enough food available, the focus of research shifted from availability to include issues of accessibility in the 1980's (Maxwell, 1996). Currently the focus is on the utilisation and stability aspects of food security. The utilization element encompasses food preparation and storage techniques, availability of clean drinking water and proper sanitary facilities, adequate diet and health care (Wiggins & Slater, 2011) which are necessary for one to have an active and healthy life. The stability element on the other hand requires that people be able to get the right food in the right quantities at all times (FAO, 2008).

Failure to realise any one of these basic dimensions results in food insecurity. Food insecurity can either be chronic (persistent in the long-term) or transitory (temporary). Chronic food insecurity mainly results from prolonged periods of having poor entitlements whilst transitory food insecurity results mainly from sudden unforseen shocks such as sudden increases in food prices. In between these lies seasonal food insecurity which is chronic in terms of predictability and transitory in terms of duration (FAO, 2008).

1.1 Who are the food insecure?

Approximately 75% of the hungry or food insecure population reside in rural areas in Asia and Africa and they are mostly smallholder farmers. As such they are highly dependent on agriculture for their livelihood and often have no other income sources. This increases their susceptibility to food crisis (World Food Program (WFP), 2014).

Food insecurity[1] is mostly prevalent among children and women and is evidenced through anthropometric indicators such as stunting, wasting and being underweight. Worldwide, approximately 162 million and 99 million children are stunted and underweight respectively (UN, 2014). Progress has been evident in all regions in reducing the number of stunted and underweight children, with the exception of sub-Saharan Africa. The UN (2014) indicates that in this region, approximately 58 million children were suffering from chronic malnutrition (stunting) in 2012 compared to 44 million in 1990. The number of underweight children in sub-Saharan Africa also increased from approximately 27 million to 32 million between 1990 and 2012 (UN, 2014).

Women are more prone to undernutrition than their male counterparts, especially in Asia (Mukhopadhyay, 2007). This is in spite of the fact that, women are actively involved in food production and an estimated 80% developing countries' food is believed to be produced by women (Ivers & Cullen, 2011; World Health Organisation (WHO), 2014). In addition, women also tend to be chiefly responsible for bearing and rearing their children. Women health and nutrition is thus important not only for current food production and economic growth but for future economic growth. Poor health and nutrition in women has ripple effects as it results in poor household and in particular poor child health and consequently poor productivity and economic growth. The World Hunger Education Service (2013) claims that one in six infants are born with low birth weight as a result of maternal undernutrition and this increases the chances of death as well as poor health outcomes in children. Moreover, poor maternal nutrition has negative impacts on a child's cognitive ability and hence negatively impacts on their future economic productivity (Hoddinott, Maluccio, Behrman,Flores & Martorell, 2008).

[1] Hunger or undernourishment and famine are the effects of food insecurity (Ayalew, 1997).

1.2 Efforts to alleviate food insecurity

Worldwide

Efforts aimed at reducing food insecurity have been and are still being made in different countries worldwide. These includes the introduction of several programs with food aid being the most prevalent followed by other special programs targeting certain groups such supplementary feeding programs for primary school children and nutrition supplement programs for HIV and AIDS patients. Recognising the importance of women in alleviating food insecurity has resulted in the introduction of women empowerment projects ranging from health awareness campaigns for pregnant women to the extension of credit facilities to women to enable them to embark upon income generating projects. These programs are being implemented through the combined effort of governments and local non-governmental organisations' (NGOs). Recently capacity building, aimed at increasing the strengths and abilities of individuals and the community at large has become a major focus of food security interventions. Capacity building is thought to be a more sustainable way of attaining household and consequently national food security because once the individual or household is empowered to embark upon a project, they can continue with that project even after the project benefactors have withdrawn (Gervais, 2004; Shah, 2007). Capacity building projects that have been promoted include livestock rearing schemes (for instance heifer rearing schemes in Afghanistan) and training in using improved agricultural technology (in Bangladesh and Laos) (TEAR Australia, 2013).

Africa

In Africa, the Comprehensive African Agricultural Development Program (CAADP) provides a formal framework for targeting efforts towards improving food security. In addition to providing emergency food aid, the CAADP also aims to alleviate food insecurity through improving nutrition and access to food and building sustainable resilience in agriculture. Under the CAADP framework, the main way of improving agricultural productivity in the long term is through the adoption and promotion of better agricultural technologies especially by smallholder farmers (AusAID, n.d).

Developed countries like Australia, which share a more or less similar tropical climate with many African countries, have been instrumental in supporting food security improvement efforts. Their support has mainly been through sharing innovations that they have adopted which have resulted in improved agricultural productivity and facilitating their adoption in Africa.

One such example is the Sustainable Intensification of Maize and Legumes in East and Southern Africa (SIMLESA) program supported by the Australian government. SIMLESA aims to promote the uptake and usage of new agricultural technologies such as conversation farming and the use of improved maize and legume varieties by African countries. This program has led to improved maize yields for farmers in Ethiopia, Kenya, Malawi, Mozambique and Tanzania ((AusAID, n.d).

In terms of improving the research base, Australian researchers are working together with organisations such as the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA), the International Maize and Wheat Improvement Centre (CIMMYT), national research agencies and other African institutions in 35 countries to develop and test new varieties of maize and wheat and promote their uptake by local farmers ((AusAID, n.d).

Nutrition based programs have also been implemented in Africa in an attempt to alleviate food insecurity. Special programs such as the community-based nutrition programs in Ethiopia targeting children under the age of 2 years have been introduced. The government is working closely with non-governmental organisations (NGO) to actively promote nutrition enhancing activities on a national level under the National Nutrition Plan (NNP) (The World Bank Group, 2013). Community-based nutrition programs have also been introduced in Kenya, Tanzania and Uganda (Iannotti & Gillespie, 2002).

Efforts have also been made to improve water and sanitation facilities with the support of NGO's under programs like the Water, Sanitation and Hygiene (WASH) and the Product Safety Net Programs (PSNP) in Ethiopia (The World Bank Group, 2013). The WASH program is also operational in other African countries. In Ghana WASH has promoted the use of soap for hand washing and in Guinea, WASH has promoted the use of better water purification methods such as chlorination for households. Improved sanitation has been the target in Zambia with households being supported and encouraged to build their own toilet facilities (UNICEF, 2009).

Programs targeted at improving the nutrition mothers and children have also been promoted. In Uganda, the government in conjunction with NGO's have introduced nutrition supplements (fortified oil food) for women and children in order to address vitamin A deficiencies. Efforts have also been made to implement nutrition based programs for women and children in Tanzania (Feed the Future, 2012).

In order to improve food security at the household level, sustainable and environmentally friendly programs have been implemented all over Africa. Nutrition gardening has been widely encouraged using drip irrigation kits adapted for small pieces of land (as small as $15m^2$), as a way of improving yields in the midst of water shortages and unpredictable climates (Kay, 2001; Postel, Polak, Gonzales & Keller, 2001) . Livestock rearing schemes to improve a household's asset base have also been implemented in countries like Tanzania (goats) and Kenya (poultry) (TEAR Australia, 2013).

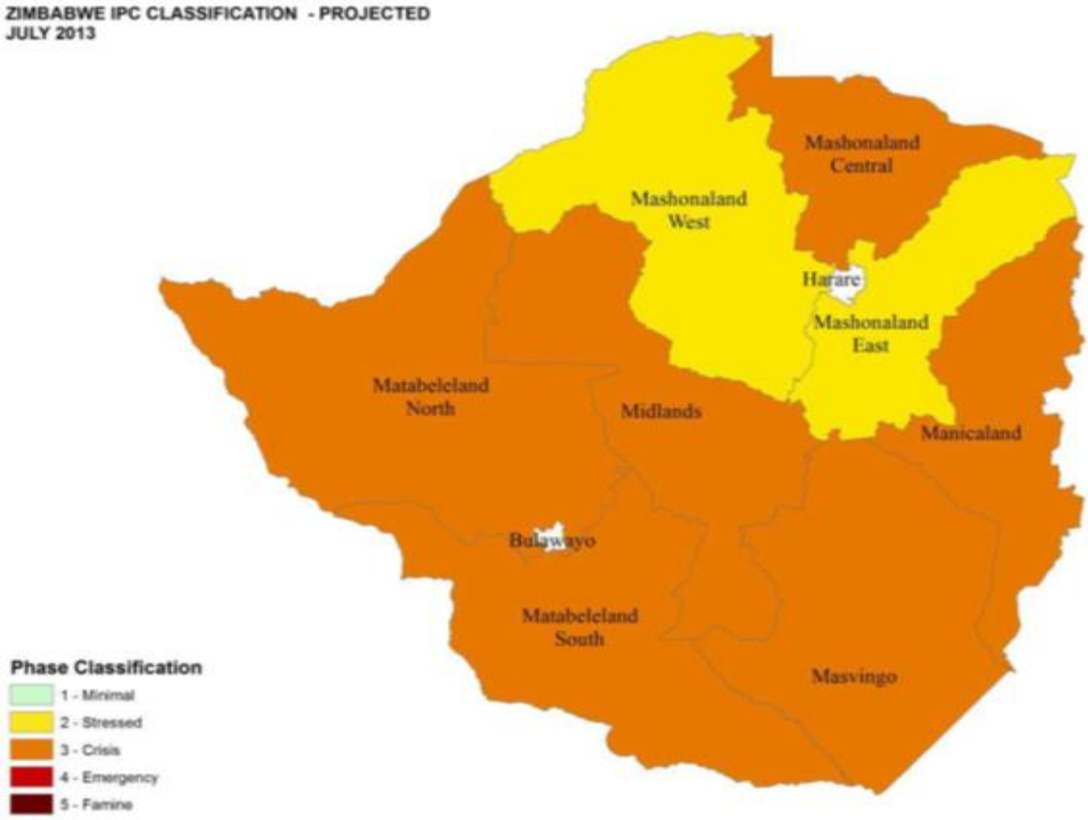
1.3 Zimbabwe

Zimbabwe is a landlocked country, located in Southern Africa and bordered by Mozambique, South Africa, Botswana and Zambia. The country has an estimated population of 13,182 million. An estimated 61.4 % of this population resides in rural areas (CIA, 2014). Zimbabwe is dependent upon rainfed agriculture (contributes about 19.5% of the GDP according to CIA, 2014) and is prone to seasonal food insecurity. Food insecurity is highest in the November to March period which is the planting to harvesting season.

Food security

Over the past few years, Zimbabwe has experienced continuous droughts and harvests have been poor. According to the Regional Food Security and Nutrition Working Group (FSNWG, 2012), the level of food insecurity in Zimbabwe is expected to increase. Approximately 19% of the rural households were expected to be severely food insecure in the 2012/13 period, the worst food insecurity experienced in the last three years (World Food Programme (WFP in OCHA, 2012). The national cereal supplies were expected only to cater for about 55% of the amount required in 2012/13 and prices have also remained high making it increasingly difficult for poor households to access the basic food. The hardest hit areas are Matebeleland North and South, parts of Mashonaland, Midlands, Manicaland and Masvingo provinces as shown in Figure 1.1 below (FSNWG, 2012; OCHA, 2012).

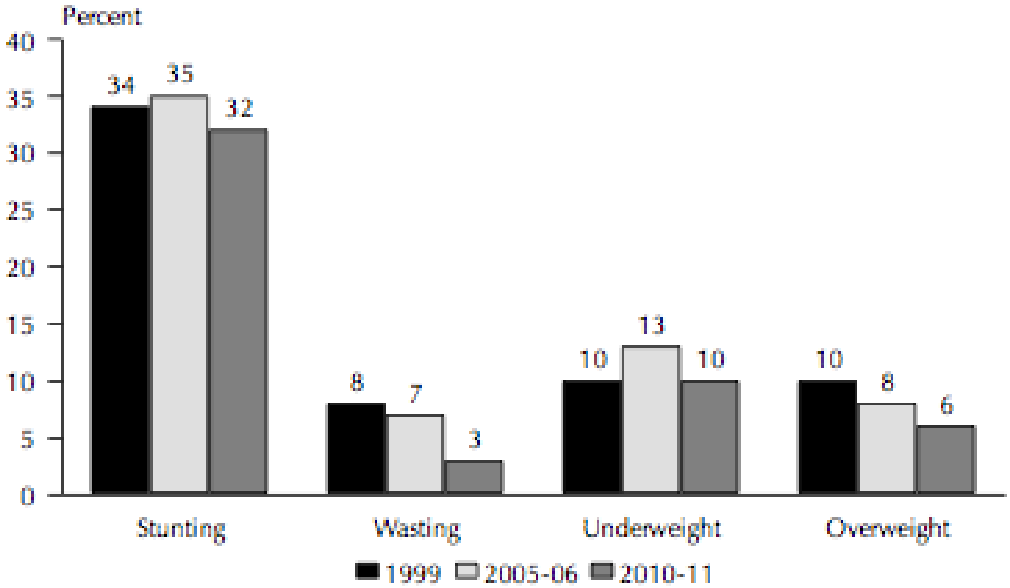
Figure 1.1 Zimbabwe's food insecurity map



Source: IPC, 2013

The prevalence of chronic malnutrition in children under the age of 5 years is very high in Zimbabwe as shown by Figure 1.2. For all the 3 years represented, stunting rates were approximately 3 times higher than wasting, underweight and overweight rates. From 2005/06 to 2010/11, all the rates have declined slightly.

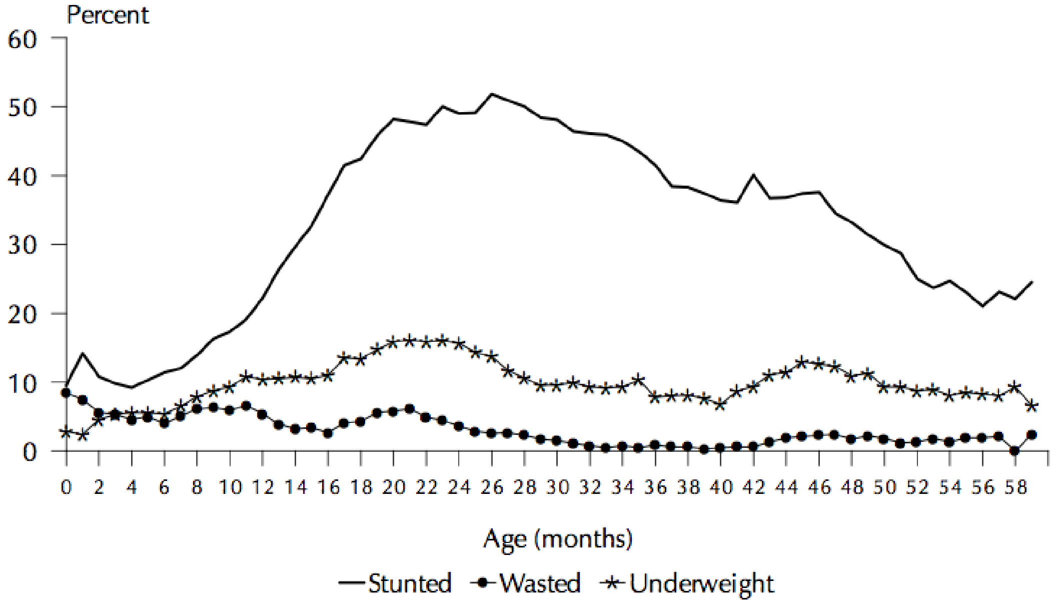
Figure 1.2: Trends in nutrition among children under 5 years



Source: 2010/11 DHS cited in FEWS NET, 2014

Figure 1.3 below shows the prevalence of the stunting, underweight and wasting by age for children less than 5 years of age. The highest prevalence is around 26 months, 21 months and 23 months for stunting, wasting and underweight respectively. Although the prevalence of wasting is higher than that of being underweight initially, wasting becomes less prevalent after 2 months of age whilst underweight becomes more prevalent.

Figure 1.3: Zimbabwe's nutritional status of children under 5 years



Source: 2010/11 DHS cited in FEWS NET, 2014

Using Zimbabwe's DHS data for 1994, 1999 and 2005/06, 5.5%, 4.4% and 7.8% of mothers aged 15-49 with children below the age of 5 were suffering from undernutrition 9BMI<18.5 kg/m^2).

Coping strategies

Most households now have to rely on food aid. Organisations such as the World Food Program (WFP) assist households with food handouts comprising mainly of cereal, pulses and cooking oil. However they have indicated that only about 43.2% of the required assistance is available which means their efforts may only be able to reach a few people (OCHA, 2013). Other households have resorted to using negative coping strategies such as withdrawing children from school so that they can earn money or food by providing casual labour, engaging in illegal activities such as gold panning, reducing the number of meals consumed in the household with priority being given to children, surviving on wild fruit, exchanging livestock with cereal and selling livestock in order to survive. Some of these coping strategies such as selling livestock deplete that household's assets and thus impacts their wealth status and their future support base (FSNWG, 2012; OCHA, 2013).

Measures to address food insecurity

OCHA (2012, 2013) notes that it is important for Zimbabwe to target efforts and resources at promoting long-term sustainable measures for improving household food security. To date, efforts have included harnessing water to improve agricultural output through promotion of technologies such as irrigation schemes and the sinking of boreholes. In addition, introduction of livestock pass-on schemes has been done at the household and school levels. Other non-farm income generating initiatives have also been promotes and credit facilities have been expended to new farmers to enable them to embark on income generating projects. These initiatives mainly targeted women and youth. Specific income generating projects and programs such as WFP's Food for Assets program aimed at creating and restoring the household asset base have also been promoted (Belder, Rohrbach, Twomlow & Aiden, 2007; Catholic Relief Services (CRS), 2013; Pozniak, 2013; OCHA, 2013).

Comprehensive programs such as the Amalima project which target the household and the community have also been introduced. At the household level, the Amalima project promotes the use of better production methods such as use of conservation agriculture and growing drought resistant crops. At the community level, promotion of better post-harvest and food storage techniques is encouraged. Nutrition interventions introduced include the provisions of appropriate supplements to pregnant and lactating mothers as well as to children below the age of 2 years (CNFA, 2014).

1.4 This research

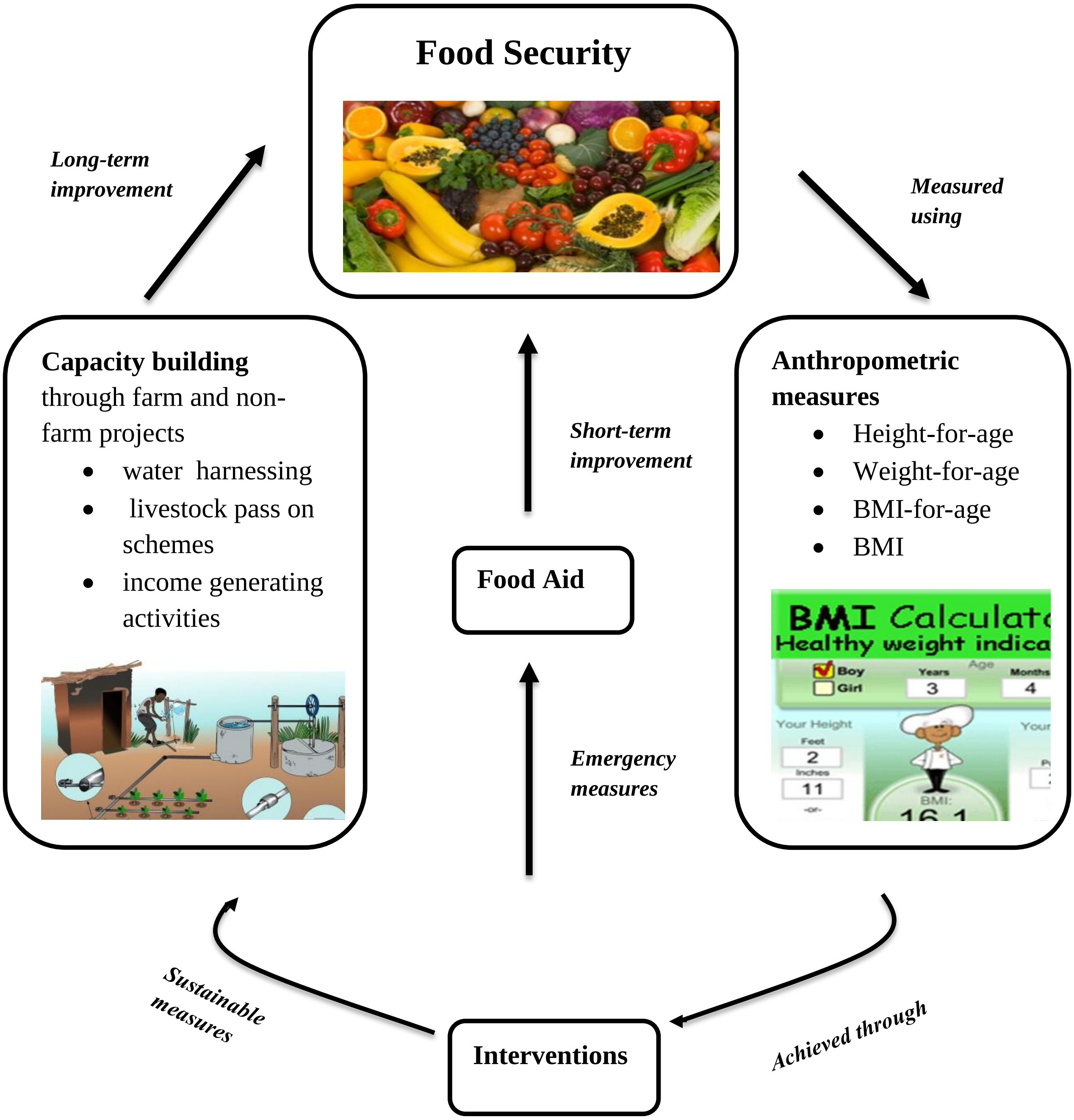
Against this background, this study intends to firstly examine the association between long-term and short-term child health, in order to establish whether better long-term health can help children cope with short-term health shocks. In addition, the implication of this result for targeting food insecure children will also be discussed. The Zimbabwe Demographic and Health Surveys (DHS) data for 2005/06 will be used for this analysis.

Secondly, this thesis will examine the role of maternal nutrition on child nutrition in order to provide clarification on which areas to concentrate on in order to improve child and maternal nutrition. The 2005/06 Zimbabwe DHS data will also be used for this analysis.

Thirdly this study will assess the degree to which a local capacity building program aimed at alleviating food insecurity has succeeded in improving household food security. The project in question is the nutritional home garden drip irrigation project that was introduced in 2003 by Plan International in conjunction with A Self-Help Assistance Program (ASAP), under the USAID initiative. The areas to be surveyed are Mutasa and Mutoko districts in the Manicaland and Mashonaland East provinces respectively. The main aim of the project was to provide better household nutrition, income, independence and self-reliance among the beneficiaries who are mainly poor families, widows and households looking after orphans and chronically ill members. Plan International provided drip irrigation kits and training on land preparation, record keeping, budgeting, marketing, the use of natural pesticides and nutrition to the beneficiaries in this area. Approximately 403 drip irrigation kits were distributed in each district. Overall, the project intends to assist in mitigating household food insecurity in a sustainable manner (Agrichem 2007). The data used in this analysis is from the 2013

Smallholder Drip Irrigation Survey conducted by the author. An overview of the thesis is illustrated in Figure 1.4 below.

Figure 1.4 Thesis overview



Pictures source: Google images

Source: Own model

CHAPTER 2

Short-term versus long-term child health: Is there an association and what are the implications for targeting the food insecure?

"Numerous studies suggest that children in food-insecure households have higher risks of health and development problems than children in otherwise similar food-secure households."

USDA/Economic Research Service 2009 – USDA Website

2.0 Introduction

Health is more than the absence of disease or infirmity. Health encompasses complete physical, emotional, mental and social wellbeing aimed at allowing one to be productive as an individual, in society and economically (World Health Organisation (WHO) in Jadad & O'Grady, 2008).

The importance of child health stems from the fact that children are the future and in order to safeguard future economic growth, it is important to ensure that favourable child health is cultivated and maintained. Worldwide, an estimated 6.6 million children under the age of five died in 2012 (WHO, 2014). According to WHO (2014), "children in sub-Saharan Africa are 16 times more likely to die compared to children in developed countries" and most vulnerable children are those born in rural areas and to poor and less educated families . Poor health or malnutrition has been identified as the fundamental cause of death in children and it is purported to increase their susceptibility to diseases such as pneumonia, diarrhoea, malaria and measles, largely responsible for deaths in children who are below the age of five. °

One of the ways in which child health is measured is through the use of anthropometric measures[2] such as the height, weight and body mass index (BMI) of a child. In particular, a child's long-term health (depicted by the height-for-age z-score) is a cumulative result of the conditions that a child is exposed to during pregnancy, at birth, in early and late life. These conditions are largely influenced by the mother's health, upbringing and household factors such as nutrition and the availability of sanitary facilities and the environment. Height z-score thus represents health stock: the taller a child is, the better their health stock is and the shorter a child is, the poorer their health stock is. A child's short-term health (depicted by the BMI-for-age z-score) on the other hand refers to acute changes in a child's health that occur as a result of conditions such as the incidence of disease and sudden food shortages which immediately impact on child health.

Poor short-term and long-term child health (BMI-for-age and height-for-age z-scores which are at least 2SD below the median of the reference population) are conventionally referred to as wasting and stunting respectively. Currently, wasting and stunting are a major challenge in the attainment of millennium development goal (MDG) 4 of reducing child mortality. In 2012, approximately 17 million children under 5 years of age suffered from wasting and 162 million suffered from stunting globally (WHO, 2009-2012).

The same anthropometric measures are used to identify children and consequently households who are food insecure. Typically, in emergency situations where selective feeding needs to be implemented, malnourished children under the age of 5 are chosen using the BMI-for-age z-score[3]. Children with a BMI-for-age z-score of between 2SD and 3SD below the median of

[2] These measures are standardised into z-scores for comparison purposes.

[3] According to Taylor and Seaman (2004), the BMI-for-age zscore is the criterion that is commonly used to identify children suffering from malnutrition. Other criteria include the mid-upper arm circumference (MUAC).

the reference population are moderately underweight[4] and are given supplementary feeding. Those with a BMI-for-age z-score below 3SD of the median are severely underweight and are recommended to receive therapeutic feeding immediately (Taylor & Seaman, 2004; WHO,2000). In cases where food or emergency aid needs to be distributed at the household level, households with children below the age of 5 suffering from malnutrition (as defined according to the BMI-for-age z-score) are selected. This selection criterion is based on the assumption that symptoms of malnutrition are first exhibited by children during food catastrophes (Salama &Collins, 2000). BMI-for-age and height-for-age z-scores are proxies for acute and chronic food insecurity respectively.

Efforts have been and are being made worldwide to address the issue of malnutrition in children through the millennium development goals (MDGs) approved by world leaders in 2000. All the eight MDG's are directly or indirectly targeted at improving child health. MDG4 and MDG5 directly state that child mortality rates must be reduced by at least 66% by 2015 and maternal health must be improved. MDG1, aimed at eradicating extreme poverty and hunger also places emphasise on reducing child malnutrition. Identified target areas for the attainment of improved child health and consequently reduced child mortality include interventions such as nutritional programs aimed at pregnant mothers and young children. Programs for young children include promotion of lactation and exclusive breastfeeding, hygienic feeding practices, immunization of infants and improved access to basic health facilities (MDG Report, 2011).

A MUAC of between 12.5cm and 13.5cm shows that the child suffers from moderate malnutrition. A MUAC of <12.5cm shows that a child is suffering from severe malnutrition (Munro, 2002).

[4] In this context, children with a low BMI-for-age z-score are referred to as underweight as opposed to wasted, according to the classification by Cole et al. (2007) and WHO (2000).

Varied levels of progress have been realised in attaining the MDG targets. Whilst some countries like Algeria are more likely to reach their 2015 MDG targets, other countries are still facing challenges in attaining their targets (MDG Report, 2011). For Zimbabwe, improvements in achieving universal primary education and gender equity in schools (MDG2 and MDG3) as well as in combating HIV and AIDS and other diseases such as malaria (MDG6) have been evident since 2000. Progress in attaining MDG1 and MDG5 of eradicating extreme hunger and poverty and improving maternal mortality has been slow. According to UN-Zimbabwe (2012), the prevalence of underweight children below the age of 5 in Zimbabwe was 10% in 2011, down from 11.8% in 2009. Globally progress in the reduction of child mortality rates is evident as infant mortality rates have reduced from 89 to 60 deaths per 1000 live births in 1990 and 2009 respectively. Sub-Saharan Africa (SSA), Asia and Oceania however are still lagging behind in reducing their infant mortality rates (MDG Report, 2011). In Zimbabwe, under 5 mortality rates declined from 102 to 84 deaths per 1000 live births and infant mortality rates declined slightly from 65 to 57 deaths per 1000 live births in 1999 to 2010/11 respectively (UN-Zimbabwe, 2012).

To date, research has revealed that in relation to obesity (high BMI-for-age) tall children are at risk in developed countries such as the USA (Freedman et al., 2004; Kain, Uauy, Lera, Taibo & Albala, 2005). However rather than focusing on the lower end of the z-score measure, focus is on the top end; children with a height z-score greater than 2[5] are more likely to have a BMI z-score that is greater than 2. For developing countries so far, research has established that there is no association between stunting (height z-score <-2) and obesity (BMI z-score >2) for South Africa, a developing country whose economy is developing at a faster pace compared to other developing countries in Sub-Saharan Africa (Jinabhai, Taylor & Sullivan,

[5] Z-scores are measured as standard deviations above or below the reference mean (Cole et al., 2007).

2003). Similar results were also obtained for Chile, a developing country undergoing nutritional transition (Stanojevic, Kain & Uauy, 2007).

There is thus need to further explore what the relationship is for poorer developing countries like Zimbabwe, whose economies are developing at a very slow or negative rate. Since the year 2000 Zimbabwe has undergone rapid economic decline exacerbated by political strife and poor climatic conditions. This has impacted severely on individuals, households and the nation at large and children have not been spared. Establishing the association between height and BMI for Zimbabwean children will help ascertain whether investing in long-term child health (height) can contribute to minimising the effects of short-term shocks such as political upheaval, droughts and famine. This result has important implications in terms of developing policies aimed at improving child health.

This research aims to explore the association between short-term and long-term child health (as depicted by the BMI-for-age and height-for-age z-scores respectively) for Zimbabwe through the use of econometric techniques which account for particular problems with the model such as selection bias and endogeneity. The BMI-for-age z-score is designed as a measure of weight which is independent of height, so on average, there should be no correlation between the BMI and height z-scores. Thus by modelling this relationship, this study aims to just establish the link between the two anthropometric measures, BMI and height rather than a cause and effect relationship. Studying this association is important as it brings to light the direction of influence that long-term health has on short-term health, a result which has important implications in terms of developing policies aimed at improving child and household health. In addition, the results of this study will be interpreted in relation to their implication on the criteria used to identify food insecure children and households in emergency situations. Salama and Collins (2000) argue that using child malnutrition to target food insecure people may result in omission of other groups of people (such as the elderly) who actually require food aid at that time, in addition to other errors. This research will shed light on what the implications of this correlation are for targeting the food insecure using only the short-term health measure (BMI-for-age z-scores) of children under 5 years of age as is the current practice.

2.1 Literature review

Extensive research has been carried out on child health issues. Medical research has focused largely on identifying the principal causes of child mortality as well as identifying preventative and curative interventions for child survival (Black et al., 2008; Black, Morris & Bryce, 2003; Bryce, Boschi-Pinto, Shibuya & Black, 2005; Darmstadt et al., 2005; Heikens, Amadi, Manary, Rollins & Tomkins, 2008; Jones, Steketee, Black, Bhutta & Morris, 2003). Leading health organisations such as the National Institute for Health and Clinical Excellence (NICE) and WHO have also established guidelines for child and maternal health, especially in the area of maternal health during pregnancy and nutrition of the newborn child.

Empirically, the determinants of child health and mortality continue to be explored. The influence of socio-economic variables such as maternal education, water and sanitation facilities, gender of the child, feeding practices (including breastfeeding and maternal and child supplementary feeding), and wealth status on child health and mortality have been discussed by researchers such as Boyle et al. (2006), Binka, Maude, Gyapong, Ross and Smith (1995), Caldwell (1979), Christiaensen and Alderman (2004) and Cleland and Ginneken (1988). These studies have revealed that determinants of child mortality and child health differ between and within countries. In all these studies, BMI-for-age (body mass index, a proxy for short-term health), height-for-age (a proxy for long-term health) and in some cases weight-for-age (a proxy for overall health) are examined independently of each other. The relationship between BMI-for-age and height-for-age has been examined mainly in relation to its influence on obesity for developed countries such as the USA and developing countries such as Chile and South Africa (Freedman et al., 2003; Jinabhai et al., 2003; Kain et al., 2005).

In addition to defining short-term, long-term and overall child health, this literature review will focus on the findings that have been made with regards to the determinants of child survival and child health. In most instances, researchers focus mainly on long-term child health revealed by the height-for-age z-score. Nonetheless there are some studies that have been carried out that focus on short-term child health and overall child-health revealed through a child's BMI-for-age or weight-for-height and weight-for-age respectively. The determinants of child health will be broadly categorised and discussed under the following sub-groups: maternal, child, household, birth, communal and environmental characteristics. Research findings on the interaction of short-term and long-term child health will also be presented.

2.2 Child health measures

A child's long-term health (depicted by the height z-score) is a cumulative result of the conditions that a child is exposed to during pregnancy, at birth, in early and late life. These conditions are largely influenced by the mother's health, upbringing and household factors such as nutrition and the availability of sanitary facilities and the environment. Height z-score represents health stock and the taller a child is, the better their health stock is and vice versa. A child's short-term health (depicted by the BMI z-score) on the other hand refers to acute changes in a child's health that occur as a result of conditions such as the incidence of disease and sudden food shortages which immediately impact on child health (Cogill, 2003; de Onis, 2000). Generally the term underweight in children refers to low weight-for-age. In this research, the adult definition of underweight (low BMI) will be used to refer to low BMI-for-age in children according to the classification by Cole, Flegal, Nicholls and Jackson (2007).

2.3 Determinants of child mortality and health

2.3.1 Maternal characteristics

Education, particularly maternal education has been found in most studies to be one of the factors that influence child survival and child health. Hobcraft (1993) purports that the more educated a woman is, the later they marry and the older they are when they give birth to their first child, given that they wait to get married before having a child. This results in increased chances of survival for the child as the mother will be more mature. The risk of maternal death is also reduced and most educated women have fewer children and this impact positively on child survival. Caldwell (1979), using data from the Changing African Family Project Nigerian Segment Survey 1, determined the effect of maternal education on child survival. His conclusions showed that maternal education increases chances of child survival, mainly through the application of education to improved health through implementing the acquired health knowledge and being empowered to a position where mothers can have more say in their children's health choices.

Following Caldwell (1979)'s work, Hobcraft (1993) looked into the effect of maternal education using demographic health survey (DHS) data for 25 countries in America, North and Sub-Saharan Africa and Asia. Results obtained also indicated that maternal education strongly influences child survival. The effect of maternal education on child survival was much stronger and significant in this study for 14 countries in Sub-Saharan Africa, compared to the results Hobcraft obtained in his earlier study in 1984. Cleland and Ginneken (1988) and Alves and Belluzo (2004) also arrived at a similar conclusion using data from developing countries and Brazil respectively. Remarkably, Desai and Alva (1998) established that the influence of maternal education on child health diminishes as one controls for individual and community level factors such as the education level of one's spouse, availability of piped water and sanitary facilities and the area of residence.

Paternal education also matters in child health as revealed by the positive impact of paternal as well as maternal education in the Philippines (Horton, 1986). In Ethiopia however, maternal education has twice as much influence on child health compared to paternal education (Christiansen & Alderman, 2004). Block and Webb (2003) further specify that for Indonesia, paternal health has a positive effect on the long-term health status of a child. Using data from Brazil to establish the direct and indirect effects of paternal education, Kassouf and Senauer (1996) found out that there was widespread malnutrition among children of parents with little or no education. Interestingly for Jamaica, only maternal education had a positive effect on child health whereas paternal education did not have a significant effect. What mattered in this instance was whether or not a child resided with his father. The study revealed that residing with their father actually improved a child's health status (Handa, 1999). Conversely, Binka et al. (1995)'s research indicated that maternal education has no significant effect on child mortality in Ghana.

In terms of the mother's health status revealed through her BMI, Alves and Belluzo (2004) found that for Brazil, BMI has a positive effect on the height-for-age z-score of a child; the healthier a mother is, the higher the chances that her child will not be stunted. Mbuya, Chidem, Chasekwa and Mishra (2010) also found that higher BMI in mothers reduces the chances of low birth weight for children in Zimbabwe. Their analysis also indicates that a mother's health status has no significant impact on long-term child health (height-for-age), which is contrary to the expected result.

A mother's age at the birth of her first child was found to have no significant effect on child health for Zimbabwe and Ghana (Mbuya, Chidem et al., 2010; Binka et al., 1995). However in their study, Alves and Belluzo (2004), using Brazilian data, found that younger mothers perform poorly in terms of raising their children compared to older mothers. Ngalinda (1998)'s findings support this as they indicate that the younger a mother is at the birth of her first baby, the higher the chances that the child dies. Binka et al. (1995) reported that violence to the mother decreases child survival chances in Ghana.

2.3.2 Child related characteristics

Child related characteristics such as gender, birth size, whether a child was born of multiple or single births, past sibling deaths and feeding practices have also been found to have different impacts on child health in different countries. With regards to the sex of a child, Mbuya, Chidem et al. (2010)'s study for Zimbabwe reveals that male children are more likely to be stunted compared to female children.

Concerning the matter of birth size, Mbuya, Chidem et al. (2010) found that the larger a child is at birth, the lower the likelihood of that child being stunted. Their study also revealed that children of born of multiple births (that is twins or triplets), are more likely to be stunted (a result also obtained by Christiaensen and Alderman (2004) for Ethiopia. Binka et al. (1995) show that past sibling deaths have no significant impact on child mortality.

Supplementary feeding is important in determining a child's health. Currie (2011), in her research on the inequalities associated with children at birth indicates that good nutrition has a positive effect on birth weight. Results from Patel et al. (2005) using data from Malawi point out that it is not supplementary feeding that is important per se, but rather the nutritional content of the supplement. Their study reveals that in Malawi, the common corn or soy-blend supplement improves health recovery by 46% in severely malnourished children. However a locally made lipid paste supplement, known as the ready-to-use therapeutic food (RUTF), comprising of peanut-butter, sugar, milk powder, vegetable oils and vitamin supplements actually increased health recovery rates in severely malnourished children by 78%. This conclusion is further reiterated in Mbuya, Humphrey et al. (2010)'s work as they indicate that vitamin A supplements in particular protect against poor long-term health in children. In contrast to the above, Mbuya, Humphrey et al. (2010) reveal that strict adherence to the recommended infant and young children feeding practices actually increases chances of stunting in a child, which is quite puzzling given that the recommended feeding practices are expected to be most favourable.

2.3.3 Birth related characteristics

Birth related variables also have an impact on child health. Firstly, child spacing or birth interval greatly influences a child's health. For northern Ghana, there is a significant increase in child deaths if the birth interval is very small (Binka et al., 1995). Horton (1986) also obtained similar results using data from the Philippines. Similar and more specific results were also obtained by Kembo and Ginneken (2009) using the 2005-2006 Zimbabwe DHS survey data. Kembo and Ginneken (2009) found that the combined effect of short interval spacing and birth order of 6+ increases the risk of infant mortality.

Secondly, breastfeeding practices also have an influence on child health and nutrition and this impact begins immediately after a child is born. Results from Binka et al. (1995) indicate that the post-neonatal mortality rate increases as a result of delayed initiation of breastfeeding as this means that the child is unable to get colostrum which contains essential nutrients for the development of a child's immunity system among others. Contrary to these, Mbuya, Humprey et al. (2010) reveals that delayed initiation of breastfeeding actually contributes to reducing the incidence of stunting in a child who is 6-23 months old. This result however is not significant.

Thirdly, a child's place of birth (be it a hospital or at home) was found not to have an important influence on child survival in studies by Binka et al. (1995). Binka et al. (1995) however found that what really matters in child survival and consequently child health is the capability of the birth assistants, as delivery by non-trained birth assistants increases the risks of child death.

2.3.4 Household related characteristics

Household infrastructure such as availability of a safe drinking water source and proper sanitary facilities have been found to have varying impacts on child health. In their study on child malnutrition in Ethiopia, Christiaensen and Alderman (2004) found that ownership of a tap by the household reduces incidence of stunting in children. Galiani, Gertler and Schargrodsky (2005)'s findings further emphasise that access to private water service improves child health through reducing child mortality. For Argentina, mortality rates for those with access to a private water source reduced by 5 to 9%. Not only does access to a private water source improve child health, Horton (1986) shows that for the Philippines access to water through the use of a public pump improves a child's long-term health. David, Moncada & Ordonez, (2004) further stipulate that for Honduras, access to tap water improves long-term child health. Quantile regression results further postulate that for those in the lowest quantile for India and Senegal, a safe water source has a positive effect on child health (Borooah, 2004; Bassolé, 2007). For Sri Lanka, Aturupane, Deolalikar and Gunewardena (2008), indicate that piped water improves child health in nearly all quantiles. Contrariwise, studies by Block and Webb (2003) and David et al. (2004) for Indonesia and Nicaragua indicate that access to tap water as well as the distance to the water source has no effect on child health.

Availability of proper sanitary facilities improves child health on the one hand as revealed by Christiaensen and Alderman (2004), Mbuya, Chidem et al. (2010) and Linnemayr, Alderman and Ka (2008) for Ethiopia, Zimbabwe and Senegal respectively. Interestingly, Valdivia (2004) discovered that increasing the number of sanitary facilities has no effect in general in Peru. This increase only becomes significant when locality is taken into account as an increase in the number of sanitary facilities in urban areas has a positive impact on a child's height-for-age score. For the rural areas though, the effect remains non-significant. For Jamaica, sanitary facilities only have a significant effect when interacted with maternal education (Handa, 1999). This result is supported by evidence from Block and Webb (2003)'s study which revealed that maternal knowledge on health and nutrition specifically plays an important role in improving child health in Indonesia.

A number of studies for Africa bring to light that wealth and wealth related variables have little significant impact on child health. These studies include that by Mbuya, Chidem et al. (2010), and Horton (1986) for Zimbabwe and Nigeria respectively. Binka et al. (1995), however, discovers a weak positive significance between the absence of a corrugated roof, one of the components used in assessing one's wealth status and child mortality. Though other similar asset related components have similar effects in their study, the results are not significant. Though it is quite unexpected for wealth and wealth related variables to have little significance on child heath, the result is quite plausible. Based on the assumption that the needs of children come first, regardless of whether they are from a poor or rich household, one would expect the wealth to have little influence on child health. Instead, the effect of wealth will be more pronounced in the carer of the child, especially the mother who will sacrifice in terms of food and other luxuries for the sake of her child.

Number of household members only weakly influences child health. Alves and Belluzo (2004) in their results indicate that the effect of a larger family size is revealed through the sibling effect as having more siblings' (implying a large number of household members) leads to poorer child health.

2.3.5 Community based characteristics

Community based factors such as the availability of health centres are also important for child health. Currie (2011) indicates that better access to medical care has a positive effect on child health. Bassolé (2007) further indicates that improved health facilities improve child health especially in rural areas for those in the 10th, 25th and 50th percentiles for Brazil. In contrast David et al. (2004) and Alderman, Hoogeveen and Rossi (2006) found that the time taken to travel to the nearest health facility has no significant impact on child health in Honduras and Tanzania respectively.

These are by no means all the factors that have an impact on child health. Research continues to identify of more factors such as environmental factors like pollution (Currie, 2011). This literature review however focused on main factors at the household level.

2.4 Short-term versus long-term child health

To date the relationship between BMI and height in children has been studied for different countries and varied results have been obtained. Most of these studies have been on developed countries such as the USA with an emphasis on the relationship between height and obesity.

Freedman et al. (2003), Freedman et al. (2004), Stovitz, Pereira, Vazquez, Lytle and Himes (2008) and Stovitz et al. (2010)'s research using USA data, reveals that there is a positive association between BMI and height, implying that taller children are more likely to be obese. Stovitz et al. (2008) further indicates that this positive relationship is evident for children in the top quintile of childhood BMI. Kain et al. (2005) also obtained results indicating that for 6 year old Chilean children, height is positively associated with increased weight for taller children.

Some studies have concluded that there is a negative relationship between height and BMI for both stunted and tall children. Kain et al. (2005), Popkin, Richards and Montiero. (1996) and Stanojevic et al. (2007) found that stunted children are more likely to be overweight. Using the weight-for-height z-scores to define obesity, Popkin et al. (1996) conclude that stunted children in China, Russia and South Africa are more likely to be overweight, regardless of their age, a result confirmed by Stanojevic et al. (2007) using BMI $\geq 95^{th}$ percentile as the cut-off. However using the weight-for-height z-score ≥2 cut-off for Stanojevic et al. (2007)'s sample renders stunting an insignificant factor in obesity, a result that has been attributed to the fact that Chile was in a post-transition nutritional phase. In addition Stanojevic et al. (2007)'s results indicated that taller children are more likely to be underweight. Studies using South African data support the former result, concluding that there is no association between stunting and being overweight (Jinabhai et al., 2003; Mukuddem-Petersen & Kruger, 2004).

The link between weight and height gains in children has also been studied by researchers such as Buchan, Bundred, Kitchiner and Cole (2007) and Maleta, Virtanen, Espo, Kulmala and Ashorn (2003) among others. Using data from England for 3 year olds from 1988-2003, Buchan et al. (2007) shows that the largest increase in BMI occurrs in the tallest children, implying that there is a positive relationship between BMI and child height and that height is crucial in examining obesity. In the shortest children, there is hardly any change in the BMI over the years. Maleta et al. (2003) on the other hand analyses the relationship between weight and height gains for children aged 0-3 years in rural Malawi and concludes that there is a weak association between weight and height gains. Maleta et al. (2003) attributes this weak association is attributed to seasonality as well as age. They argue that their findings are consistent with the fact that countries experiencing seasonal food supplies are likely to have complementary foods that are low in nutrition and this is likely to increase incidences of diarrhoea and disease in children. This in turn impacts negatively on weight gains. It is likely that these issues of lack of access to suitable food in certain seasons is not as much of a problem in countries like England, which can explain why Buchan et al (2007) found the opposite effect.

In terms of the appropriateness of using BMI (W/H^2) as the weight-for-height measure to categorise children as overweight or obese as opposed to using the Benn (W/H^ρ) and the Rohrer (W/H^3) indices, Freedman et al. (2003) concluded that BMI is a more suitable measure for grading tall children into weight categories as it constantly maintained a robust association with height than the other weight-for-height indices especially for boys. For girls, the results though positive were not significant for the 3 to 7 and 14 to 17 years olds. Franklin (1999)'s results from a comparative study of boys aged 6 to18 years from USA, UK, Japan and Singapore also concludes that BMI is an appropriate adiposity indicator for boys aged 6 to 7 and 17 to 18 years. Freedman et al. (2004) further revealed that the ρ value that minimises the correlation between weight and height (W/H^{ρ}) varies according to age. For their study, the ρ values ranged from 1.68 to 2.99 for 5 to 8 and 12 to 14 years old children respectively. This result is consistent with that obtained by Franklin (1999), who concluded that ρ varies with age from approximately 2.0 to 3.5 at 18 and 10 years of age respectively, for the USA, Japan and Singapore.

Since BMI is a transformed variable, constructed using the weight and height of an individual ($weight/height^{2}$), it is bound to be correlated to height. This has been acknowledged by some studies as a constraint in establishing and interpreting the relationship between BMI and height (Benn, 1971; Franklin, 1999 and Fung et al., 1990 in Freedman et al., 2004). To try and address this issue, Franklin (1999) used other weight-for-height indices where the power to which height was raised (ρ) was varied. Conclusions drawn from this study showed that raising height to a power greater than 2 was inclined to result in a positive relationship between BMI and height (that is tall children were more likely to have higher BMI than short children). Results obtained from using other weight-for-height indices constructed using different values for ρ and linking them with skin-fold thickness for different age groups led Frankin (1999) to conclude that a $\rho \approx 2$ (which is the power to which ρ is raised for the BMI index) gave the best association for children. The effect was however dependent on the age of the children. In this case, BMI gave the best association with height for children aged 6-7 and

17-18 years, but not for children aged 8-16 years. Comparing skin fold thickness and percentage body fat, which can also be used to measure obesity instead of BMI, Freedman et al. (2004)'s results showed that height is also positively related to these measures just like it is positively correlated with the BMI. Their results also confirmed that the age of the child matters as the magnitude of the relationship between height and BMI, skinfold thickness and percentage body fat tended to decrease with age.

Similar to the studies above, this study endeavours to establish the relationship between BMI and height for children aged 0-5 years from a poor, developing country, Zimbabwe whose major challenge is underweight as opposed to overweight children who have been the subject of the studies highlighted above. In addition, this research will account for potential sample selection bias and endogeneity issues, which have not been accounted for by previous research. An attempt will be made to extrapolate the mechanism by which the relationship between short-term and long-term health is brought about. Popkin et al. (1996) suggested mechanisms though they did not explore them in their study.

Given that height-for-age is a proxy for a child's long-term health, this research equates height-for-age to health stock. The taller a child is, the better their health stock. Thus taller children are healthier and are better able to recover from short-term health shocks such as food shortages than shorter children. If this is the case, then the expectation is that there should be a positive relationship between BMI and height. A positive relationship between BMI-for-age and height-for-age z-scores means a child with a high BMI-for-age z-score also has a high height-for-age z-score, as found by Freedman et al. (2003), Freedman et al. (2004), Stovitz et al. (2008) and Stovitz et al. (2010). This implies that a child with a low BMI-for-age z-score also has a low height-for-age z-score; that is, a child who is underweight is also stunted. As indicated in section 2.0, BMI-for-age is currently used to identify food insecure children below the age of 5 (Taylor & Seaman, 2004; WHO, 2000). If the positive relationship holds, using the BMI-for-age z-score for targeting underweight children, means that the problem of stunting will also be addressed indirectly. As a result, targeting using BMI-for-age will have the added advantage of addressing chronic malnutrition. This is by no means a causal relationship but rather an interpretation of the direction of effect.

2.5 Methods and procedures

2.5.1 The study population

The Demographic Health Survey (DHS) data for Zimbabwe for 2005-2006 is used in this research. The survey was carried out by Zimbabwe's Central Statistics Office (CSO) from August 2005 and February 2006 as part of the Zimbabwe National Household Survey Capability Program (ZNHSCD) and the worldwide Measure DHS. This survey is the 4th DHS survey to be carried out in Zimbabwe following the surveys done in 1988, 1994 and 1999. The main aim of the survey was to make available current information on reproductive (including information on fertility control, sexually transmitted infections (STI's) and HIV/AIDS), mortality and nutrition issues especially pertaining to women and children among others. Data was collected at national and provincial level. The country was divided into 34 strata, 4 strata for each of Zimbabwe's 8 provinces (Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West, Matebeleland North, Matebeleland South, Midlands and Masvingo) and one each for Harare and Bulawayo, the two cities that have been accorded provincial status. Strata were identified based on land use practises and were divided into large-scale commercial farming areas (LSCFA), small-scale commercial farming areas (SSCFA), urban and semi-urban areas, communal lands and resettlement areas.

Three questionnaires were administered; the household, women and men questionnaires. The household questionnaire mainly collected information on the features of residential units including information pertaining to the type of roofing, flooring and wall material for the house as well as sanitary facilities and drinking water facilities available. Information on asset ownership was also collected for durable goods such as refrigerators, radios and cars, as well as data pertaining to the total number of household members, household composition and the household head. The household questionnaire also served as the basis for identifying eligible women (aged 15-49years) and eligible men (aged 15-54 years) to whom the women and men questionnaires were administered. Out of 10,752 selected households, 9,778 were currently occupied and 9,285 were successfully interviewed.

A total of 8,907 out of the selected 9,870 eligible women were interviewed. In addition to the questions directly pertaining to the respondent such as their educational status, birth history, fertility preferences and pregnancy experience, respondents were also asked questions relating to their children, including birth related issues such as size of the child at birth, vaccinations received by the child, breastfeeding practices as well as supplementary infant feeding practices. Children aged 0-5 years for all the eligible women were weighted and their height and age at the time of the interview were also recorded.

The selected men were also asked more or less the same questions as women excluding questions relating to maternal and child nutrition as well as reproductive history. A total of 7,175 men were interviewed (out of the selected 8,761 men). The reason why some households, women and men were not interviewed was mainly due to the household not being there anymore, and the respondents being absent from the household despite repeated visits being paid to their dwellings. It was noted that men were often absent from their homes and they were absent for longer periods than women (CSO & Macro Inc., 2007).

2.5.2 Anthropometry

The analysis will mainly be based on anthropometric measures for children, which are widely used in determining child health. This study will use two indices namely: BMI, which is the adjusted measure of weight when height is taken into account and is computed as:

$$BMI = \frac{weight\ (kg)}{height^2\ (m^2)}$$

It generally is a representation of short-term nutritional status while height-for-age is a measure used to determine the long-term nutritional status. Children with a BMI z-score and height z-score below -2SD are underweight and stunted respectively. Generally the term underweight in children refers to a low weight-for-age. In adults underweight indicates low BMI. The term underweight in this research is used to refer to low BMI-for-age in children according to the classification by Cole et al. (2007).

Conventionally z-scores are used for anthropometric indicators. Z-scores are useful as they are based on a common reference standard that is set for the standard height, weight and BMI for children of each age group and gender. Z-scores also allow for the estimation of summary statistics (such as the mean and standard deviations) for populations or sub-populations, a property which other measures such as percentiles do not possess. Sufficient identification of fixed points in the distribution of indices across different ages is also possible through the use of z-scores (Cogill, 2003).

The z-scores for BMI-for-age and height-for-age measures are constructed in this research using the 1990 British[6] Growth Reference charts (Vidmar, Carlin, Hesketh & Cole 2004) which is advantageous over the 1974 US National Centre for Health Statistics (NCHS) measure, as it covers our sample 0-59 months for the two measures. The NCHS measure only provides BMI-for-age and the height-for-age z-score for children who are 2 to 20 years old. The NCHS does not provide measures for children below 2 years. Using this measure will result in a reduction of the sample population by 44.3%.

Z-scores are obtained using the formula below:

$$z - score = \frac{observed\ value - median\ value\ of\ the\ reference\ population}{standard\ deviation\ of\ the\ reference\ population}$$

where the observed value is the observed height, weight or BMI value for each child and 1990 British Growth Reference measure is the reference population. All the z-scores are constructed using the zanthro function in STATA12 (Vidmar et al. 2004). The BMI-for-age z-score is the dependent variable for all the models to be estimated whilst height-for-age z-score is the main explanatory variable.

2.6 Data analysis

2.6.1 The main empirical specification

The main model purports that there is a linear relationship between BMI and height given by:

$$BMIzscore_i = \alpha_0 + \delta heightzscore_i + \beta X_i' + \varepsilon_i \qquad (2.1)$$

[6] The data used to develop these reference charts was obtained from 17 UK surveys conducted between 1978 and 1993 (Vidmar et al., 2004).

where X_i' is a 1x k vector of independent variables comprising of maternal, child and household characteristics defined in Table 2.1. ε_i represents all unobservable factors that influence child health and is assumed to be normally distributed with a mean zero and a constant variance ($\varepsilon_i \sim N(0, \sigma^2)$) , while α_0 is the constant. In order to ensure that consistent estimators are obtained sample selection bias and endogeneity need to be accounted for. Robust standard errors and bootstrapping will be used for all the models. This will enable the correct standard errors to be estimated, accounting for clustering[7] at the household level, as there may be children from the same household with correlated unobserved characteristics in the sample. Ignoring clustering overstates the precision of the estimates (Deaton, 1997; Long & Freese, 2006).

Explanatory variables

The main explanatory variable in this study as mentioned in section 2.5.2 is the z-score for height-for-age (*heightzscore)*. In order to make the models more comprehensive, maternal, child and household variables will also be included, on the basis of findings from other literature, as discussed in sections 2.1 to 2.4.

Maternal variables include mother's BMI represented by the dummy variables *bmimumunder*, *bmimumnorm*, *bmimumover* which indicate that the mother is underweight (BMI<18.5), of normal weight (18.5< BMI<25) and overweight (BMI>25) respectively in accordance with the recommended WHO BMI cut off levels (WHO, 2011). The mother's education level is represented by: *noeducation*, *primarylev*, *secondarylev* and *higher*, dummy variables signifying that the mother is not educated, has primary or secondary level education and has higher than secondary level education respectively. The mother's marital status is denoted by

[7] There are 2978 to 3063 clusters in this sample for the main model.

the dummy variables *married*, *notmarry*, *divorced* and *widow* are defined as the mother is married or living together with the father of her child or children, not married, divorced or not living together with the father of her child or children and widowed respectively. All the above dummy variables will take the value 1 if the above mentioned educational level, BMI or marital status is realised. The variable for maternal height, mumheight comprises of the actual values for height.

Child related variables include the size of the child at birth represented by the dummy variables *verysmall*, *belowaverag*, *average*, *aboveaverage* for children who were very small, smaller than average, average and above average at birth respectively, gender of the child (*childmale)*, whether the child was born as a singleton or as a twin(*childtwin)*,whether the child suffered from diarrhoea two weeks preceding the survey *(diarrhoea)* and whether the child received any vaccination for DPT, polio, measles and BCG (*vaccination)*. The child's age is represented by *ageA* (0-6 months), *ageB* (7-24 months), *ageC* (25-48 months) and *ageD* (49-59 months). The age categories are divided into these four categories in order to show the variations if any that a certain age has on short-term health of a child. Types of food consumed will be represented by *grain*, *fruitveg, meat*. The interaction variables *ageAgrain*, *ageAmeat* and *ageAfruitveg* are included for children less than 6 months old as they are expected to be exclusively breastfed at this age. Early introduction to food supplements has adverse effects on a child's short-term health. All the above dummy variables will take the value 1 if the above mentioned birth size, sex, birth status, incidence of diarrhoea, receipt of vaccinations, age and receipt of food supplements are realised. Actual values are used for the breast feeding duration and the squared breastfeeding duration, represented by *breastfeedduration* and *sqbreastfeedduration* respectively.

Household variables include type of toilet facilities available; *notoilet*, *toiletflush* and *toiletpit* representing, absence of toilet facilities, presence of a flushing toilet[8] and the presence of a pit toilet[9] in the household respectively. The type of drinking water facility available are represented by *unprotwater*, *drinkwatertap*, *drinkwaterother indicating* that a household gets drinking water from an unprotected water source (unprotected dug well, spring, rainwater, cart water and surface water from a dam, pond or stream), from protected tap water and from other protected water sources (borehole, tube well, protected dug well and or a protected spring) respectively. The variables *rural* and *malehhdhead* will stand for household location and the sex of the household head respectively. All the variables above are dummy variables and take the value 1 if the characteristic mentioned is present and 0 otherwise. For the period the interview was conducted, the dummy variables *interviewaugsept*, *interviewoctdec* and *interviewjanapril* will take the value 1 if the interview was conducted in August or September, October to December and January to April respectively.

The wealth status will be represented by 5 classes' namely *wealthquintile1*, *wealthquintile2*, *wealthquintile3*, *wealthquintile4* and *wealthquintile5*. For each class, a dummy variable is created with the value 1 signifying that the household is in the above mentioned class and 0 if the household is not in the named class. These wealth index categories are constructed through the use of principal component analysis whereby consumer household assets such as cars, televisions, bicycle and dwelling characteristics such as roofing and floor type of the household, drinking water source and the type of sanitation facilities available in a household are allocated factor scores. The factor scores are then summed up for each household to form a wealth index. Individuals are then allocated a wealth quintile based on their household score. The 5 wealth quintiles result in the 5 wealth classes mentioned above (CSO & Macro Inc.,

[8] Flushing toilets are flushed either to a piped sewer system, a septic tank or to a latrine.

[9] Pit toilets include ventilated improved pit toilets with or without a slab or non-ventilated improved pit toilets with or without a slab.

2007). Continuous variables *hhdmember, chnunder5, agehhdhead* and *sqagehhdhead* denoting the total number of household members, the number of children under five years of age and the age and squared age of the household head will also be included.

Other factors such as the distance one has to travel to the nearest health facility also affect a child's health (Hendryx, Ahern, Lovrich & McCurdy, 2000). However, our data has no information on this variable and thus we are unable to include the variables in our model.

The variables are described in Table 2.1. For continuous variables, the mean and standard deviation is reported whereas the number and the percentage of observations in each category is reported for all dummy variables. The variables are introduced separately into the model in order to determine whether their impact on the main explanatory variable (*heightzscore*) differs. Models 1, 2 and 3 in the main empirical specification will thus include maternal, maternal and child related and maternal, child related and household variables respectively.

2.6.2 Sample selection bias

The sample consists only of children who were alive at the time of the survey. All the children who were dead[10] but could have been part of the sample based on their ages had they been alive are excluded from the sample. This presents a potential sample selection bias if there are some unobservable variables that directly and indirectly influence a child's survival chances and a child's current health status respectively. Presence of such unobserved variables results in correlation between the error term and the explanatory variables, which leads to inconsistent OLS estimates if ignored (Kennedy, 2003).

[10] 7.7% of the children died before 5 years of age.

The Heckman two-stage procedure is used to account for sample selection bias. The selection (first-stage) part of the model is given by the child survival equation (2.2) below.

$$Y_i^* = b_0 + \beta X_i' + \gamma V_i' + u_i \tag{2.2}$$

where Y_i^* is the latent propensity of a child to survive, b_0 is the constant, X_i' and V_i' are vectors of some of the independent variables in equation (2.1) and identification variables that influence child survival and are excluded from the child health model respectively and u_i is the error term. The identification variables, *prenatal* and *agefirstbirth* corresponding to whether the mother received prenatal care during her pregnancy and the age at which she first gave birth respectively have been selected based on evidence from other studies (Ngalinda, 1998; NICE, 2008). Y_i^* in equation (2.2) is unobserved. What is observed is whether or not a child is alive *(childalive)*, denoted by Y_i, a binary variable taking the value 1 if the child is alive and 0 otherwise. Y_i is related to Y_i^* through the equation below:

$$Y_i = \begin{cases} 1 \; if \; Y_i^* > 0 \\ 0 \; if \; Y_i^* \leq 0 \end{cases} \tag{2.3}$$

It is assumed that ε_i and u_i follow a bivariate normal distribution with mean 0 and standard deviation σ_ε and σ_u respectively (ε_i , u_i ~ BVN (0,0, σ_ε , σ_u, ρ[11])). Y_i and V_i are observed only for a random sample of individuals whereas $BMIzscore_i$ is only observed when $Y_i = 1$. The conditional expectation is given by:

$$E(BMIzscore_i|Y_i = 1) = E(BMIzscore_i|Y_i^* > 0)$$

$$= E(BMIzscore_i|u_i > -\gamma V_i')$$

$$= \beta X_i' + E\,(\varepsilon_i|u_i - \gamma V_i')$$

[11] ρ is the correlation coefficient between the two error terms ε_i and u_i.

$$= \beta X_i' + \rho\sigma_\varepsilon \lambda_i(\alpha_u)$$

$$= \beta X_i' + \beta_\lambda \lambda_i(\alpha_u) \quad (2.4)$$

where $\beta_\lambda = \rho\sigma_\varepsilon$ and $\lambda_i(\alpha_u)$ is the inverse mills ratio (IMR). If ε_i and u_i are independent, the term $E\ (\varepsilon_i | u_i - \gamma V_i')$ becomes 0 and there will be no bias. In this case, the simple OLS regression of $BMIzscore_i$ on $heightzscore_i$ and X_i' in equation (1) will give consistent σ and β estimates. For this study, it is assumed that the error terms are not independent and thus the IMR (ratio of the normal density function (ϕ) and the normal distribution function (Φ) of the selection (child survival) equation's residuals for each child) is estimated. The IMR is included in equation (2.1) as an explanatory variable, removing the correlation between the error term and the explanatory variables. The resultant equation below is estimated by OLS and produces consistent estimates.

$$BMIzscore_i = a_0 + \delta heightzscore_i + \beta X_i' + \beta_\lambda \lambda_i(\alpha_u) + \varepsilon_i \quad (2.5)$$

2.6.3 Endogeneity

Endogeneity between *BMIzscore* and *heightzscore* may possibly arise from the presence of unobservable maternal factors and or unobserved child related factors that influence the determination of both the BMI and height of a child. The OLS model only accounts for observable maternal and child factors such as the mother's height and the child's gender, thus the estimators are inconsistent in the presence of endogeneity. The maternal fixed effects (maternal fixed effects) and the instrumental variable (IV) models will be used to account for endogeneity respectively, in order to obtain consistent estimates.

The maternal fixed effects model

To account for the effect of unobservable maternal factors, the maternal fixed effects model (maternal fixed effects) is estimated for households with at least 2 children who are less than 5 years old, with the same mother.

The relationship between *BMIzscore* and *heightzscore* for child *i* with mother *j* is therefore given by:

$$BMIzscore_{ij} = \alpha_j + \delta heightzscore_{ij} + \gamma R_{ij} + \varepsilon_{ij} \qquad (2.6)$$

$$for\ i = 1, \ldots N\ and\ j = 1, \ldots \ldots J$$

where R'_{ij} is a 1x k vector of child related factors affecting the *BMIzscore*. α_j and ε_{ij} are the unobserved maternal fixed factors and the idiosyncratic error respectively. Suppose α_i is correlated with the $heightzscore_{ij}$ and R_{ij}, use of the OLS method results in inconsistent estimators of σ and γ . In order to correct for this, there is need to account for α_j , either through introducing an identification factor or removing α_j . α_j is unobserved so an identification factor cannot be used. Instead α_j is removed through mean-differencing as shown below.

$$(BMIszcore_{ij} - \overline{BMIszcore_j}) = (\alpha_j - \overline{\alpha_j}) + (heightzscore_{ij} - \overline{heightzscore_j})\beta$$

$$+ \left(R_{ij} - \overline{R_j}\right)\gamma + \left(\varepsilon_{ij} - \overline{\varepsilon_j}\right) \qquad (2.7)$$

where $\overline{BMIzscore_j} = \frac{1}{N_j}\sum_{i=1}^{N_j} BMIzscore_{ij}$; $\overline{heightzscore_j} = \frac{1}{N_j}\sum_{i=1}^{N_j} heightzscore_{ij}$; $\overline{R_j} = \frac{1}{N_j}\sum_{i=1}^{N_j} R_{ij}$; $\overline{\alpha_j} = \alpha_j$ and $\overline{\varepsilon_j} = \frac{1}{N_j}\sum_{i=1}^{N_j} \varepsilon_{ij}$ (the averages of the factors across children with the same mother). Since $\overline{\alpha_j} = \alpha_j$, the unobserved maternal fixed effects are eliminated and OLS estimation of the mean-differenced equation (2.7), yields consistent estimators of β and δ.

$$(BMIszcore_{ij} - \overline{BMIszcore_j}) = (heightzscore_{ij} - \overline{heightzscore_j})\beta$$

$$+ (r_{ij} - \overline{r_j})\gamma + (\varepsilon_{ij} - \overline{\varepsilon_j}) \qquad (2.8)$$

The maternal fixed effects model is advantageous as it allows for consistent parameter estimates to be obtained even if there is correlation between the explanatory variables and the error term, provided the endogeneity is due to unobserved maternal characteristics (Cameron &Trivedi, 2010; Levy & Duncan, 2000).

The IV model

Given that *BMIzscore* and *heightzscore* measures are both obtained from the same child, it is reasonable to assume that they are determined simultaneously. Suppose there are unobservable child specific variables that influence both the *BMIzscore* and the *heightzscore, heightzscore* in equation (2.1) becomes an endogenous regressor and is correlated to ε_i. This renders OLS estimator inconsistent as the assumption of no correlation, $cov(\varepsilon_i, heightzscore_i = 0)$ is violated. The resultant OLS estimator will not be able to estimate the pure effect of *heightzscore*.

To account for endogeneity, some instrumental variables V_i' are identified. These are corresponding to the breastfeeding duration (*breastfeedduration*), the squared breastfeeding duration (*sqbreastfeedduration*), the breastfeeding duration of a child aged 25 to 48 months (*breastfeedduration2548*), the breastfeeding duration of a child aged 49 to 59 months (*breastfeedduration4959*) and whether a child ever received a vitamin A dose (*vitaminA*) respectively. These variables are likely to impact *BMIzscore*, only through height and hence can be excluded from the *BMIzscore* equation. The variables are valid instruments as they measure what happened in the past (long-term) as opposed to the current status (short-term). Evidence from other studies also indicates that these factors influence *heightzscore* (Bhandari et al., 2001; Hadi et al., 2000; Mbuya, Chidem et al., 2010; Stanojeveic et al., 2007).

The two stages least squares (2SLS) method is employed to estimate firstly the reduced form equation (2.9) for *heightzscore* on V_i' :

$$heightzscore_i = \beta_0 + \beta X_i' + \lambda V_i' + \mu_i \qquad (2.9)$$

where X_i is a vector of other independent variables comprising of maternal, child and household characteristics (defined in Table 2.1) and β_0 is the constant. The predicted value $\widehat{heightzscore}_i$ is obtained and substituted for *heightzscore* structural equation (2.1). The resultant equation is then estimated by OLS in the second stage (equation (2.10) below) and gives rise to consistent estimators as endogeneity is accounted for.

$$BMIzscore_i = \alpha_0 + \sigma \widehat{heightzscore}_i + \beta X_i' + \varepsilon_i \qquad (2.10)$$

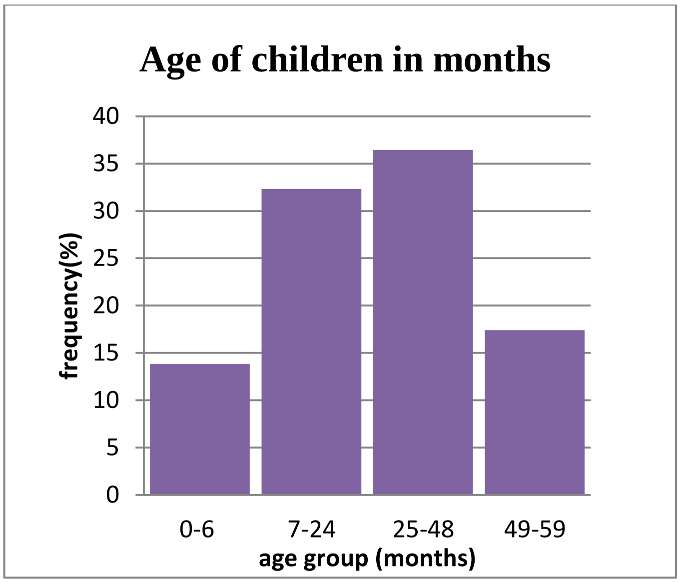
(Cameron & Trivedi, 2010; Murray, 2006).

2.7 Results and discussion

2.7.1 Descriptive analysis

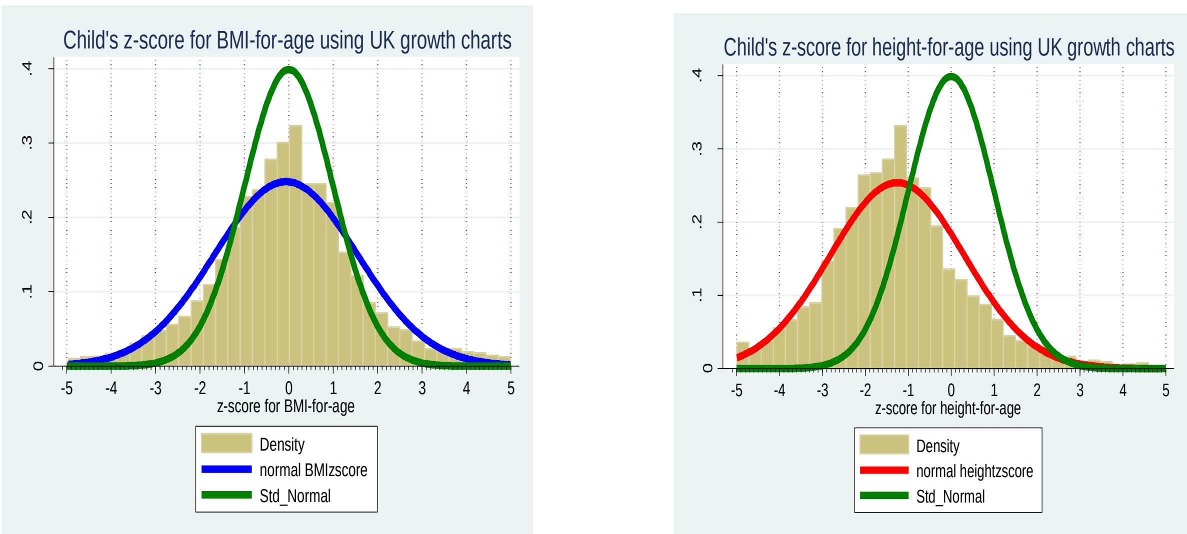
The sample consists of 4536 children below the age of 5. Figure 2.1 below shows that there is more or less an equal representation of children in the 7-24 and 25-48 months age groups (32% and 37% respectively). The lowest representation is for children aged 0-6 months (14%).

Figure 2.1: Age distribution for children aged 0-59 months



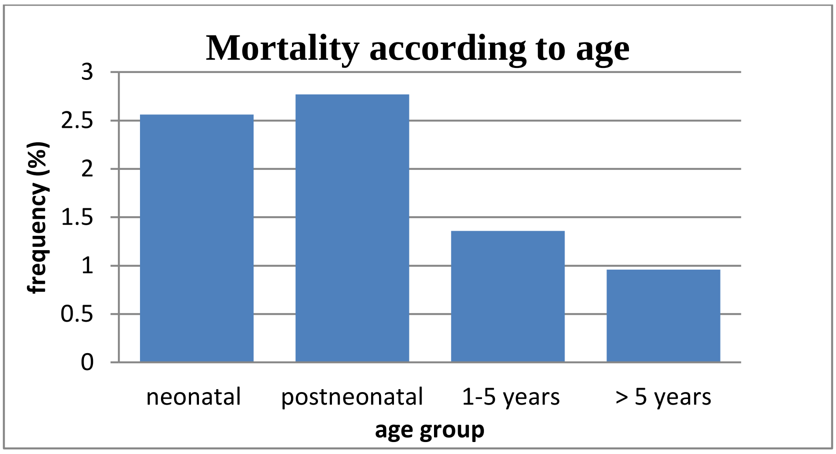
10.5% and 31.2% of the 4536 children in the sample are underweight and stunted respectively. The z-scores distribution (Figure 2.2 below) shows that children in Zimbabwe are generally shorter (height-for-age mean -1.256SD) and slightly underweight (BMI-for-age mean -0.063SD) and the distribution of the two measures is more widespread compared to the reference population.

Figure 2.2: Z-score distribution for BMI-for-age and height-for-age



An estimated 7.7% of the children were deceased by the time the survey was done. This presents a potential selection problem, as the children who are dead but would have qualified to be in the sample are selected against. Figure 2.3 below shows that most (approximately 5.33%) children die before they are 1 year old (neonatal[12] and post-neonatal[13] deaths). The least number of deaths occurs above 5 years of age.

Figure 2.3: Child mortality distribution



There is an almost equal representation of male and female children with males being slightly more than females (50.4%). 3.3% of the children are born twins. Most of the children are of average size[14] (2.5kg) at birth and 15.4% and 37.8% are born below average (<2.5kg) and above average (>2.5kg) respectively. Almost 66% of the children are breastfed immediately after birth and an additional 10.25% are put to breast within the first hour of birth. 93.4% of the children are breastfed and 23.5% of the children are vaccinated[15] before they are 5 years old.

[12] Neonatal deaths occur from birth to the time a child is 28 days old (WHO, 2011d).
[13] Post-neonatal deaths occur from 29 days old to 1 year.
[14] All the sizes are based on the classification in the DHS report for 2005-06.
[15] There are 4 common vaccinations administered to children namely: BCG (1 dose), DPT (3 does), polio (3 doses) and measles (1 dose).

Approximately 66.2% of the households in the sample are in the lowest 3 quintiles of the wealth class. This suggests that poor households have slightly more representation in this sample than rich households as the distribution is expected to be 20% in each quintile. Provincial representation ranges from 6.4% for Bulawayo to 13.7% for Midlands. Approximately 25% and 75% of the population resides in the urban and rural areas respectively. Almost half of the population dwell in houses with no proper sanitary facilities. 24.7% and 34.5% live in households with flushing and pit toilets respectively. The majority of households obtain their drinking water from a protected water source (70.5%), either through tap water or protected boreholes, springs and wells. The rest of the households obtain their drinking water from unprotected water sources ranging from unprotected wells and springs to rain water and surface water from dams, lakes, ponds and streams.

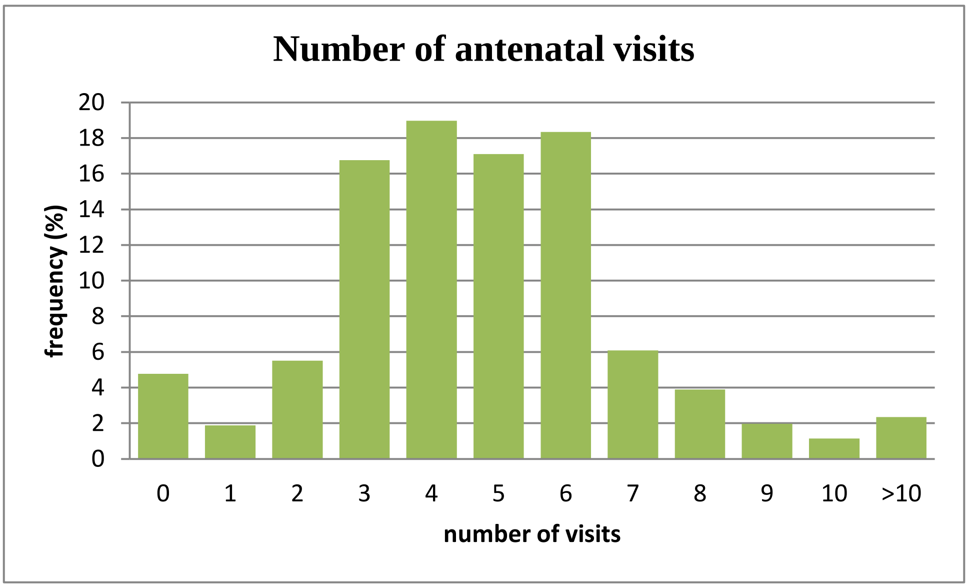
The total number of household members in each household ranges from 1 to 24 and the most common household size is 5 members (18.2%). In terms of household composition, most households have one child who is at most 5 years old (37.3%) and approximately a third have no children who are 5 years old or younger. The maximum number of children under or equal to 5 years old residing in a household is 6. About 60.1% of the households are headed by males and the ages of the household heads are from 16-95 years. Overall most of the female and male household heads are in the 35-44 and 45-54 years old groups respectively. 36.1%, 41.2% and 22.7% of the interviews took place in the August-September, October-December and January-April periods respectively. Timing of the interviews is important as Zimbabwe suffers from seasonal food insecurity. Food insecurity is highest from January to April which is the period just before the harvest (CIA, 2010).

With reference to maternal characteristics, approximately 4.3% of the mothers are not educated. 39.7% and 2.2% of the mothers in the sample completed primary and tertiary level education respectively. Just about 70.6% of the mothers are classed as healthy in terms of their BMI ($18.5 \leq BMI \leq 25$), whilst 21.7% are overweight ($BMI>25$) and 7.8% are underweight ($BMI<18.5$). The majority of the mothers are married or living together with their spouses (85.2%). 6.7% and 3.9% are widows and divorced or separated mothers respectively. Only 4.3% of the mothers have never been married.

Pregnancy and birth related issues

An estimated 52.6% of the women use contraceptives for family planning purposes. On average, pregnant women in Zimbabwe have 5 antenatal visits during their pregnancy period and very few have more than 10 visits as shown in Figure 2.4 below.

Figure 2.4: Antenatal visits



4.78% of the women did not make any antenatal visits when they were pregnant. The most common supplementary foods for pregnant women are from grains and tubers such as bread, noodles, cassava and potatoes (32.1%) which are part of the staple diet. Meat based supplements are less common (15.6%) and at least one fifth of pregnant women consume vitamin based food supplements which include fruits, vegetables and legumes. Women are generally as young as 10 and as old as 39 when they give birth to their first baby. The mean age at first birth was 19.3years. Most of the women delivered their babies naturally and an estimated 4.8% delivered by caesarean. Approximately two thirds of the women give birth in hospitals (private or public), clinics and missionary institutions. 79.1% were assisted by trained medical personnel such as doctors, nurses and midwives during birth.

Table 2.1: Descriptive statistics

Variable described	Continuous variables	Mean	Standard deviation
BMI-for-age z-score	BMIzscore	-0.06	1.61
Height-for-age z-score	heightzscore	-1.26	1.57
Number of household members	hhdmember	6.22	2.85
Mother's height	mumheight	159.73	6.94
Breast feeding duration (months)	breastfeedduration	15.41	6.85
Number of children under 5	chnunder5	1.81	0.93
Age of household head	agehhdhead	40.09	14.56
Mother's age at first birth	agefirstbirth	19.27	3.22
	Dummy variables	**Observations**	**Percentage (%)**
Maternal			
Underweight (BMI<18.5)	bmimumunder	306	7.76
Normal weight(18.5≤BMI≤25)	bmimumnorm	2781	70.55
Overweight (BMI>25)	bmimumover	855	21.69
Not educated	noeducation	173	4.33
Attended primary education	primarylev	1584	39.66
Attended secondary and tertiary education	secondaryabove	2237	56.01
Mother is not married	notmarry	170	4.26
Mother is married	married	3402	85.17
Mother is divorced or widowed	divorcewidow	422	10.57
Mother received prenatal care	prenatal	2985	74.76
Child related			
Size at birth (subjective)			
Smaller than average at birth	belowaverage	598	15.22
Average size at birth	average	1818	46.28
Above average at birth	aboveaverage	1512	38.49
Had diarrhoea in the last 2 weeks before survey	diarrhoea	528	13.22
Received vaccination for DPT, polio, measels, BCG	vaccinated	287	7.26
Vitamin A supplement received	vitaminA	1944	49.37
Child is male	childmale	1992	49.87
Child is a twin	childtwin	53	1.33
Aged 0-6 months	ageA	484	12.12
Aged 7-24 months	ageB(7-24mnths)	1302	32.60
Aged 25-48 months	ageC(25-48mnths)	1494	37.41
Aged 49-59 months	ageD(49-59mnths)	714	17.88
Received grain based supplements	grain	679	17.03
Received fruit and or vegetable based supplements	fruitveg	1249	31.37
Received meat based supplements	meat	961	24.15
Household			
No toilet facilities	notoilet	1724	43.23
Flushing toilet facilities available	toiletflush	897	22.49
Pit toilet facilities available	toiletpit	1367	34.28
Unprotected water source	drinkunprotectedwater	1170	29.95
Protected tap water	drinkwatertap	1112	28.46
Protected water from a borehole, spring or well	drinkwaterother	1625	41.59
First wealth quintile	wealthquintile1	1067	26.72
Second wealth quintile	wealthquintile2	922	23.08
Third wealth quintile	wealthquintile3	757	18.95
Fourth wealth quintile	wealthquintile4	739	18.50
Fifth wealth quintile	wealthquintile5	509	12.74
Resides in the rural area	rural	3069	76.84
Household head is male	malehhdhead	2692	67.40
Interviewed in August- September	interviewaugsept	1440	36.05
Interviewed in October - December	interviewoctdec	1647	41.24
Interviewed in January- April	interviewjanapril	906	22.68

The base categories are bmimumover, noeducation, married, belowaverage, ageA, notoilet, drinkunprotectedwater, wealthquintile1 and interviewaugsept

All dummy variables take the value 1 for the condition mentioned and 0 otherwise

2.7.2 Empirical analysis

The main (OLS), sample selection (Heckman) and endogeneity (maternal fixed effects, IV and IV on maternal fixed effects) models results are presented in Tables 2.2 to Table 2.7. As mentioned in section 2.6.1, three models are estimated whereby maternal, child and household variables are introduced separately in order to assess their impact on the main variable (*heightzscore*) for the main and sample selection models. For endogeneity (IV) three models are estimated depending on the instruments used. Only one model is estimated for the IV on maternal fixed effects.

2.7.3 Discussion of results

Child survival

Results in Table 2.2 below are for the child survival model. The identifying variables, receipt of prenatal care (*prenatal*) and the age at which a mother gave birth to her first child (*agefirstbirth)* significantly improve child survival chances when maternal, child and household factors are controlled for. This is consistent with the results obtained by other research (Ngalinda, 1998; NICE, 2008). In addition *chnunder5* significantly improves whilst marital status (*divorced* and *widow*), *hhdmember* and *malehhdhead* significantly reduce chances of survival in children.

Table 2.2: Child survival model for all children 0-59 months old

Dependent variable : childalive (the child is alive)

	Model 1		Model 2		Model 3	
	coef	**se**	**coef**	**se**	**coef**	**se**
Maternal variables						
bmimunder	-0.195	(0.125)	-0.201	(0.126)	-0.242	(0.160)
bmimnorm	-0.047	(0.082)	-0.049	(0.072)	-0.081	(0.060)
mumheight	0.013**	(0.006)	0.013**	(0.006)	0.015***	(0.005)
primarylev	0.101	(0.185)	0.100	(0.176)	0.106	(0.143)
secondabove	0.049	(0.178)	0.046	(0.179)	0.042	(0.156)
notmarry	-0.294**	(0.125)	-0.300**	(0.130)	-0.247*	(0.127)
divorcewidow	-0.584***	(0.106)	-0.583***	(0.101)	-0.525***	(0.128)
Child variables						
size at birth						
average	0.156*	-0.09	0.155	(0.097)	0.143*	(0.086)
aboveaverage	0.104	(0.093)	0.104	(0.106)	0.079	(0.091)
childmale	-0.043	(0.065)	-0.044	(0.067)	-0.039	(0.058)
Household variables						
hhdmember	-0.072***	(0.019)	-0.072***	(0.018)	-0.095***	(0.019)
chnunder5	0.863***	(0.105)	0.862***	(0.099)	0.962***	(0.097)
malehhdhead	-0.186**	(0.089)	-0.186***	(0.072)	-0.158*	(0.089)
agehhdhead	0.015	(0.014)	0.015	(0.013)	0.021*	(0.011)
sqagehhdhead	-0.000	(0.000)	-0.000	(0.000)	-0.000*	(0.000)
Birth experience variables						
prenatal	1.118***	(0.084)	1.118***	(0.094)	1.165***	(0.090)
agefirstbirth	0.030***	(0.010)	0.030**	(0.012)	0.029***	(0.009)
constant	-3.167***	(1.013)	-3.153***	(0.964)	-3.554***	(0.755)
no. of observations	4,183		4,165		4,078	

Robust standard errors in parentheses

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

Table 2.3a: OLS and Heckman results for all children aged 0-59 months

Dependent variable : BMIzscore

	Model 1				Model 2			
	OLS		Heckman		OLS		Heckman	
	coef	se	coef	se	coef	se	coef	se
Main variable								
heightzscore	-0.271***	(0.019)	-0.271***	(0.022)	-0.313***	(0.020)	-0.314***	(0.019)
Maternal variables								
bmimunder	-0.923***	(0.107)	-0.920***	(0.102)	-0.817***	(0.104)	-0.825***	(0.111)
bmimnorm	-0.316***	(0.061)	-0.316***	(0.057)	-0.291***	(0.060)	-0.295***	(0.064)
mumheight	0.016***	(0.004)	0.016***	(0.005)	0.015***	(0.004)	0.015***	(0.004)
primarylev	0.260**	(0.109)	0.257**	(0.123)	0.240**	(0.108)	0.242**	(0.103)
secondabove	0.482***	(0.106)	0.481***	(0.109)	0.450***	(0.107)	0.451***	(0.107)
notmarry	0.024	(0.097)	0.027	(0.105)	0.020	(0.098)	0.011	(0.104)
divorcewidow	-0.256***	(0.089)	-0.248**	(0.099)	-0.192**	(0.088)	-0.208**	(0.089)
Child variables								
size at birth								
average					0.529***	(0.072)	0.535***	(0.062)
aboveaverag					0.662***	(0.074)	0.668***	(0.060)
diarrhoea					-0.264***	(0.075)	-0.265***	(0.077)
childmale					0.020	(0.046)	0.018	(0.050)
childtwin					-0.167	(0.209)	-0.179	(0.193)
ageB(7-24mnths)					-0.749***	(0.106)	-0.750***	(0.101)
ageC(25-48mnths)					-0.570***	(0.099)	-0.582***	(0.088)
ageD(49-59mnths)					-0.702***	(0.100)	-0.721***	(0.092)
grain					0.040	(0.074)	0.041	(0.072)
fruitveg					-0.007	(0.065)	-0.005	(0.068)
meat					0.190***	(0.065)	0.189***	(0.057)
0-6mnthsategrain					-0.345	(0.379)	-0.346	(0.402)
0-6mnthsatefruitveg					-0.495	(0.304)	-0.499*	(0.276)
0-6mnthsatemeat					0.627	(0.398)	0.628	(0.418)
Household variables								
toiletflush								
toiletpit								
drinkwatertap								
drinkwaterother								
hhdmember								
chnunder5								
wealthquintile2								
wealthquintile3								
wealthquintile4								
wealthquintile5								
rural								
malehhdhead								
agehhdhead								
sqagehhdhead								
interviewoctdec								
interviewjanapril								
lambda			-0.084	(0.229)			0.196	(0.186)
constant	-3.084***	(0.726)	-3.037***	(0.775)	-2.871***	(0.705)	-2.989***	(0.586)
no. of observations	3,820		4,183		3,802		4,165	

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

Table 2.3b: OLS and Heckman results for all children aged 0-59 months

Dependent variable : BMIzscore

	Model 3			
	OLS		**Heckman**	
	coef	**se**	**coef**	**se**
Main variable				
heightzscore	-0.314***	(0.020)	-0.314***	(0.021)
Maternal variables				
bmimunder	-0.709***	(0.106)	-0.712***	(0.124)
bmimnorm	-0.211***	(0.062)	-0.213***	(0.060)
mumheight	0.014***	(0.004)	0.014***	(0.005)
primarylev	0.227**	(0.109)	0.228**	(0.110)
secondabove	0.305***	(0.110)	0.306***	(0.114)
notmarry	-0.047	(0.101)	-0.050	(0.085)
divorcewidow	-0.238**	(0.093)	-0.244***	(0.085)
Child variables				
size at birth				
average	0.518***	(0.073)	0.520***	(0.072)
aboveaverag	0.637***	(0.074)	0.639***	(0.079)
diarrhoea	-0.265***	(0.076)	-0.265***	(0.080)
childmale	0.028	(0.046)	0.028	(0.047)
childtwin	-0.195	(0.202)	-0.203	(0.185)
ageB(7-24mnths)	-0.754***	(0.107)	-0.754***	(0.108)
ageC(25-48mnths)	-0.594***	(0.099)	-0.596***	(0.107)
ageD(49-59mnths)	-0.717***	(0.101)	-0.723***	(0.109)
grain	0.019	(0.076)	0.019	(0.088)
fruitveg	-0.003	(0.066)	-0.003	(0.069)
meat	0.154**	(0.066)	0.153**	(0.071)
0-6mnthsategrain	-0.502	(0.371)	-0.502	(0.361)
0-6mnthsatefruitveg	-0.552*	(0.303)	-0.553	(0.343)
0-6mnthsatemeat	0.614	(0.406)	0.614	(0.378)
Household variables				
toiletflush	0.150	(0.178)	0.150	-0.174
toiletpit	0.185***	(0.067)	0.185***	(0.070)
drinkwatertap	0.216	(0.131)	0.216*	(0.121)
drinkwaterother	0.040	(0.059)	0.040	(0.063)
hhdmember	0.005	(0.013)	0.004	(0.013)
chnunder5	-0.037	(0.036)	-0.031	(0.049)
wealthquintile2	-0.050	(0.073)	-0.050	(0.078)
wealthquintile3	0.073	(0.083)	0.073	(0.092)
wealthquintile4	-0.070	(0.123)	-0.069	(0.109)
wealthquintile5	0.144	(0.163)	0.146	(0.151)
rural	-0.025	(0.139)	-0.024	(0.166)
malehhdhead	-0.089	(0.055)	-0.091*	(0.050)
agehhdhead	-0.001	(0.010)	-0.001	(0.010)
sqagehhdhead	0.000	(0.000)	0.000	(0.000)
interviewoctdec	-0.043	(0.054)	-0.042	(0.053)
interviewjanapril	0.018	(0.072)	0.019	(0.081)
lambda			0.065	(0.229)
constant	-2.756***	(0.748)	-2.811***	(0.786)
no. of observations	3,714		4,078	

Robust standard errors in parentheses

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

Table 2.4: Maternal fixed effects model results

Dependent variable : BMIzscore						
	Model 1		**Model 2**		**Model 3**	
	coef	**se**	**coef**	**se**	**coef**	**se**
heightzscore	-0.280***	(0.024)	-0.289***	(0.024)	-0.316***	(0.024)
size at birth						
average			0.468***	(0.092)	0.483***	(0.089)
aboveaverag			0.654***	(0.095)	0.659***	(0.093)
childmale			-0.035	(0.058)	-0.020	(0.057)
childtwin			-0.129	(0.236)	-0.134	(0.235)
ageB(7-24mnths)					-0.727***	(0.126)
ageC(25-48mnths)					-0.502***	(0.112)
ageD(49-59mnths)					-0.608***	(0.113)
diarrhoea					-0.400***	(0.094)
grain			0.057	(0.096)	0.105	(0.094)
fruitveg			-0.069	(0.083)	0.036	(0.086)
meat			0.162*	(0.083)	0.214**	(0.083)
0-6mnthsategrain			-0.626	(0.531)	-1.006*	(0.517)
0-6mnthsatefruitveg			0.493	(0.392)	0.149	(0.391)
0-6mnthsatemeat			0.803*	(0.414)	0.585	(0.434)
constant	-0.481***	(0.031)	-0.970***	(0.086)	-0.482***	(0.120)
observations	3,870		3,852		3,852	
no. of mothers	1,391		1,390		1,390	

Robust standard errors in parentheses, adjusted for clustering at trhe mother's level
**** p<0.01, ** p<0.05, * p<0.1*

Table 2.5: First-stage IV regression results

Dependent variable : heightzscore		
	coef	**se**
Maternal variables		
bmimumunder	-0.273***	(0.102)
bmimumnorm	-0.099*	(0.060)
mumheight	0.045***	(0.004)
primarylev	-0.024	(0.119)
secondabove	-0.034	(0.121)
notmarry	-0.143	(0.094)
divorcewidow	-0.196**	(0.096)
Child variables		
size at birth		
average	0.225***	(0.068)
aboveaverage	0.326***	(0.070)
diarrhoea	-0.116	(0.071)
childmale	-0.045	(0.047)
childtwin	-0.733***	(0.210)
ageB(7-24mnths)	-0.415***	(0.134)
ageC(25-48mnths)	-1.425***	(0.198)
ageD(49-59mnths)	-1.404***	(0.265)
grain	0.146**	(0.072)
fruitveg	-0.084	(0.062)
meat	0.073	(0.065)
0-6mnthsategrain	0.136	(0.398)
0-6mnthsatefruitveg	0.514*	(0.287)
0-6mnthsatemeat	0.168	(0.352)
Household variables		
toiletflush	0.148	(0.169)
toiletpit	-0.095	(0.064)
drinkwatertap	-0.397***	(0.123)
drinkwaterother	-0.127**	(0.058)
hhdmember	-0.002	(0.013)
chnunder5	-0.115***	(0.034)
poorer	-0.040	(0.070)
wealthquintile2	0.043	(0.082)
wealthquintile3	0.102	(0.119)
wealthquintile4	0.268*	(0.159)
wealthquintile5	-0.043	(0.138)
malehhdhead	-0.012	(0.054)
agehhdhead	-0.003	(0.010)
sqagehhdhead	0.000	(0.000)
interviewoctdec	0.124**	(0.055)
interviewjanapril	0.004	(0.066)
Identification variables		
breastfeedduration	-0.063***	(0.015)
sqbreasfteedduration	-0.000	(0.000)
breastfeedduration2548	0.066***	(0.013)
breastfeedduration4959	0.077***	(0.015)
vitaminA	0.096*	(0.050)
constant	-7.004***	(0.697)
no. of observations	3,620	
Endogeneity test		
Durbin score	1.946	(0.163)[P]
Wu-Hausman	1.926	(0.165)[P]
Weak instruments test		
F-statistic	12.765	(0.000)[P]
Minimum eigen value statistic	12.765	
2SLS critical value 5% level	18.37	
Instrument validity (OID test)		
Sargan score	3.405	(0.493)[P]
Basmann	3.368	(0.498)[P]

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, [p] is the p-value for the different tests*

Table 2.6: Two stage least squares (2SLS) results

Dependent variable : BMIzscore

Instruments	**breasfeeding duration, breastfeedingduration*age, vitaminA**	
	coef	**se**
Main variable		
heightzscore	-0.141	(0.127)
Maternal variables		
bmimumunder	-0.699***	(0.108)
bmimumnorm	-0.187***	(0.062)
mumheight	0.007	(0.007)
primarylev	0.225*	(0.120)
secondabove	0.293**	(0.122)
notmarry	-0.020	(0.097)
divorcewidow	-0.198**	(0.101)
Child variables		
size at birth		
average	0.470***	(0.074)
aboveaverage	0.577***	(0.081)
diarrhoea	-0.233***	(0.073)
childmale	0.038	(0.048)
childtwin	-0.039	(0.230)
ageB(7-24mnths)	-0.581***	(0.164)
ageC(25-48mnths)	-0.400**	(0.177)
ageD(49-59mnths)	-0.548***	-0.157
grain	0.006	(0.077)
fruitveg	0.011	(0.065)
meat	0.157**	(0.066)
0-6mnthsategrain	-0.525	(0.403)
0-6mnthsatefruitveg	-0.636**	(0.297)
0-6mnthsatemeat	0.566	(0.357)
Household variables		
toiletflush	0.091	(0.173)
toiletpit	0.202***	(0.066)
drinkwatertap	0.323**	(0.135)
drinkwaterother	0.056	(0.061)
hhdmember	0.007	(0.013)
chnunder5	-0.024	(0.037)
wealthquintile2	-0.047	(0.071)
wealthquintile3	0.062	(0.083)
wealthquintile4	-0.103	(0.122)
wealthquintile5	0.084	(0.165)
rural	-0.027	(0.140)
malehhdhead	-0.084	(0.055)
agehhdhead	-0.000	(0.010)
sqagehhdhead	0.000	(0.000)
interviewoctdec	-0.068	(0.058)
interviewjanapril	0.020	(0.067)
constant	-1.596	(1.157)
no. of observations	3,620	

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

Table 2.7: IV on maternal fixed effects results

Dependant variable	First stage heightzscore		2SLS -second stage BMIzscore	
	coef	**se**	**coef**	**se**
Main variable				
heightzscore			-0.109	(0.176)
Child related				
size at birth				
average	0.222**	(0.087)	0.438***	(0.094)
aboveaverage	0.264***	(0.089)	0.598***	(0.100)
diarrhoea	-0.163*	(0.090)	-0.374***	(0.094)
childmale	0.008	(0.059)	-0.023	(0.059)
childtwin	-0.675***	(0.242)	-0.026	(0.265)
ageB(7-24mnths)	-0.351**	(0.170)	-0.513**	(0.218)
ageC(25-48mnths)	-1.325***	(0.237)	-0.263	(0.238)
ageD(49-59mnths)	-0.903***	(0.328)	-0.420**	(0.201)
grain	0.238**	(0.093)	0.050	(0.104)
fruitveg	-0.131	(0.084)	0.058	(0.088)
meat	0.147*	(0.083)	0.198**	(0.086)
0-6mnthsategrain	0.036	(0.495)	-0.983**	(0.491)
0-6mnthsatefruitveg	-0.095	(0.377)	0.177	(0.375)
0-6mnthsatemeat	0.179	(0.476)	0.574	(0.473)
Instruments				
breastfeedduration	-0.079***	(0.018)		
sqbreasfteedduration	0.001	(0.001)		
breastfeedduration2548	0.060***	(0.016)		
breastfeedduration4959	0.052***	(0.019)		
constant	-0.276**	(0.126)		
observations	3,805		3,201	
no. of respondents	1,385		781	
Underidentification test				
Anderson N*CDEV	31.57	(0.000)[P]		
Cragg-Donald N*CDEV	31.99	(0.000)[P]		
Weak identification test				
Cragg-Donald Wald F-statistic	7.94	(0.000)[P]		
5%maximal IV relative bias	16.85			
Weak instruments test				
F-statistic	12.24	(0.000)[P]		
Instrument validity (OID test)				
Anderson-Rubin Wald Test	1.7	(0.146)[P]		
Sargan score	6.85	(0.076)[P]		

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

coef and se refer to coefficient and standard error respectively

Main assumption

As indicated in section 2.2, *heightzscore* is assumed to be equivalent to health stock. Thus a taller child has better health stock compared to a shorter child. It is therefore expected that taller children are better able to respond to and recover from short-term health shocks such as food shortages and the incidence of disease. Drawing from this assumption, the expected outcome is that there is a positive relationship between short-term (*BMIzscore*) and long-term (*heightzscore*) health.

Main result

Overall, the main OLS results (Tables 2.3a and 2.3b) indicate that there is a robust negative relationship between the short-term (*BMIzscore*) and long-term (*heightzscore*) measures of child health. On average, comparing two children with the same maternal, child and household characteristics, the child who has a 1SD higher *heightzscore* is expected to have a lower *BMIzscore* by between 0.271SD and 0.314SD (Models 1 to 3 in Tables 2.3a and 2.3b). This implies that the taller the child (high *heightzscore*), the thinner (low *BMIzscore*) they are, which is contrary to the initial expectation of a positive association. Possible reasons for this negative association are explored in section 2.9.

Sample selection bias

Accounting for potential sample selection bias (Tables 2.3a and 2.3b - Heckman) which may arise from common factors influencing a child's survival chances and their *BMIzscore* does not make much of a difference as the relationship between *BMIzscore* and *heightzscore* remains negative. The magnitude of this negative association remains similar especially for model 2 and 3 (Tables 2.3a and 2.3b) which controls for maternal, child and maternal, child and household factors respectively. For both models, lambda is not significant. For the two models, the magnitude of change is maintained at approximately 0.314SD decrease in *BMIzscore* for a unit increase in *heightzscore*. OLS results will thus be used for this discussion.

Endogeneity

The results remain robust when endogeneity that arises from unobservable maternal factors is accounted for as shown by the maternal fixed effects (maternal fixed effects) results in Table 2.4. The magnitude of effect is similar (0.316SD decrease on average in *BMIzscore* for a 1SD increase in *heightzscore* in Model 3 ceteris paribus) to that of the OLS results (0.314SD in Tables 2.3a and 2.3b). This implies that given two children below the age of 5, with similar child characteristics, the same mother and living in the same household, but one child's *heightzscore* is 1SD higher, the child with the higher *heightzscore* will have a *BMIzscore* that is lower by 0.316SD compared to the one with a lower *heightzscore*.

The negative association between *BMIzscore* and *heightzscore* is maintained when the IV (-0.141SD in Table 2.6) and IV on maternal fixed effects (-0.109SD in Table 2.7) methods are used to account for endogeneity caused by unobserved child related factors. Both results are not significant probably due to fairly weak instruments, as indicated by the F-statistics (12.765 and 12.24 in Tables 2. 5 and 2.7 respectively) which just exceed Staiger and Stock (1997)'s recommended F-statistic of 10. Staiger and Stock's recommendation is based on the rule that an F-statistic for the first-stage of the IV regression that is less than 10 signifies the presence of weak instruments (Cameron &Trivedi, 2010; Stock & Yogo, 2005). The high standard errors of the IV (0.127 in Table 2.6) and IV on maternal fixed effects (0.176 in Table 2.7) compared to 0.019 - 0.022 for the OLS models in Tables 2.3a and 2.3b also indicate that the instruments are weak. These high standard errors cause losses in accuracy when using IV

(Cameron & Trivedi, 2010). The instruments used for the IV method (Table 2.5) are nutritional factors (*breastfeedduration*,*sqbreastfeedduration*, *breastfeedduration2548*, *breastfeedduration4959* and *vitaminA*) and they all are significant for determining a child's long-term health (*heightzscore*).

Results for the first stage of the IV regression in Table 2.5 show that it is questionable whether *heightzscore* is endogenous in this equation. Both the Durbin score and the Wu-Hausman scores (p-values of 0.163 and 0.165 respectively) suggest that *heightzscore* is an exogenous variable. According to Sargan and Basmann test results, the instruments used are valid as all the p-values for these 2 tests are above 0.05 (p-values from 0.493 to 0.498). That *heightzscore* is not endogenous in the *BMIzscore* equation is plausible, given that the *BMIZscore* is constructed in such a way that the correlation with *heightzscore* is minimised or removed.

Inference from this result suggests that the robust negative relationship between a child's short-term (*BMIzscore*) and long-term (*heightzscore*) health is brought about through nutritional factors. This result is corroborated by the maternal fixed effects results. However this conclusion remains a mere suggestion as more analysis needs to be done using consumption data in order to verify the results.

Overall, the OLS and Heckman and maternal fixed effects regression methods all indicate that there is a robust negative relationship between *BMIzscore* and *heightzscore* for children aged 0 to 59 months in Zimbabwe. The maternal fixed effects results are more plausible than the OLS and Heckman results as they have the additional advantage of addressing the issue of endogeneity that could arise from unobserved maternal or household factors.

Other results

Maternal factors

Model 3 (Tables 2.3a and 2.3b) results indicate that maternal factors such as BMI and education levels positively impact on child health as highlighted by other literature (Rahman et al., 1993; Özaltin et al., 2010). *mumheight* influences a child's *BMIzscore* positively (0.014SD). Considering two children of the same height, one with a tall mother and one with a short mother, the child who has a tall mother is expected to have a higher BMI compared to the child with a short mother all other factors being equal. The child with the taller mother though will be undersized as genetically, one would expect a tall mother to have a tall child. So this effect implies that the genetic component of a child's height (measured through the mother's height) has a positive contribution to a child's BMI. However, the results also indicate that there is a negative relationship between a child's *BMIzscore* and *heightzscore*. This means that supposing there are two children, whose mothers are of the same height and all other factors are the same except their height, the taller child would be expected to have a lower BMI compared to the shorter child. Since genetically, a child's predicted height (through the mother's height) has a positive effect on the child's BMI, this negative association suggests that there are other factors that influence a child's height and contribute negatively to the child's BMI. This implies that the negative relationship captured by the child's *heightzscore* in this case thus effectively measures deviations from a child's predicted height (through the mother's height) and the long-term influence of factors such as nutrition and disease.

On average, a child whose mother is divorced or widowed has a 0.238SD lower *BMIzscore* compared to a child whose mother is married ceteris paribus. This is plausible for Zimbabwe as divorced mothers are expected to receive maintenance from their ex-husbands for their children, which in most cases is not forthcoming. Divorced women and their children thus are more likely to have less income and to be more vulnerable compared to their married counterparts. Widows on the other hand are officially recognised as part of the vulnerable population. They rely mainly on assistance from the community, relatives, the government and NGO's for their survival. This assistance is not certain and this makes widows and their children more vulnerable than their married counterparts.

Child factors

Child related factors such as birth size and the incidence of diarrhoea also influence short-term child health positively and negatively respectively, as is expected. In terms of type of food consumed, eating meat significantly improves a child's short-term health status. A child who consumes meat has on average a 0.154SD higher *BMIzscore* for a unit increase in *heightzscore* compared to a child who does not consume meat, all things being equal. Early introduction of solids especially fruit and vegetables (*0-6fruitveg*) has a negative impact on a child's *BMIzscore*. This is plausible considering the medical recommendations by health organisations such as the World Health Organisation (WHO) that a child should be exclusively breastfed for the first 6 months of their life (WHO, 2011). Early introduction of supplementary foods may lead to adverse reactions such as allergies and diarrhoea (Kuo et al., 2011). In spite of this, children are only exclusively breastfed for at most 2 months in Zimbabwe (CSO and Macro Inc., 2007). The results for supplementary food however are to be taken with caution as these variables are potentially endogenous and thus lending these results to some small bias. Gender and whether a child is born as a singleton or twin have no significant influence on a child's *BMIzscore.*

Household factors

At the household level, only the availability of pit toilet facilities significantly improves a child's short-term health. A child from a household with a pit toilet has a 0.185SD higher *BMIzscore* compared to a child from a household with no sanitary facilities and a child from a household with a flushing toilet. Given the rampant water shortages that Zimbabwe experienced during this period, which saw households going without tap water for as much as three weeks, depending on their location (IRIN, 2006; Kwidini, 2007), this result is expected. These water shortages resulted in less water being available to use for important activities such as flushing toilets, thus rendering pit toilets more hygienic in terms of location (generally detached from the main house) and usability. Results from Mbuya, Chidem et al. (2010) using the same data indicate that improved toilet facilities enhance a child's long-term health. Results from this research lend further clarification that the type of toilet facility actually matters. Household wealth (*wealthquintile2- wealthquintile5*) has no significant impact on a child's short-term health. This is consistent with results obtained by other research (Horton. 1986; Mbuya, Chidem et al., 2010). This is probably because wealth at this stage has no direct impact on the child but rather the impact is indirect through the mother as discussed in section 2.3.4 on page 27-28.

2.8 Robustness tests

Having established from the results above (Table 2.2 to Table 2.7) that there is a significant negative relationship between short-term (*BMIzscore*) and long-term (*heightzscore*) child health, this section will analyse further this relationship according to age, gender, and wealth and height categories. The results for this analysis are presented and discussed below.

2.8.1 By age categories of the child

The data is grouped into four age categories; 0 to 6 months, 7 to 24 months, 25 to 48 months and 49 to 59 months. According to Popkin et al. (1996), stunting in children begins at around 3 months of age and is complete by 24 months. A study by Maleta et al. (2003) also revealed that gains in height occur steadily, 3 months after gains in weight in children aged 2 years and beyond. Moreover, Freedman et al. (2004) revealed that a high *BMIzscore* and is significantly associated with a high *heightzscore* for children below the age of 12. In order to ascertain that the negative relationship between *BMIzscore* and *heightzscore* is not a result of age-dependent differences in phases of height and weight gain, the OLS and Heckman models are estimated for children in different age categories and the results are presented in Table 2.8a and 2.8b below.

Discussion

The results in Tables 2.8a and 2.8b below indicate that the negative relationship between short-term (*BMIzscore*) and long-term (*heightzscore*) child health is still robust for all the four age categories (0-6, 7-24, 25-48 and 49-59 months) with the magnitude of effect varying between 0.212SD to 0.359SD which is more or less similar to the magnitude of the main results (0.271SD to 0.314SD in Tables 2.3a and 2.3b). The incidence of diarrhoea (for children above 6 months old) and the introduction of fruit or vegetable based supplements (for children aged 0-6 months) maintain a significant negative association with the *BMIzscore* as established by the general model.

Interestingly, maternal BMI has no significant effect on a child's BMI-for-age z-score for the first 6 months, which is surprising given that maternal nutrition status (represented by the mother's BMI score) is expected to determine a child's nutritional status (Maleta et al., 2003).

Maternal BMI only affects the *BMIzscore* of a child from age 7 months onwards. Maternal height has a positive effect on a child's BMI-for-age z-score only for the first two years of the child's life and maternal education is critical only for a child aged 0-6 months. This is plausible given that a child's health status in the first few months of life determines the child's health status in the future. Higher education in this instance enables the mother to make the right choices in terms of child nutrition and important issues surrounding the child's health (Alves and Belluzo, 2004; Caldwell, 1979). If the mother is divorce or widowed only negatively affects a child's short-term health if the child is aged 25-48 months compared to a child of the same age whose mother is married. The reason for this is unclear.

Birth size positively influences a child's BMI-for-age z-score after across all ages. Meat supplements improve a child's short-term health, even for children aged 0-6 months and 25-48 months. Pit toilet facilities availability significantly improves the short-term health status for children aged 25-48 months.

The results for a household's wealth status and the period in which the interview was conducted are mixed and a clear conclusion cannot be reached. In the general model though (Tables 2.3a and 2.3b) both variables have no significant effect on a child's short-term health status. The IMR (*lambda*) is not significant for all age categories indicating that the OLS results do not suffer from selection bias. All other household variables such as household composition and age and sex of the household head remain insignificant.

Table 2.8a: OLS and Heckman results by age: 0-6 and 7-24 months

Dependent variable:BMIzscore

	OLS		**Heckman**		**OLS**		**Heckman**	
	0-6 months				**7-24 months**			
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable								
heightzscore	-0.313***	(0.051)	-0.312***	(0.054)	-0.359***	(0.033)	-0.359***	(0.032)
Maternal variables								
bmimumunder	-0.546	(0.406)	-0.551	(0.346)	-0.802***	(0.205)	-0.802***	(0.199)
bmimumnorm	-0.101	(0.220)	-0.100	(0.227)	-0.200	(0.133)	-0.203	(0.134)
mumheight	0.051***	(0.014)	0.051***	(0.014)	0.019**	(0.008)	0.019**	(0.008)
primarylev	0.962**	(0.467)	0.968	(0.600)	0.062	(0.253)	0.051	(0.300)
secondabove	1.287***	(0.484)	1.292**	(0.593)	0.091	(0.259)	0.078	(0.288)
notmarry	-0.166	(0.295)	-0.169	(0.288)	0.057	(0.213)	0.070	(0.205)
divorcedwidow	-0.523	(0.342)	-0.537	(0.356)	-0.129	(0.164)	-0.114	(0.180)
Child variables								
size at birth								
average	0.562**	(0.275)	0.564*	(0.309)	0.656***	(0.150)	0.652***	(0.146)
aboveaverage	0.651**	(0.291)	0.652*	(0.340)	0.848***	(0.152)	0.844***	(0.158)
diarrhoea	-0.231	(0.338)	-0.234	(0.381)	-0.212*	(0.112)	-0.210*	(0.107)
childmale	0.190	(0.172)	0.191	(0.142)	-0.055	(0.089)	-0.054	(0.094)
childtwin	-0.852	(0.693)	-0.871	(0.665)	-0.409	(0.474)	-0.353	(0.610)
grain	-0.675	(0.415)	-0.677*	(0.396)	0.080	(0.116)	0.079	(0.121)
fruitveg	-0.664**	(0.302)	-0.663**	(0.274)	0.056	(0.101)	0.053	(0.083)
meat	0.972**	(0.376)	0.972**	(0.382)	0.148	(0.105)	0.146	(0.107)
Household variables								
toiletflush	0.730	(0.529)	0.733	(0.636)	0.072	(0.337)	0.076	(0.277)
toiletpit	0.237	(0.222)	0.238	(0.263)	0.146	(0.120)	0.149	(0.140)
drinkwatertap	0.016	(0.436)	0.014	(0.324)	0.174	(0.247)	0.173	(0.271)
drinkwaterother	-0.116	(0.208)	-0.117	(0.200)	0.082	(0.108)	0.079	(0.087)
hhdmember	0.060	(0.043)	0.059	(0.044)	0.003	(0.023)	0.006	(0.023)
chnunder5	-0.173	(0.108)	-0.166	(0.114)	-0.071	(0.069)	-0.089	(0.080)
wealthquintile2	0.284	(0.250)	0.284	(0.287)	0.192	(0.131)	0.194	(0.129)
wealthquintile3	0.053	(0.284)	0.053	(0.317)	0.352**	(0.153)	0.352**	(0.167)
wealthquintile4	0.504	(0.401)	0.504	(0.338)	0.331	(0.218)	0.330	(0.206)
wealthquintile5	0.146	(0.571)	0.146	(0.487)	0.752**	(0.304)	0.746***	(0.267)
rural	0.513	(0.482)	0.513	(0.532)	0.016	(0.267)	0.013	(0.257)
malehhdhead	0.064	(0.188)	0.060	(0.164)	-0.145	(0.101)	-0.141	(0.096)
agehhdhead	0.014	(0.031)	0.014	(0.022)	0.006	(0.017)	0.006	(0.015)
sqagehhdhead	-0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)
interviewoctdec	-0.387**	(0.187)	-0.387**	(0.163)	0.181*	(0.100)	0.180*	(0.101)
interviewjanapril	-0.020	(0.232)	-0.019	(0.233)	0.312**	(0.143)	0.310**	(0.130)
lambda (IMR)			0.026	(0.262)			-0.090	(0.214)
constant	-10.505***	(2.508)	-10.541***	(2.261)	-4.890***	(1.358)	-4.765***	(1.258)
no. of observations	441		793		1,167		1,519	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

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

Table 2.8b: OLS and Heckman results by age: 25-48 and 49-59 months

Dependent variable:BMIzscore

	OLS		**Heckman**		**OLS**		**Heckman**	
	25-48 months				**48-59months**			
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable								
heightzscore	-0.277***	(0.033)	-0.278***	(0.036)	-0.212***	(0.051)	-0.220***	(0.048)
Maternal variables								
bmimumunder	-0.515***	(0.146)	-0.529***	(0.147)	-0.891***	(0.219)	-0.689**	(0.269)
bmimumnorm	-0.121	(0.087)	-0.130	(0.085)	-0.537***	(0.113)	-0.419***	(0.142)
mumheight	0.007	(0.006)	0.008	(0.006)	-0.002	(0.008)	-0.009	(0.010)
primarylev	0.204	(0.134)	0.204	(0.160)	0.133	(0.199)	0.144	(0.223)
secondabove	0.220	(0.135)	0.218	(0.146)	0.223	(0.202)	0.220	(0.255)
notmarry	-0.097	(0.246)	-0.117	(0.238)	-0.107	(0.348)	0.163	(0.391)
divorcedwidow	-0.250**	(0.121)	-0.266*	(0.142)	-0.032	(0.143)	0.074	(0.164)
Child variables								
size at birth								
average	0.323***	(0.112)	0.331***	(0.125)	0.679***	(0.133)	0.623***	(0.150)
aboveaverage	0.471***	(0.113)	0.479***	(0.115)	0.656***	(0.140)	0.644***	(0.162)
diarrhoea	-0.235*	(0.133)	-0.233*	(0.138)	-0.323*	(0.179)	-0.353*	(0.193)
childmale	0.041	(0.070)	0.041	(0.079)	0.048	(0.094)	0.049	(0.111)
childtwin	0.032	(0.279)	0.016	(0.318)	0.072	(0.308)	0.130	(0.283)
grain	-0.169	(0.113)	-0.170	(0.105)	0.106	(0.169)	0.128	(0.137)
fruitveg	-0.083	(0.093)	-0.079	(0.090)	0.209	(0.153)	0.220	(0.140)
meat	0.159*	(0.094)	0.159*	(0.089)	0.132	(0.153)	0.167	(0.130)
Household variables								
toiletflush	0.165	(0.242)	0.168	(0.252)	0.026	(0.358)	0.049	(0.361)
toiletpit	0.232**	(0.095)	0.231**	(0.098)	0.152	(0.126)	0.161	(0.111)
drinkwatertap	0.201	(0.164)	0.203	(0.164)	0.492*	(0.289)	0.490**	(0.221)
drinkwaterother	0.091	(0.085)	0.090	(0.091)	-0.012	(0.113)	-0.006	(0.113)
hhdmember	-0.009	(0.018)	-0.014	(0.021)	-0.019	(0.027)	0.024	(0.040)
chnunder5	0.004	(0.049)	0.024	(0.064)	0.032	(0.073)	-0.194	(0.162)
wealthquintile2	-0.192*	(0.108)	-0.187	(0.116)	-0.222	(0.138)	-0.214*	(0.127)
wealthquintile3	-0.015	(0.119)	-0.012	(0.127)	-0.083	(0.169)	-0.097	(0.159)
wealthquintile4	-0.341*	(0.178)	-0.334*	(0.176)	-0.563**	(0.277)	-0.594**	(0.271)
wealthquintile5	-0.154	(0.236)	-0.148	(0.197)	-0.357	(0.342)	-0.403	(0.330)
rural	-0.199	(0.181)	-0.195	(0.168)	-0.068	(0.302)	-0.078	(0.304)
malehhdhead	-0.122	(0.081)	-0.127*	(0.065)	0.067	(0.106)	0.134	(0.127)
agehhdhead	-0.013	(0.015)	-0.011	(0.015)	-0.013	(0.018)	-0.045	(0.028)
sqagehhdhead	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000*	(0.000)
interviewoctdec	-0.183**	(0.082)	-0.180**	(0.083)	0.039	(0.101)	0.029	(0.105)
interviewjanapril	-0.278***	(0.097)	-0.278***	(0.091)	0.096	(0.149)	0.069	(0.136)
lambda (IMR)			0.132	(0.203)			-0.802	(0.490)
constant	-1.322	(1.124)	-1.547	(1.089)	-0.385	(1.372)	2.006	(2.000)
no. of observations	1,361		1,713		682		1,034	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level
**** p<0.01, ** p<0.05, * p<0.1*

2.8.2 By gender of the child

Anthropometric measures also vary by gender. Some studies have shown that male children are more likely to be stunted than female children (Mbuya, Chidem et al., 2010) and others have indicated that teenage girls have a higher tendency of subcutaneous fat building up compared to boys and thus teenage girls are more prone to obesity compared to boys (Mukuddem-Petersen &Kruger, 2004). The association between the *BMIzscore* and *heightzscore* will be analysed by gender in order to establish the influence of gender and the results are presented in Table 2.9.

Discussion

Table 2.9 below results indicate that the negative relationship between short-term and long-term child health status is very similar for both boys and girls. Maternal BMI, maternal height, marital status, birth size, the incidence of diarrhoea and age of the child all remain significant as expected and in accordance with the results for the general model (see results in Table 2.3a and 2.3b). Surprisingly, maternal education and availability of improved sanitary facilities (both pit and flushing toilets) appears to be important determinants of boys' short-term health status and not for girls. On the other hand, food supplements especially meat and fruit and vegetable supplements and the period during which the interview was conducted are important determinants of girls’ short-term health status and not for boys. The results are important especially for policy intervention programs aimed at promoting child health based on gender, as they provide insight on important factors that need to be addressed in order for successful implementation of policies. The IMR remains insignificant for both boys and girls as do other household variables such as household composition and age and sex of the household head.

Table 2.9: OLS and Heckman results by gender

Dependant variable: BMI-zscore

	Male				**Female**			
	OLS		**Heckman**		**Heckman**		**OLS**	
	coef	**se**	**coef**	**se**	**coef**		**coef**	**se**
Main variable								
heightzscore	-0.314***	(0.028)	-0.314***	(0.026)	-0.307***	(0.030)	-0.307***	(0.032)
Maternal variables								
bmimumunder	-0.627***	(0.155)	-0.658***	(0.165)	-0.745***	(0.148)	-0.719***	(0.159)
bmimumnorm	-0.249***	(0.088)	-0.259***	(0.077)	-0.196**	(0.088)	-0.180**	(0.091)
mumheight	0.013**	(0.006)	0.015**	(0.006)	0.015**	(0.006)	0.014**	(0.005)
primarylev	0.224	(0.149)	0.241	(0.162)	0.207	(0.155)	0.202	(0.135)
secondabove	0.344**	(0.151)	0.358**	(0.168)	0.249	(0.153)	0.241*	(0.132)
notmarry	0.011	(0.185)	-0.021	(0.191)	-0.119	(0.200)	-0.086	(0.186)
divorcedwidow	-0.317**	(0.125)	-0.373***	(0.140)	-0.115	(0.136)	-0.066	(0.171)
Child variables								
size at birth								
average	0.465***	(0.111)	0.503***	(0.119)	0.618***	(0.098)	0.616***	(0.117)
aboveaverage	0.721***	(0.113)	0.758***	(0.118)	0.606***	(0.102)	0.611***	(0.111)
diarrhoea	-0.212*	(0.109)	-0.212**	(0.102)	-0.312***	(0.107)	-0.313***	(0.096)
childtwin	-0.130	(0.262)	-0.207	(0.270)	-0.279	(0.328)	-0.231	(0.295)
ageB(7-24mnths)	-0.790***	(0.155)	-0.788***	(0.168)	-0.727***	(0.154)	-0.727***	(0.184)
ageC(25-48mnths)	-0.588***	(0.150)	-0.613***	(0.148)	-0.606***	(0.140)	-0.582***	(0.158)
ageD(49-59mnths)	-0.723***	(0.151)	-0.779***	(0.150)	-0.703***	(0.139)	-0.660***	(0.160)
grain	0.095	(0.114)	0.089	(0.117)	-0.072	(0.103)	-0.070	(0.098)
fruitveg	-0.003	(0.094)	-0.002	(0.085)	0.047	(0.092)	0.044	(0.087)
meat	0.011	(0.094)	0.012	(0.093)	0.274***	(0.092)	0.278***	(0.089)
0-6mnthsategrain	-0.455	(0.389)	-0.461	(0.459)	-1.127	(0.907)	-1.136	(1.158)
0-6mnthsatefruitveg	-0.249	(0.421)	-0.253	(0.422)	-1.065**	(0.422)	-1.056**	(0.455)
0-6mnthsatemeat	0.445	(0.550)	0.455	(0.564)	0.965*	(0.504)	0.980**	(0.458)
Household variables								
toiletflush	0.441**	(0.217)	0.433**	(0.216)	-0.110	(0.275)	-0.111	(0.216)
toiletpit	0.241**	(0.095)	0.231**	(0.096)	0.110	(0.090)	0.110	(0.086)
drinkwatertap	0.133	(0.164)	0.139	(0.169)	0.333*	(0.202)	0.337**	(0.170)
drinkwaterother	-0.022	(0.085)	-0.015	(0.090)	0.094	(0.078)	0.097	(0.076)
hhdmember	0.037**	(0.018)	0.026	(0.018)	-0.025	(0.018)	-0.017	(0.019)
chnunder5	-0.083*	(0.047)	-0.027	(0.062)	0.005	(0.048)	-0.041	(0.053)
wealthquintile2	-0.061	(0.104)	-0.051	(0.109)	-0.025	(0.093)	-0.027	(0.091)
wealthquintile3	0.059	(0.118)	0.069	(0.115)	0.078	(0.118)	0.075	(0.121)
wealthquintile4	-0.035	(0.167)	-0.016	(0.170)	-0.113	(0.182)	-0.121	(0.145)
wealthquintile5	0.037	(0.226)	0.065	(0.199)	0.230	(0.236)	0.217	(0.200)
rural	0.162	(0.173)	0.166	(0.174)	-0.164	(0.198)	-0.170	(0.198)
malehhdhead	-0.091	(0.079)	-0.109	(0.073)	-0.070	(0.081)	-0.058	(0.084)
agehhdhead	-0.017	(0.013)	-0.013	(0.015)	0.012	(0.014)	0.008	(0.013)
sqagehhdhead	0.000	(0.000)	0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)
interviewoctdec	0.043	(0.077)	0.045	(0.083)	-0.144**	(0.072)	-0.150**	(0.069)
interviewjanapril	0.123	(0.101)	0.128	(0.102)	-0.114	(0.093)	-0.119	(0.109)
lambda (IMR)			0.403	(0.274)			-0.302	(0.207)
constant	-2.535**	(1.000)	-3.015***	(1.001)	-2.969***	(1.007)	-2.567***	(0.950)
no. of observations	1,826		2,178		1,825		2,177	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level
**** p<0.01, ** p<0.05, * p<0.1*

2.8.3 By household wealth class

So far there is varied evidence on the impact of wealth on anthropometric measures in children. Binka et al. (1995) indicates that there is a weak positive relationship between wealth and child health. Other research indicates that there is no association between wealth and child health (Horton, 1986). The influence of wealth on the relationship between *BMIzscore* and *heightzscore* will be examined to see if the direction of the association varies. The maternal fixed effects model will be estimated according to wealth classes as well, so as to determine whether there is any difference between two children from a richer and two children from a poorer household. The results are presented in Table 2.10 and 2.11 below.

Discussion

OLS and Heckman results in Table 2.10 as well as those of the maternal fixed effects (maternal fixed effects) model according to wealth quintiles in Table 2.11 indicate that the significant negative relationship between short-term and long-term child health status is sustained across all wealth quintiles.

For the OLS and Heckman results (Table 2.10), maternal BMI and marital status have a significant negative impact on a child's *BMIzscore*. For households in the bottom 60% of the wealth index (*wealthquintile1-wealthquintile3*), according to the DHS wealth index, the mother's height and education level, size of the child at birth, meat consumption, availability of improved toilet and protected water facilities significantly improve a child's *BMIzscore*. For households in the top 40% of the wealth index (*wealth quintile4- wealthquintile5*) the number of household members significantly improves whilst the number of children fewer than 5 present in a household significantly reduces a child's *BMIzscore*. The former result, though surprising can be plausible assuming that top 40% are in a better position to cater for more people compared to their counterparts in the bottom 60%. Maternal fixed effects by wealth category results (Table 2.11) are more or less similar with more factors (birth size, grain and meat supplements) affecting the *BMIzscore* of children from poorer households compared to children from richer households. The incidence of diarrhoea has a significant negative impact on short-term health for children from households in all wealth categories.

Table 2.10: OLS and Heckman according to wealth categories

Dependent variable:BMI-zscore

	Bottom 60% (poorer)				**Top 40% (richer)**			
	OLS		**Heckman**		**Heckman**		**OLS**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable								
heightzscore	-0.333***	(0.024)	-0.332***	(0.022)	-0.267***	(0.040)	-0.267***	(0.040)
Maternal variables								
bmimumunder	-0.781***	(0.121)	-0.781***	(0.108)	-0.456*	(0.238)	-0.363	(0.300)
bmimumnorm	-0.236***	(0.079)	-0.233***	(0.069)	-0.245***	(0.094)	-0.214**	(0.095)
mumheight	0.018***	(0.005)	0.019***	(0.005)	0.007	(0.008)	0.005	(0.008)
primarylev	0.191*	(0.114)	0.200*	(0.104)	0.232	(0.394)	0.317	(0.459)
secondabove	0.296**	(0.119)	0.301***	(0.114)	0.347	(0.389)	0.416	(0.436)
notmarry	-0.086	(0.150)	-0.109	(0.182)	0.020	(0.261)	0.046	(0.278)
divorcewidow	-0.165	(0.111)	-0.199	(0.140)	-0.449**	(0.194)	-0.384*	(0.207)
Child variables								
size at birth								
average	0.571***	(0.084)	0.583***	(0.084)	0.427***	(0.144)	0.408***	(0.153)
aboveaverage	0.714***	(0.091)	0.717***	(0.108)	0.511***	(0.149)	0.475***	(0.167)
diarrhoea	-0.252***	(0.088)	-0.252***	(0.064)	-0.227	(0.166)	-0.228	(0.153)
childmale	0.023	(0.054)	0.026	(0.049)	0.018	(0.086)	0.030	(0.068)
childtwin	0.025	(0.204)	-0.012	(0.203)	-0.716	(0.495)	-0.633	(0.485)
ageB(7-24mnths)	-0.785***	(0.123)	-0.785***	(0.122)	-0.790***	(0.214)	-0.798***	(0.262)
ageC(25-48mnths)	-0.499***	(0.117)	-0.520***	(0.120)	-0.908***	(0.207)	-0.904***	(0.229)
ageD(49-59mnths)	-0.636***	(0.113)	-0.672***	(0.137)	-0.982***	(0.208)	-0.951***	(0.250)
grain	0.067	(0.092)	0.067	(0.087)	-0.096	(0.136)	-0.092	(0.134)
fruitveg	0.042	(0.079)	0.044	(0.075)	-0.012	(0.125)	-0.011	(0.114)
meat	0.153*	(0.081)	0.153*	(0.083)	0.147	(0.114)	0.148	(0.143)
0-6mnthsategrain	-1.062**	(0.528)	-1.059**	(0.500)	-0.275	(0.459)	-0.286	(0.415)
0-6mnthsatefruitveg	-0.658	(0.436)	-0.666*	(0.380)	-0.462	(0.371)	-0.465	(0.417)
0-6mnthsatemeat	0.636	(0.646)	0.632	(0.542)	0.461	(0.428)	0.46	(0.462)
Household variables								
toiletflush	0.711*	(0.391)	0.745**	(0.320)	0.408	(0.328)	0.415	(0.344)
toiletpit	0.189***	(0.061)	0.188***	(0.069)	0.344	(0.285)	0.353	(0.311)
drinkwatertap	0.298*	(0.170)	0.302*	(0.183)	-0.019	(0.266)	-0.015	(0.283)
drinkwaterother	0.056	(0.063)	0.057	(0.064)	-0.219	(0.238)	-0.217	(0.260)
hhdmember	-0.012	(0.015)	-0.018	(0.015)	0.057**	(0.024)	0.067**	(0.027)
chnunder5	0.014	(0.040)	0.048	(0.046)	-0.193**	(0.075)	-0.253***	(0.087)
rural	-0.188	(0.363)	-0.173	(0.350)	-0.044	(0.152)	-0.049	(0.127)
malehhdhead	-0.077	(0.065)	-0.088	(0.090)	-0.080	(0.118)	-0.067	(0.107)
agehhdhead	0.004	(0.012)	0.007	(0.012)	-0.021	(0.021)	-0.023	(0.021)
sqagehhdhead	-0.000	(0.000)	-0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
interviewoctdec	-0.030	(0.062)	-0.026	(0.074)	-0.064	(0.104)	-0.070	(0.109)
interviewjanapril	0.031	(0.088)	0.035	(0.075)	0.009	(0.133)	0.004	(0.146)
lambda			0.361	(0.311)			-0.562	(0.589)
constant	-3.514***	(0.936)	-3.830***	(0.991)	-0.983	(1.472)	-0.617	(1.535)
no. of observations	2,520		2,772		1,131		1,231	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level
**** p<0.01, ** p<0.05, * p<0.1*

Table 2.11: Maternal fixed effects according to wealth categories

Dependent variable: BMIzscore

	Bottom 60% (poor)		**Top 40% (rich)**	
	coef	**se**	**coef**	**se**
heightzscore	-0.326***	(0.031)	-0.278***	(0.053)
Child variables				
size at birth				
average	0.489***	(0.117)	0.414**	(0.203)
aboveaverag	0.711***	(0.119)	0.432*	(0.243)
childmale	-0.072	(0.072)	-0.069	(0.125)
childtwin	0.064	(0.235)	-1.081**	(0.515)
ageB(7-24mnths)	-0.745***	(0.150)	-0.824***	(0.309)
ageC(25-48mnths)	-0.378***	(0.133)	-1.112***	(0.283)
ageD(49-59mnths)	-0.496***	(0.135)	-1.116***	(0.284)
diarrhoea	-0.271**	(0.114)	-0.333	(0.209)
grain	0.311**	(0.127)	-0.242	(0.217)
fruitveg	-0.006	(0.109)	0.114	(0.206)
meat	0.213*	(0.118)	-0.003	(0.190)
0-6mnthsategrain	-1.589**	(0.714)	-0.437	(0.626)
0-6mnthsatefruitveg	0.326	(0.539)	0.072	(0.553)
0-6mnthsatemeat	0.475	(0.631)	-0.383	(0.641)
constant	-0.699***	(0.150)	0.455	(0.294)
observations	2,595		1,193	
no. of mothers	1,152		680	

Robust standard (se) errors in parentheses, adjusted for clustering at the mother's level

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

2.8.4 By child height categories

The link between *BMIzscore* and *heightzscore* will be analysed according to height categories in order to determine whether being stunted or tall leads to a positive or negative impact on weight compared to being of normal height. Popkin et al. (1996) in their study indicated that being tall and being short both lead to increased likelihood of obesity (*BMIzscore*>2SD) in children. The relationship between height and BMI will be analysed in for the tall and the short as well as with relation to the probability of being underweight (underweight is represented by a dummy variable which takes the value 1 if the child is underweight and 0 otherwise) as this is the major problem facing Zimbabwe. The results for the based on all the height categories of the child are presented in Tables 2.12 below.

Discussion

From the main results (Tables 2.3 and 2.3b) there is a significant negative association between *BMIzscore* and *heightzscore*. When *heightzscore* is divided into 3 categories; stunted (*heightzscore*<-2SD), normal (-2SD< *heightzscore*<2SD) and tall (*heightzscore*>2SD) results reveal that impact on *BMIzscore* differs. A stunted child has on average a significantly higher (0.611SD) *BMIzscore* compared to a child of normal height whereas a tall child has on average a significantly lower (-1.066SD) *BMIzscore* compared to a child of normal height ceteris paribus (Table 2.12). This is consistent with the results obtained in Tables 2.3a and 2.3b.

Analyses of the impact of *heightzscore* on the probability of being underweight (*BMIzscore* <-2SD) indicated that generally a unit increase in *heightzscore* is associated with a higher likelihood of being underweight (Table 2.12), confirming the main results in Tables 2.3a and 2.3b. When separate height categories are used, the results show that among stunted children, the probability of being underweight is reduced by 0.069SD on average whereas for tall children the probability is increased by 0.135SD on average compared to a normal child, all things being equal. These results are similar to those of the OLS and Heckman model according to height categories. The result implies that taller children are more likely to be underweight whereas shorter children are more likely to be overweight. This implication is consistent with the results obtained in the main model (Tables 2.3a and 2.3b) as well as through the maternal fixed effects model (Table 2.4).

Table 2.12: Results according to height categories

Dependent variable OLS & Heckman: BMIzscore
Dependent variable Probit: Underweight(=1 if child has a BMIzscore<-2 and 0 otherwise)

	OLS & Heckman results				**Probit model results**			
	OLS		**Heckman**		**Actual height**		**height categories**	
	coef	**se**	**coef**	**se**	**marginal effects**	**se**	**marginal effects**	**se**
Main variable								
heightzscore					0.033***	(0.004)		
stunted	0.611***	(0.058)	0.612***	(0.055)			-0.069***	(0.012)
tall	-1.066***	(0.203)	-1.064***	(0.158)			0.135***	(0.024)
Maternal variables								
bmimumunder	-0.662***	(0.110)	-0.675***	(0.132)	0.078***	(0.018)	0.071***	(0.018)
bmimumnorm	-0.193***	(0.063)	-0.200***	(0.058)	0.009	(0.013)	0.010	(0.013)
mumheight	0.007*	(0.004)	0.008**	(0.004)	-0.001*	(0.001)	-0.001	(0.001)
primarylev	0.273**	(0.113)	0.277**	(0.133)	0.009	(0.024)	0.003	(0.024)
secondabove	0.338***	(0.116)	0.343***	(0.122)	-0.009	(0.024)	-0.015	(0.024)
notmarry	0.124	(0.135)	0.111	(0.129)	0.017	(0.025)	-0.002	(0.025)
divorcewidow	-0.161	(0.106)	-0.184*	(0.100)	0.036**	(0.019)	0.035*	(0.018)
Child variables								
size at birth								
average	0.543***	(0.076)	0.550***	(0.072)	-0.061***	(0.013)	-0.060***	(0.013)
aboveaverage	0.634***	(0.080)	0.640***	(0.073)	-0.090***	(0.014)	-0.089***	(0.013)
diarrhoea	-0.285***	(0.078)	-0.250***	(0.073)	0.042***	(0.014)	0.038***	(0.014)
childmale	0.000	(0.048)	-0.001	(0.040)	-0.003	(0.010)	-0.004	(0.010)
childtwin	-0.181	(0.206)	-0.203	(0.198)	0.011	(0.036)	0.007	(0.037)
ageB(7-24mnths)	-0.515***	(0.106)	-0.516***	(0.115)	0.067***	(0.016)	0.046***	(0.015)
ageC(25-48mnths)	-0.348***	(0.102)	-0.359***	(0.114)	0.001	(0.017)	-0.026	(0.016)
ageD(49-59mnths)	-0.527***	(0.100)	-0.549***	(0.103)	-0.005	(0.019)	-0.029	(0.018)
grain	-0.049	(0.082)	-0.050	(0.081)	-0.004	(0.015)	-0.000	(0.015)
fruitveg	0.073	(0.072)	0.074	(0.063)	0.004	(0.013)	-0.000	(0.013)
meat	0.094	(0.073)	0.093	(0.070)	-0.049***	(0.014)	-0.040***	(0.013)
0-6mnthsategrain	-0.163	(0.406)	-0.167	(0.417)	0.013	(0.073)	-0.018	(0.073)
0-6mnthsatefruitveg	-0.743**	(0.334)	-0.747**	(0.336)	0.013	(0.055)	0.014	(0.054)
0-6mnthsatemeat	0.769*	(0.465)	0.774	(0.569)	-0.062	(0.103)	0.006	(0.071)
Household variables								
toiletflush	0.035	(0.183)	0.034	(0.203)	-0.062*	(0.035)	-0.049	(0.035)
toiletpit	0.175**	(0.074)	0.173***	(0.066)	-0.028**	(0.013)	-0.026**	(0.013)
drinkwatertap	0.254*	(0.139)	0.254**	(0.126)	-0.001	(0.023)	-0.008	(0.024)
drinkwaterother	0.075	(0.065)	0.074	(0.060)	0.001	(0.011)	-0.002	(0.011)
hhdmember	-0.001	(0.014)	-0.005	(0.015)	-0.002	(0.003)	-0.001	(0.003)
chnunder5	-0.024	(0.036)	-0.002	(0.040)	-0.001	(0.007)	-0.003	(0.007)
wealthquintile2	-0.006	(0.076)	-0.004	(0.065)	-0.001	(0.013)	-0.004	(0.013)
wealthquintile3	0.059	(0.094)	0.061	(0.097)	-0.013	(0.017)	-0.013	(0.017)
wealthquintile4	-0.047	(0.139)	-0.040	(0.144)	0.001	(0.024)	-0.002	(0.024)
wealthquintile5	0.193	(0.183)	0.200	(0.193)	-0.033	(0.033)	-0.040	(0.033)
rural	-0.073	(0.149)	-0.071	(0.148)	-0.034	(0.029)	-0.038	(0.030)
malehhdhead	-0.067	(0.060)	-0.072	(0.052)	0.017	(0.011)	0.016	(0.011)
agehhdhead	-0.003	(0.010)	-0.001	(0.011)	0.001	(0.002)	0.000	(0.002)
sqagehhdhead	0.000	(0.000)	0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)
interviewoctdec	-0.038	(0.058)	-0.035	(0.049)	0.022*	(0.012)	0.026**	(0.012)
interviewjanapril	0.053	(0.075)	0.055	(0.073)	0.042***	(0.014)	0.043***	(0.014)
lambda (IMR)			0.238	(0.235)				
constant	-1.587**	(0.697)	-1.786***	(0.642)				
no. of observations	3,766		4,118		3,651		3,766	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level
**** p<0.01, ** p<0.05, * p<0.1*

2.9 Possible explanations for negative association

Some reasons can be proposed to explain the robust negative relationship obtained between *BMIzscore* and *heightzscore* for Zimbabwean children.

Firstly, this negative relationship may be influenced by the reference population used in the construction of *BMIzscore and heightzscore*. Z-scores are obtained as follows:

$$z - score = \frac{observed\ value - median\ value\ of\ the\ reference\ population}{standard\ deviation\ of\ the\ reference\ population}$$

The reference population used in this paper is the 1990 British Growth Reference as indicated in section 2.5.3. The median and standard deviation of this reference population were constructed using data from 17 cross-sectional surveys carried out between 1978 and 1993 in the UK. This reference population is thus more suitable for the UK population and other developed countries with similar economic and social backgrounds as the UK. In 2006, a more general reference population, the 2006 WHO Growth Standards was developed for preschool children (from birth to 60 months old). Longitudinal and cross-sectional data from breastfed children in Brazil, Ghana, Norway, Oman, India and the USA was used to develop this standard. Unlike other growth references, the 2006 WHO Growth standards are more prescriptive than descriptive as they suggest how children should grow as opposed to how they are growing. The underlying assumption in the development of this reference was that in the presence of adequate feeding and health care, all children can realise favourable height and weight outcomes (Wang and Chen, 2012). A comparison is made using the main results (Table 2.3), where the z-scores are constructed using the 1990 British Growth Reference versus results obtained from z-scores constructed for the same data using the 2006 WHO Growth Standards, which is more suitable for Zimbabwe. If this standardisation is at fault, then the latter result should exhibit a different association between *BMIzscore* and *heightzscore* than the former result (see Tables 2.13 and 2.15).

Secondly, this may simply be as a result of standardisation problems in the construction of the BMI. As indicated in section 2.5.3, BMI is the weight measure adjusted for height

$$BMI = \frac{weight\ (kg)}{height\ ^2(m^2)}$$

Suppose, as discussed in section 2.4, the exponent of height for the ideal standardisation is some value other than 2, then the negative effect that is estimated by the OLS and maternal fixed effects models could be a result of this misspecification. One way to examine this is to do a comparison for another country. Using the Longitudinal Survey of Australian Children (LSAC[16]) data the OLS model is estimated to determine whether this is the case. Expectations are that if indeed the measurement of the BMI is at fault, then a negative relationship will also be realised between the *BMIzscore* and *heightzscore* for Australian children. The results are presented in Tables 2.14 to 2.16 below.

[16] LSAC is the longitudinal survey that follows children in Australia. In order to compare with Zimbabwe's cross-sectional data, only Wave 2 data for cohort B children aged 27-46 months is used.

Table 2.13: 2006 WHO versus 1990 British Growth References

	2006 WHO BMIzscore	heightzscore	1990 British BMIzscore	heightzscore
mean	0.238	-1.367	-0.063	-1.256
standard deviation	1.441	1.583	1.608	1.571
minimum	-4.920	-5.960	-4.990	-4.967
maximum	4.980	5.850	4.887	4.992
observations	**3909**	**3909**	**3994**	**3996**
	number	**percentage**	**number**	**percentage**
BMI categories				
underweight (<-2SD)	244	6.2%	418	10.5%
normal weight	3301	84.5%	3218	80.6%
overweight (>2SD)	364	9.3%	358	9.0%
total	**3909**	**100%**	**3994**	**100%**
Height categories				
stunted (<-2SD)	1314	33.6%	1239	31.2%
mormal height	2485	63.6%	2594	65.4%
tall (>2SD)	110	2.8%	133	3.4%
total	**3909**	**100%**	**3966**	**100%**

Table 2.14: Australia versus Zimbabwe: Children aged 27 to 46 months

	Australia BMIzscore	heightzscore	Zimbabwe BMIzscore	heightzscore
mean	0.462	0.250	0.065	-1.511
standard deviation	1.076	1.059	1.439	1.399
minimum	-4.976	-3.956	-4.707	-4.990
maximum	4.853	4.566	4.971	4.261
observations	4514	4526	1271	1250
	number	**percentage**	**number**	**percentage**
BMI categories				
underweight (<-2SD)	75	1.6%	90	7.1%
normal weight	4149	91.9%	1083	85.2%
overweight (>2SD)	290	6.4%	98	7.7%
total	**4514**	**100%**	**1271**	**100%**
Height categories				
stunted (<-2SD)	93	2.2%	449	35.9%
mormal height	3945	92.6%	785	62.8%
tall (>2SD)	221	5.2%	16	1.3%
total	**4259**	**100%**	**1250**	**100%**

Table 2.15: OLS results: 1990 British growth versus 2006 WHO growth reference

Dependent variable:BMI-zscore	1990 British growth		2006 WHO	
	coef	**se**	**coef**	**se**
Main variable				
heightzscore	-0.313***	(0.021)	-0.292***	(0.019)
Maternal variables				
bmimumunder	-0.706***	(0.103)	-0.677***	(0.095)
bmimumnorm	-0.220***	(0.059)	-0.192***	(0.056)
mumheight	0.015***	(0.004)	0.013***	(0.004)
primarylev	0.203*	(0.112)	0.220**	(0.105)
secondabove	0.285**	(0.115)	0.315***	(0.107)
notmarry	-0.026	(0.131)	-0.051	(0.120)
divorcewidow	-0.229**	(0.096)	-0.228**	(0.093)
Child variables				
size at birth				
average	0.540***	(0.072)	0.440***	(0.065)
aboveaverage	0.659***	(0.077)	0.542***	(0.069)
diarrhoea	-0.258***	(0.077)	-0.251***	(0.070)
childmale	0.021	(0.046)	0.061	(0.043)
childtwin	-0.214	(0.213)	-0.285	(0.215)
ageB(7-24mnths)	-0.765***	(0.105)	-0.223**	(0.099)
ageC(25-48mnths)	-0.602***	(0.100)	-0.177*	(0.093)
ageD(49-59mnths)	-0.713***	(0.098)	-0.443***	(0.092)
grain	0.005	(0.079)	-0.015	(0.075)
fruitveg	0.016	(0.068)	-0.024	(0.064)
meat	0.149**	(0.068)	0.182***	(0.063)
0-6mnthsategrain	-0.493	(0.369)	-0.278	(0.349)
0-6mnthsatefruitveg	-0.570*	(0.310)	-0.535*	(0.295)
0-6mnthsatemeat	0.619	(0.412)	0.619	(0.411)
Household variables				
toiletflush	0.141	(0.178)	0.159	(0.163)
toiletpit	0.180**	(0.069)	0.154***	(0.059)
drinkwatertap	0.220*	(0.131)	0.143	(0.123)
drinkwaterother	0.040	(0.061)	0.043	(0.056)
hhdmember	0.005	(0.013)	0.015	(0.011)
chnunder5	-0.038	(0.035)	-0.048	(0.032)
wealthquintile2	-0.030	(0.072)	-0.032	(0.063)
wealthquintile3	0.082	(0.090)	0.103	(0.080)
wealthquintile4	-0.052	(0.129)	-0.042	(0.118)
wealthquintile5	0.158	(0.169)	0.145	(0.156)
rural	-0.021	(0.136)	-0.010	(0.127)
malehhdhead	-0.082	(0.057)	-0.062	(0.054)
agehhdhead	-0.002	(0.010)	-0.007	(0.009)
sqagehhdhead	0.000	(0.000)	0.000	(0.000)
interviewoctdec	-0.050	(0.055)	-0.061	(0.050)
interviewjanapril	0.004	(0.072)	-0.059	(0.067)
constant	-2.813***	(0.713)	-2.382***	(0.649)
no. of observations	3,651		3,643	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level
**** p<0.01, ** p<0.05, * p<0.1*

Table 2.16: Australian versus Zimbabwean children (27-46months old)

Dependent variable: BMIzscore

	Australia		Zimbabwe	
	coef	se	coef	se
Main variable				
heightzscore	0.053**	(0.024)	-0.257***	(0.037)
Maternal variables				
bmimumunder	-0.449***	(0.089)	-0.606***	(0.153)
bmimumnorm	-0.204***	(0.069)	-0.160*	(0.091)
bmimumoverweight	-0.040	(0.075)		
mumheight	-0.319	(0.353)	0.007	(0.007)
primarylev			0.180	(0.148)
secondabove			0.146	(0.152)
bachelorslev	-0.020	(0.054)		
postgradlev	-0.016	(0.064)		
notmarry			0.086	(0.241)
divorcewidow			-0.280*	(0.154)
smokes	0.223***	(0.077)		
alcoholprob	0.099	(0.076)		
depressed	-0.085	(0.087)		
Child variables				
size at birth				
average			0.371***	(0.118)
aboveaverage			0.521***	(0.123)
diarrhoea			-0.208	(0.142)
healthneed	0.079	(0.071)		
childmale	0.072	(0.044)	0.008	(0.076)
childtwin			0.147	(0.304)
childage	-0.017**	(0.008)	0.002	(0.008)
grain			-0.221*	(0.124)
fruitveg	0.153	(0.163)	-0.101	(0.109)
meat			0.218*	(0.117)
Household variables				
toiletflush			0.236	(0.268)
toiletpit			0.294***	(0.102)
drinkwatertap			0.113	(0.173)
drinkwaterother			0.058	(0.094)
hhdmember	-0.023	(0.025)	0.003	(0.019)
chnunder5			-0.018	(0.051)
incometog	0.000	(0.000)		
wealthquintile2			-0.211*	(0.111)
wealthquintile3			0.026	(0.134)
wealthquintile4			-0.369*	(0.197)
wealthquintile5			-0.238	(0.264)
rural			-0.281	(0.207)
metropolitan	-0.050	(0.048)		
malehhdhead			-0.127	(0.093)
agehhdhead	0.041	(0.049)	-0.011	(0.017)
sqagehhdhead	-0.001	(0.001)	0.000	(0.000)
interviewoctdec			-0.173*	(0.092)
interviewjanapril			-0.245**	(0.107)
constant	0.816	(1.061)	-1.370	(1.312)
no. of observations	2,191		1,157	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level
**** p<0.01, ** p<0.05, * p<0.1*

2.9.1 Discussion of results

Descriptive statistics

From the descriptive statistics in Table 2.13, the 2006 WHO Growth Standard suggests that in general Zimbabwean children aged 0-59 months are generally slightly overweight (mean 0.238SD) compared to the reference population. The 1990 British Growth Reference on the other hand purports that the same children are slightly underweight compared to the reference population (mean -0.063SD). Both measures show that a high percentage of Zimbabwean children are stunted compared to the reference populations. In terms of *BMIzscore* categorisation, the 2006 WHO measure indicates that a lower percentage of children are underweight (6.24%) compared to the 1990 British reference (10.47%). This is expected as the 2006 WHO measure is constructed using more generic data including data from an African country which has conditions that are more similar to Zimbabwe than those of the UK. The percentage of normal and overweight children is more or less the same under both measures. The latter result is not surprising as research has indicated that developing countries are also being faced with the challenge of overweight and obese children, especially those that are experiencing nutritional transition (Stanojevic et al., 2007). For the *heightzscore* categories, both measures indicate that almost a third (33.61% and 31.24% for the 2006 WHO and 1990 British Growth References respectively) of the children in the sample are stunted. The distribution of children of normal height and tall children is more or less the same for both measures.

With regards to Australian and Zimbabwean children aged 27 to 46 months, Table 2.14 results indicate that the average child from both countries is slightly overweight (Australia mean (0.462); Zimbabwe mean (0.065)) compared to the reference population (1990 British Growth Reference). Zimbabwe’s children are only slightly overweight though which is expected. The *heightzscore* means indicate that compared to the 1990 British Growth Reference, Australian children are taller whilst Zimbabwean children are stunted. There is a higher percentage of underweight children in Zimbabwe (7.08%) compared to Australia (1.66%) and slightly more children are overweight in Zimbabwe (7.71%) than in Australia (6.42%). Zimbabwe's main challenge is stunted children (35.95%) compared to Australia (2.18%). Australia has a higher percentage of tall children (5.19%) compared to Zimbabwe (1.28%). The data for both measures and both countries is more spread out compared to the reference population.

Growth Reference Measure

Table 2.15 results indicate that the robust negative association is maintained despite the reference population used to construct the z-scores. There is only a slight change in magnitude of *heightzscore*, -0.313SD and -0.292SD for the 1990 British Growth and 2006 WHO Growth references respectively. Therefore the negative correlation between *BMIzscore* and *heightzscore* cannot be attributed to the reference population used.

BMI standardisation issue

Table 2.16 results indicate that for Australia, there is a positive relationship between the *BMIzscore* and *heightzscore* for children aged 27 to 46 months, which is opposite to that of Zimbabwean children. As BMI is a universal measure, this difference in direction of impact lends credibility to the conclusion that the negative relationship between short-term and long-term health is unlikely to be as a result of measurement error in the construction of the BMI.

This negative relationship could be as a result of endogeneity, arising from unobserved individual child specific factors that influence a child’s height and weight, which causes bias in the coefficient of the *heightzscore*. However, the conflicting results (Table 2.16) suggest that these unobserved factors, if they are present have a different effect on children from Australia and Zimbabwe. These factors would result in taller children being overweight and underweight for Australia and Zimbabwe respectively. So what explains the opposite signs?

One likely factor could be intra-household food rationing, an occurrence common in a poor country like Zimbabwe and not in a developed country like Australia. This effect is consistent with the results for the maternal fixed effects model which show a robust negative relationship between *BMIzscore* and *heightzscore*. Consider a typical household in Zimbabwe with a fixed amount of food to be shared among all household members. If all children in the household get equal portions, one would expect the shorter child to have their nutritional needs met more than the taller child as the taller child has a larger frame to fill than the shorter child. If this food share is just enough for the shorter child to be full, then the taller child will be slightly hungry. If food continues to be shared without taking height into account then it would be reasonable to assume that the shorter child (low *heightzscore*) will have higher *BMIzscore* than the taller child, giving rise to a negative association. This is unlikely to be the case in Australia. Food rationing however remains only a possible mechanism in this case as more research needs to be carried out to prove that it is indeed the mechanism by which the negative relationship is brought about. Other research has also hinted that the relationship between BMI and height could be as a result of poor diet and hormonal factors (Popkin et al., 1996). However, little research has been done to investigate this suggestion.

2.10 Conclusion and policy implications

This study has considered the association between short-term and long-term health in children in Zimbabwe and attempts to identify the possible mechanism through which this association occurs. Overall, the results revealed that there is a negative association between short-term (*BMIzscore*) and long-term (*heightzscore*) child health. This relationship is consistent across all age groups, gender, wealth classes and height categories. The possible channel through which this negative effect is conveyed is most likely through upbringing factors such as the intra-household food rationing.

This result has several implications on policies targeted at improving the health of children less than 5 years of age in Zimbabwe. The negative correlation between *BMIzscore* and *heightzscore* suggests that children with better long-term health (higher *heightzscore*) are more likely to have poorer short-term health (lower *BMIzscore*). In a food security context, this implies that being tall is associated with being underweight.

The results from the 2005-2006 DHS survey (section 4.1) show that prevalence of stunting (low *heightzscore*) is much higher than the prevalence of being underweight (31.2% versus 10.5% respectively) for Zimbabwean children. This means that in identifying food insecure children using the *BMIzscore* only as is the current practice for emergency situations, there is a risk that children suffering from chronic food insecurity (lower *heightzscore*) can be omitted in as they will have a higher *BMIzscore*. In this context, the prevalence of stunting is almost thrice that of being underweight. Thus identification of food insecure children using only the short-term health measures (*BMIzscore*) will likely leave out a large number of children and consequently households already suffering from chronic malnutrition. In light of this result, the *heightzscore* may need to be considered in addition to the *BMIzscore* currently used, to identify children for selective feeding programs in emergency situations. These implications are by no means suggesting that using *BMIzscore* for targeting food insecure children in emergency situations is inappropriate. Rather the results advocate for incorporating chronic food insecurity in targeting the food insecure through the use of the *heightzscore*. The conclusions drawn from this research for food security are mainly a direct application of the negative correlation found between the *BMIzscore* and the *heightzscore* and they do not imply any causality or carry any medical connotations.

In addition to improving targeting of food aid, policies aimed at child feeding interventions (for children below the age of 5) emphasising on breastfeeding practices and the inclusion of meat in their diets as well as promoting prenatal care for pregnant women, will go a long way in improving child health. Incorporating divorced mothers into the vulnerable population will also contribute towards improving child health. The promotion of the establishment of pit as opposed to flushing toilet facilities will be beneficial not only to children but to the household as a whole in terms of health, given the rampant water shortages often experienced in Zimbabwe.

CHAPTER 3

The role of maternal nutrition in determining child nutrition in Zimbabwe

"When women are fully involved, the benefits can be seen immediately: families are healthier and better fed; their income, savings and reinvestment go up. And what is true of families is also true of communities and, in the long run, of whole countries".

Kofi Annan, 2003

Secretary General of the United Nations (January 1997-December 2006)

3.0 Introduction

The right to food remains an important issue in today's society. Worldwide, efforts are being made to improve global, national and household food security, under the formalised millennium development goals (MDGs) adopted in 2000 (Millenium Project, 2006). In particular, MDG1 is targeted at halving the hungry population and alleviating poverty by 2015. Improvements in food security are being addressed from all the four aspects namely; availability, accessibility, utilisation and stability (FAO, 2008). Food must be there and people must have the access to it either through purchasing it, producing it or receiving it in the form of donations from relatives, friends or more formally from the government and or donor organisations, in accordance with the entitlements theory highlighted by Sen (1981). Food also needs to be of the right quality, prepared under the right conditions and consumed in the right quantities in order to satisfy the utilisation aspect of food security. Food supplies must always continue to be there in order to satisfy the stability aspect (FAO, 2008; Maxwell S., 1996). Anthropometric measures such as the body mass index (BMI), height and mid-upper arm circumference (MUAC) are mainly used to determine whether or not individuals are receiving the right nutrition (Chakraborty, 2011; Mwangome, 2012). Individuals who are receiving inadequate nutrition are referred to as malnourished or food insecure.

According to Girma and Genebo (2002), children and women in their reproductive age are most at risk of suffering from malnutrition. This is especially evident in environments characterised by inequalities in intra-household food distribution, poor food preparation and storage methods as well as where cultural values and taboos in relation to diets are upheld. For women, their nutritional status is also adversely affected by pregnancy and lactation. Poor nutrition in women increases chances of women giving birth to children with a low birth weight as well as chances of experiencing stillbirths. Chances of experiencing complications such as miscarriages are also higher in women who are malnourished. On the whole, all these challenges lead to increased mortality in children around birth (Kader & Perera Perera, 2014).

Researchers such as Osmania and Sen (2003) and Reinhard and Wijagartne (2002) in their studies highlight that maternal nutrition is a very important but neglected aspect in determining a child's health status. The mother is mostly responsible for multiple roles relating to child health, from giving birth to and rearing the child to production, procurement, preservation and distribution of food within the household. Maternal nutrition (depicted by BMI) is thus very important, especially during pregnancy as it closely determines a child's nutritional status (Rahman et al., 2003). Bio-medically it has been established that maternal short stature is a reflection of the nutritional status a mother has been subjected to during her childhood. Short stature in women results in poor maternal organ development which has negative implications on the supply of adequate nutrients to the foetus during pregnancy. This gives rise to poor intrauterine growth and low birth weight in children and this in turn affects their survival, their development later in life in terms of cognitive development and educational achievements which will impact their productivity and future economic growth. For female children, their reproductive ability is also compromised as they are also likely to be stunted as adults and hence the same shortcomings will be passed onto their children (Dewey & Begum, 2011; Özaltin, Hill & Subramanian, 2010).

Studies have been carried out to determine the impact of maternal nutrition (through maternal BMI) on child health. As early as 1975, it was established that for pre-industrial countries, improved maternal nutrition during pregnancy resulted in a notable decrease in the occurrence of low birth weight in infants which in turn led to lower child mortality rates in these countries (Lechtig et al., 1975). This finding is also supported and extended by Roberfroid et al. (2008)'s study which indicated that use of multiple micronutrients supplements during pregnancy contributes more to increasing foetal growth than using single micronutrient supplements like folic acid alone. In addition to this Rahman et al. (1993)'s study highlighted that maternal nutrition is a crucial and immediate determinant of a child's nutritional status. Their results show that an underweight mother is likely to give birth to an underweight child and whilst a mother with normal weight is likely to give birth to a child with normal birth weight. Other empirical studies on child health have also supported this finding (Girma & Genbo, 2002; Mbuya, Chidem et al., 2010). These studies among others have mainly incorporated maternal BMI simply as an explanatory variable in the child health equation.

Our contribution

Similar to previous research, this study will explore the impact of maternal nutrition (represented by the mother's body mass index (BMI)) on child nutrition in the short-term (represented by the child's BMI z-score) for Zimbabwe. Maternal nutrition is can represent the overall nutritional choices of the household, which affect both the mother and the child.

Thus if the mother's nutrition is good (high BMI), this implies that the household makes good nutritional choices and thus it follows that the child's nutrition will also be good. On the other hand, a low BMI indicates poor maternal nutrition for the mother and the household and this will in turn imply poor nutrition for the child. So a positive relationship between maternal BMI and a child's BMI is expected in this case. This is by no means a causal relationship but rather suggests that there is a common channel (household nutritional choices) influencing both maternal and child nutrition.

In addition, the influence of a mother's nutrition on the child can be direct. For instance, better maternal nutrition can result in better breastfeeding practices which will result in better nutrition for the child. Better maternal nutrition also implies that the mother is healthy and is thus in a position to provide better care for their child in terms of practical activities such as ensuring that the child is grows up in a clean environment. This will help reduce incidences of diseases like diarrhoea and thus improve a child's nutrition and health.

3.1 Literature review

Studies have been carried out to explore the impact of various maternal factors on different aspects of a child's health.

3.1.1 Maternal education

Extensive research carried out on the influence of education on child nutrition has revealed that there is a positive association between maternal education and child nutrition (Bicego & Ahmad, 1996; Cleland & van Ginneken, 1988). Maternal education is thought to impact on a child's health through improving a mother's ability to identify and address child health problems as well as to make mothers more amenable to modern medicines. Educating the mother on health issues also contributes directly to improving child health and nutrition (Frost, Forste & Haas, 2005). This influence has been found both at the individual and community levels. Communities with more educated mothers tend to be better off in terms of sanitation facilities and health care (Alderman, Hoddinott & Kinsey, 2003, Desai & Alva, 1998). General maternal literacy is also important for child nutrition as revealed by Thomas, Strauss & Henriques (1991)'s study. After controlling for the gender and age, their results indicate that access to information (reading papers, watching television) are the mechanisms through which maternal education affects child height.

Desai and Alva (1998) go a step further to suggest that maternal education has an indirect effect on a child's nutrition. They argue that the mechanism by which maternal nutrition impacts on child nutrition is through household socioeconomic status and location. After controlling for these factors in their model, the impact of maternal education on child nutrition diminished. This led them to conclude that maternal education is a proxy for household socioeconomic status and location. The influence of maternal education on child nutrition through socioeconomic status is confirmed by Frost et al. (2005) using data from Bolivia. Their results disclose that socioeconomic status is the most crucial channel through which maternal education affects child nutrition.

3.1.2 Maternal height

Research has shown that maternal height is important for child mortality. Results on the impact though have been varied with most studies concluding there is an inverse relationship between maternal height and child mortality. Subramanian, Ackerson, Davey Smith and John (2009)'s study revealed that better height in mothers reduces the threat of child mortality amongst children in India. Similar results were also obtained by Enwerem, Obirieze and

Bishai (2014) and Özaltin et al. (2010) for Nigeria and other low and middle-income countries respectively. In fact, Enwerem et al. (2014) reveal that a unit increment in maternal height is associated with a 7-9% reduction in the likelihood of death in children below the age of 5 years, whose mothers are of the reproductive age (between 15 and 49 years old).

With regards to the influence of maternal height on child birth weight, shorter mothers are more likely to give birth to children with a low birth weight compared to taller mothers. Britto et al. (2013)'s study also confirms this result and also reveals that a higher BMI in shorter mothers is advantageous. Shorter mothers who are obese face a lower risk of giving birth to children with a low birth weight. For taller mothers, lower socio economic status proved to be associated with increased chances of giving birth to low birth weight babies. Lower BMI (being underweight) in mothers was found to result in lower birth weight for children regardless of the mother's height.

3.1.3 Maternal nutrition

Andersson and Bergeström (1997) using maternal weight as a long term nutrition measure, found that maternal nutrition is the key factor in determining the birth weight of children. Using data on an African community with a high prevalence of chronic maternal malnutrition, they concluded that a positive correlation exists between maternal weight and a child's birth weight. Ayoola, Stommel and Nettleman (2009) and Ugwa (2014)'s studies also obtained similar results for Nigeria. Moreover, Ugwa (2014) found a strong positive association between maternal body mass index (BMI) during pregnancy and a child's birth weight. Maternal height on the other hand was found to be a poor predictor of birth weight.

In addition Andersson and Bergeström (1997) showed that better socio-economic status of the mothers (denoted by the type of work the husband or partner was involved in) is crucial in reducing the incidence of low birth weight in children. Women with husbands or partners involved in professional work were found to have better long-term nutritional status (higher weight) and gave birth to children with a higher birth weight than their counterparts whose husbands or partners were employed in agriculture.

Rahman et al. (1993)'s results on the role of maternal nutrition in determining child health revealed that maternal nutrition has a positive impact on a child's health or nutritional status for Bangladesh, ceteris paribus. Mothers with better nutrition (higher BMI) tended to have children with better nutrition (higher weight-for-age and weight-for-height) and mothers with poor nutrition tended to have children with poor nutrition.

3.1.4 Other maternal factors

Various studies have found that other maternal factors such as birth interval, parity, tobacco exposure, suffering from anaemia, maternal age, maternal blood pressure and religion also influence child heath (Deshmukh et al., 1998; Dhall & Bagga, 1995; Ensor & Cooper , 2004). Religious beliefs determine whether or not a mother seeks medical attention during pregnancy, at birth and during any illness for herself and for her family. This has direct effects on her general health as well as her reproductive health. For some religious sects, seeking medical attention for health related matters is not an option as they regard health matters to be spiritual. Ensor and Cooper (2004) also bring to light the importance of incorporating community factors such as religion and other cultural factors when analysing issues of health.

In Africa, religion plays an important role in detecting whether women seek health services from the regular health centres. Some religions such as the apostolic sect also known as the Zionists or white garment churches believe in spiritual healing for ailments and as such do not encourage seeking help health institutions. This means that pregnant mothers do not get to benefit from antenatal services as well as giving birth in medical facilities. Rather they give birth at home or at healing centres set up by their religious groups, mostly in the presence of assistants who have no medical training. This exposes them and their children to greater health risks (Ha, Salama, Gwavuyu & Kanjala, 2012). Although the DHS survey data used for this study collected information on religion, it is not possible to distinguish between respondents who belong to the modern apostolic sects that believe in seeking medical attention and those that belong to the white garment churches which believe in seeking spiritual help only for all health matters.

3.1.5 This research

Drawing from the study by Rahman et al. (1993) on the role of maternal nutrition in determining child health for Bangladesh, this research focuses on establishing this impact for Zimbabwe. In addition to modelling a linear association between maternal nutrition (denoted by the mother's BMI), this study will also explore the issue of simultaneity or endogeneity between the determinants of maternal and of child nutrition (maternal and child BMI). Simultaneity bias in this case could arise because the child and the mother both reside in the same household. Rahman et al. (1993) restrict their sample to 239 children aged 0 to 36 months taken from 2 hospitals and a community clinic in Bangladesh. In this study, we use a more representative sample from a household survey, the Measure DHS survey for 2005/06 for Zimbabwean children aged 0 to 59 months. In their study, Rahman et al. (1993) do not account for endogeneity. Failing to account for endogeneity may lead to inconsistent results as the resultant estimator for the effect of mother's BMI will include both the direct effect of maternal nutrition on child nutrition and the indirect effect through overall household nutrition. This will affect the interpretation of the result as well as the implications it has for policies aimed at improving child nutrition. In this study, we use instrumental variable regression to isolate the direct from the indirect effect of maternal nutrition on child nutrition, so as to identify the channel through which maternal nutrition influences child nutrition.

3.2 Methods and procedures

3.2.1 The study population

This study is based on the 2005-2006 DHS data for Zimbabwe. The data was collected at provincial level and all of Zimbabwe's 10 provinces were represented. The aim of the survey was to collect information on reproductive, mortality and nutrition related issues for women and children. Among the questionnaires administered were the household and women questionnaires and information on children below the age of 5 years was also collected. The information collected from these questionnaires will be used in this study.

Although 19,489 women aged 15-49 years (reproductive age) were interviewed, this research will use only information from 3,994 women who had children aged 0-59 months whose weight and heights were also recorded. More information on the DHS survey is presented in the previous chapter and in the DHS report by CSO and Macro Inc. (2007).

3.2.2 Anthropometry

The dependent variable for the analysis is the body mass index (*BMIzscore*) for children under 5 years. BMI is the weight measure adjusted for height and is given by:

$$BMI = \frac{weight\ (kg)}{height^2\ (m^2)}$$

Z-scores are standardised measures for anthropometric indicators. They are constructed using a reference population and are computed as follows:

$$z - score = \frac{observed\ value - median\ value\ of\ the\ reference\ population}{standard\ deviation\ of\ the\ reference\ population}$$

where the observed value is the observed height, weight or BMI value for each child.

The reference population sets a common standard for the BMI, height and weight of children, taking into account their age and gender. In this case the 1990 British[17] Growth Reference is used as the reference population and the z-scores are constructed using STATA 12's zanthro function (Vidmar et al., 2004). The 1990 British Growth reference covers all the children in our sample (aged between 0-59 months).

The BMI z-score for children in this case is used as a proxy for a child's nutrition. As a rule, children with a BMI z-score below -2SD are classified as underweight (Cole et al., 2007).

3.3 Data analysis

3.3.1 The main empirical specification

The main model is based on the assumption that there is a linear relationship between a child's short-term nutrition (proxied by the *BMIzscore*) and the overall household nutrition (proxied by *mumbmi*). This linear association is modelled as:

[17] The data used to develop these reference charts was obtained from 17 UK surveys conducted between 1978 and 1993 (Vidmar et al., 2004).

$$BMIzscore_i = \alpha_0 + \beta mumbmi_i + \gamma' child_i' + \sigma' maternal_i' + \tau' household_i' + \varepsilon_i \quad (3.1)$$

where $child_i'$, $maternal_i'$ and $household_i'$ are 1x k vectors of independent variables comprising of child, other maternal and household characteristics defined in Table 3.1. ε_i is the idiosyncratic error term, representing all unobservable factors that influence a child's short-term nutrition and is assumed to be normally distributed with a mean zero and a constant variance ($\varepsilon_i \sim N(0, \sigma^2)$) , while α_0 is the constant. Clustering[18] of standard errors at the household level is accounted for as there may be children from the same household with the same household level information in the sample. This will ensure that robust standard errors are obtained and will correct for overstated precision in the estimates (Deaton, 1997; Long & Freese, 2006).

Explanatory variables

The main explanatory variable in this study is the mother's BMI (*mumbmi*) which can be used as a proxy for the overall nutrition choices of the household. The mother's BMI is provided in the DHS data. If the mother's BMI is high, this implies that the mother's nutrition is good and thus the overall household nutrition is good. This in turn will mean that the child's nutrition should be good (Girma & Genebo, 2002; Rahman et al., 1993).

Maternal variables

In addition to the mother's BMI, the mother's age (*agemum*), education level and marital status are also controlled for. Past studies have indicated that women of a reproductive age (15-49 years old) are more prone to malnutrition. Conversely, Teller and Yimar (2000, as

[18] There are 462 clusters in this sample.

cited in Girma & Genebo, 2002) report that only women in the 15-19 and 40-49 age categories are most vulnerable to malnutrition, compared to those aged 20-39.

Maternal education levels are represented by *noeducation, primarylev* and *secondaryabove*, dummy variables signifying that the mother is not educated, has completed primary education and has completed secondary or higher education respectively. Maternal education has been shown to be important in determining maternal, household and child nutrition as indicated in section 3.1. The mother's marital status is denoted by the dummy variables *married, notmarry, divorcewidow* defined as the mother is married or living together with the father of her child or children, not married or is not living together with her partner and the mother is or widowed respectively. Research has revealed that negative changes in marital status translate to negative nutritional outcomes. Teller and Yimar (2000 as cited in Girma & Genebo, 2002)'s study revealed that in Ethiopia, malnutrition levels are higher among unmarried and divorced or separated women in rural and urban areas respectively. All the above dummy variables will take the value 1 if the above mentioned educational level or marital status is realised, whilst *agemum* comprises of the actual values for the mother's age.

Child related variables

Child related variables include the size of the child at birth represented by the dummy variables *belowaverage*, *average* and *aboveaverage* for children who were smaller than average, average and above average size at birth respectively and whether the child suffered from diarrhoea two weeks preceding the survey *(diarrhoea).* Studies have shown that birth weight influences a child's health and hence nutritional status (Mbuya, Chidem et al., 2010). Incidences of diarrhoea in children also have an adverse effect on a child's short-term nutrition. In addition, suffering from diarrhoea also has implications on the status of the environment a child is growing in. Food contamination, usually from stool (indicative of poor sanitary facilities) and other bacteria from drinking unclean water and not washing hands adequately before preparing food usually cause diarrhoea (Christiaensen &Alderman, 2004; Linnemayr et al., 2008). A child's birth order also affects their health through affecting their birth weight. Past studies have revealed that the higher the birth order (5+), the more likely it is that the child is malnourished (Jeyaseelan & Lashman, 1997).

Household variables

Household variables controlled for include type of sanitary facilities available, drinking water sources used by the household, household socio-economic status, location of the household and household demography factors. In terms of sanitary facilities, the dummy variables *notoilet*, *toiletflush* and *toiletpit* represent the absence of toilet facilities, presence of a flushing toilet[19] and the presence of a pit toilet[20] in the household respectively. Dummy variables representing the household's drinking water source are *unprotectedwater*, *protectedwatertap* and *protectedwaterother* indicating that a household gets drinking water from an unprotected water source (unprotected dug well, spring, rainwater, cart water and surface water from a dam, pond or stream), from protected tap water and from other protected water sources (borehole, tube well, protected dug well and or a protected spring) respectively. Adequate and appropriate sanitary facilities and drinking water sources improve the health environment under which a child grows and this influences nutritional outcomes for the child, mother and the household (Getaneh et al., 1998 & Sommerfelt et al., 1994 as cited in Girma & Genebo, 2002).

[19] Flushing toilets are flushed either to a piped sewer system, a septic tank or to a latrine.
[20] Pit toilets include ventilated improved pit toilets with or without a slab or non-ventilated improved pit toilets with or without a slab.

The model also includes the number of household members (denoted by *hhdmember)* and the number of children below the age of (represented by *childunder5*). The presence of more members and or children in the household means that there are more mouths to feed. This in turn implies that in the presence of limited amounts of resources, the rations received by each individual are more likely to become smaller. This directly impacts on the nutritional status of the individual.

The location of the household is also controlled for using the dummy variable *rural* (resides in the rural areas). Research has revealed that household location matters in determining nutritional status with children and women in rural areas being more vulnerable to malnutrition compared to those in urban areas (Yimer , 2000 & Zerihun et al., 1997 as cited in Girma & Genebo, 2002).

The variables are described in Table 3.1, with the mean and standard deviation reported for continuous variables and the number and the percentage of observations in each category reported for all dummy variables. The variables are introduced separately into the model in order to determine whether their impact on the main explanatory variable (*mumbmi*) differs. Models 1, 2 and 3 in the main empirical specification will thus include child related, child and maternal related and child, maternal and household related variables respectively.

3.3.2 Simultaneity bias

Given that the mother and the child under study all reside in the same household, it is likely that there could be potential endogeneity or simultaneity bias issues arising from the joint determination of the mother and child's BMI. The mother's BMI can be correlated to the child's BMI via unobservable household factors which renders OLS estimates inconsistent.

In addition there could be a more direct effect of the mother's BMI on the child's BMI that translates better maternal nutrition (higher BMI) to better child nutrition. The IV model is employed to account for potential endogeneity or simultaneity bias.

The IV model

The two stages least squares (2SLS) method is employed to estimate firstly the reduced form equation (3.2) for $mumbmi_i$ on V_i' :

$$mumbmi_i = \beta_0 + \gamma' child_i' + \sigma' maternal_i' + \tau' household_i' + \lambda V_i' + \mu_i \qquad (3.2)$$

where $child_i'$, $maternal_i'$ and $household_i'$ are 1x k vector of independent variables comprising of child, other maternal and household characteristics defined in Table 3.1 and u_i is the idiosyncratic error term, representing all unobservable factors that influence a mother's BMI. u_i is assumed to be normally distributed with a mean zero and a constant variance ($u_i \sim N(0, \sigma^2)$) , while β_0 is the constant. The identifying variable (V_i') is the household's wealth index. This wealth index was constructed by Measure DHS using principal component analysis as indicated in section 2.6.1. Household wealth will be classified according to 5 wealth quintiles represented by the dummy variables; *wealthquintile1, wealthquintile2, wealthquintile3, wealthquintile4 and wealthquintile5*. Based on the assumption that mothers always consider their child first in terms of nutrition, regardless of their household wealth, it is plausible that household wealth has a more direct effect on the mother's and an indirect effect on the child's nutrition through the mother. So in a poor household with limited food resources, the mother forgoes her food share in order to ensure that her child gets enough food. In a richer household, the child will get enough food and the mother will also be better off compared to her counterpart from a poor household. Thus using household wealth as an identifying variable for the mother's nutrition is reasonable.

A number of studies have also revealed that household wealth has little significant impact on a child's nutrition using data from African countries such as Nigeria (Horton, 1986). Mbuya, Chidem et al. (2010) also obtained similar results for Zimbabwe, using the 2005/06 DHS survey data. Our results using the 2005/06 DHS data (section 2.7.2, Table 2.3b) also reveal that the household's wealth class has no statistically significant impact on a child's *BMIzscore*.

Child and maternal BMI can be categorised into three categories namely the underweight, normal weight and overweight categories. The underweight category consists of children with a BMI z-score <-2SD and mothers whose BMI is <18.5kg/m^2. Children with a BMI z-score between -2SD (inclusive) and 2SD and mothers with a BMI of 18.5kg/m^2 inclusive and 25 kg/m^2 are in the normal weight category. Children with a BMI z-score ≥2SD and mothers with a BMI ≥25kg/m^2 are overweight. It is possible that nonlinearities could arise in the case of the mother's BMI effect as being overweight is not good for one's health. In order to account for this, robustness checks are done by re-estimating models according to the 3 BMI categories for the mother and the child.

3.4 Results and discussion

3.4.1 Descriptive analysis

The sample consists of 4536 children below the age of 5. As shown in Figure 2.1 (section 2.7.1) the 25-48 months age-group has the highest representation (37%) in the sample and the lowest if for children aged 0-6months (14%). In terms of gender, representation of male and female children is an almost equal. Roughly 15.2% and 38.5% of the children were below and above the average weight at birth respectively, based on the subjective valuation by their mothers. Almost all the children in the sample (93.4%) were breastfed at some point and less than a quarter of the children sampled (23.5%) were vaccinated before the age of 5 years. The prevalence of underweight children (*BMIzscore* <-2SD) in the sample is 10.5%.

About 60% of the mothers are classed as healthy in terms of their BMI ($18.5 \leqslant \text{BMI} \leqslant 25$), whilst nearly a third are overweight (BMI>25) and a sizeable 7.45% are underweight (BMI<18.5). In terms of education, approximately 39.7% and 56.0% of the mothers completed primary and secondary and higher education respectively. The majority of the mothers are married or living together with their spouses (85.2%) whilst around 10.6% are widows or divorced or separated mothers respectively.

Almost half of the population dwell in houses with no sanitary facilities. 22.5% and 34.3% live in households with flushing and pit toilets respectively. Approximately 30% of the sampled households obtain their drinking water from unprotected water sources ranging from unprotected wells and springs to rain water and surface water from dams, lakes, ponds and streams. The rest of the households obtain their drinking water from protected water sources such as municipality taps and boreholes. On average, a household has 6 members and about 2 children below the age of 5 years. Table 3.1 below summarises the descriptive statistics.

Table 3.1: Descriptive statistics

Variable described	Continous variables	Mean	Standard deviation
child's BMI-for-age z-score	BMIzscore	-0.06	1.61
height-for-age z-score	heightzscore	-1.26	1.57
mother's body mass index (BMI) (kg/m2)	mumbmi	22.82	3.72
mother's height (cm)	mumheight	159.74	6.94
mother's age (years)	agemum	27.86	6.65
number of members in the household	hhdmember	6.22	2.85
number of children under 5 years in the house	childunder5	1.81	0.93
child's birth order number	birthorder	2.85	1.95
	Dummy variables	**Observations**	**Percentage (%)**
Maternal			
mother is not educated (base category)	noeducation	173	4.33
attended primary level education	primarylev	1584	39.66
attended secondary and or tertiary education	secondaryabove	2237	56.01
mother is not married	notmarry	170	4.26
mother is married	married	3402	85.18
mother is divorced or widowed	divorcewidow	422	10.56
Child related			
Size at birth (subjective)			
smaller than average at birth	belowaverage	598	15.22
average size at birth	average	1818	46.28
above average at birth	aboveaverage	1512	38.49
had diarrhoea in the 2 weeks before the survey	diarrhoea	528	13.22
Household			
No toilet facilities	notoilet	1724	43.23
flushing toilet facilities available	toiletflush	897	22.49
pit toilet facilities available	toiletpit	1367	34.28
Unprotected water source	unprotected water	1170	29.95
Protected tap water	protectedwatertap	1112	28.46
Protected water from a borehole, spring or well	protectedwaterother	1625	41.59
Resides in the rural area	rural	3069	76.84
Instruments			
First wealth quintile	wealthquintile1	1067	26.72
Second wealth quintile	wealthquintile2	922	23.08
Third wealth quintile	wealthquintile3	757	18.95
Fourth wealth quintile	wealthquintile4	739	18.5
Fifth wealth quintile	wealthquintile5	509	12.74

The base categories are noeducation, married, belowaverage, notoilet, drinkunprotectedwater and wealthquintiel1

All dummy variables take the value 1 for the condition mentioned and 0 otherwise

3.4.2 Empirical analysis

Table 3.2: Determinants of maternal nutrition (IV first stage results)

Dependent variable: mother's BMI (mumbmi)	model 1 IV first stage		model 2 IV first stage		model 3 IV first stage	
	coef	**se**	**coef**	**se**	**coef**	**se**
Maternal variables						
mumheight	-0.056***	(0.012)	-0.062***	(0.012)	-0.064***	(0.012)
agemum	0.111***	(0.010)	0.077***	(0.016)	0.072***	(0.016)
primarylev	1.055***	(0.369)	1.091***	(0.367)	1.118***	(0.371)
secondabove	1.110***	(0.379)	1.222***	(0.376)	1.220***	(0.380)
notmarry	-0.444**	(0.226)	-0.308	(0.228)	-0.279	(0.229)
divorcewidow	-0.279	(0.228)	-0.200	(0.233)	-0.198	(0.232)
Child variables						
size at birth						
average			0.405**	(0.167)	0.418**	(0.170)
aboveaverage			0.570***	(0.175)	0.556***	(0.178)
diarrhoea			-0.136	(0.172)	-0.124	(0.176)
birthorder			0.149**	(0.061)	0.169***	(0.061)
heightzscore			0.122***	(0.037)	0.117***	(0.037)
Household variables						
toiletflush					0.906**	(0.462)
toiletpit					0.150	(0.168)
drinkwatertap					0.020	(0.329)
drinkwaterother					0.124	(0.151)
hhdmember					-0.000	(0.028)
chnunder5					-0.126	(0.090)
rural					0.274	(0.394)
Instruments						
wealthquintile2	0.560***	(0.164)	0.559***	(0.166)	0.512***	(0.174)
wealthquintile3	0.823***	(0.185)	0.850***	(0.187)	0.755***	(0.216)
wealthquintile4	2.072***	(0.212)	2.111***	(0.216)	1.753***	(0.352)
wealthquintile5	3.259***	(0.261)	3.284***	(0.266)	2.801***	(0.489)
constant	26.667***	(1.865)	27.821***	(1.900)	28.063***	(1.965)
no. of observations	3,942		3,820		3,732	
Endogeneity test						
Durbin score	16.699	(0.000)^{P}	17.001	(0.000)^{P}	0.703	(0.402)^{P}
Wu-Hausman	16.731	(0.000)^{P}	17.02	(0.000)^{P}	0.696	(0.404)^{P}
Weak instruments test						
F-statistic	77.75	(0.000)^{P}	50.959	(0.000)^{P}	10.774	(0.000)^{P}
Minimum eigen value statistic	77.75		50.959		10.774	
2SLS critical value 5% level	16.85		16.85		16.85	
Instrument validity (OID test)						
Sargan score	6.803	(0.078)^{P}	4.363	(0225)^{P}	7.082	(0.069)^{P}
Basmann	6.797	(0.079)^{P}	4.346	(0.227)^{P}	7.042	(0.079)^{P}

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1,* ^{P} *is the p-value for the robust regression test score*

Table 3.3a: Maternal nutrition as a determinant of child nutrition (OLS and IV results)

Dependent variable: child's BMIzscore

	model 1				**model 2**			
	OLS		**IV**		**OLS**		**IV**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable								
mumbmi	0.059***	(0.007)	0.161***	(0.028)	0.063***	(0.007)	0.157***	(0.026)
Maternal variables								
mumheight	0.004	(0.005)	0.009*	(0.005)	0.015***	(0.004)	0.021***	(0.005)
agemum	-0.006	(0.004)	-0.018***	(0.005)	-0.001	(0.006)	-0.012*	(0.007)
primarylev	0.278**	(0.119)	0.141	(0.129)	0.236**	(0.109)	0.112	(0.119)
secondabove	0.435***	(0.120)	0.201	(0.138)	0.398***	(0.113)	0.188	(0.129)
notmarry	0.046	(0.102)	0.096	(0.103)	0.033	(0.100)	0.071	(0.100)
divorcewidow	-0.101	(0.094)	-0.062	(0.095)	-0.216**	(0.088)	-0.185**	(0.089)
Child variables								
size at birth								
average					0.527***	(0.072)	0.481***	(0.074)
aboveaverage					0.653***	(0.073)	0.583***	(0.077)
diarrhoea					-0.295***	(0.073)	-0.274***	(0.074)
birthorder					-0.026	(0.020)	-0.025	(0.021)
heightzscore					-0.287***	(0.019)	-0.300***	(0.020)
Household variables								
toiletflush								
toiletpit								
drinkwatertap								
drinkwaterother								
hhdmember								
chnunder5								
rural								
constant	-2.325***	(0.751)	-4.908***	(1.044)	-5.030***	(0.729)	-7.550***	(1.020)
no. of observations	3,942		3,942		3,820		3,820	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

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

Table 3.3b: Maternal nutrition as a determinant of child nutrition (OLS and IV results)

Dependent variable: child's BMIzscore

	model 3			
	OLS		**IV**	
	coef	**se**	**coef**	**se**
Main variable				
mumbmi	0.056***	(0.007)	0.095*	(0.058)
Maternal variables				
mumheight	0.015***	(0.004)	0.018***	(0.006)
agemum	-0.007	(0.006)	-0.010	(0.008)
primarylev	0.214*	(0.110)	0.165	(0.129)
secondabove	0.295**	(0.115)	0.236*	(0.140)
notmarry	0.011	(0.101)	0.024	(0.103)
divorcewidow	-0.216**	(0.090)	-0.208**	(0.090)
Child variables				
size at birth				
average	0.525***	(0.072)	0.507***	(0.076)
aboveaverage	0.642***	(0.074)	0.618***	(0.081)
diarrhoea	-0.298***	(0.075)	-0.293***	(0.075)
birthorder	-0.005	(0.021)	-0.011	(0.023)
heightzscore	-0.285***	(0.019)	-0.290***	(0.021)
Household variables				
toiletflush	0.120	(0.167)	0.044	(0.206)
toiletpit	0.186***	(0.059)	0.165**	(0.067)
drinkwatertap	0.236*	(0.128)	0.211	(0.131)
drinkwaterother	0.053	(0.059)	0.045	(0.060)
hhdmember	0.009	(0.012)	0.009	(0.012)
chnunder5	-0.038	(0.035)	-0.032	(0.036)
rural	0.014	(0.138)	0.017	(0.138)
constant	-4.835***	(0.750)	-5.946***	(1.784)
no. of observations	3,732		3,732	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

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

3.4.3 Discussion of results

Determinants of maternal nutrition

As expected, the results in Table 3.2, model 3 suggest that a mother's height, age, education level and marital status significantly influence a mother's BMI. All other things being equal, a mother who is 10 years older than her counterpart is expected to have a higher BMI by 0.72. This is consistent with evidence from other studies which conclude that age has a positive effect on a mother's weight and or BMI (Teller and Yimar, 2000 as cited in Girma & Genebo, 2002). The more educated a mother is, the better their nutrition is expected to be. In fact, a mother who has obtained primary level education is expected to have a higher BMI by 1.118 whilst a mother who has completed secondary or higher education is expected to have a higher BMI by 1.220 compared to a mother who has no education ceteris paribus. Education is important as it enables mothers to understand better the importance of nutrition when they are taught through different programs implemented to improve the health and nutrition of mothers and children. Other research has also obtained similar results (Teller and Yimar, 2000 as cited in Girma & Genebo, 2002).

As expected, a mother who is divorced or widowed will on average have a lower BMI (by -0.198) compared to a mother who is married. This is plausible given that divorced women mostly rely on their own income as well as maintenance from their former partners or husbands (which is rarely forthcoming) for their upkeep. In most cases very few women are formally employed and few own or have access to land for agriculture. This renders divorced women more vulnerable to poor nutrition (more likely to have lower BMI) due to increased difficulties in accessing food. Divorced women are not officially part of the targeted vulnerable population and this increasingly makes them vulnerable to poor nutrition.

Widows on the other hand rely mostly on food from donations by relatives, the government and other donors, thus rendering them vulnerable to poor nutrition as well.

In terms of household factors, the presence of a toilet facility in the house improves the mother's BMI and hence overall household nutrition. A mother from a household with a flushing toilet has a higher BMI by 0.906, compared to mothers from households without any toilet facilities ceteris paribus. All other household factors do not have a statistically significant impact on the mother's BMI.

The identifying variable household wealth (represented by *wealthquintile2*- *wealthquintile5*) has a significant positive influence on maternal BMI in all the quintiles. As expected, the magnitude of effect increases from the lower (*wealthquintile2*) to the highest (*wealthquintile5*) wealth category. Given that the results for child *BMIzscore* (section 2.7.2, Table 2.3b) clearly show that household wealth has no significant impact on a child's BMI, the result in Table 3.2 lends credibility to the use of the wealth variable as an instrument for the mother's BMI.

On the whole, the identifying variables are quite strong using Staiger and Stock (1997)'s criteria (F-statistics between 17.87 and 34.89 as shown in Table 3.2). They state that an F-statistic that is less than 10 for the first-stage regression indicates that there may be a problem of weak identifying variables (Cameroon and Trivedi, 2010).

Maternal nutrition as a determinant of child nutrition

The discussion below is centred mainly on the OLS and IV results for model 3 (Table 3.3b) where maternal, child and household variables are all controlled for. The dependent variable *BMIzscore* is measured in terms of standard deviations (SD from the mean of a normal distribution) and the main independent variable *mumbmi* is measures in kg/m^2. In order to change the units for *mumbmi* to SD, 1SD of BMI =3.72 kg/m^2 according to the results in Table 3.1. This will make the results more meaningful.

Main result

Overall, the main OLS results (Tables 3.3a and 3.3b) indicate that there is a robust positive association between maternal nutrition (*mumbmi*) and child nutrition or child health (*BMIzscore)*. The BMI for a child whose mother has a BMI that is a 1 unit higher is expected to be between 0.056 and 0.063 units higher than that of a child whose mother's BMI is lower ceteris paribus. In terms of SD units, a child whose mother has a BMI that is 1SD higher is expected to have a higher BMI by between 0.208 and 0.234SD compared to a child whose mother has a lower BMI ceteris paribus. Given that better maternal (hence household) nutrition is likely to mean better child nutrition, this result is plausible. Rahman et al. (1993)'s study on Bangladesh women also revealed that maternal nutrition has a positive impact on a child's nutrition.

Once we account for simultaneity and potential endogeneity bias through the IV model, the results show that maternal BMI still has a significant positive impact on a child's BMI. The magnitude of effect is higher (between 0.095 and 0.161 units higher *BMIzscore* for a unit increase in *mumbmi*) compared to that of the OLS results (between 0.056 and 0.063 units for a unit increase in *mumbmi*). Considering model 3 (Table 3.3b), which controls for child, maternal and household factors, a child whose mother has a BMI that is 1SD higher is expected to have a higher BMI by 0.095SD compared to a child whose mother has a lower BMI ceteris paribus.

The OLS model captures both the direct and indirect effect of maternal BMI on child BMI whilst the IV model captures only the direct effect. As such, one would expect the magnitude of effect to be lower for the direct (IV model) impact of maternal on child BMI compared to the direct and indirect effect (OLS model). In this case, the results indicate that the magnitude of effect is higher for the direct effect, which suggests that the indirect effect of maternal BMI on child BMI is negative. However, since the magnitude of effect is not much larger for the direct (0.095) compared to the indirect (0.056) effect, this suggests that the indirect effect may be small and not significant.

Other studies have also obtained results which show that OLS estimates are biased downwards, compared to IV estimates. Trostel, Walker and Woolley (2002) obtained IV estimates that were over 20% higher than their OLS estimates for returns to schooling. They used pooled national surveys for 28 countries over an 11 year period. After conducting a number of robustness checks, they concluded that there was indeed a downward bias in the OLS estimates. Their results were consistent with those obtained by Card (1999 as cited in Trostel et al., 2002). The reason for this downward bias as suggested by Card (1999) was differences in the discount rates of individuals. Individuals with high discount rates tend to choose low levels of schooling with high marginal rates of schooling.

One of the robustness checks conducted by Trostel et al. (2002) was using the F-test for the first-stage regression of the IV to test whether the instruments were strong. Weak instruments are believed to be a possible reason for bias in IV estimates. In our study, the F-test results show that our instruments are strong, as mentioned in the discussion above. The F-statistic for the comprehensive model however is just barely above the cut-off point of 10 which indicates that the instruments are not very strong. Endogeneity tests (Durbin score and the Wu

Hausman score) for models 1 and 2 which control for maternal and maternal and child related characteristics indicate that the mother's BMI is endogenous to the *childBMI* model. However for the more comprehensive model 3, which also accounts for household factors, the results indicate that endogeneity may not be an issue. The Sargan and Basman score are consistent across all models indicating that the instruments used are valid.

These results show that maternal BMI has both a direct (IV results) and indirect (OLS results) impact on a child's BMI. The possible mechanism through which maternal nutrition influences child nutrition directly is through household wealth. Failure to account for potential endogeneity or simultaneity bias results in understating the effect of maternal on child BMI.

Other results

Maternal factors

As found in other studies, the results (Table 3.3b) suggest that maternal education plays a significant role in the determination of a child's nutrition (Teller and Yimar, 2000 as cited in Girma & Genebo, 2002; Thomas et al., 1991). Teller and Yimar (2000) reveal that for Ethiopia, maternal education improved child nutrition as it enabled women to understand better the importance of nutrition and to adopt better standards for their households. Having a mother who is divorced or widowed has a negative impact whilst mother's height has a positive impact on a child's *BMIzscore*. This is consistent with the results obtained in Table 2.3b. There is no evidence to show that a mother's age has any statistically significant impact on determining a child's BMI.

Child factors

As expected, a child's size at birth has a positive influence on their BMI. The incidence of diarrhoea and a child's height have a negatively impact on the child's BMI. These results are consistent for both the OLS and IV models (Table 3.3b) as well as with those obtained in Table 2.3b. All things being equal, children who are born with average or above average size are more likely to have a higher BMI (by between 0.507 and 0.642 respectively) compared to children who are below average size at birth. A child who has had diarrhoea in the 2 weeks preceding the survey has a BMI which is lower by between 0.293 and 0.298 compared to a child who has not has diarrhoea ceteris paribus. This is expected, as experiencing diarrhoea directly impacts a child's weight. A child with 1SD higher *heightzscore* is more likely to have a lower BMI by between 0.285 and 0.290SD, a result also consistent with that obtained in Table 2.3b.

Interestingly, birth order has no significant impact on a child's BMI. Other studies though suggest that birth order has a positive impact on a child's birth weight and hence one would expect there to be a significant positive relationship between birth order and a child's nutrition (Kembo and Ginneken, 2009). However this result is plausible given that birth weight has been controlled for.

Household factors

Only the availability of pit toilet facilities significantly improves a child's nutrition. A child from a household with a pit toilet has a higher BMI z-score by between 0.165 and 0.186 compared to a child from a household with no toilet facilities, all things being equal. The presence of a flushing toilet does not have significant impact on a child's nutrition, unlike the significant positive effect it has on the determination of a mother's nutrition (Table 3.3b).

This is probably due to the fact that Zimbabwe has been suffering from rampant water shortages and mothers, by virtue of being older are better able to manage using flushing toilets and ensuring that conditions remain hygienic despite the water shortages. Children on the other hand may find it difficult to manage if water is not readily available. In these instances, most of the water for use in household activities such as flushing toilets is kept in storage containers which are mostly kept out of reach of children. This means the chances of children not washing their hands after use of toilets is very high. In addition, there is also a chance that toilets go for long periods without being flushed after children use them. This promotes incidences of diseases such as cholera and diarrhoea which impact negatively on a child's BMI. Pit toilets on the other hand are mostly located away from the main household and do not require water for flushing thus making them more hygienic where there are water shortages. Presence of a protected drinking water source impacts positively on a child's nutrition. This result is significant only for the OLS model and is similar to that obtained for maternal nutrition (Table 3.2) and is expected as drinking from a protected water source helps maintain one's health. Other household factors such as the number of household members and location of the household have no statistically significant impact on a child's BMI.

3.5 Robustness tests

3.5.1 Models using maternal and child BMI categories

The results in Tables 3.2, 3.3a and 3.3b above indicate that there is a significant positive relationship between maternal and child nutrition, which remains robust after accounting for potential endogeneity and simultaneity bias in maternal BMI. A higher BMI implies better health to a certain point (*BMIzscore*=2SD and BMI=25kg/m^2 for children and mothers respectively) and after that, further increases in BMI become a health problem (overweight and obesity). In order to determine how each category of maternal BMI impacts on child's

BMI, a model will be estimated to allow for non-linearity according to different maternal categories. Maternal BMI will be classified into 3 sub-groups namely: Underweight (*mumbmi*<18.5), normal weight (18.5 ≤ *mumbmi* <25) and overweight (*mumbm*i≥25). Model 3 (Table 3.3b) which controls for other maternal, child and households related variables for all the subgroups is estimated according to the maternal BMI categories. The results are presented in Table 3.4.

Table 3.4: Maternal nutrition as a determinant of child nutrition: maternal BMI categories

Dependent variable	mumunderweight		mumoverweight		BMIzscore		BMIzscore	
	Model 1		Model 2		Model 3		Model 4	
	First stage IV results				OLS		IV	
	coef	se	coef	se	coef	se	coef	se
Main variable								
mumunderweight					-0.544***	(0.096)	0.473	(2.303)
mumoverweight					0.225***	(0.063)	1.115	(0.843)
Maternal variables								
mumheight	0.003***	(0.001)	-0.004***	(0.001)	0.014***	(0.004)	0.014**	(0.007)
agemum	-0.000	(0.001)	0.009***	(0.002)	-0.005	(0.006)	-0.013	(0.010)
primarylev	-0.115***	(0.038)	0.075*	(0.038)	0.198*	(0.111)	0.244	(0.249)
secondabove	-0.108***	(0.038)	0.069*	(0.040)	0.292**	(0.116)	0.331	(0.243)
notmarry	0.021	(0.023)	-0.011	(0.026)	0.008	(0.100)	0.000	(0.117)
divorcewidow	-0.038**	(0.016)	-0.016	(0.027)	-0.244***	(0.091)	-0.191	(0.137)
Child variables								
size at birth								
average	-0.029*	(0.015)	0.035*	(0.019)	0.525***	(0.073)	0.521***	(0.092)
aboveaverage	-0.032**	(0.015)	0.033*	(0.019)	0.649***	(0.074)	0.650***	(0.097)
diarrhoea	-0.001	(0.014)	-0.011	(0.019)	-0.303***	(0.075)	-0.292***	(0.079)
birthorder	-0.002	(0.004)	0.010	(0.007)	0.000	(0.021)	-0.005	(0.023)
heightzscore	-0.008***	(0.003)	0.009**	(0.004)	-0.284***	(0.019)	-0.285***	(0.024)
Household variables								
toiletflush	0.023	(0.028)	0.028	(0.060)	0.193	(0.168)	0.075	(0.206)
toiletpit	-0.009	(0.014)	0.020	(0.021)	0.190***	(0.059)	0.175**	(0.077)
drinkwatertap	-0.027	(0.020)	0.022	(0.037)	0.228*	(0.129)	0.202	(0.152)
drinkwaterother	-0.005	(0.014)	0.030*	(0.017)	0.051	(0.059)	0.028	(0.065)
hhdmember	0.001	(0.002)	-0.001	(0.003)	0.010	(0.012)	0.009	(0.012)
chnunder5	0.008	(0.007)	-0.007	(0.011)	-0.039	(0.035)	-0.039	(0.040)
rural	-0.018	(0.026)	-0.010	(0.047)	0.015	(0.138)	0.071	(0.152)
Instruments								
wealthquintile2	-0.034**	(0.017)	0.032	(0.020)				
wealthquintile3	-0.044**	(0.018)	0.044*	(0.026)				
wealthquintile4	-0.066***	(0.023)	0.159***	(0.040)				
wealthquintile5	-0.087***	(0.030)	0.298***	(0.054)				
constant	-0.263	(0.169)	0.374*	(0.209)	-3.492***	(0.746)	-3.554***	(0.893)
no. of observations	3,732		3,732		3,732		3,732	
F-statistic	3.15		15.25					
Partial r-squared	0.0018		0.0062					

Robust standard errors (se) in parentheses, adjusted for clustering at the household level
**** p<0.01, ** p<0.05, * p<0.1*

Discussion of results using maternal and child BMI categories

Similar to the main result (Tables 3.3a and 3.3b), results according to specific BMI categories of the mother (Tables 3.4) show that maternal nutrition has an indirect negative impact on a child's nutrition (OLS model) for a mother who is underweight compared to a mother who is of normal weight, all things being equal. For a mother who is overweight, the impact of maternal BMI on a child's BMI is positive compared to a mother who is of normal weight, all things being equal. These results are expected as one would expect a mother who is underweight to also have a child who is underweight and a mother who is overweight to also have a child who is overweight. This result also lends credibility to the overall positive effect reported in the main results under the OLS model. The magnitude of the positive effect is small (0.056 in Model 3, Table 3.3b) which is plausible given that the negative effect that is reported for underweight mothers is almost twice the magnitude of the positive effect reported for mothers who are overweight (-0.544 and 0.225 respectively in Table 3.4) . Overall, once we account for potential endogeneity and simultaneity bias in the mother's BMI, this variable has no significant impact for both categories.

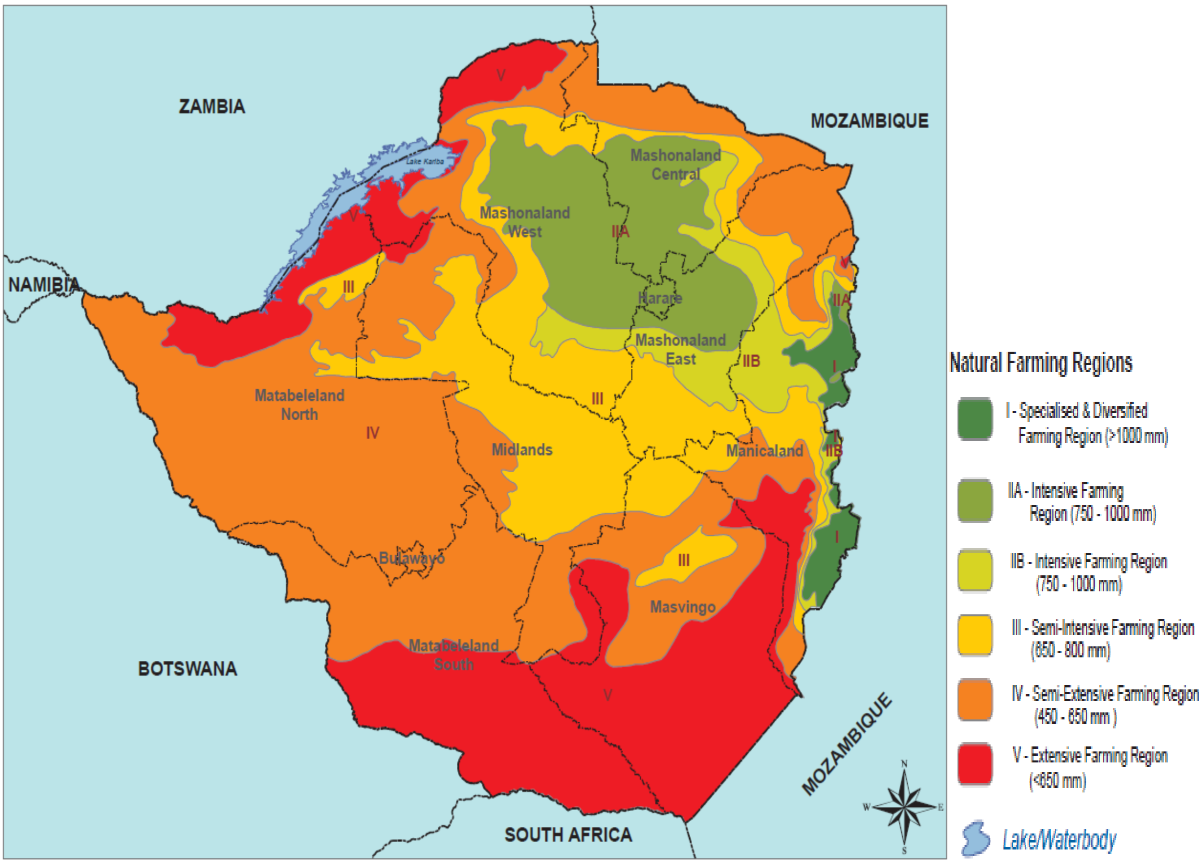
The instrumental variables continue to be significant in determining maternal BMI across the two categories as reported in Model 1 and 2. However, the F-test indicates that the instruments are weak (F-statistic = 3.15 in Model 1) for the sample of underweight mothers and strong (F-statistic = 15.25 in Model 2) for the sample of overweight mothers. The weak instruments are likely to be the cause of insignificant effect in the child BMI equation as shown by the very large standard errors in Model 4 on mother's weight.

3.5.2 Provincial effect

Zimbabwe is divided into 8 provinces and 2 major cities (Harare and Bulawayo) which have been accorded provincial status. Each of the provinces is in different agro-ecological zones and they have different sources of livelihood. According to FAO (2013) agro-ecological or natural regions are categorised according to the amount of rainfall received, soil types and vegetation. Natural region I receives the most rainfall (>1000mm per annum) and natural region V receives the least amount of rainfall (<450mm per annum). Intensive farming is practiced in natural region I and II with dairy farming, maize, tobacco, coffee and cotton production being the main sources of livelihood. Farming becomes extensive as we move towards region V. Region IV and V's main source of livelihood is cattle ranching and growing of drought resistant fodder crops. Regions III to V are vulnerable to droughts and rainfall is often erratic even in the rain season (FAO, 2013).

Figure 3.1 below shows a map of Zimbabwe's provinces according to natural farming regions and Table 3.5 below gives the total area and population in each province. Natural regions I and II cover a small part of the country whilst a larger part of the country is in natural regions III to V. The largest proportion of the population (15%) dwells in Harare city which covers a very small area. Farming in the urban areas is mainly carried out without municipality consent on unoccupied plots. The harvest from these plots is barely to meet the household's demand for food. However households have little choice in this matter, given that the prices of food are becoming increasingly unaffordable even for those who are employed (Banda, 2014; IRIN, 2007).

Figure 3.1: Agro-ecological zones by province



Source: Reliefweb, 2009

Table 3.5: Distribution of provinces in Zimbabwe

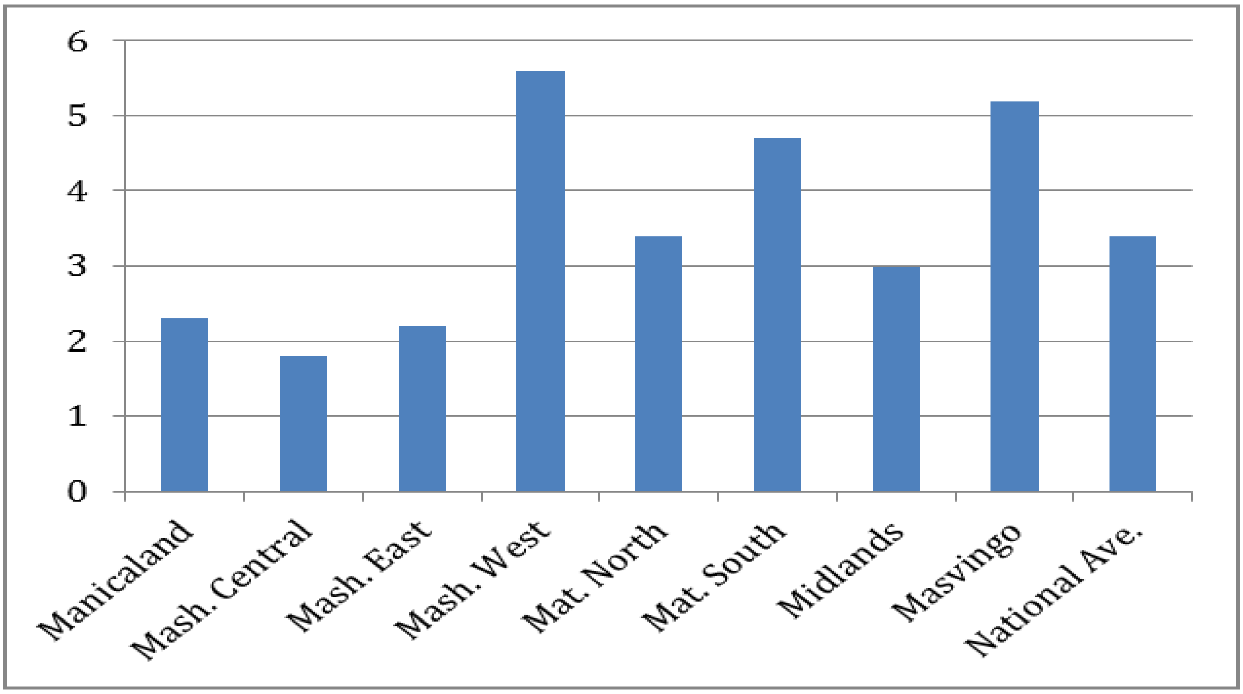
Province	% Area	% Population	Agro-ecological region
Bulawayo	0.1	6	IV
Harare	0.2	15	IIA
Manicaland	9.3	13	I, IIA, IIB
Mashonaland Central	7.3	9	IIA, III, 1V
Mashonaland East	8.2	10	IIA, IIB
Mashonaland West	14.7	11	IIA, III, IV
Masvingo	14.5	11	III, IV, V
Matabeleland North	19.2	6	III, IV, V
Matabeleland South	13.9	6	IV, V
Midlands	12.6	13	III, IV, V
Total	**100**	**100**	

Source: Law (2010)

As such issues of food availability, accessibility, utilisation and stability vary according to provinces. Matebeleland North and South, Masvingo and Midlands provinces are vulnerable to chronic droughts whilst Harare, Bulawayo, Masvingo and parts of Manicaland provinces experience cyclic droughts (FEWS NET, 2014).

According to ZimVAC (cited in FEWS NET, 2014) stunting rates are highest in Mashonaland province whilst wasting and underweight prevalence is highest in Matebeleland North Province. Boys are more at risk of malnourishment compared to girls. The provincial malnutrition prevalence rates (based on the weight-for-height measure) for children less than 5 years old are shown in Figure 3.2 below.

Figure 3.2: Under-five acute malnutrition rates (%) by province



Source: FEWS NET, 2014

Overall, Figure 3.2 above shows that acute malnutrition (wasting) rates for Zimbabwe are on average 3.3%. The prevalence of wasting was highest in Mashonaland West, followed by Masvingo and Matebeleland South provinces (approximately 5.6%, 5.25 and 4.8% respectively). The lowest prevalence of malnutrition was in Mashonaland Central (an estimated 1.8%).

Our results (Table 3.3a and 3.3b) show that there is a robust direct and indirect positive effect between maternal and child BMI. This section will establish whether this relationship varies across provinces. The results for the impact of maternal BMI on child BMI according to provinces are presented in Tables 3.7a to 3.8d below.

Table 3.6a: First-stage results by province

Dependent variable: mother's BMI (mumbmi)

	Mashonaland Central		**Mashonaland East**		**Mashonaland West**		**Matebeleland North**		**Matebeleland South**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Maternal variables										
mumheight	-0.009	(0.028)	-0.073*	(0.038)	-0.068*	(0.037)	-0.029	(0.033)	-0.102*	(0.059)
agemum	-0.071*	(0.042)	0.044	(0.071)	0.042	(0.041)	0.082**	(0.040)	-0.032	(0.055)
primarylev	-0.590	(0.769)	2.208	(1.678)	0.315	(1.055)	2.106***	(0.635)	1.190	(2.084)
secondabove	-0.533	(0.779)	2.018	(1.598)	0.369	(1.151)	2.618***	(0.675)	2.736	(2.157)
notmarry	-0.917*	(0.552)	0.107	(1.357)	-1.392	(0.997)	-0.460	(0.654)	-0.267	(0.576)
divorcewidow	0.350	(0.604)	-0.845	(0.806)	-1.007	(0.657)	0.562	(0.924)	0.513	(1.060)
Child variables										
size at birth										
average	-0.268	(0.477)	-0.313	(0.706)	0.727	(0.496)	0.553	(0.449)	0.026	(0.627)
aboveaverage	0.013	(0.483)	0.010	(0.715)	0.791*	(0.463)	0.669	(0.490)	0.422	(0.680)
diarrhoea	-0.007	(0.544)	-1.095	(0.665)	-0.143	(0.478)	0.815	(0.608)	0.550	(0.766)
birthorder	0.554**	(0.216)	0.365	(0.286)	-0.023	(0.173)	-0.065	(0.136)	0.840***	(0.230)
heightzscore	0.116	(0.139)	-0.080	(0.140)	0.104	(0.101)	0.255**	(0.116)	0.190	(0.199)
Household variables										
toiletflush	3.211**	(1.423)	2.663	(2.163)	0.212	(1.060)	0.611	(2.346)	-2.629	(2.243)
toiletpit	0.939**	(0.453)	0.300	(0.566)	-0.556	(0.539)	0.568	(0.470)	-0.369	(0.694)
drinkwatertap	-0.807	(0.868)	-0.479	(1.012)	-1.227	(0.892)	-1.003	(0.720)	2.785**	(1.392)
drinkwaterother	-0.214	(0.530)	0.342	(0.521)	0.626	(0.519)	-0.586	(0.455)	1.414**	(0.570)
hhdmember	-0.049	(0.081)	-0.039	(0.103)	0.094	(0.078)	0.113	(0.082)	-0.109	(0.106)
chnunder5	-0.226	(0.212)	-0.208	(0.451)	-0.506**	(0.241)	-0.220	(0.324)	0.029	(0.284)
rural	2.551*	(1.535)	1.835	(1.731)	-2.215**	(1.012)	0.365	(2.335)	-0.391	(2.189)
Instruments										
wealthquintile2	-0.241	(0.462)	0.660	(0.672)	1.251**	(0.631)	-0.052	(0.434)	0.311	(0.692)
wealthquintile3	0.109	(0.578)	1.578*	(0.867)	1.685**	(0.690)	-0.120	(0.736)	0.966	(0.889)
wealthquintile4	1.760*	(1.056)	1.805*	(1.082)	2.622***	(0.950)	1.521	(1.208)	0.823	(1.051)
wealthquintile5	3.206**	(1.379)	4.453**	(1.912)	1.880	(1.491)	4.805*	(2.456)	3.345	(2.460)
constant	22.266***	(5.068)	27.401***	(6.143)	32.763***	(6.484)	21.201***	(5.571)	35.546***	(10.211)
no. of observations	420		268		325		355		286	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, [p] is the p-value for the robust regression test score*

Table 3.6b: First-stage results by province

Dependent variable: mother's BMI (mumbmi)

	Manicaland		**Midlands**		**Masvingo**		**Harare**		**Bulawayo**	
	coef	se	coef	se	coef	se	coef	se	coef	se
Maternal variables										
mumheight	-0.037	(0.029)	-0.097***	(0.031)	-0.094***	(0.032)	-0.088*	(0.046)	-0.069	(0.062)
agemum	-0.019	(0.038)	0.102**	(0.043)	0.154***	(0.047)	0.134**	(0.059)	0.408***	(0.091)
primarylev	0.861	(0.908)	0.321	(0.812)	1.937**	(0.871)	-0.405	(0.688)	-4.216**	(1.682)
secondabove	0.383	(0.960)	0.396	(0.805)	2.331**	(0.904)			-5.030***	(1.654)
notmarry	0.882	(0.866)	-0.236	(0.634)	0.226	(0.549)	-0.755	(0.935)	0.227	(1.084)
divorcewidow	-0.202	(0.459)	0.468	(0.502)	-0.604	(0.532)	-0.720	(1.299)	1.243	(1.069)
Child variables										
size at birth										
average	0.161	(0.419)	0.345	(0.361)	0.655	(0.487)	0.846	(0.644)	1.291	(0.915)
aboveaverage	-0.158	(0.466)	0.757*	(0.413)	0.824	(0.527)	1.672**	(0.675)	-0.022	(0.916)
diarrhoea	0.263	(0.491)	-0.477	(0.390)	-0.212	(0.452)	-0.559	(0.569)	-1.604	(1.012)
birthorder	0.302**	(0.148)	0.123	(0.137)	-0.130	(0.140)	0.301	(0.294)	-0.596*	(0.340)
heightzscore	-0.013	(0.107)	0.063	(0.088)	0.118	(0.090)	0.253*	(0.144)	0.195	(0.182)
Household variables										
toiletflush	-0.009	(1.697)	-1.042	(1.771)	2.308**	(1.057)	-4.188***	(0.729)	-0.381	(1.117)
toiletpit	0.563	(0.410)	0.028	(0.392)	-0.698	(0.479)	-4.814***	(0.924)	-0.275	(0.172)
drinkwatertap	1.841**	(0.793)	-0.309	(1.239)	-1.505	(0.996)	3.857***	(1.132)	0.390	(0.621)
drinkwaterother	0.287	(0.419)	0.015	(0.335)	-0.236	(0.371)	3.039**	(1.291)		
hhdmember	-0.055	(0.072)	-0.081	(0.076)	0.039	(0.062)	0.112	(0.117)		
chnunder5	-0.078	(0.204)	0.048	(0.252)	-0.116	(0.217)	-0.553	(0.382)		
rural	0.607	(1.482)	-1.365	(1.594)	-0.438	(1.314)				
Instruments										
wealthquintile2	0.816	(0.513)	0.586	(0.381)	0.279	(0.418)				
wealthquintile3	0.151	(0.520)	1.235**	(0.514)	1.032*	(0.626)	-0.815	(1.301)		
wealthquintile4	1.854**	(0.764)	3.088***	(0.786)	0.781	(0.883)	-0.581	(0.581)	-0.653	(0.744)
wealthquintile5	1.950	(1.646)	3.809**	(1.693)	2.318	(2.507)	0.000	(0.000)	0.000	(0.000)
constant	26.374***	(4.997)	34.897***	(5.439)	31.210***	(5.480)	34.666***	(7.686)	31.859***	(9.494)
no. of observations	495		561		459		379		187	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, p is the p-value for the robust regression test score*

Table 3.7a: 2SLS result: Mashonaland province

Dependent variable: child's BMIzscore

	Mashonaland Central OLS				Mashonaland East OLS				Mashonaland West OLS			
	OLS		IV		OLS		IV		OLS		IV	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Main variable												
mumbmi	0.068***	(0.018)	-0.162	(0.131)	0.001	(0.035)	0.077	(0.152)	0.103***	(0.027)	0.280*	(0.147)
Maternal variables												
mumheight	0.025**	(0.012)	0.023*	(0.014)	-0.001	(0.017)	0.004	(0.018)	-0.009	(0.020)	0.004	(0.022)
agemum	0.000	(0.018)	-0.013	(0.021)	0.006	(0.028)	-0.000	(0.029)	-0.042**	(0.020)	-0.050**	(0.020)
primarylev	0.001	(0.211)	-0.102	(0.254)	0.752*	(0.384)	0.577	(0.560)	0.715**	(0.337)	0.620*	(0.357)
secondabove	-0.143	(0.225)	-0.192	(0.271)	0.793**	(0.369)	0.628	(0.536)	1.014***	(0.373)	0.872**	(0.385)
notmarry	-0.081	(0.320)	-0.324	(0.386)	-0.768	(0.682)	-0.756	(0.638)	-0.614	(0.443)	-0.414	(0.446)
divorcewidow	-0.057	(0.311)	0.023	(0.356)	-0.652*	(0.354)	-0.567	(0.382)	-0.401	(0.332)	-0.251	(0.352)
Child variables												
size at birth												
average	0.216	(0.205)	0.168	(0.222)	0.271	(0.266)	0.290	(0.270)	0.732**	(0.297)	0.591*	(0.303)
aboveaverage	0.261	(0.203)	0.283	(0.214)	0.548**	(0.231)	0.537**	(0.232)	0.986***	(0.287)	0.833***	(0.293)
diarrhoea	-0.324	(0.213)	-0.324	(0.249)	-0.269	(0.261)	-0.208	(0.282)	-0.328	(0.256)	-0.310	(0.250)
birthorder	-0.014	(0.063)	0.101	(0.094)	-0.187	(0.114)	-0.208*	(0.117)	0.172**	(0.078)	0.178**	(0.078)
heightzscore	-0.276***	(0.055)	-0.243***	(0.064)	-0.328***	(0.075)	-0.324***	(0.076)	-0.469***	(0.057)	-0.489***	(0.060)
Household variables												
toiletflush	0.146	(0.490)	1.303	(0.885)	-0.388	(0.580)	-0.738	(0.909)	-1.723***	(0.489)	-1.915***	(0.516)
toiletpit	0.223	(0.138)	0.453**	(0.197)	0.394	(0.251)	0.330	(0.275)	0.322	(0.229)	0.299	(0.234)
drinkwatertap	0.217	(0.235)	0.199	(0.288)	0.731*	(0.415)	0.722*	(0.420)	0.129	(0.384)	0.180	(0.360)
drinkwaterother	0.054	(0.139)	0.033	(0.173)	-0.078	(0.222)	-0.114	(0.222)	0.236	(0.263)	0.104	(0.294)
hhdmember	0.017	(0.030)	0.005	(0.035)	0.069	(0.058)	0.070	(0.055)	-0.037	(0.043)	-0.053	(0.045)
chnunder5	-0.030	(0.091)	-0.064	(0.104)	-0.120	(0.171)	-0.091	(0.182)	0.009	(0.118)	0.111	(0.146)
rural	0.127	(0.540)	0.754	(0.692)	-0.113	(0.491)	-0.255	(0.440)	-1.723***	(0.315)	-1.400***	(0.412)
constant	-6.598***	(2.025)	-1.691	(3.598)	-1.476	(2.738)	-3.437	(4.837)	-0.631	(3.475)	-6.458	(5.926)
no. of observations	420		420		268		268		325		325	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, [p] is the p-value for the robust regression test score*

Table 3.7b: 2SLS result: Manicaland, Midlands and Masvingo provinces

Dependent variable: child's BMIzscore

	Manicaland				**Midlands**				**Masvingo**			
	OLS		**IV**		**OLS**		**IV**		**OLS**		**IV**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable												
mumbmi	0.064***	(0.022)	-0.090	(0.148)	0.047**	(0.019)	0.025	(0.098)	0.018	(0.020)	0.380	(0.276)
Maternal variables												
mumheight	0.022**	(0.010)	0.017	(0.013)	0.001	(0.011)	-0.002	(0.015)	0.008	(0.012)	0.040	(0.032)
agemum	-0.010	(0.015)	-0.013	(0.017)	0.028	(0.019)	0.031	(0.023)	0.028*	(0.017)	-0.025	(0.045)
primarylev	-0.337	(0.329)	-0.167	(0.331)	0.143	(0.261)	0.151	(0.260)	0.808**	(0.369)	0.044	(0.791)
secondabove	-0.546	(0.349)	-0.435	(0.330)	0.244	(0.251)	0.257	(0.250)	0.899**	(0.387)	-0.062	(0.929)
notmarry	-0.116	(0.401)	0.009	(0.396)	0.448	(0.328)	0.440	(0.325)	0.192	(0.282)	0.121	(0.349)
divorcewidow	0.005	(0.179)	-0.034	(0.188)	-0.263	(0.254)	-0.250	(0.263)	-0.131	(0.196)	0.106	(0.309)
Child variables												
size at birth												
average	0.248	(0.199)	0.286	(0.219)	0.458**	(0.190)	0.467**	(0.194)	0.876***	(0.244)	0.636*	(0.357)
aboveaverage	0.703***	(0.214)	0.689***	(0.218)	0.372*	(0.196)	0.389*	(0.202)	0.797***	(0.251)	0.498	(0.396)
diarrhoea	-0.175	(0.182)	-0.143	(0.191)	-0.413**	(0.199)	-0.424**	(0.211)	-0.394**	(0.173)	-0.314	(0.240)
birthorder	-0.024	(0.052)	0.024	(0.075)	-0.060	(0.060)	-0.060	(0.059)	-0.022	(0.064)	0.014	(0.077)
heightzscore	-0.332***	(0.048)	-0.336***	(0.050)	-0.239***	(0.054)	-0.237***	(0.054)	-0.288***	(0.044)	-0.332***	(0.062)
Household variables												
toiletflush	0.292	(0.641)	0.440	(0.736)	0.090	(0.618)	0.090	(0.597)	0.546	(0.427)	-0.386	(0.927)
toiletpit	0.162	(0.154)	0.273	(0.184)	0.238	(0.182)	0.252	(0.201)	0.212	(0.156)	0.346	(0.230)
drinkwatertap	-0.424	(0.307)	-0.024	(0.474)	0.628	(0.628)	0.662	(0.622)	-0.209	(0.332)	0.190	(0.635)
drinkwaterother	-0.115	(0.157)	-0.059	(0.174)	0.094	(0.153)	0.096	(0.152)	-0.030	(0.153)	0.026	(0.197)
hhdmember	0.041	(0.033)	0.034	(0.036)	-0.021	(0.034)	-0.022	(0.035)	-0.014	(0.029)	-0.033	(0.042)
chnunder5	-0.156*	(0.085)	-0.176**	(0.088)	-0.014	(0.104)	-0.014	(0.102)	0.012	(0.101)	0.053	(0.122)
rural	-0.365	(0.617)	-0.245	(0.711)	0.344	(0.435)	0.314	(0.434)	-0.120	(0.406)	0.199	(0.637)
constant	-4.687**	(2.019)	-0.816	(4.747)	-3.029	(1.933)	-2.255	(4.035)	-4.305**	(2.056)	-15.536	(9.520)
no. of observations	495		495		561		561		459		459	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, [p] is the p-value for the robust regression test score*

Table 3.7c: 2SLS result: Matebeleland province

Dependent variable: child's BMIzscore

	Matebeleland North				**Matebeleland South**			
	OLS		**IV**		**OLS**		**IV**	
	coef	se	coef	se	coef	se	coef	se
Main variable								
mumbmi	0.093***	(0.030)	0.370	(0.232)	0.024	(0.021)	0.281	(0.245)
Maternal variables								
mumheight	0.036**	(0.015)	0.044**	(0.019)	0.005	(0.017)	0.034	(0.035)
agemum	-0.040*	(0.021)	-0.065**	(0.031)	-0.025	(0.021)	-0.020	(0.024)
primarylev	0.275	(0.330)	-0.297	(0.609)	0.235	(0.442)	-0.089	(0.755)
secondabove	0.535	(0.343)	-0.192	(0.704)	0.529	-0.479	-0.233	(0.983)
notmarry	-0.066	(0.267)	0.024	(0.295)	-0.200	(0.220)	-0.155	(0.260)
divorcewidow	-0.227	(0.326)	-0.368	(0.474)	0.007	(0.341)	-0.134	(0.362)
Child variables								
size at birth								
average	0.898***	(0.206)	0.731***	(0.280)	0.369	(0.238)	0.366	(0.274)
aboveaverage	0.774***	(0.222)	0.567*	(0.315)	0.668***	(0.208)	0.568**	(0.266)
diarrhoea	-0.161	(0.336)	-0.377	(0.404)	-0.243	(0.195)	-0.372	(0.330)
birthorder	0.050	(0.071)	0.072	(0.086)	0.049	(0.065)	-0.158	(0.208)
heightzscore	-0.269***	(0.067)	-0.349***	(0.102)	-0.158*	(0.081)	-0.218**	(0.111)
Household variables								
toiletflush	0.909*	(0.547)	0.145	(0.868)	-0.298	(0.415)	0.268	(0.809)
toiletpit	0.070	(0.239)	-0.093	(0.291)	0.233	(0.175)	0.232	(0.216)
drinkwatertap	-0.105	(0.455)	0.169	(0.477)	0.413*	(0.233)	-0.296	(0.809)
drinkwaterother	-0.052	(0.222)	0.117	(0.293)	0.300*	(0.170)	-0.062	(0.400)
hhdmember	0.020	(0.043)	-0.006	(0.051)	-0.010	(0.034)	0.017	(0.049)
chnunder5	-0.037	(0.123)	0.016	(0.165)	0.047	(0.119)	0.049	(0.124)
rural	1.375***	(0.476)	1.432*	(0.799)	-0.171	(0.480)	0.293	(0.681)
constant	-9.939***	(2.466)	-15.887***	(6.149)	-2.103	(2.949)	-12.000	(10.160)
no. of observations	355		355		286		286	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, [p] is the p-value for the robust regression test score*

Table 3.7d: 2SLS result: Harare and Bulawayo

Dependent variable: child's BMIzscore

	Harare				**Bulawayo**			
	OLS		**IV**		**OLS**		**IV**	
	coef	se	coef	se	coef	se	coef	se
Main variable								
mumbmi	0.045***	(0.017)	0.337	(0.391)	0.079**	(0.033)	0.025	(0.342)
Maternal variables								
mumheight	0.022*	(0.012)	0.047	(0.039)	0.012	(0.022)	0.008	(0.030)
agemum	-0.008	(0.018)	-0.048	(0.057)	-0.001	(0.032)	0.022	(0.153)
primarylev	-0.063	(0.272)	0.100	(0.375)	1.148	(0.752)	0.926	(1.610)
secondabove					1.280*	(0.684)	1.020	(1.807)
notmarry	0.254	(0.333)	0.493	(0.513)	0.254	(0.397)	0.256	(0.404)
divorcewidow	-0.328	(0.317)	-0.147	(0.483)	-1.137***	(0.383)	-1.099**	(0.451)
Child variables								
size at birth								
average	0.588**	(0.228)	0.330	(0.439)	0.516	(0.354)	0.582	(0.526)
aboveaverage	0.698***	(0.217)	0.198	(0.693)	0.841**	(0.363)	0.838**	(0.352)
diarrhoea	-0.324	(0.294)	-0.178	(0.359)	0.002	(0.600)	-0.078	(0.821)
birthorder	-0.083	(0.082)	-0.169	(0.158)	-0.099	(0.134)	-0.135	(0.278)
heightzscore	-0.210***	(0.064)	-0.285**	(0.135)	-0.224***	(0.083)	-0.212**	(0.103)
Household variables								
toiletflush	-1.046***	(0.303)	0.134	(1.613)	0.011	(0.255)	-0.060	(0.537)
toiletpit	-1.022**	(0.401)	0.435	(1.979)				
drinkwatertap	1.243	(0.987)	0.080	(1.770)				
drinkwaterother	0.693	(0.964)	-0.188	(1.451)				
hhdmember	0.055*	(0.031)	0.015	(0.073)	0.050	(0.069)	0.041	(0.086)
chnunder5	-0.119	(0.122)	0.059	(0.305)	-0.136	(0.225)	-0.118	(0.222)
rural								
constant	-5.046**	(2.317)	-14.907	(13.713)	-5.575	(3.776)	-3.844	(11.072)
no. of observations	379		379		184		184	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, [p] is the p-value for the robust regression test score*

Discussion of results by province

Determinants of maternal BMI

The results in Tables 3.6a and 3.6b show that the effect of household wealth (the identification variable) varies according to provinces. For Midlands and Mashonaland East and West provinces, at least three wealth quintiles are significant and at least one quintile is significant for Matebeleland North, Manicaland and Masvingo. For Matebeleland South, Harare and Bulawayo, household wealth has no significant influence on the mother's BMI. This is probably because of the smaller sample sizes (from 187 for Bulawayo to 561 for Midlands). In Bulawayo, only the top two wealth quintiles are represented. Given that Bulawayo is in natural region IV (Table 3.6) which practices mostly cattle ranching, it is plausible that more households be in the top two wealth quintiles as cattle are a major form of wealth (FAO, 2013). The principal component analysis used by the DHS to construct the wealth index takes into consideration the number of cattle a household owns, in addition to other assets.

The impact of other maternal and household factors varies across provinces. Maternal height is significant for 6 of the 10 provinces, mother's age is significant for 5 provinces and mother's education is significant in only 3 provinces. Availability of flushing toilet facilities in the house is significant in only 3 provinces and drinking water from protected water sources is significant in only 2 provinces.

Determinants of a child's BMI

The positive indirect effect of mother's BMI on a child's BMI is maintained across most of the provinces except Mashonaland East, Matebeleland South and Masvingo (Tables 3.7a - 3.7d). The magnitude of effect is between 0.045 and 0.103 units increase in BMI for a 1 unit increase in the mother's BMI. Only two provinces (Midlands 0.047 and Harare 0.045) have a lower magnitude compared to that obtained in Table 3.3b of 0.056. With regards to the direct effect of maternal BMI on child BMI, only Mashonaland West results show a significant positive effect similar to that shown by our original results in Table 3.3b. The magnitude of effect is approximately 5 times higher (0.280 units increase on average in a child's BMI for a unit increase in maternal BMI). This implies that changes in the nutritional state of children in Mashonaland West province from an improvement in household and maternal nutrition are more evident compared to other provinces. The direct impact suggests that children in Mashonaland West province are would benefit almost thrice as much from having healthier mothers compared to having better overall household nutrition. This is beneficial as it implies that programs and policies aimed at improving maternal and household nutrition will result in better child nutrition. Mashonaland West has the highest prevalence of acute malnutrition for children below the age of 5 as shown in Figure 3.2.

A child's *heightzscore* maintains a significant negative relationship throughout all the provinces, similar to the results obtained in Tables 3.3a and 3.3b. The impact of other child, maternal and household factors varies across all provinces. To draw a more authoritative conclusion about differences between provinces would require larger sample sizes in more focused areas.

3.5.3 Removing mother's height and using actual birth size

From Chapter 2, a negative relationship was found between a child's BMI and height z-scores. In the first- stage IV regression results in Table 3.2, a significant negative relationship is also found between the mother's BMI and her height. In order to establish whether this negative impact of the mother's height on BMI influences the second stage relationship, the mother's height was removed from the first-stage regression as well as the OLS regression. Birth size categories were also replaced with the actual birth size of the child to allow for more variation.

Results from Table 3.8 show that household wealth is a significant determinant of the mother's BMI across all the 4 models. For models 1 and 2, the endogeniety tests show that the *mumbmi* is endogenous (Durbin and Wu-Hausman p-value of 0.000 in Table 3.8) in the *childbmi* equation. The test for models 3 and 4 show that *mumbmi* is an exogenous variable in the *childbmi* equation (Durbin and Wu-Hausman p-values of 0.0.402 and 0.404 and 0.125 and 127 respectively in Table 3.8). With regards to the strength of the instruments used, the F-statistic (74.856) and the minimum eigen values (74.856) for models 1 and 2 are both above the 2SLS critical value of 16.85, indicating that the instruments used are not weak. For models 3 and 4 however, both test statistics (F-statistic and minimum eigen values of 10.715 and 9.896 for models 3 and 4 respectively) are below the 2SLS critical value and thus are indicating that the instruments are weak. For all the for models, the instruments used are valid according to the Sargan and Basmann test results. All the p-values for these 2 tests are above 0.05 (p-values from 0.064 to 0.221) thus the hypothesis that the instruments are valid cannot be rejected. This result for the validity of instruments is made with caution though as failure to reject the null hypothesis does not necessary mean that all the instruments are valid, as indicated by Cameron & Trivedi (2010).

The results in Tables 3.9a to 3.9b below show that the impact of a mother's BMI on the child's BMI remains the same as obtained in the model where the mother's height is included as a determinant of the mother's and child's BMI. A significant positive relationship is obtained of similar magnitude of effect (0.042-0.059 for the OLS and 0.092 – 0.163 for the IV methods) as that obtained in Table 3.2 (0.056-0.063 for the OLS and 0.095 – 0.161 for the IV methods). Interestingly, the IV effect when maternal, child and household related variables are accounted for is no longer significant (Model 3, Table 3.9b). This has something to do with the drinking water source variable as removing these variable results in a significant positive relationship between the mother's BMI and the child's BMI (Model 4, Table 3.9b). It is unclear why this is so. It may also be due to the negative endogeneity test results as well as the presence of weak instruments mentioned in the discussion above.

Table 3.8: Determinants of maternal nutrition (IV first stage results)

Dependent variable: mother's BMI (mumbmi)

	model 1		**model 2**		**model 3**		**model 4**	
	IV first stage		**IV first stage**		**IV first stage**		**IV first stage**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Maternal variables								
agemum	0.106***	(0.010)	0.091***	(0.019)	0.086***	(0.019)	0.086***	(0.019)
primarylev	0.970***	(0.368)	0.460	(0.647)	0.475	(0.658)	0.496	(0.646)
secondabove	0.960**	(0.378)	0.799	(0.648)	0.818	(0.659)	0.816	(0.648)
notmarry	-0.488**	(0.227)	-0.272	(0.283)	-0.208	(0.285)	-0.234	(0.284)
divorcewidow	-0.286	(0.228)	-0.292	(0.272)	-0.209	(0.277)	-0.234	(0.273)
Child variables								
birthsize			0.739***	(0.135)	0.706***	(0.137)	0.712***	(0.135)
diarrhoea			-0.137	(0.214)	-0.115	(0.220)	-0.147	(0.214)
birthorder			0.163**	(0.078)	0.189**	(0.079)	0.194**	(0.078)
heightzscore			0.101**	(0.045)	0.093**	(0.045)	0.091**	(0.045)
Household variables								
toiletflush					0.632	(0.485)	0.986**	(0.409)
toiletpit					0.049	(0.209)	0.175	(0.197)
drinkwatertap					-0.250	(0.390)		
drinkwaterother					0.006	(0.196)		
hhdmember					-0.024	(0.034)	-0.028	(0.032)
chnunder5					-0.125	(0.113)	-0.089	(0.106)
rural					0.200	(0.394)	0.414	(0.372)
Instruments								
wealthquintile2	0.574***	(0.165)	0.488**	(0.213)	0.480**	(0.224)	0.455**	(0.221)
wealthquintile3	0.820***	(0.185)	0.659***	(0.228)	0.645**	(0.266)	0.582**	(0.258)
wealthquintile4	2.053***	(0.212)	2.049***	(0.244)	1.951***	(0.401)	1.655***	(0.344)
wealthquintile5	3.213***	(0.261)	3.031***	(0.287)	2.915***	(0.530)	2.522***	(0.469)
constant	17.920***	(0.497)	16.124***	(0.888)	16.449***	(0.987)	16.125***	(0.955)
no. of observations	3,942		2,685		2,621		2,681	
Endogeneity test								
Durbin score	17.171	(0.000)^P	18.452	(0.000)^P	0.703	(0.402)^P	2.349	(0.125)^P
Wu-Hausman	17.212	(0.000)^P	18.497	(0.000)^P	0.698	(0.404)^P	2.336	(0.127)^P
Weak instruments test								
F-statistic	74.856	(0.000)^P	49.161	(0.000)^P	10.715	(0.000)^P	9.896	(0.000)^P
Minimum eigen value statistic	74.856		49.161		10.715		9.896	
2SLS critical value 5% level	16.85		16.85		16.85		16.85	
Instrument validity (OID test)								
Sargan score	6.831	(0.078)^P	4.421	(0.078)^P	7.229	(0.064)^P	4.557	(0.209)^P
Basmann	6.825	(0.078)^P	4.405	(0.078)^P	7.241	(0.065)^P	4.512	(0.211)^P

Robust standard errors in parentheses

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

^P represents the p-value for the different tests

Table 3.9a: Maternal nutrition as a determinant of child nutrition (OLS and IV results)

Dependent variable: child's BMIzscore

	model 1				**model 2**			
	OLS		**IV**		**OLS**		**IV**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable								
mumbmi	0.059***	(0.007)	0.163***	(0.028)	0.050***	(0.008)	0.166***	(0.031)
Maternal variables								
agemum	-0.005	(0.004)	-0.017***	(0.005)	0.000	(0.007)	-0.015*	(0.009)
primarylev	0.286**	(0.119)	0.153	(0.129)	0.271	(0.172)	0.186	(0.201)
secondabove	0.449***	(0.120)	0.223	(0.136)	0.418**	(0.174)	0.203	(0.207)
notmarry	0.049	(0.102)	0.105	(0.104)	0.119	(0.120)	0.163	(0.122)
divorcewidow	-0.100	(0.094)	-0.060	(0.095)	-0.261**	(0.107)	-0.208*	(0.111)
Child variables								
birthsize					0.443***	(0.054)	0.363***	(0.061)
diarrhoea					-0.230**	(0.089)	-0.197**	(0.093)
birthorder					-0.042	(0.026)	-0.043	(0.028)
heightzscore					-0.283***	(0.022)	-0.299***	(0.024)
Household variables								
toiletflush								
toiletpit								
drinkwatertap								
drinkwaterother								
hhdmember								
chnunder5								
rural								
constant	-1.623***	(0.225)	-3.495***	(0.549)	-3.136***	(0.319)	-4.993***	(0.587)
no. of observations	3,942		3,942		2,685		2,685	

Robust standard errors in parentheses

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

Table 3.9b: Maternal nutrition as a determinant of child nutrition (OLS and IV results)

Dependent variable: child's BMIzscore	**model 3**				**model 4**			
	OLS		**IV**		**OLS**		**IV**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable								
mumbmi	0.042***	(0.008)	0.092	(0.063)	0.043***	(0.008)	0.137**	(0.069)
Maternal variables								
agemum	-0.005	(0.007)	-0.010	(0.009)	-0.005	(0.007)	-0.014	(0.010)
primarylev	0.246	(0.172)	0.213	(0.184)	0.247	(0.171)	0.187	(0.195)
secondabove	0.311*	(0.175)	0.252	(0.196)	0.315*	(0.174)	0.210	(0.207)
notmarry	0.110	(0.121)	0.124	(0.123)	0.104	(0.120)	0.134	(0.123)
divorcewidow	-0.262**	(0.110)	-0.252**	(0.110)	-0.242**	(0.109)	-0.222**	(0.110)
Child variables								
birthsize	0.471***	(0.054)	0.436***	(0.071)	0.460***	(0.053)	0.394***	(0.074)
diarrhoea	-0.209**	(0.091)	-0.203**	(0.092)	-0.219**	(0.090)	-0.203**	(0.093)
birthorder	-0.020	(0.028)	-0.028	(0.029)	-0.023	(0.027)	-0.040	(0.030)
heightzscore	-0.282***	(0.023)	-0.287***	(0.024)	-0.285***	(0.022)	-0.293***	(0.024)
Household variables								
toiletflush	0.056	(0.176)	-0.029	(0.213)	0.215	(0.134)	0.015	(0.196)
toiletpit	0.141*	(0.073)	0.119	(0.079)	0.146**	(0.071)	0.097	(0.078)
drinktwatertap	0.208	(0.149)	0.185	(0.151)				
drinkwaterother	-0.048	(0.075)	-0.052	(0.075)				
hhdmember	0.005	(0.014)	0.005	(0.014)	0.007	(0.013)	0.008	(0.014)
chnunder5	-0.008	(0.045)	-0.000	(0.046)	-0.020	(0.042)	-0.005	(0.045)
rural	-0.061	(0.140)	-0.053	(0.140)	-0.116	(0.126)	-0.097	(0.127)
constant	-2.970***	(0.366)	-3.794***	(1.111)	-2.912***	(0.348)	-4.504***	(1.213)
no. of observations	2,621		2,621		2,681		2,681	

Robust standard errors in parentheses

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

3.5.4 Comparison with Malawi

In order to establish whether the direct and indirect effect of maternal BMI on child BMI is similar for other developing countries, a comparison will be made using the DHS data for Malawi for 2004.

Like Zimbabwe, Malawi is also a developing country dependent mostly on rain fed agriculture. Both countries are former British colonies and are landlocked. As shown by the statistics in Table 3.10 below, the population, life expectancy and prevalence of underweight in children below the age of 5 years are more or less similar, making the two countries comparable.

Table 3.10: Zimbabwe and Malawi population and economic statistics

	Zimbabwe	**Malawi**
Year gained independence	1980	1964
Location	Southern Africa, between South Africa and Zambia	Southern Africa , east of Zambia and North of Mozambique
Population	Estimated 13.7 million	Estimated 17 million
Life expectancy	55.68 years	59.99 years
HIV prevalence	14.7%	10.8%
Underweight prevalence (children below 5 years of age)	10.1%	13.8%
GDP per capita (2005)	446.74	219.91
GDP – agriculture	20.1%	29.4%
Agriculture labour force	66.0%	90.0%
Population below the poverty line	68.0%	53.0%
Exports	Mostly agricultural products and minerals	Mostly agricultural products

Source: CIA, 2014; Trading Economies, 2014.

The trend in terms of economic performance for Zimbabwe and Malawi is shown in Figure 3.3 below.

Figure 3.3: Trends in Zimbabwe and Malawi's GDP per capita

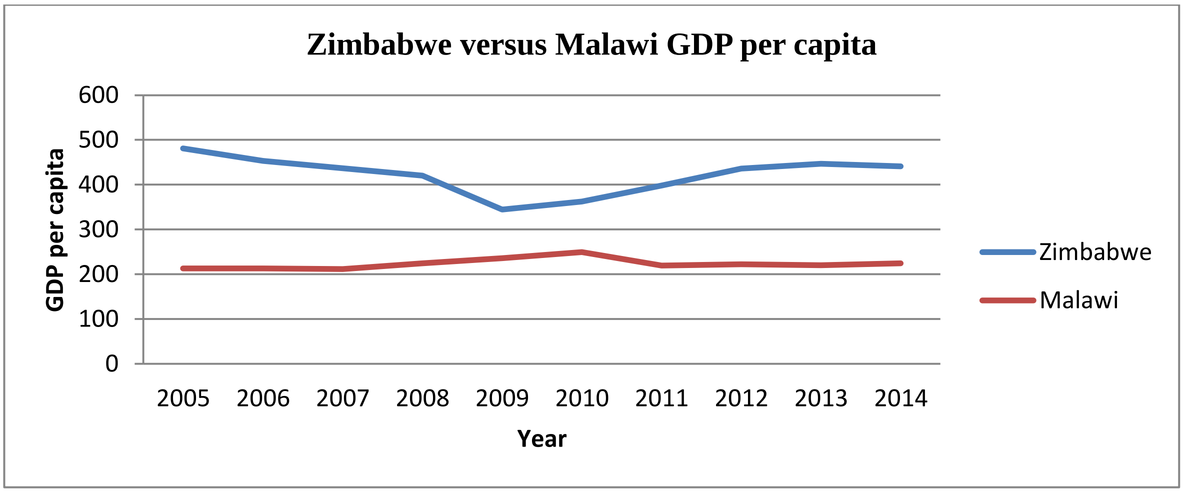


Figure 3.3 above shows that Zimbabwe's GDP per capita has always been above that of Malawi for the years under consideration. However the GDP per capita for both countries is quite low and the Borgen Group (2013) lists both Malawi and Zimbabwe to be among the 10 poorest countries in the world. Both countries depend on rain-fed agriculture for food. However they suffer from chronic and cyclic droughts and Malawi is also prone to flooding (FEWS NET, 2014; Pauw, Thurlow & van Seventer, 2010).

As with the analysis conducted using the data for Zimbabwe, two propositions will be tested. Firstly, the impact of overall household nutrition (denoted by the mother's BMI) will be tested using OLS. Secondly, potential simultaneity and or endogeneity bias in the effect of mother's BMI will be accounted for using IV regression. The IV model will also serve to establish whether maternal BMI (or nutrition) has any direct influence on the determination of a child's BMI (or nutrition). This comparison using data from Malawi will lend credibility to our results for Zimbabwe as well as provide further evidence for the importance of maternal nutrition in child nutrition for across countries.

Table 3.11: First stage results: Zimbabwe and Malawi comparison

Dependent variable: mother's BMI (mumbmi)

	Zimbabwe		**Malawi**	
	IV first stage		**IV first stage**	
	coef	**se**	**coef**	**se**
Maternal variables				
mumheight	-0.064***	(0.012)	-0.047***	(0.010)
agemum	0.072***	(0.016)	0.007	(0.011)
primarylev	1.118***	(0.371)	0.182*	(0.098)
secondabove	1.220***	(0.380)	0.341*	(0.183)
notmarry	-0.279	(0.229)	-0.368**	(0.151)
divorcewidow	-0.198	(0.232)	-0.248	(0.153)
Child variables				
size at birth				
average	0.418**	(0.170)	0.065	(0.099)
aboveaverage	0.556***	(0.178)	0.319***	(0.106)
diarrhoea	-0.124	(0.176)	-0.073	(0.078)
birthorder	0.169***	(0.061)	0.159***	(0.036)
heightzscore	0.117***	(0.037)	0.097***	(0.022)
Household variables				
toiletflush	0.906**	(0.462)	1.091**	(0.521)
toiletpit	0.150	(0.168)	-0.000	(0.115)
drinkwatertap	0.020	(0.329)	0.098	(0.153)
drinkwaterother	0.124	(0.151)	0.113	(0.089)
hhdmember	-0.000	(0.028)	0.015	(0.026)
chnunder5	-0.126	(0.090)	0.024	(0.067)
rural	0.274	(0.394)	-0.545***	(0.181)
Instruments				
wealthquintile2	0.512***	(0.174)	0.081	(0.121)
wealthquintile3	0.755***	(0.216)	0.136	(0.130)
wealthquintile4	1.753***	(0.352)	0.419***	(0.144)
wealthquintile5	2.801***	(0.489)	1.194***	(0.196)
constant	28.063***	(1.965)	28.446***	(1.603)
no. of observations	3,732		7,473	
F-statistic	17.87		13.43	
Partial r-squared	0.0148		0.0104	
Robust regression test score	0.474	0.491[p]	1.324	0.250[p]

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

**** p<0.01, ** p<0.05, * p<0.1, [p] is the p-value for the robust regression test score*

Table 3.12: 2SLS results: Zimbabwe and Malawi comparison

Dependent variable: child's BMIzscore

	Zimbabwe				**Malawi**			
	OLS		**IV**		**OLS**		**IV**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
Main variable								
mumbmi	0.056***	(0.007)	0.095*	(0.058)	0.081***	(0.006)	0.144***	(0.055)
Maternal variables								
mumheight	0.015***	(0.004)	0.018***	(0.006)	0.019***	(0.003)	0.022***	(0.004)
agemum	-0.007	(0.006)	-0.010	(0.008)	-0.008*	(0.005)	-0.009*	(0.005)
primarylev	0.214*	(0.110)	0.165	(0.129)	0.096**	(0.040)	0.080*	(0.043)
secondabove	0.295**	(0.115)	0.236*	(0.140)	0.117*	(0.068)	0.073	(0.079)
notmarry	0.011	(0.101)	0.024	(0.103)	0.024	(0.076)	0.052	(0.080)
divorcewidow	-0.216**	(0.090)	-0.208**	(0.090)	0.061	(0.065)	0.083	(0.068)
Child variables								
size at birth								
average	0.525***	(0.072)	0.507***	(0.076)	0.308***	(0.051)	0.304***	(0.051)
aboveaverage	0.642***	(0.074)	0.618***	(0.081)	0.441***	(0.054)	0.421***	(0.057)
diarrhoea	-0.298***	(0.075)	-0.293***	(0.075)	-0.310***	(0.040)	-0.304***	(0.040)
birthorder	-0.005	(0.021)	-0.011	(0.023)	-0.001	(0.014)	-0.009	(0.016)
heightzscore	-0.285***	(0.019)	-0.290***	(0.021)	-0.344***	(0.012)	-0.351***	(0.014)
Household variables								
toiletflush	0.120	(0.167)	0.044	(0.206)	0.118	(0.158)	0.023	(0.188)
toiletpit	0.186***	(0.059)	0.165**	(0.067)	0.014	(0.050)	0.005	(0.051)
drinkwatertap	0.236*	(0.128)	0.211	(0.131)	-0.077	(0.057)	-0.099	(0.061)
drinkwaterother	0.053	(0.059)	0.045	(0.060)	0.011	(0.039)	0.007	(0.040)
hhdmember	0.009	(0.012)	0.009	(0.012)	0.005	(0.010)	0.001	(0.011)
chnunder5	-0.038	(0.035)	-0.032	(0.036)	0.009	(0.026)	0.010	(0.026)
rural	0.014	(0.138)	0.017	(0.138)	0.086	(0.068)	0.136*	(0.082)
constant	-4.835***	(0.750)	-5.946***	(1.784)	-5.498***	(0.504)	-7.275***	(1.630)
no. of observations	3,732		3,732		7,473		7,473	

Robust standard errors (se) in parentheses, adjusted for clustering at the household level

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

3.5.5 Discussion of results for Zimbabwe and Malawi

Determinants of maternal BMI

The results in Table 3.11 show that the determinants of a mother's nutrition (represented by *mumbmi*) are similar for both Zimbabwe and Malawi. With regard to the identification variable, the results for Zimbabwe and Malawi show that household wealth has a positive impact on a mother's BMI. For Zimbabwe, the impact is significant across all wealth quintiles whereas for Malawi, the impact is significant for the top two quintiles. Overall the F-statistic (17.87 and 13.43 for Zimbabwe and Malawi respectively) indicated that wealth status is a fairly strong instrument for maternal BMI. Maternal and household factors such as height, education and the presence of flushing toilet facilities are important in determining the mother's BMI for both countries. For Zimbabwe, the age of the mother (*agemum*) significantly affects the mother's BMI whereas for Malawi, marital status and location (that is whether the household is in the rural or unban area) significantly influences *mumbmi*.

Determinants of a child's BMI

Main result

For both countries, the main OLS results (Table 3.12) indicate that there is a robust positive association between maternal nutrition (*mumbmi*) and child nutrition or child health (*BMIzscore).* The effect is still positive and significant when potential endogeneity or simultaneity bias is accounted for. The magnitude of effect is higher for Malawi than for Zimbabwe. For Malawi, a unit increase in *mumbmi* results in between 0.081 and 0.144 unit increases in a child's BMI. For Zimbabwe, a unit increase in *mumbmi* results in an increase of between 0.056 and 0.095 units in a child's BMI. These results suggest that the impact of promoting good household nutrition as well as good maternal nutrition on child nutrition is even more evident in Malawi than in Zimbabwe.

Other variables

The mother's height and education levels as well as the child's birthsize, heightzscore and the incidence of diarrhoea significantly influence a child's short-term nutrition for both Zimbabwe and Malawi. The magnitude of effect is higher for Zimbabwe for education levels and a child's birth size. For Malawi, the magnitude of effect is higher for the mother's height, the child's *heightzscore* and for the incidence of diarrhoea. This shows that although the same factors influence a child's BMI for different countries, they can have different levels of importance. Marital status, having a pit toilet and drinking water from a tap significantly influences a child's nutrition for Zimbabwe only and for Malawi, the mother's age and whether the household is in the rural or urban area significantly affects a child's BMI.

3.6 Conclusion and policy implications

This research is based on determining the effect of overall household nutrition choice (denoted by the mother's BMI) on a child's nutritional status (denoted by the child's BMI z-score). Similar to other studies, a linear association is purported between overall household nutrition and a child's nutrition. In addition, potential endogeneity and simultaneity bias arising from the mother's BMI is accounted for. Furthermore a comparison is made with Malawi, a country with a similar climate and facing similar challenges in terms of maternal and child nutrition.

For Zimbabwe and Malawi, the results show that overall household nutrition has a positive impact on a child's nutrition. Accounting for potential simultaneity and endogeneity bias in maternal BMI for both countries shows that maternal BMI also has a direct effect on a child's BMI. In terms of magnitude of effect, the direct effect of maternal BMI on child BMI has a higher impact for both countries. Moreover, the importance of other factors such as the mother's education and marital status, a child's size at birth and whether the child suffered from diarrhoea in the 2 weeks that preceded the survey, presence of sanitary facilities in the house (pit or flushing toilets) and the type of drinking water source is also established by the results. For Malawi, whether or not the household is located in the rural areas influences a child's BMI.

For the OLS and IV regression models estimated, obtaining a significant positive relationship for both methods would imply that promoting overall household nutrition would improve both the mother and child's nutrition. However, promoting better maternal nutrition would directly lead to improvements in child nutrition as the IV method separates out this direct effect and finds it significant. In terms of policy, this would mean that in addition to policies targeted at improving overall household nutrition, it would be beneficial to include policies targeting maternal nutrition in a bid to improve child nutrition.

From the results of this research, it is evident that maternal BMI has an important role to play in determining a child's nutrition and this effect is both direct and indirect. The indirect effect is through overall household nutrition, whilst the direct effect is possibly channelled through household wealth. This means that in order to improve child nutrition, efforts targeted at improving overall household nutrition as well as those aimed at enhancing only maternal nutrition will improve both the child and the mother's nutrition. The results suggest that enhancing maternal nutrition has a better impact than enhancing overall household nutrition. Investing in maternal nutrition from these results is important for the mother before the child is born as this improves child's size at birth as well as after the child is born as this improves the mother's capacity to look after the child.

In addition, the results suggest that consideration of divorced and widowed mothers in targeting of nutrition based programs will also lead to improvements in child nutrition and health. Education also plays a crucial role in determining a child's health and thus has to be promoted among mothers and indeed among female children who are the mothers of tomorrow. When one is educated, they are better able to understand the need for better household nutrition. Better maternal education will also assist mothers in maintaining a clean home environment (clean and appropriate toilet facilities and protected drinking water sources) which will contribute towards reducing incidence of diseases like diarrhoea and hence improve child health and nutrition. In terms of location, the results for Malawi suggest that there is need to consider mothers and children in the urban areas when targeting nutrition based programs as they are worse off than their rural counterparts. For Zimbabwe, the impact of maternal BMI on child BMI varies according to provinces. The indirect effect is more significant that the direct effect and this suggest that promoting interventions targeting household food security will probably do better compared to those targeting improvements in mother's nutrition. However for provinces like Mashonaland West, promoting better maternal nutrition may prove to be more beneficial compared to household nutrition interventions.

CHAPTER 4

The 2013 Smallholder Drip Irrigation Survey

"There is no reason why Africa cannot be self-sufficient when it comes to food. It has sufficient arable land. What's lacking is the right seeds, the right irrigation, but also the right kinds of institutional mechanisms that ensure that a farmer is going to be able to grow crops, get them to market, get a fair price"

President Obama, G8, Italy, 10 July 2009[21].

4.0 Introduction

This chapter presents the details of a survey that was carried out among households who benefited from the smallholder[22] drip irrigation program implemented by Plan International[23] in Mutasa and Mutoko districts in Zimbabwe. The survey was carried out by the author for her PhD research.

The survey was designed with an aim of analysing the role of capacity building in the attainment of food security through the smallholder drip irrigation project. Capacity building is aimed at increasing the strengths and abilities of individuals and the community at large, enabling them to utilise available resources to safeguard and improve their food security in a sustainable manner (Gervais, 2004). Under capacity building, benefactors introduce a suitable project and beneficiaries who take up the project are expected to continue with this project

[21] From Lankford, 2009

[22] 'Smallholder' in this research refers to informal small-scale rural plots which are privately owned by the farmer. The farmer makes their own decisions about how, where and when to use drip irrigation and on the crops to grow. Their families provide most of the labour and they can hire labour at their own discretion. It also includes those farmers who operate in groups but work their own small garden within the group garden (Kay, 2001).

[23] Plan International will also be referred to as just Plan in this research.

after the benefactors have withdrawn. This renders capacity building a more sustainable way of addressing food insecurity.

Smallholder drip irrigation is one of the technologies that were developed under a system of technologies collectively known as micro-irrigation or low-cost irrigation technologies. Micro-irrigation technologies were aimed at modifying the existing large scale sprinkler and drip irrigation technologies in order to come up with similar technologies that are suitable for small-scale farmers and households. In addition to having low operating costs, smallholder drip irrigation kits are more advantageous than other micro-irrigation technologies as they save water (Postel et al., 2001). The smallholder drip irrigation program has been implemented in developing countries such as India, Nicaragua, Kenya and Zimbabwe. The main objective of this project was to improve household food security through improved nutrition. Under this program, households were encouraged to establish home gardens where they grew a variety of vegetables mainly for household consumption. Households were also expected to sell any surpluses and use the income to purchase other complementary foods which they did not produce.

Smallholder drip irrigation has gained in importance in the quest to alleviate food insecurity. The International Water Management Institute (IWMI, 2006) has predicted that by 2025, approximately 33% of the world’s population will be suffering from water shortages. Zimbabwe, a country which relies mainly on rain-fed agriculture for food is at the moment suffering from rampant water shortages. Smallholder drip irrigation, which utilises 30-60% less water than other watering systems thus remains a highly feasible solution in terms of increasing production and food security at the household and consequently at the national level (Maisiri, Senzanje, Rockstrom & Twomlow, 2005).

The smallholder drip irrigation project was implemented on a fairly large scale in Zimbabwe by the United States Agency for International Development (USAID) through 30 locally based NGOs under the Linkages for the Economic Advancement of the Disadvantaged (LEAD) program. Plan International Zimbabwe was one of the NGO's who partnered with USAID. The implementation of this project began in 2002 and lasted until 2007. Initially the program aimed to distribute 20,000 drip kits sufficient to irrigate a $100m^2$ garden to vulnerable[24] households but the target was exceeded as other partners joined and supplied more drip kits (DAI, 2003, 2004). Belder et al. (2007) indicates that since 2002, over 70,000 drip irrigation kits have been distributed in Zimbabwe, far above the intended target of USAID. This is because some of the NGO's working in partnership with USAID also bought and distributed additional kits.

Evaluations of the smallholder drip irrigation project carried out in Zimbabwe revealed that there was a high dropout rate during the implementation phase of the project. Belder et al. (2007) highlighted that by the third year of project implementation; only about 17% of the beneficiaries were still using the drip irrigation kits. Merrey, Sullivan, Mangisoni, Mugabe and Simfukwe (2008)'s study also revealed that dropout rates were high. Little is known about why beneficiary dropout rates have been so high in this project. Given that the smallholder drip irrigation project was implemented on such a large scale, it is important to find out why beneficiaries have dropped out of this project especially at this time where the attainment of food security is a major goal of each and every country.

[24] Vulnerable households included child, elderly and female headed households, households looking after orphans as well as widows.

The survey was thus conducted between January and March 2013 to collect information on possible factors for why beneficiary dropout rates have been so high. General demographic information such as age and gender of the household head; drip irrigation specific information including the year the beneficiary received the kit and any challenges they faced in using it; information on various crops grown by the household under drip irrigation as well as under rain-fed agriculture was collected for each household. Data was collected on the beneficiaries' experiences in cropping and household food security before, during and after they received the drip irrigation kit. Factors that are of particular interest in this research include the timing of receipt of the drip kit by the beneficiary and the time at which they received training in operating and maintaining the drip kit, the impact of gender and the receipt of remittances by the household as well as characteristics of early versus late dropouts.

Results from this study are of importance to the government, policy makers and other NGOs who are interested in replicating the project and or implementing other similar projects as it will enable them to have an idea of the issues they ought to address in order for this and other projects to succeed.

4.1 Literature review

4.1.1 Background to smallholder irrigation

Irrigation has been used in agriculture for decades. Prior to the 1980's, the main thrust was on large scale commercial irrigation (LSCI), spearheaded by the government, NGO's and other stakeholders. LSCI involved huge capital outlays and required high levels of skill to operate and maintain the equipment. In addition, the expected high gains from LSCI were almost always not realised. Given all these limitations, focus shifted around the 1980's to incorporate smaller irrigation schemes and this led to the development of micro-irrigation or small-scale irrigation technologies (Carter, 1989; Postel et al., 2001).

Small-scale irrigation technologies include micro-sprinklers and micro-tube drip systems and commercialised micro-irrigation systems such as the traditional sprinkler systems. In contrast to LSCI systems, small-scale irrigation systems are characterised by farmer involvement at all stages, from planning and designing the schemes to harvesting and marketing of the produce. The equipment used in these technologies is fairly simple to use, can be operated and maintained easily by the farmers, can be manufactured locally, is affordable, expandable and is believed to be highly profitable (Carter, 1989; Postel et al., 2001; IWMI, 2006). As such, cost effectiveness and usability renders small-scale irrigation suitable for poor smallholder farmers who are among the main victims of food insecurity, especially in countries whose livelihoods depend on rain-fed agriculture.

Drip or trickle irrigation is a method that involves the application of water at slow rates, directly to the area where the plant roots grow (Brouwer, Prins, Kay & Heibloem, 1988). Drip irrigation is thus advantageous in that it reduces water losses due to deep percolation, evaporation and surface runoff. This increases production efficiency. Additional benefits of drip irrigation are that it is suitable for use in marginal lands where soils and the terrain are poor. By targeting the area around the plant roots, drip irrigation allows for effective application of fertilisers and pesticides. Small-scale drip irrigation has the additional benefit that it has low operational and management costs compared to large scale irrigation costs. Thus small-scale drip irrigation can also be referred to as low-cost drip irrigation (LCDI). LCDI can be operated effectively for small and larger plots by varying the size of water containers and length of pipes used. The bucket and drum systems can be used to irrigate smaller and larger plots respectively (Brouwer et.al., 1988; Postel et al., 2001).

4.1.2 Institutions and their role in irrigation

It goes without say that the major ingredient for all irrigation systems is water. Access to water (which is increasingly becoming a scarce commodity (IWMI, 2005)), varies from one country to the next and within a country, from one area to the next. Rules governing the usage of water are embedded in 3 distinct structures: water law, water policy and water organisations. Water law deals with issues of water rights, conflict resolution, issues of the extent of private participation as well as accountability issues in the usage of water. Water policy on the other hand deals with issues of priority setting in the usage of water, project selection, cost recovery and water transfers. Water organisation encompasses institutions such as the government who are responsible for managing water resources and deal mainly with water administration aspects, pricing or fee collection, regulation or accountability and information and technical capability (Saleth & Dinar, 2005).

With regards to irrigation, two of the main institutions that are crucial for sustainable irrigation and agriculture are co-ordination and property rights institutions as identified by Meinzen-Dick (2014). The levels of co-ordination required for agriculture differs with the tenure of the proposed system and the proposed size of the venture. Some innovations such as drip irrigation can be adopted at an individual level. Farmers can adopt and manage this on their own plots without needing to consult anyone. Other innovations require consultation with the community and indeed at a national level, depending on the scale of the proposed water using technology and the main water source under consideration. The use of small water sources such as tube wells, check dams and watersheds can be co-ordinated at community level through forming local groups (collective action) and putting in place rules to govern water usage. The government can also be involved in community co-ordination through water installation and setting up of water charges for farmers. Use of trans-boundary basins involves co-ordination at government levels. Co-ordination is important to regulate water use so as to try and ensure that all the people involved have equal access to water as well as to provide a framework for resolving disputes.

Property rights institutions assist in clarifying water usage rights and governing the type of projects that can be undertaken. Relationships within a community with regards to water usage (social institutions) and the rules they set to govern their water usage are of particular importance as are land, infrastructure and water rights. The length of land tenure is of particular importance here as it determines whether one should invest in long term activities such as building of canals and terracing or short term activities such as installing smallholder drip irrigation kits. More secure tenure is preferred for major developments involving water usage (Meinzen-Dick, 2014).

Rules and laws governing water rights are not so clear cut and they vary depending on the source they are from. In the context of irrigation, it is important to recognize that in addition to the formal laws, customary laws also exist. Moreover religious practices and laws are also exercised by some communities in relation to water rights (Faruqei et al., 2001; Onyango et al., 2007 as cited in Meinzen-Dick, 2014) Although they may be interpreted differently in relation to water rights, these rules all work together (legal pluralism) to try and ensure fair and easy water access to all the people involved. Thus there is need to acknowledge and recognise these inter-relationships for successful irrigation practices to be implemented (Meinzen-Dick & Nkonya, 2007 as cited in Meinzen-Dick, 2014).

Although the role of institutions governing water in drip irrigation is important, in our study, only a small number of the beneficiaries (about 5%) indicated that they paid for the water they used for drip irrigation. None of the beneficiaries indicated ever having faced problem over water usage rights. So in this research, the role of water institutions in smallholder drip irrigation will is not explored.

4.1.3 Smallholder drip irrigation in India and Nepal

According to Postel et al. (2001), low cost drip irrigation (LCDI) or trickle irrigation technology firstly was promoted in India and Nepal and has been promoted for over 30 decades now. An estimated 225,000ha is under smallholder drip irrigation in India and high value crops such as vegetables and flowers are grown (Singh et al., 1993 as cited in Kay 2001). Smallholder drip irrigation systems are gaining in popularity and use mainly because they are affordable. Government subsidies for smallholder drip irrigation and readily available spare parts for the system also encourage adoption of the drip system by smallholder farmers in India (Kay, 2001).

Evaluations of the uses of LCDI have also been carried out in different parts of India and Nepal. A study of farmers who adopted the smallholder drip and bucket irrigation systems in Gujarat and Maharashtra in India and Nepal respectively showed that drip irrigation improves the crop type and yield of farmers. Farmers shifted from growing crops such as groundnuts and oil seeds to water intensive high value crops like bananas and vegetables. The use of smallholder drip irrigation also led to increased productivity as the system uses less water to produce per unit compared to the conventional flood irrigation system. Yields also increased as farmers were able to have multiple harvests in a year. Polak and Sivanappan (1998 as cited in Kay, 2001) report that yield increases realised averaged around 20 – 40 percent. Farmers were also able to plant early and guard against the effects of droughts. Livelihoods and household food and nutrition security improved as women were now able to increase their production. Women from smallholder farms benefited from the income they received from selling their surplus whilst women with large scale farms benefited from labour saving as drip irrigation requires less labour compared to flood irrigation. Lack of representation of poor farmers due to higher adoption rates being realised among rich and middle class compared to poor farmers proved to be a major challenge in evaluating the merits of smallholder drip irrigation (IWMI, 2006). The huge subsidies by the government in this area also compromised the evaluation of smallholder drip irrigation in India (Polak and Sivanappan, 1998 as cited in Kay, 2001). Howbeit, Postel et al. (2001)'s study revealed that for small scale farmers in India and Nepal, the critical factors in the adoption and success of drip irrigation are market and micro credit access. After realising that indeed LCDI technology can assist in helping alleviate food problems for smallholder farmers, the technologies were disseminated to other developing countries including Africa.

4.1.4 Smallholder irrigation in sub-Saharan Africa

Originally in sub-Saharan Africa (SSA), huge investments were made around the 1970's and 1980's in large scale irrigation (LSI) schemes. LSI schemes were characterised by a top-down approach whereby donors and the government had the upper hand and controlled the design and implementation of the project, as well as cropping and harvesting practices. Farmers involved in these schemes were just labourers. Investments were made with an expectation of high returns but in most of sub-Saharan Africa (SSA), these returns failed to materialise. Reasons cited for this failure include poor provision of services especially with regards to timing of cultivation and harvesting (Carter, 1989; Kay, 2001).

Lessons learnt from the experience with LSI schemes indicated that it is better to allow farmers to have the upper hand and let them make decisions at all stages in order to increase productivity. From the 1980's onwards, smallholder irrigation started off in SSA, mainly as informal enterprises. Farmers simply embarked on irrigation projects using traditional technologies such as flood and swamp irrigation individually with little or no support from the government and donors. The traditional irrigation technology employed here was simple to use and farmers were able to manage their enterprises well. Over the past two decades however, government and donor attention also shifted to smallholder irrigation as evidence showed that there was potential for smallholder irrigation to succeed in Africa. The main resources required land and water, were available. The missing links identified were poor market access and lack of additional support for smallholder farmers who generally tend to be risk averse and thus concentrate mainly on growing subsistence crops. The need to improve on existing traditional irrigation technologies as well as promote accompanying interventions such as constructing boreholes and canals to boost smallholder irrigation were also identified (Carter, 1989; Kay, 2001).

In response to this, promotion of modern low cost irrigation technology (mainly trickle or drip and sprinkler irrigation) began in Africa. These technologies had already been used successfully in Asia. In addition to being affordable, the modern low cost irrigation technologies were adapted so that they could be successfully used on plots as small as $15m^2$ for drip irrigation (Kay, 2001; Postel et al., 2001). Better ways of lifting water, such as the use of treadle pumps which are affordable for smallholder farmers, were also introduced to improve irrigation. FAO (n.d) indicates that the uptake of treadle pumps has been very high in SSA especially since the late 1990's. In Malawi alone, an estimated 120,000 treadle pumps have been given out by FAO with other countries such as Mozambique encouraging adoption of treadle pumps.

According to Kay (2001) success levels in the use of both LSI and SSI have varied and each country's experience has provided insight on how to improve the uptake and use of irrigation in Africa. Gaining cooperation from smallholder farmers is especially important as evidenced by Cameroon's experience. Cameroon is one of the few countries in which LSI schemes succeeded. Success mainly stemmed from the use of expatriate management and co-operation of the smallholder farmers. Though the farmers were treated as labourers, they complied because of lack of better opportunities and the high returns they realised from the irrigation schemes. In countries such as Niger, Nigeria, Mali and Burkina Faso, public LSI schemes failed largely because of poor administration and lack of prioritisation in input acquisition. Success though was evident in private sector irrigation where individual farmers owned and made decisions and investments in smallholder irrigation. In Niger, Nigeria and Mali, the expansion of the private sector itself lend weight to the success of smallholder irrigation. In addition, countries like Nigeria subsidised equipment and inputs and improved rural market infrastructure to boost smallholder irrigation. The use of low-cost technology and assistance from donor organisations proved to be the backbone of Chad's success in irrigation amid civil strife. In Burkina Faso, success stemmed mainly for the use of already existing irrigation infrastructure from failed LSI schemes and a fairly conducive macro-economic structure (Kay, 2001). In Libya, the ease of use of the centre pivot sprinkler irrigation system contributed to the success of irrigation. Furthermore, Kulecho and Weatherhead (2006)'s study revealed that for farmers in Kenya, developed water resources, efficient technological and institutional support services and efficient marketing facilities are essential in encouraging farmers to adopt smallholder drip irrigation.

Whilst other countries were experiencing varying levels of success in SSI, Senegal's case was totally different. In spite of trying out a number of irrigation technologies, from large scale public owned schemes to parastatal irrigation to government assisted smallholder schemes to non-public sector irrigation, success eluded them. The main reason for this failure was the top-down approach used by the government and donors which led to construction of unsuitable irrigation boundaries and poor crop selection. This resulted in low uptake rates as farmers were demoralised and so the projects failed (Kay, 2001). Failure to incorporate existing indigenous systems also results in low uptake rates as revealed in the case of Sierra-Leone (FAO, 1984 as cited in Carter, 1989). In other countries like South Africa, although irrigation systems using the centre pivot and linear move machines have been disseminated to smallholder farms on a fairly large scale (irrigating approximately 3,000ha); limited information is available on how successful the project has been (Kay, 2001).

Currently, smallholder irrigation continues to be promoted in Africa in a bid to improve food and nutritional security and has gained in importance since 2000. The technology is promoted widely by NGO's such as FAO, USAID, World Vision and International Development Enterprises (IDE) among others (FAO, n.d; Kay, 2001). Smallholder drip irrigation is mainly targeting households to improve their nutrition and food security through encouraging the establishment of vegetable gardens. Farmers are encouraged to grow a variety of vegetables to improve their diet and obtain income from selling surplus vegetables (Dever, 2008).

Limited information exists on the use of smallholder drip irrigation in SSA (Kay, 2001). Available research reveals that in Ethiopia, smallholder drip irrigation has been successful in improving the lives of HIV affected women in urban areas, enabling them to establish nutritional home gardens. The impact though has been relatively small (Dever, 2008). Van Averbeke and Khosa (2007)'s study has shown that it is conceivable that smallholder drip irrigation can improve availability of micro-nutrients such as vitamin A and C for households in South Africa. However protein and iron deficiencies in the diets of extremely poor and all households respectively are not addressed.

Before adopting the treadle pump, an estimated 70% of households in Malawi indicated that they were food insecure (did not have enough food to last them until the following harvest). When these households adopted the treadle pump, only 9% reported that they were still food insecure. Thus in Malawi, adoption of new technologies associated with drip irrigation improved household nutrition (Mangisoni, 2008 as cited in Domenech and Ringler, 2013). For Kenya and Tanzanian households, adoption of the treadle pump increased share of irrigated crops sold compared to rain-fed crops. This is a result of an increase in growing of commercial crops by smallholder farmers. Sales of garden crops such as tomatoes and cabbage to the local community also increased, thus improving availability of food to non-irrigators as well (Nkonyana et al., 2011 as cited in Domenech and Ringler, 2013).

Spill over effects also enabled non-irrigators to benefit in Ethiopia from employment by smallholder irrigators (Aseyeheyn et al., 2012 as cited in Domenech and Ringler, 2013). Food security also improved in the Sudano-Sahel region for those who owned communal gardens under irrigation. They were able to continue consuming vegetables throughout the dry season (Burney et al., 2010 as cited in Domenech and Ringler, 2013).

4.1.5 Smallholder drip irrigation in Zimbabwe

In Zimbabwe sprinkler and drip irrigation were mainly used in the large scale commercial farms (LSCF) as well as in large scale irrigation schemes. The LSI schemes normally comprised of a number of smallholder farmers and were operated under the government using irrigation systems such as the sprinkler system. This system was the same system used in the LSCF's but adjustments were made in terms of the layout and more flexible hose pipes were used instead of the aluminium pipes used in the LSI's. Though the government spearheaded most of the irrigation schemes through the Department of Agriculture and Rural Extension Services (Agritex), the idea was to encourage farmers in the scheme to own the scheme. After a few years, the government expected to relinquish control to the farmers and they would manage the scheme all by themselves. Owning the scheme amounted to farmers being responsible for paying the bills, allocating plots to each other, deciding what the plant and managing the watering regime (Kay, 2001).

Success stories were apparent in schemes such as the Chitora Scheme. The government implemented this scheme and provided initial funding and inputs for 18 young farmers (aged 22 to 27 years). After the first year, the farmers were expected to support themselves. The young farmers embraced the project from the start and made good crop choices. As a result they were able to make a profit and continue with the scheme on their own.

Amid success, failure also exists. The Ngezi Mamina Scheme is one such example in Zimbabwe. Built at the same time as the Chitora Scheme, the Ngezi Mamina Scheme experienced problems from the onset of the project. Farmers involved complained that they were not consulted and they did not like the setup of the scheme. In addition, poor crop choices resulted in the farmers realising little profits. Thus the farmers failed to own the project and the government continued to run the scheme. These schemes were large scale in terms of land utilisation (9 ha and 216 ha for the Chitora and Ngezi schemes respectively) but small-scale in terms of the farmers involved. The Chitora scheme comprised of 18 farmers with 2 ha each whilst the Ngezi scheme has 154 plots ranging from 0.5 to 1.5 ha in size (Kay, 2001).

With the advent of the new low cost drip irrigation technology, Zimbabwe began to promote smallholder drip irrigation at the household level. Since then, laboratory and field trials as well as surveys have been conducted in different areas of Zimbabwe to evaluate smallholder drip irrigation. Chigerwe, Manjengwa, van der Zaag, Zhakata and Rockström (2004) conducted a laboratory study using 8 drip kits and concluded that drip systems with micro tube emitters are better in terms of emitter flow rates and are less prone to suffer from clogging problems compared to those that use in-line emitters. Replacement of micro tube emitter kits was also found to be more flexible compared to that of in-line emitter kits. Imported kits such as the Netafim and Plastro kits were found to perform better compared to the locally produced IDE kit. The researchers' concluded that it is worthwhile for one to engage in drip irrigation for plots of at least 1,000m^2. Otherwise it was more efficient to water by hand.

A field trial of smallholder drip irrigation was conducted at the Zholube irrigation scheme in Matebeleland South in order to ascertain the merits of low cost drip irrigation (LCDI) compared to the traditional surface irrigation. 9 farmers grew vegetables such as tomatoes, rape and onions under drip irrigation as well as surface irrigation. Assessments carried out with regards to the fresh weight of the produce and water use efficiency revealed that drip irrigation is superior to surface irrigation in terms of water use. Drip irrigation only used 35% of the water used by surface irrigation for the same crop. Generally the gross margin was higher under drip irrigation but surface irrigation proved to do better in terms of returns per variable cost. Other than this, drip irrigation was found not to be labour saving especially where water was lifted manually into the drum. Yields proved to be similar for both drip and surface irrigation and only differed significantly when fertiliser was applied (Maisiri et al., 2005).

Belder et al. (2007) indicates that more than 70,000 smallholder drip irrigation kits have been distributed to vulnerable households in Zimbabwe since 2002. The program, aimed at promoting the establishment of home nutritional gardens was spear headed by the USAID under the Linkages for the Economic Advancement of the Disadvantaged (LEAD) program in conjunction with other NGO's. Using data for 14 district surveys in Zimbabwe, Belder et al. (2007) evaluated the impact as well as the sustainability of the smallholder drip irrigation project. Their results indicate that by the 3rd year of the project life, more than three quarters of the beneficiaries had stopped using micro drip irrigation. Overall the project did not have much impact as an estimated 90% of the beneficiaries already had gardens and they were using buckets for watering. Introduction of the micro drip irrigation kit failed to increase their yields or their crop range. The program was poorly targeted as some of the beneficiaries were slightly wealthier than the non-beneficiaries. In terms of water and labour saving, their results revealed that all that took place was a substitution of the bucket for micro drip irrigation but approximately the same amount of labour and water were still being used. The most common problems faced by the beneficiaries were failure to access water, conflicts over water access rights, clogging of the pipes, lack of training in repairing and maintaining the drip kit as well as lack of support and insufficient follow ups from government extension officers and other stakeholders. Smallholder drip irrigation in this study proved to be unsuitable for children and the sick as considerable strength is required to lift the water into the containers.

Moyo, Love, Mul, Mupangwa and Twomlow (2006)'s results using information from Gwanda and Beitbridge districts also identified that targeting of the beneficiaries was poor. Only about 54% of the beneficiaries met the selection criteria of owning no livestock. Poor yields (only 2% of the beneficiaries were able to use the micro drip kit to produce the expected 5 harvests in 2 years), water access related problems and inability to use the drip kit efficiently were also identified to be the major challenges faced by beneficiaries in this area. In addition, their research indicated that pests and diseases were a major problem in this area. Based on their findings, Moyo et al. (2006) concluded that low cost drip irrigation can only be sustainable as a long-term relief measure and its impact improved by extensive collaboration among many stakeholders. One of the major challenges found was that the donor organisations themselves had no capacity to conduct the follow ups. Collaboration with other stakeholders could have resulted increased capacity for follow ups.

A qualitative assessment of smallholder drip irrigation was carried out in Gweru district targeting farmers who beneficiated from drip irrigation kits distributed by the Organisation of Rural Associations for Progress (ORAP). Similar to Belder et al. (2007), this study revealed that high dropout rates (approximately 90% of the beneficiaries had dropped out 3 to 4 years after receiving the kits) were experienced. Problems of overwatering also emerged as farmers were used to the conventional ways of watering their gardens. High staff turnovers in the donor organisations also proved to be problematic as they resulted in delays in the distribution of the kits. The appropriateness of the technology as well as targeting of vulnerable households was also questioned in view of the challenges farmers faced in trying to operate the kit. Farmers interviewed indicate that training in cropping practises is essential for encouraging the uptake of smallholder drip irrigation (Merrey et al., 2008).

Mugabe, Chivishe and Hungwe, (2008) also carried out a qualitative study using beneficiaries who benefited from the smallholder drip irrigation kits under ORAP in Gweru district and the Family Aids Counselling Trust (FACT) in Bikita district in Zimbabwe. Their study assessed the impact of the drip kits on non-adopters, dis-adopters (those who used the kit for a while and then stopped) and adopters (still using the kit). Their results revealed that the majority of the beneficiaries were male in both districts, a finding their attributed to the Zimbabwean culture which is patrilineal. The organisations had different ways of providing extension support to the beneficiaries. ORAP trained lead farmers within the community and these assisted other beneficiaries whereas FACT provided the extension services directly to each farmer. Plastro, IDE and Netafim kits were distributed but the results reveal that no particular type was favoured over the other. Investigations into why beneficiaries dropped out revealed that water problems, shortages of inputs and labour, health issues, old age, lack of spare parts for the kits and damage of kits by rodents led to drop outs. An attempt to evaluate the contribution of drip kits to food security proved to be challenging as both adopters and non-adopters indicated that their food security improved since the introduction of the kits. Conflicting results were also found in terms of income whereby adopters in Bikita and non-adopters in Gweru indicated that they received more income from their garden crops than field crops compared to their counterparts. This was attributed to the size of the gardens. These differences between adopters, non-adopters and dis-adopters were all not statistically significant.

The use of drip kits was also extended to institutional facilities such as schools and hospitals during this period. Merrey et al. (2008) indicated that the LEAD program in particular also extended to support the establishment of institutional smallholder drip irrigation gardens. Findings from 20 hospitals supported in using drip irrigation through the Catholic Relief

Services (CRS) indicated that the gardens benefited the hospital and surrounding communities including HIV/AIDS affected household. The hospital also benefited from income from selling surplus produce.

In addition, the use of the treadle pump to ease the access of water has also been promoted in Zimbabwe. However Kay (2001) indicated that shortages of the treadle pump in the local market have resulted in limited use. Nevertheless, laboratory tests carried out by Chigerwe et al. (2004) proved that combining the treadle pump with the drip kit is likely to have a positive impact on crop yields for smallholder farmers. This avenue continues to be explored in Zimbabwe (Kay, 2001).

4.2 The 2013 Smallholder Drip Irrigation survey background

The 2013 Smallholder Drip Irrigation survey was carried out in Zimbabwe, in Mutasa and Mutoko district among the beneficiaries of the smallholder drip irrigation project implemented by Plan International in Zimbabwe.

Zimbabwe is a landlocked country in south central Africa, covering 390,580 square kilometres in extent. It is shares boundaries with Mozambique to the east, South Africa to the south, Botswana to the west and Zambia to the north as shown in Figure 4.1 below *(*Encyclopaedia of Nations*)*. In 2009, Zimbabwe's population currently stands at 13,182 million and the population growth rate is 4.38%. An estimated 38.6 % of this population resides in urban areas. Currently, the life expectancy rate for Zimbabweans is 53.86 years with females having a slightly higher life expectancy (53.93 years) than males (53.79 years). Approximately 68% of the population live below the poverty line and an estimated 10.1% of children under the age of 5 years are underweight (CIA, 2014).

Figure 4.1: Map of Africa showing Zimbabwe's location

Source: Google images

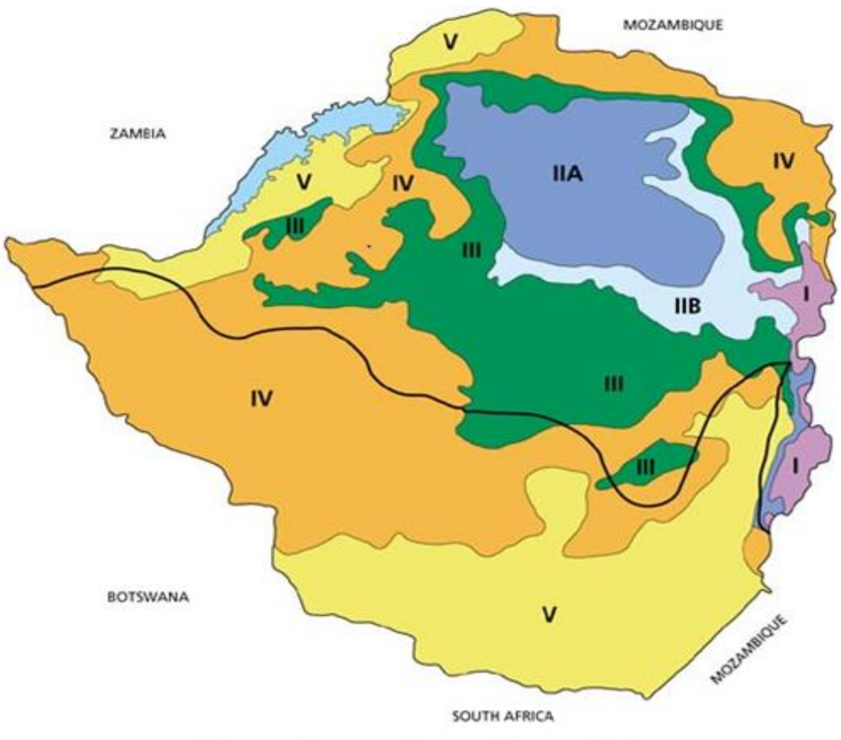
The adult HIV/AIDS prevalence rate is 14.7% (CIA, 2014). WHO (2005) observes that the HIV prevalence rate is higher in the large scale commercial farming areas, administrative centres, high growth areas outside cities and towns , state lands and in mining areas. The HIV prevalence rate in urban areas is also higher than that in rural areas. The group that is mainly affected by HIV and AIDS includes women involved in sex work, uniformed personnel and orphaned children.

Zimbabwe is divided into 5 agro-ecological zones[25] or natural farming regions based mainly on annual rainfall received, soil quality and vegetation as shown in Figure 4.2 and Table 4.1 below. Table 4.1 below also shows that the area occupied by different agro-ecological zones has changed in area since the classification in 1960 by Vincent and Thomas (Mugandani,

[25] Agro-ecological zones are also known as natural regions.

Wuta, Makarau & Chipindu, 2012). The new classification shows that natural regions I, IV and V have increased whilst natural regions II and III have decreased in size.

Figure 4.2: Agro-ecological zones or natural regions in Zimbabwe



Source: FAO (2013)

Table 4.1: Agro-ecological regions in Zimbabwe

Agro-ecological zone	Area covered		Annual rainfall(mm)	Farming system
	1960's	Currently		
I	1.8%	4.0%	>1000	Specialised and diversified farming
II	15.0%	7.6%	750 - 1000	Intensive farming
III	18.7%	16.1%	650 - 800	Semi-intensive farming
IV	37.8%	39.9%	450 - 650	Semi-extensive farming
V	26.7%	32.5%	<450	Extensive farming
Total	**100%**	**100%**		

Source: Mugandani et al. (2012)

Agriculture is the mainstay of Zimbabwe's economy and it accounts for approximately 20.3% of the country's gross domestic product (GDP) and employs about 66% of the population. The main crops grown include cotton, tobacco, wheat, coffee, sugarcane and peanuts and sheep, goats and pigs are kept as livestock (CIA, 2014). Zimbabwe's agriculture is mainly rain fed agriculture. The country experiences one rainy season from mid-November to March , a cold dry season from April to June and a hot and dry season from August to mid- November (Chikobvu et al., 2010).

Zimbabwe suffers especially from transitory food insecurity due to seasonality of production. Food insecurity is highest in the November to March period which is the period between planting and harvesting. Harvests occur mainly at the end of March and the food insecurity situation improves until late October. The major challenge is in terms of accessibility as most poor household have very low income and very small resource endowments such as land and draft power for production. An estimated 75% of the communal households live in agro-ecological regions IV and V which receive very low and unreliable rainfall annually. Crop production in these areas is highly unreliable and this makes it difficult for the households to get sufficient food to meet their daily requirements. As a result, all communal areas suffer from varying levels of malnutrition, ranging from 10-15% to 20-25% for children between the ages of 1 and 5 years in low rainfall communal areas. Other areas such as Nyanga, Binga and some areas in Matabeleland province have malnutrition rates which are as high as 30-40% (Rukuni and Jayne, 1995 in Mudimu, no date).

See appendix A1 for more information on Zimbabwe.

4.2.1 Plan International's smallholder drip irrigation project

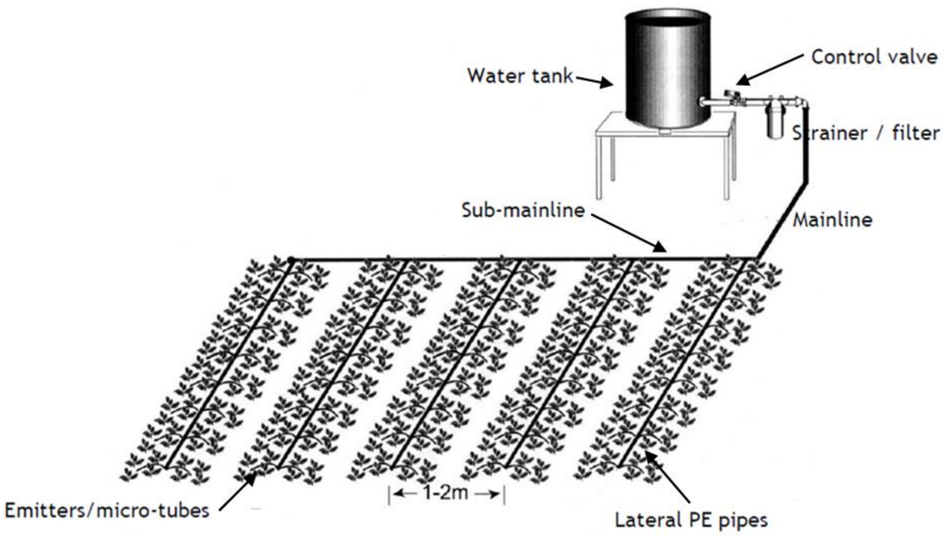
The smallholder drip irrigation project was implemented in Kwekwe, Mutasa, Mutoko, Chiredzi, Mutare, Chipinge and Tsholotsho districts (shown in Figure 4.3 below). This study focuses on Mutoko and Mutasa districts.

Figure 4.3: Plan drip irrigation project areas in Zimbabwe

Source: Plan (2013)

The project, implemented from 2003 to 2007 was targeted mainly at disadvantaged households especially female; child and elderly headed households as well as households looking after orphans and those affected by HIV/AIDS. This implies that food security was below average for all the beneficiary households before the intervention. Beneficiary households were given a drip irrigation kit capable of irrigating 100m^2 of land. Each kit comprised of a tap, water filters, sub-mains, lateral pipes, drip emitters, some spares as well as two elevated plastic refuse bins to be used as water tanks. The basic design of a low cost drip irrigation system is shown in Figure 4.4 below. Beneficiary households were expected to establish a vegetable garden with 10 beds, each measuring 10x1m^2 where they would grow vegetables.

Figure 4.4: Drip irrigation kit components



Source: (RCSD 2008)

Initially, a pilot project was carried out by LEAD in conjunction with 12 NGO's in Zimbabwe. Plan International was one of the NGO's used. 20 kits were distributed to Kwekwe, Mutoko and Mutasa. Results from the pilot project revealed that drip kits use a third of the amount of water and half the labour used by gardens using the bucket system and hose pipes and yields more compared to these traditional systems (Pemba, 2004; Matengarufu, 2007). After this pilot project, the project was then rolled out in 3 phases.

Phase 1: Plan- LEAD phase

During this phase, which commenced in 2003, 206 drip irrigation kits were distributed to beneficiaries in impact wards in Mutasa and Mutoko districts (103 in each district).

Beneficiaries in this phase comprised mainly of contact [26] farmers, schools and other beneficiaries. Beneficiaries were subsequently selected based on availability, reliability and distance to the water source from their homestead and or garden as well as the means they used to transport water. From the beneficiaries, contact farmers were selected based on their merits in farming and their gardens were used for demonstration purposes. They were attached to other current and potential beneficiaries in their area so that they would be able to lend them support in drip irrigation. Drip irrigation co-ordinators supported by both LEAD and Plan were deployed in Mutasa and Mutoko. Their main task was to provide technical support for the farmers with relation to growing crops under irrigation (Pemba, 2004; Matengarufu, 2007).

Phase 2: Plan- ECI Africa phase

ECI Africa is the organisation which represented LEAD during this phase, which commenced in 2004. LEAD donated 100 drip kits and Plan acquired 200 drip kits for each of the program units. ECI Africa also supported Plan in purchasing inputs such as seed and fertiliser packs for the beneficiaries. In addition, ECI also continued with the LEAD role of assisted in supporting the drip irrigation co-ordinators so that they continued to support the project beneficiaries (ECI Africa, 2004).

Phase 3- Plan –Practical Action

This phase commenced in 2005 to 2007. This phase was aimed at promoting the establishment of sustainable and viable links between farmers and support institution. Emphasise was given to improving marketing systems and water harvesting techniques available to farmers. More demonstration plots were also established to boost acceptance of

[26] Contact farmers are leaders of farmer groups established by Plan International in each area. The contact farmer is responsible for assisting the farmers in his or her group with farming related advice and most demonstrations of new farming technologies are carried out at their plot or farm.

drip irrigation technology. Some drip kits that had not yet been distributed during Phase 1 and 2 were also distributed during this phase.

Overall, approximately 403 kits were distributed in each district giving a total of about 806 beneficiaries (Matengarufu, 2007).

Project aims

- To increase household self-sufficiency in vegetable production and improve household income through selling surplus vegetables.
- To improve the nutrition of HIV/AIDS affected households
- To increase the community's capacity to feed orphans through the use of community gardens
- To reduce the costs of disease control as drip irrigation limits the spread of soil diseases among crops.

Measureable outcomes

- All households were expected to produce at least 2 harvests of fresh vegetables each year.
- Saving water by switching from the conventional bucket and hose pipe system to using drip irrigation
- Improved child health, empowerment and family involvement in food production.

Direct benefits

- Increased availability of food in the form of vegetables
- Improve the household's income from sales of surplus vegetables.

- Create employment through piece-work in gardens (Pemba, 2004).

4.3 The survey design

As indicate in section 4.1.4, the smallholder drip irrigation program implemented initiated by USAID in conjunction with about 30 NGO's under the LEAD program has distributed over 70,000 drip kits to vulnerable households in Zimbabwe since 2002. Evaluations conducted so far on this project indicated that dropout rates were very high during the project life (Belder et al., 2007; Merrey et al., 2008). In light of such high dropout rates, Mugabe et al. (2008)'s study brought to light several challenges that contributed to drop out decisions by households. Factors identified included water access problems, inputs, labour and spare parts shortages, poor health and old age on the part of the beneficiaries and damage to the drip irrigation pipes and tanks by rodents. Similar challenges were also identified by Belder et al. (2007). In addition Belder et al. (2008) and Moyo et al. (2006) also revealed that inadequate training on repair and maintenance of the drip kit, pests and diseases and lack of follow ups by the donor organisation and government extension workers also contributed to the high dropout rates.

Although the studies above identified the reasons why beneficiaries dropped out of the smallholder drip irrigation project, they did not establish which factors significantly contributed to dropping out due to the nature of their data. Identifying factors with a statistically significant influence on dropout rates is important as it gives an insight on priority areas that can be targeted to improve the uptake and sustainability of smallholder drip irrigation and other projects. Prioritisation is important given that there are limited resources available. This survey was conducted to collect data on the identified and other possible reasons which will enable the author to carry out quantitative analysis to establish the significance and hence importance of these factors to drop out decisions by smallholder drip irrigation farmers. In addition, the data from the survey will be used to find out whether the main goal of the smallholder drip irrigation project of improving household food security was achieved.

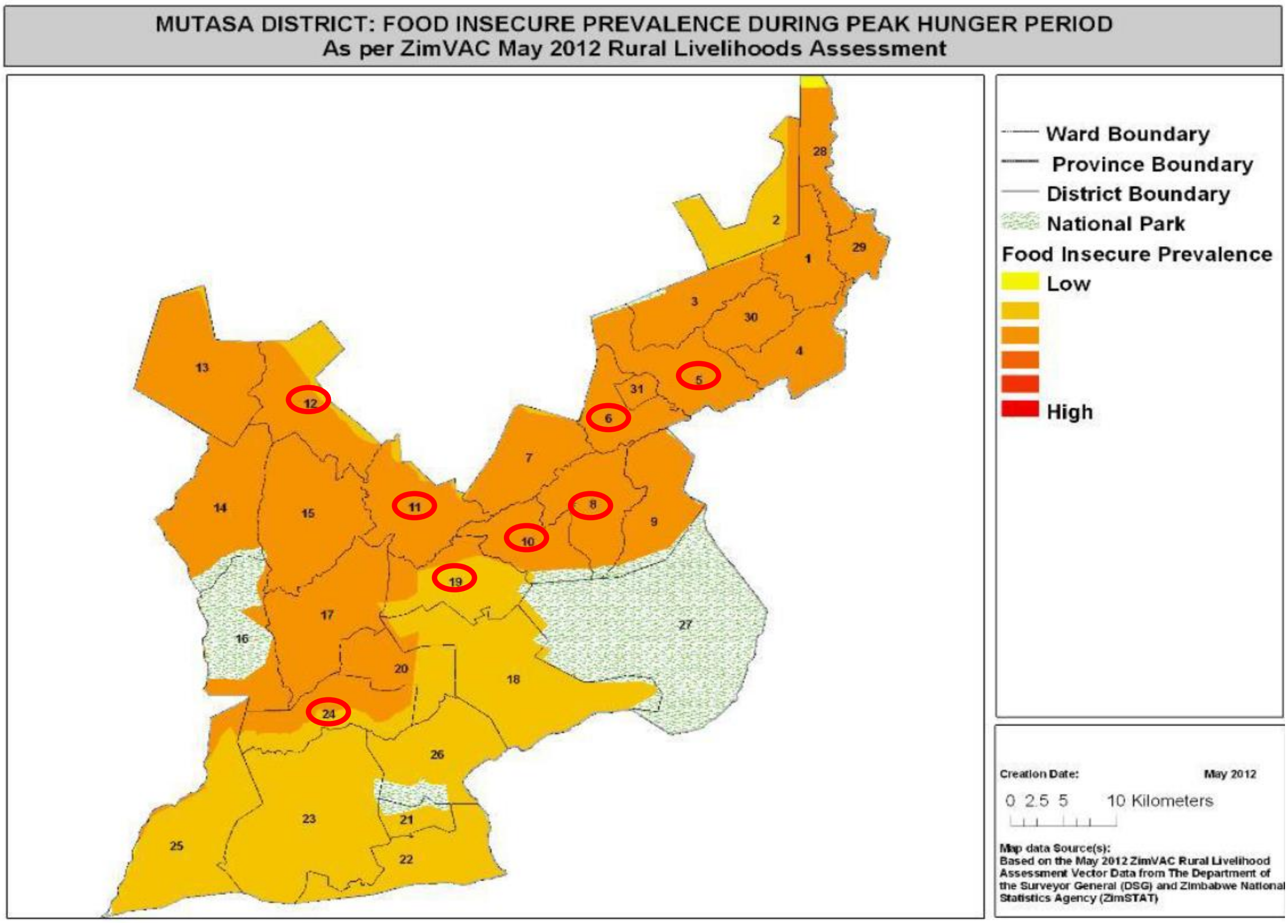
4.3.1 Project sites

Mutasa district

Located in the eastern part of Zimbabwe, Mutasa district is one of the 7 districts in Manicaland province. Its population currently stands at 169,756 (ZIMSTAT, 2012). The district has various areas that are in agro-ecological zones I to IV and receives an average annual rainfall of 850mm. Temperatures in this district average 26° Celsius. Mutasa is an agro-based community which depends largely on rain fed agriculture. Major crops grown in this district include maize, groundnuts and beans. The district also has commercially operated banana, coffee and tea plantations which provide employment to the local inhabitants. Some smallholder farmers also produce bananas, tea and coffee. HIV and AIDS prevalence rates are around 15.5% (Ndlovu, 2001). Mutasa shares a border with Mozambique and thus is affected by migration of the working age population to Mozambique, either legally or illegally.

Over the past decade, Mutasa has suffered from poor, unreliable rainfall and repeated droughts which have greatly reduced the yields and impacted negatively on household food security in the area. Women, elderly and child headed households are mostly vulnerable to food insecurity as well as households which have chronically ill members (Ndlovu, 2001). Generally, all of Mutasa suffers from varying degrees of food insecurity as shown in Figure 4.5 below. According to ZimVAC (2012), an estimated 5% of the households in Mutasa are food insecure. The project was implemented in 14 wards. Beneficiaries interviewed were selected from 8 wards 5, 6, 8, 10, 11, 12, 19 and 24 (Muparutsa, Samanga A, Samaringa, Sanyamandwe, Sadziwa, Doweguru, Sahumani and Gondenyakudyara respectively).

Figure 4.5: Mutasa map showing the wards and levels of food insecurity

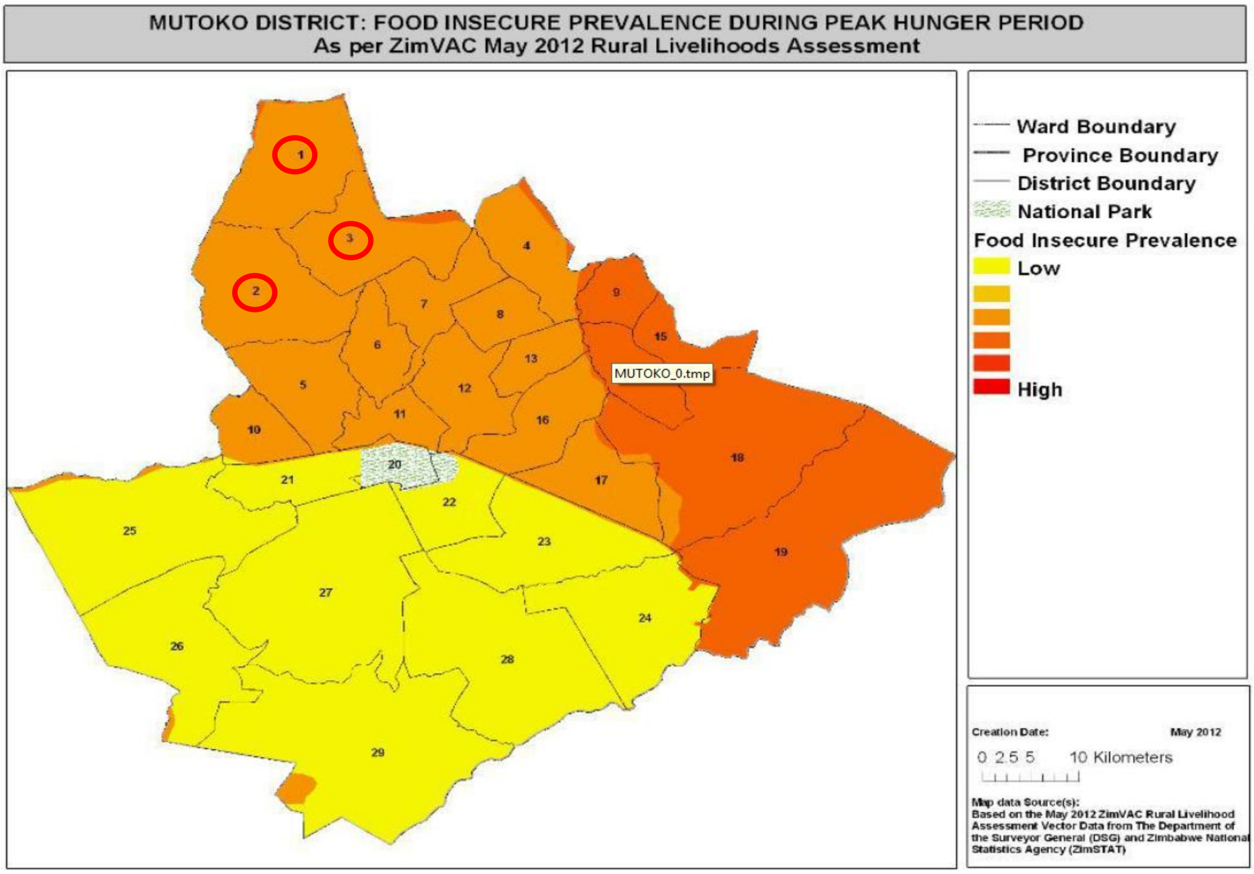


Source: ZimVAC, 2012

Mutoko district

Mutoko district is one of the districts in Mashonaland East province and it lies 150km north east of Harare. Currently, the population of Mutoko is 145,676 (ZIMSTAT, 2012). The district is mainly in agro-ecological zone III and mostly semi-intensive farming is practised here. Sandy loamy soils of granite origin which are poor in nutrients characterise the district. Dry land crops such as maize, millet, tobacco and cotton are mostly grown in Mutoko and are a major source of income. Additional income is also received from sales of vegetables, non-formal and casual work as well as remittances from urban areas. The region suffers from mid-season dry spells and suffers varying degrees of food insecurity as shown in Figure 4.6 below. According to ZimVAC (2012), an estimated 10% of the households in Mutoko are food insecure. Beneficiaries were selected from wards 1, 2 and 3 (Charehwa B, Chindenga and Charehwa A respectively). These were the only wards where Plan was operating in Mutoko district in 2003.

Figure 4.6: Mutoko map showing the wards and levels of food insecurity



Source: ZimVAC, 2012

4.3.2 Objective of the survey

The survey aims to answer the following questions:

i. Why have beneficiaries dropped out from the project?

ii. Are the characteristics of early dropouts similar to those of late dropouts?

iii. Does receipt of remittances from within and outside Zimbabwe influence a beneficiary's decision to continue with or dropout of the smallholder drip irrigation project?

iv. Do social support systems (ease of access to water facilities, access to training and advice from extension workers, access to inputs) available to the beneficiaries influence dropout decisions?

v. Has this project lead to the anticipated long term positive changes in household food security?

4.4 Organisation of the survey

4.4.1 Survey instrument

The survey was conducted through the administration of a 45 minute questionnaire to 170 households in Mutasa and Mutoko districts in Zimbabwe between January and March 2013. The questionnaire comprised of the following sections:

General information section: included basic interviewer and interviewee information including the respondent's and project beneficiary's names, their location and contact details as well as details on the receipt and usage of the kit. A consent form was also included for the beneficiary to indicate their willingness to participate in the survey.

Household characteristics section: This section included details of all household members including their age, gender, marital and educational status along with their occupation. Household specific details such as drinking and irrigation water sources, toilet facilities available, organisation and make of household dwellings, type of lighting and cooking fuel used by the household and household asset ownership information were also collected in this section.

Drip irrigation section: Included in this section are details of training received by the beneficiaries that have a direct impact on their performance in the project, whether or not the beneficiaries had a garden before they received the kit, crops grown before they received the kit, when and why they stopped using the kit. In addition, information of who carries out different chores in the garden, challenges faced in using drip irrigation and a self-rating of their knowledge of drip irrigation and improvement in food security as a result of drip irrigation was also collected. The section also captured information to do with repairs and maintenance of drip kits and group membership information.

Cropping section: The main focus of this section was collecting information relating to crops that the beneficiary household grew before, during and after the inception of the drip irrigation project. Details on changes in area allocated to the crop, yields, sales and consumption patterns were also included here.

Marketing, income and expenditure section: Information on where the beneficiary household sold their crops, the distance they travelled and any transport costs they incurred in the last 12 months was recorded in this section. In terms of income, the beneficiary's main occupation, months, days and hours worked in the last 12 months was obtained in this section. Other income sources (including aid received) besides the main occupation and income received from selling their crops in the last 12 months was included in this section. The expenditure section collected information on the beneficiary household's spending in the last 30 days before the survey. This included a subjective valuation of the amount the household would have spent procuring any items they received through aid from government, NGO's and or relatives.

Health and food security section: Details of any household members suffering from chronic illnesses were obtained under the health section. The food security section centred on collecting dietary diversity and coping strategy information in addition to general questions such as the number of meals a household takes per day.

Remittances: The focal point of the last section was to collect information of any remittances the household received in the last 12 months from within and outside Zimbabwe. This information also included details on the sender's relationship to the recipient, the amount they sent and what the money was used for by the recipient.

A copy of the questionnaire is attached in Appendix B1.

4.4.2 Ethics approval

Ethical clearance was obtained from Monash University for the survey to be conducted. Plan International Zimbabwe also provided the necessary clearance. At the local level, the Rural District Council (RDC), the District Administrator (DA)'s office and other relevant government stakeholders including the Department of Agricultural Research and Extension services (AREX) and the Mechanisation department for Mutasa and Mutoko also allowed the research to be conducted in their areas (see Appendix B2 and B3).

4.4.3 Procedures undertaken to ensure data quality

The questionnaire was designed using similar information from other surveys and studies carried out in Zimbabwe and other African countries. These surveys include Coates, Swindale and Bilinsky, (2007), Living Standards Measurement Surveys (LSMS), Maxwell, Watkins, Wheeler and Collins (2003), the Measure DHS surveys, van der Geest (2004) and Yokwe (2004). This was done in order to ensure that the questions asked were asked in a manner that the interviewees would understand.

After the questionnaire was drafted, it was pre-tested among 5 fellow university colleagues[27] in order to improve on face validity and the content. Adjustments were made according to the findings.

Training of enumerators

In order to ensure that all the enumerators have a consistent understanding of the questions, the 4 enumerators who assisted with the survey underwent training for 2 days. During this intensive training session, the enumerators were briefed on the purpose and background of the survey. The questionnaire was then explained and the purpose of all the sections and the type of information required in each section was highlighted. The enumerators then engaged in role plays and received feedback on their performance.

[27] The colleagues included 3 masters' students and 1 PhD student from Zambia, Kenya, Tanzania and Uganda and an elderly colleague with experience in field surveys from Uganda.

Pre-testing the questionnaire in the field

After the training, a pre-test of the questionnaire was done using 8 smallholder drip irrigation farmers in Sanyamandwe ward. Each enumerator was given a chance to conduct the interview whilst the rest of the team took note of their performance as well as areas that needed clarification in the questionnaire. Pre-testing was done in order to ensure that the questions captured the relevant data and that the interviewer and interviewee understood the questions in the same way. Pre-testing also ensured that the questions were adapted to the settings in order to reduce ambiguity and chances of inaccurate responses from the respondents. Additional amendments were made to the questionnaire after it had been administered for the first two days in Mutasa district. After implementing the necessary changes to the questionnaire, the first batch of questionnaires were printed out.

Sample selection

The beneficiaries to be interviewed were selected based on representativeness, practicality in terms of reaching the wards as well as convenience. The expected sample size was 200 beneficiaries (100 in Mutasa and 100 in Mutoko).

In Mutasa, the project was administered in 14 wards. 8 wards namely Muparutsa[28], Samanga A, Sahumani, Samaringa, Sanyamandwe, Sadziwa, Doweguru and Gondenyakudyara were selected. The wards were selected in such a way that all the livelihood zones were represented. Issues of ease of access to the wards and their proximity to each other were also considered. Beneficiaries were chosen randomly[29] from a combined updated list provided by Plan

[28] The ward codes are as follows: Muparutsa (5); Samanga A (6); Sahumani (8); Samaringa (10); Sanyamandwe (11); Sadziwa (12); Doweguru (19); Gondenyakudyara (24).
[29] The updated list was numbered and random numbers were used to select the sample.

International using random numbers generated in Excel. A total of 110 households were visited in Mutasa and the response[30] rate was 73.87%.

In Mutoko, the smallholder drip irrigation project was implemented in wards 1, 2 and 3 namely Charehwa B, Chindenga and Charehwa A respectively. The beneficiaries were also randomly selected from a combined updated list. A total of 110 households were visited and the response[31] rate was 80%. The questionnaires were administered over a month and a half (3 weeks for each district).

Endogenous treatment

This issue arises when comparing treated versus control groups as there can be unobserved characteristics that influence the selection process. In this sample, all the respondents interviewed received smallholder drip irrigation kits from Plan international and as such were all treated. Thus the problem of endogenous treatment is not an issue in this survey.

4.4.4 Acknowledgements

I would like to acknowledge Monash University for providing the funding for the survey. I would also like to acknowledge my supervisor Professor Brett A. Inder for his support and guidance throughout the preparations and conducting of this survey and research. Furthermore, I would like to acknowledge Plan Mutasa and Mutoko program units for providing me with the necessary transport and technical support for carrying out the surveys (through Mr Stanley Dawa and Mr Vengesai Mukutiri, the program unit co-ordinators for Mutasa and Mutoko respectively).

[30] 82 questionnaires were administered and 28 beneficiaries were not available (9 beneficiaries were deceased and the homestead has been abandoned, 2 beneficiaries were ill, 3 had relocated and 19 others were not at home).
[31] 88 questionnaires were administered and 22 beneficiaries were not available (4 were deceased and the rest were not at home).

CHAPTER 5

Capacity building and the attainment of food security: Why do smallholder farmers drop out of drip irrigation projects in Zimbabwe?

"Within agriculture and food security, there are a lot of conflicts of policy, a lot of conflicts of priority, but as long as you recognise that farmers particularly smallholder farmers are at the centre of it, then the thing can start to improve"

David Nabarro[32], 2011

UN Special Representative for Food Security and Nutrition

5.0 Introduction

Globally, the attainment of food security is a major concern. In the last decade, each and every country has been involved in the fight against hunger and poverty, in a bid to meet the targets set for the attainment of the Millennium Development Goals (MDG's). Millennium development goal (MDG) 1 is aimed at eradicating extreme hunger and poverty. Developing countries are of major concern as it has been noted that they are still lagging behind in terms of reducing the number of people who are hungry as well as maternal and child mortality rates (MDG Report, 2011).

Different programs have been introduced in a bid to improve food security in developing countries. Food aid has been by far the most popular intervention. Earlier efforts include emergency or relief, project and program food aid. Emergency food aid is given in cases of

[32] Comments given in a live interview by David Nabarro, UN Special Representative for Food Security and Nutrition just after the 'Food for Everyone- Towards a Global Deal' conference held in Brussels on 23 June 2011 at the European Economic and Social Committee Premise.

severe food shortages such as in the event of natural disasters. This has been by far the most common type of food aid, accounting for an estimated 68% of the total food aid distributed in between 2006 and 2008. Project food aid aims to promote special goals such as nutrition, food security and economic development. Project aid includes programs targeting specific groups of people as school children and pregnant mothers and programs like food-for-work aimed at community development. Project food aid distribution accounted for approximately 22% of the food aid distributed in 2006/2008. Ranking third was program food aid aimed at increasing food supplies in countries as a form of bilateral trade, which accounted for about 12% of the total food distribution. Under program food aid, donor countries grow food which they sell to recipient countries at lower prices ("The British Geographer, n.d"; Shah, 2007; USAID, 2011).

In the last 3 decades, the nature of food aid has altered. Relief food aid has increased due to the increase in the number of natural disasters and the adverse effects of climate change. Program food aid has increasingly been replaced by food aid where the food is obtained from one developing country and sold to another. Donors have also shifted from providing project food aid to a more sustainable form of aid, capacity building ("The British Geographer, n.d"; Shah, 2007). Capacity building is aimed at increasing the strengths and abilities of individuals, organisations and the community at large, enabling them to utilise available resources to safeguard and improve their food security situation in a sustainable manner (Gervais, 2004). In so doing, capacity building interventions focus on addressing not only the problem of food shortages but also that of development at local levels. Capacity building efforts towards alleviating food insecurity include training in agricultural production methods such as the use of organic fertilisers in Bangladesh and kitchen gardening Laos. Livestock rearing schemes have also been implemented in countries like Tanzania (goats), Afghanistan (heifers) and

Kenya (poultry). Income generating projects outside agriculture have also been promoted as a form of capacity building (the sawmill co-operatives in Bangladesh) (TEAR Australia, 2013). In Zimbabwe, capacity building projects introduced include livestock pass-on schemes to households as well as schools, water harnessing projects to promote nutritional home gardens as well as non-farm income generating initiatives and the extension of credit facilities to new farmers, women and youth so that they can embark upon different income generating projects, so as to improve their access to food (Belder et al., 2007; CRS, 2013; Pozniak, 2013).

The main issue underlying capacity building is that of sustainability, centred on the expectation that beneficiaries are able to continue the project after the benefactors have withdrawn. Gervais (2004) argues that although capacity building activities have always been incorporated in food security initiatives, monitoring, evaluating and documentation of these activities has been insufficient. It is important for capacity building activities to be assessed so as to establish the successes and failures of different projects in order to improve future development and targeting of projects. For Zimbabwe as a country, the attainment of food security and efforts towards this goal are crucial especially at this moment where the country is facing growing political as well as economic challenges.

This research aims to contribute to the body of literature on the role of capacity building in the attainment of food security. As noted in Chapter 4, studies on the impact and sustainability of the smallholder drip irrigation program in Zimbabwe have indicated that dropout rates in particular have been quite high(Belder et al., 2007; Merrey et al., 2008). Issues such as water availability and usage rights, lack of maintenance and availability of extension services have been identified as some of the challenges faced by the beneficiaries which caused them to discontinued the project (Kulecho and Weatherhead, 2005; Mugabe et al., 2008).

Drawing upon studies that have revealed that examining dropout behaviours has important economic implications and gives valuable information in project evaluation (Chan and Hamilton, 2006; Lamiraud and Geoffard, 2007; Philipson and Desimone, 1997; Rogers, 2003; Weinstein & Sandman, 2002), this research aims to establish some of the factors that have resulted in these high dropout rates, ten years after the project was first implemented and five years after the benefactors withdrew. This research will add to the body of existing literature by establishing which among the factors identified by other research as influencing dropout rates contributes significantly to drop out decisions among smallholder farmers in Zimbabwe. The research will also go a step further by including other factors not identified in previous research and evaluating their impact.

It is important to establish the factors that cause high dropout rates in order to inform future policies on areas that can be targeted for maximum impact. Focus on smallholder drip irrigation is important as the future is centred on sustainability, and the goal of reducing the food insecure population is still to be attained. Research shows that smallholder farmers contribute substantially to the world's food production. Kremen, Iles and Bacon (2012) indicates that smallholder agriculture accounts for 50%, 60% and 75% of the world's cereal, meat and dairy production respectively. Notwithstanding, many smallholder farmer households are chronically food insecure due to the resource constraints they face which prevent them from producing enough food for their own consumption. To compound this, investments in increasing agricultural production for smallholder farmers were minimal until recently (Bosc et al., 2012; Dioula, Deret, Morel, Vachat & Kiaya, 2013; IFAD & UNEP, 2013; Kremen et al., 2012).

Moreover, given that IWMI (2006) predicts that by the year 2025, approximately 33% of the world population will suffer from water shortages especially in Asia, the Middle East and sub-Saharan Africa (SSA), it is essential that technologies aimed at improving water use efficiency as well as increasing crop production continue to be promoted. Postel et al. (2001) argues that drip irrigation thus remains a more feasible and sustainable option to increase production, given its high efficiency in terms of water usage and yield increases (Postel et al., 2001). It is thus imperative that ways be found of making smallholder drip irrigation work.

5.1 Literature review

5.1.1 Dropout behaviour

5.1.1.1 Adherence

The term adherence is commonly used in relation to medication. When a patient complies and they take all their medication according to the doctor's orders, they adhere to the medical advice. Non-adherence occurs when patients fail to fully follow the doctor's instructions and they do not take their medications as prescribed. The patient may decide not to take the medication for a while, but later change their mind and begin taking the medication again. Attrition [33] is a special form of non-adherence whereby the patient stops taking their medication completely. This is not reversible (Lamiraud and Geoffard, 2007). Once one stops the medication, they do not take it up at a later date. Non-adherence can be used to evaluate the efficacy of treatments. Non-adherence though is not only confined to the medical field but has also been used in economics. In this section, non- adherence will be discussed in medical terms and a microeconomic perspective will also be put forward.

[33] The term attrition is commonly used in microeconomic studies to refer to subjects who are not available for follow up longitudinal surveys for a variety of reasons.

5.1.1.2 Medical perspective

Conventionally, non-adherence to a treatment or project is a phenomenon that has been associated with irrational behaviour and lack of information and or knowledge pertaining to the benefits of a treatment. The situation is such that the patient or recipient of the treatment is expected to fully obey the instructions given by their doctor, thus rendering patients passive participants in their treatment (Lamiraud and Geoffard, 2007). Others however have argued that non-adherence is actually driven by rational choices that a patient makes (Johnston-Roberts and Mann, 2003; Lamiraud and Geoffard, 2007). A patient evaluates the benefits and costs (side effects) of a treatment and they decide whether or not they will take their medication. The patient's choice is also determined by their perception of how likely they are to succumb to this disease (susceptibility) and how serious they perceive the consequences of not taking the medication to be (severity) (Becker and Mainar, 1975; Rosenstock, 1974). As such, a patient actively participates in their treatment.

Lamiraud and Geoffard (2007) analysed patient welfare using the longitudinal CNAF3007 data for France from surveys conducted from 1998 to 2001. They determined how patients complied with HIV treatment. Their sample of 195 people was divided into 2 groups. One group received the standard dose consisting of 4 pills per day and the other group received a more complicated dose of 11 pills per day. Their main assumption was that non-adherence to treatment by patients is a rational choice they make after weighing the benefits and costs associated with the treatment. Endogeneity of adherence or compliance was accounted for using the simultaneous equation approach, with the adherence and health outcome (either a reduced viral load and or an increase in the CD4 cell count) equations being estimated. Their results revealed that before accounting for endogeneity, adherence was significantly associated with the type of treatment in the health model. Patients who received the standard dose (4 pills per day) were more likely to adhere to the treatment compared to those who received the more complicated treatment (11 pills per day). Accounting for endogeneity however rendered adherence insignificant. A possible bias arising from attrition was also accounted for through the use of a trivariate model. Results revealed that both the adherence and the health outcome are not correlated with attrition. Their findings also revealed that the onset of side effects as well as a better health status (higher CD4 cell count) before treatment begins increases the likelihood of non-adherence to treatment. The likelihood of adherence was found to increase when the patient was not taking any other associated medication, when their disease was in a less advanced stage before treatment began and also if the treatment was simple. In addition this research proved that it is important to account for adherence endogeneity when dealing with patient's welfare.

Chan and Hamilton (2006) developed a framework to evaluate randomised experiments based on recipients' utility. They applied this framework to evaluate treatment effects through analysing subjects' dropout behaviours. Using longitudinal data from the AIDS randomised clinical trial ACTG 175 for USA and Puerto Rico; they evaluated the impact of 4 different treatments on HIV-infected adults who had an initial CD4 cell count of 200 to 500 per cubic millimetre. Similarly to Lamiraud and Geoffard (2007) they assume that a subject's decision to drop out of the treatment is a rational choice. Subjects consider the trade-offs between public outcome or benefits (increased CD4 count) and private outcomes or side-effects (such as nausea and vomiting) of the treatment and they decide whether to or not to comply with the treatment. Unlike most treatment evaluation studies which focus on public outcomes, Chan and Hamilton focus on the private outcomes as well, which enables subject's welfare to be determined. Chan and Hamilton's results however reveal that the treatment with less impact on the CD4 cell count (AZT) was also associated with less side-effects, thus it yielded the highest utility for the subject. Their results also reveal that a learning process influences the timing of dropouts from a treatment. Early dropouts from a treatment are as a result of side-effects whereas later dropouts are as a result of weakening of the public outcome (reduction in CD4 cell count). The main limitation of this study was the lack of information from non-participants. Chan and Hamilton also indicate that this framework can also be used to examine partial adherence, non-adherence to treatment as well as crossovers from one treatment to the next.

5.1.1.3 Microeconomic studies

Attrition (completely dropping out) has been commonly treated as a statistical concern that is addressed using sample selection methods in econometrics (Efron and Feldman, 1991; Heckman, Smith and Taber, 1998). However Heckman et al. (1998) in their study indicated that attrition is more than just a statistical concern. Rather they put forward that understanding attrition is a valuable tool that can be used to divulge how treatment or project beneficiaries value the treatment or project. Project or treatment beneficiaries in this case are thought to be rational beings who make a decision on whether or not to continue with a project or a treatment by weighing the benefits and the costs (side effects) they derive from the treatment or project. Dropout decisions are also influenced by the public outcome (the expected outcome of the treatment such as a drop in the viral load in the treatment of HIV and AIDS), private outcomes (side effects that the beneficiaries experience from the treatment), access to alternative treatment methods and the beneficiary's preference for the treatment and its outcomes (Chan and Hamilton, 2006; Lamiraud and Geoffard, 2007).

Attrition or dropout rates have been the subject of most of the microeconomic studies as opposed to non-adherence (whereby a patient drops out of the treatment and after a while begins to use the treatment again) in the medical field. Studying dropout behaviour enables one to obtain valuable information on the effectiveness and potential undesirable effects of a treatment or project (Chan and Hamilton, 2006; Philipson and De Simone, 1997; Philipson and Hedges, 1998).

Bring and Carling (2000)'s study highlighted the importance of analysing dropout behaviour in unemployment duration modelling. Using data from Sweden on registered unemployed individuals, they concluded that accounting for attrition using right censoring results in an underestimation of the escape rate to employment by about 20%. They indicated that right censoring is based on the assumption that exit to employment is independent of attrition which is false as shown by the results. They surveyed 200 drop outs and found that 45% of them actually dropped out of the unemployment registers because of employment.

Chatfield, Brayne & Mathews (2005) carried out a systematic review of factors affecting individual characteristics of dropouts in longitudinal studies on a variety of issues affecting the elderly. Attrition in the elderly is mainly from death and other factors such as lack of interest by the respondents, outright refusal to participate and ineligibility due to illness. Using 25 studies from Canada, Brazil, USA, Europe, Australia, UK and Japan, they concluded that dropouts in the elderly are mainly influenced by age and mental status. Older elderly people are more likely to drop out of the study as are people who are more cognitively impaired. Social characteristics appear not to influence dropout rates. Overall they established that the health of respondents who continue in the study is better than that of those who cannot be contacted for one reason or the other.

Mathews, Chatfield & Brayne (2006)'s study focused on determining whether the characteristics of dropouts from longitudinal studies for cognitive ability and ageing in the long-term differed from characteristics of dropouts in the short-term. In this study, dropouts are intended participants who are alive and they are classified as either refusers or movers. Refusers are the elderly who were once interviewed at baseline but declined to be interviewed after 10 years. Movers on the other hand are those elderly people who moved from the area of study or those who could not be located at their current addresses. Using data from the Medical Research Council Cognitive Function and Ageing Study (MRC CFAS) from five areas in England and Wales, they concluded that there is consistency between dropout characteristics in the short and long term. Their results revealed that generally women, with little education, poor mental health and who have no family history of dementia tended to be refusers. Similar to Chatfield et al. (2005), they concluded that older people with poorer health tend to be movers.

Different factors influence one's decision to adhere or not to adhere to a treatment. Franke et al. (2011) established that there is a positive association between lack of enough food at the household level (food insecurity) and sub-optimal[34] adherence to antiretroviral therapy for HIV-infected individuals in Peru. Their study revealed that those individuals in households that had experienced food shortages in the month leading to the interview, tended to be in the group of sub-optimal adherers. This is because HIV-infected individuals are believed to require more energy compared to their counterparts and some of the medication they take requires them to eat first (Batterham, 2005 as cited in Franke et al., 2011). If the individual fails to get sufficient food, they may experience side-effects. Experiencing side-effects is one of the drivers of non-adherence by patients to taking their prescribed medication (Lamiraud

[34] Sub-optimal adherence in this study referred to individuals who took less than 100% of their prescribed antiretroviral therapy medication.

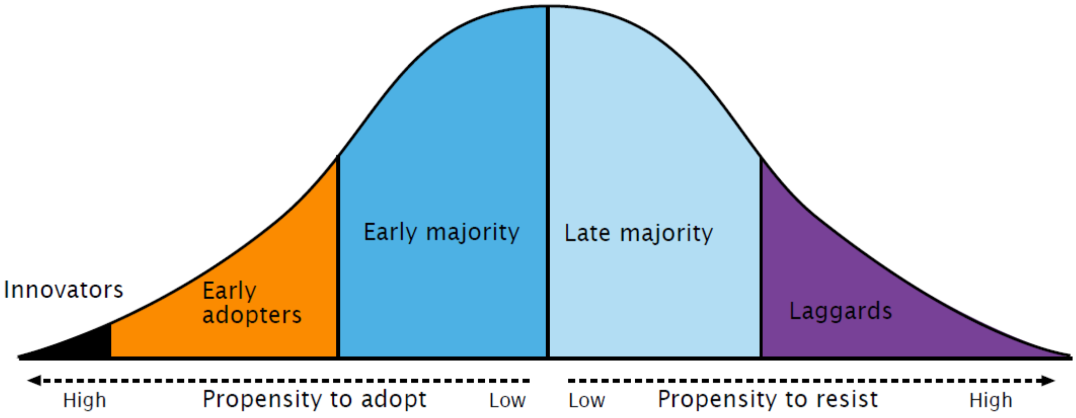
and Geoffard, 2007). Thus an individual may opt not to take the medication if they do not have enough food in order to avoid suffering from side-effects. In their study, Franke et al. (2011) also found that households which were food insecure at the baseline also tended to report frequent food shortages throughout the survey.

5.1.1.4 Dissemination of innovation and dropouts

Sections 5.1.1.1 to 5.1.1.3 above focus on dropping out as it relates to the medical and micro-economic fields. In this section, focus is on dropping out from innovations. According to Rogers (2003, page 12), an innovation is "an idea, practice or object that is perceived as new by an individual or other unit of adoption". Similar to the medical perspective, put forward by Chan and Hamilton (2006), participants can make a choice to adopt (fully utilise) an innovation or to discard it from the onset. However, their decision may change in the future. After personally weighing the relevance and benefits of the innovation, adopters may choose to now discard the innovations; a term Rogers (2003) refers to as "discontinuance". Those participants who had initially discarded the innovation can actually take up the innovation in the future, based on information gathered from their counterparts. This entire decision making procedure occurs in 5 steps, identified by Rogers (2003) in the Theory for Diffusion of Innovations. Ideally, the knowledge stage (where information is dispersed on the innovation and how it works), the persuasion stage (where individuals judge the innovation based on the knowledge they have) and the decision stage (where individuals dig deeper to find out more about the innovation and they form an opinion whether the project is suitable for them or not) all occur before adoption. The implementation stage is the main feature of the adoption stage where the innovation is now put to use. After this stage, comes the confirmation stage where the individual now assesses their decision to adopt or discard the new idea and decide whether they made the right choice, in which case they continue using the new idea or discontinue if they feel they made the wrong choice. The sequence of these stages, as Rogers (2003) stipulates, depend on how the new idea is being rolled out, that is whether it is up to the intended beneficiary to decide to take up the idea or whether the idea is presented to the beneficiary for them to take up, in which case they begin in the knowledge stage and move straight into the implementation stage. The persuasion, decision and confirmation stages will occur thereafter.

The issue of examining dropping out from an innovation presents several challenges. There is need to identify who the adopter of the technology or innovation is, in order to address questions to the relevant person. Soniia David (1998, as cited in Rodgers, 2003) highlights the importance of this identification. Results from her study show that for Nigeria, where the male head of a farm household was interviewed with regards to the adoption of hedgerow intercropping (a better alternative to the slash and burn practice), it turned out that the wife was the one who actually made the decision to adopt or discard the innovation. Thus the male head had very little to contribute in responding to questions to do with the innovation. There is also need to classify adopters according to times of adoption and to be aware of the different behavioural response associated with each group. Rogers (2003) identifies 5 different stages ranging from innovators (the first 2.5% of those who adopt the innovation) to laggards (the last 16% of those who adopt), as shown in Figure 5.1 below.

Figure 5.1: Adopter categorisation



Source: Robinson, 2009

Innovators are usually the first to try a new idea and are willing risk takers. Early adopters are people who respond positively to change. They generally are in leadership roles and others tend to follow them. The early majority group consists of people who make a decision to adopt based on evidence of success of the new idea or technology. The late majority group consists of risk averse people, who only adopt the innovation after it has been widely tried. The laggards group consists of highly conservative individuals who are suspicious of change and who prefer to follow systems that have served them to over the years and systems that they are familiar with. All these different categories are important as the strategies to engage people in these different categories vary. The easiest to convince are the innovators who are already enthusiastic from the beginning and the laggards are the hardest group to bring on board (Boston School of Public Health, 2009; Robinson, 2009; Rogers, 2003). These categories are however not fixed and one can decide on the number of categories to use based on their data (Rogers, 2003).

Adoption of an innovation not only depends on the individual or organisation taking up the innovation, but also depends on the innovation itself. This is the main trust of the Theory of Diffusion of Innovations as the focus is on coming up with new, improved ideas or practices that will better serve those who will use them. These new ideas or practices are aimed at replacing the existing ideas which may no longer be efficient. Rodgers (2003) identifies 5 qualities which determine the adoptability of innovations. In essence, the new idea has to be a more superior option than the idea it is meant to replace to the target population (relative advantage). Superiority can be measured in terms of benefits accrued economically and socially as well as suitability for the target population. The new idea also has to uphold the values, past experiences and needs of the target population (compatibility), it has to be simple to understand and operate, it has to be one that can be tested first to reduce risk to potential users (trialability) and it also has to have observed results available. Observed results are required to engage the early and late majority as well as the laggards (Robinson, 2009).

In addition to qualities of the innovation influencing its adoption, one also has to consider the aspect of behavioural change. Indeed when one considers the different categories in which adopters fall (Figure 5.1), one realises that the people in each category have different behavioural attributes, and as such need different approaches to be persuaded to make decisions. In order to succeed in disseminating an innovation, there is need to know about behavioural change, as this is key to the decision making process. How an individual comes to make the decision to adopt or to discard a new idea, practice or innovation can be analysed by looking at the different stages that one goes through, from a state of ignorance to a state of taking action, as surmised by Weinstein and Sandman (2002), in their Stage Theories Approach. In essence, Weinstein and Sandman put forward that knowing the different stages can assist those responsible for distributing new ideas or practices in coming up with the right message for the potential users. Focus has to be placed on knowing the target population, identifying the key stages and the different elements that can assist people to progress to the next stage. Having done this a message can now be constructed that will address these areas as a way of encouraging progression in decision making.

Applying the stage theories' approach to a health issue, Weinstein and Sandman (2002) use the Precaution Adoption Process Model (PAPM) that applies to decision making on relinquishing unsafe behaviour and adopting new preventative measure. The approach comprises of 7 stages which are: stage 1 - where one is ignorant about an issue, stage 2 – where one learns about the issue without getting personally involved; stage 3- where one begin to actively think actively about the issue and consider whether or not to engage in it; stage 4- where one either decides to discard the issue, in which case the process ends here, or alternatively they decide to get involved in which case they move to stage 5which is the involvement process; stage 6- the implementation stage where one actively adopts the behavioural change and uses it and stage 7- which is the assessment stage where one continues with the behaviour adopted in stage 6 if it is suitable for them or discards it if it is not. This is similar to the 5 steps identified by Rogers (2003) in the adoption of innovation, alluded to earlier in this section. The PAPM adds weight to the adoption process by highlighting the need to look beyond external factors influencing each stage and concentrate on internal factors linked to behavioural change. In essence, for one to adopt or discard a new idea in any field, one's behaviour needs to change.

5.1.2 Duration analysis

Duration analysis has been used to investigate the influence of time dependent as well as time independent factors on the conditional likelihood that an event occurs in the next time t, given that the subject in question has survived to that particular time. In relation to agriculture, the determinants of time to adoption of technology such as drip irrigation technology have been explored via the use of duration analysis.

Unlike the studies mentioned above, Läpple (2010) studied both factors that influence adoption and abandonment of organic farming by farmers in Ireland. The results of this study revealed that the main drivers of adoption and abandonment of organic farming are similar. Farmer's attitudes, market effects and time effects proved to be important determinants in this case. Risk averse farmers were less likely to adopt organic farming whilst concern for the environment reduced the chances of abandoning organic farming. Burton, Rigby and Young (2003)'s findings confirm this result and indicates that gender is also involved as attitudes of male and female farmers towards the environment influenced the adoption of organic horticultural technology in the UK. Increase in the profitability of conventional farming proved to have a negative impact on the adoption of organic farming whilst decoupling of payments by the 2003 CAP reform increased the likelihood of adoption of organic farmers (Läpple, 2010). This result is similar to that obtained by Dadi, Burton & Ozanne(2004) in their study which indicated that economic incentives were the key determinants of the uptake of herbicides and fertilisers by smallholder farmers in Ethiopia.

In addition to the influence of market prices, also highlighted by Läpple (2010), Dadi et al. (2004) indicates that distance to the market itself is also an important determinant of the adoption of fertilisers and herbicides. Furthermore, D'Emden, Llewellyn and Burton (2006)'s study reiterated the importance of market effects, highlighted by Läpple (2010). Their findings revealed that factors influencing the price of herbicides proved to be important in determining adoption of conservation tillage in South Australia. Läpple (2010)'s research revealed that farmers were more likely to adopt organic farming in the first year and abandon it after 5 years. Likewise Dadi et al. (2004) also proved the timing is important by revealing that the uptake of fertilisers was faster than that of herbicides for Ethiopian smallholder farmers. Moreover, availability and use of technical information also proved to be relevant in determining adoption rates.

With regards to drip irrigation, which is the main thrust of this research, Alcon, de Miguel and Burton (2011) used the Weibull model to investigate why some farmers in Spain adopted drip irrigation technology faster than others. Their findings indicated that education, availability of credit, availability and the price of water as well as information networks play a significant role in influencing the adoption of drip technology. Policy factors, the ease with which farmers could understand how to operate the technology, as well as the associated benefits also affected the rate of adoption.

5.1.3 Why smallholder farmers drop out of drip irrigation projects

Kulecho and Weatherhead (2005) investigated why smallholder farmers in Kenya stopped using low-cost micro-irrigation. Information obtained via the use of 35 semi-structured questionnaires revealed that dropout reasons included problems faced with the water supply, major source of food for the household, shortage of spare parts, method used to procure the drip kit and the type of drip kit used. Water supply problems included shortages due to prolonged droughts, low quality water (mainly saline or with impurities that blocked the pipes) and management of the available water supply between competing uses. In terms of major food sources, households relying on food aid as their main source of food were less likely to stop using micro-irrigation compared to those rely mainly on purchasing their own food. Farmers who acquired the kits using subsidies (less dedicated), where they shared the costs were more likely to drop out compared to those who purchased the kit by cash (more dedicated to micro-irrigation). An element of profitability is revealed in the result that farmers using the small bucket kit ($15m^2$) were more likely to dropout than those using the drum kits. Overall approximately 70% of the farmers in this study stopped using drip irrigation within 2 years of starting.

5.1.4 This research

Drawing from previous studies on adherence, duration analyses and adoption of innovations (section 5.1.1 and 5.1.2) and similar to Kulecho and Weatherhead (2005)'s study, this research aims to explore the determinants of dropout rates in smallholder drip irrigation farmers in two districts in Zimbabwe. In drawing from medical theories of adherence, this research is simply incorporating the conceptual aspects of these theories in as far as they stipulate that adherence to a treatment is accompanied by associated benefits and costs, which an individual has to assess for themselves and then decide whether or not to continue with the treatment. In the case of smallholder drip irrigation, the beneficiaries of the projects are faced with costs when implementing the project and they expect benefits from this project. Whether or not they realise these benefits and the extent to which they think these benefits are profitable to them, after considering the associated costs then influences their decision to continue with or drop out of the project. The associated benefits and costs though differ from the medical perspective and the drip irrigation perspective as the severity of the costs associated with these aspects and consequences of non-adherence are more critical from a medical viewpoint.

In addition to identifying the determinants, this research will go a step further to firstly establish the factors that have a significant influence on dropout rates in smallholder drip irrigation farmers. Kulecho and Weatherhead (2005) failed to conduct any significance tests due to the nature of their data. Whilst some of the relevant factors identified by Kulecho and Weatherhead (2005) will be employed, additional factors such as whether the farmer is an early or late adopter, yield and training factors will also be used. In this study, the term adopter is used to refer to someone who used the drip kit at any point in time after having received it from the donor organisation. Whether one is an early or late adopter is simply defined by the year in which the beneficiary received the kit. Secondly, this research will also look into the determinants of the time a farmer lasts before they drop out from the smallholder drip irrigation project.

The study population used in this research differs from that used by Kulecho and Weatherhead (2005) in that all the farmers involved received the kit from Plan International, a NGO in Zimbabwe as part of the smallholder drip irrigation project. Thus the initial capital outlay is not of importance here. All the farmers also received a kit that is sufficient to irrigate $100m^2$ of land whereas in Kulecho and Weatherhead (2005)'s study, the size of the kits varied with the smallest kit being $15m^2$. Farmer types in Kulecho and Weatherhead (2005)'s study varied from subsistence vegetable to commercial horticultural production. All the smallholder farmers in the Zimbabwean data had a universal goal of subsistence production of recommended vegetables and sale of any surplus vegetables.

This research is somewhat in line with the quantitative analysis conducted by Mugabe et al. (2008) using beneficiaries who received kits from ORAP and FACT in Gweru and Bikita districts of Zimbabwe respectively. Their main objective was to assess the impact and outcome of the drip kit technology and to identify the main factors responsible for the success or failure of the project. Their findings revealed some problems such as water, labour and input shortages as well as health issues which are believed to have induced beneficiaries to drop out of the project. These factors will be incorporated in this research. Mugabe et al. (2008)'s thrust was on identifying whether there were significant differences between non-adopters, dis-adopters (those who used the kit for a while and then stopped) and adopters (still using the kit) in outcomes for the two districts. Unlike Mugabe et al. (2008), this research focuses only on two groups: dropouts and non-dropouts or adopters and seeks to establish significant factors that caused dropouts.

5.2 Methods and procedures

5.2.1 The Economic Framework

Based on the assumption that smallholder farmers are rational beings, it is plausible to represent them as individuals seeking to maximise their utility (benefits (b) accrued from drip irrigation) subject to certain constraints (costs (c)) associated with drip irrigation. If the benefits outweigh the cost involved, the smallholder farmer or beneficiary is expected to continue using the drip kit and if the costs outweigh the benefits, the farmer is expected to drop out.

The main aim of engaging in smallholder drip irrigation is to improve household food security through improving a household's availability and accessibility to garden produce. Additional income realised from selling surplus garden crops is expected to be used to purchase additional food which the household does not produce.

Initially, a beneficiary's utility function is given by:

$$u(G, W) \tag{5.1}$$

where G are the household's initial returns from gardening prior to engaging in smallholder drip irrigation and W are the net returns from other activities that contribute to the household's welfare (food security in this case). Other activities include net income from wage labour, food received from various organisations as food aid, income received from remittances and net benefits from field crop production. If the household was not involved in gardening prior to using drip irrigation, $G = 0$ and for households involved in gardening prior to using the kit, $G > 0$. In addition, we follow the standard assumption that $u_G > 0$, $u_{GG} < 0$, $u_W > 0$, $u_{WW} < 0$ and $u_{GW} \geq 0$. Initially all households are poor in terms of their welfare as only households with low food security benefited from the project.

Based on the assumption that all beneficiaries begin using the drip kit upon receiving it, each beneficiary now has a new utility function given by:

$$u(G_D, W_D) \tag{5.2}$$

where $G_D \geq G$ and $W_D \leq W$. $G_D = G + b$ and $W_D = W - c$, where b represents the additional garden returns such as increased garden crop yields, gains realised from early adoption versus late adoption and from early versus late receipt of training in operating and managing the drip kit. c represents the costs faced by the beneficiary's household from engaging in drip irrigation, including the amount of time spent fetching water and manning the garden, the opportunity cost of time allocated to drip irrigation related activities instead of other activities such as wage employment and other household chores as well as the costs associated with challenges faced in drip irrigation such as input acquisition costs. The net loss from this reallocation of time is reflected on the overall welfare of the household. All these factors are fully described and presented in section 5.3.2 and are incorporated in the subsequent model estimated to show the determinants of dropout rates among smallholder drip irrigation farmers in section 5.3.1.

The utility function of a beneficiary involved in drip irrigation can thus be represented as :

$$u(G + b\ , W - c) \tag{5.3}$$

Compared to the beneficiary's initial status, the beneficiary is expected to realise a net gain in utility from using drip irrigation if:

$$u(G + b\ , W - c) > u(G, W), \tag{5.4}$$

that is, the beneficiary is better off in terms of returns from drip irrigation compared to before they began using drip irrigation.

5.3 The Discrete Choice Framework

Each beneficiary is faced with a choice of whether or not to continue using drip irrigation (for a beneficiary who continues using drip irrigation, $Y_i = 0$ and if the beneficiary drops out of the smallholder drip irrigation program, $Y_i = 1$, where i represents an individual beneficiary). Dropping out in this case is defined as spending a whole year without using[35] the drip kit.

[35] Beneficiaries in Mutasa and Mutoko normally use the drip irrigation kit during the dry season (from late April to late October each year). During the rainy season, beneficiaries concentrate mainly on growing field crops and rely on rains for watering garden crops.

Based on the assumption of rationality in decision making, a beneficiary chooses to continue or drop out of the drip irrigation program based on the trade-off between the benefits and costs they realise. By and large if the benefits outweigh the costs, the beneficiary is expected to continue with the project and vice versa.

So the probability that a beneficiary drops out of the project is given as:

$$\Pr(u(G_i + b_i) + u(W_i - c_i) < u(G_i) + u(W_i)) \tag{5.5}$$

which means

$$\Pr(Y_i = 1) = f(G_i + b_i, W_i - c_i, G, W) \tag{5.6}$$

Thus the utility derived by the beneficiary from dropping out is a function of the benefits and costs associated with this enterprise.

Assuming that there is an unobserved propensity for a beneficiary to drop out of the project, denoted by an ancillary random variable y_i^*, whose relationship to the explanatory variables (X_i') is given by:

$$y_i^* = \beta_0 + X_i'\beta + \varepsilon_i \tag{5.7}$$

where X_i' is a 1x k vector of independent variables comprising of the main drip irrigation, yield related, training, problems faced, beneficiary and household variables that influence the relative costs and benefits of continuing with the scheme. These variables are fully explained in section 5.3.2 below.

Since y_i^* is unobserved, what is observed is whether or not one drops out (Y_i). The relationship between y^* and Y_i is given as:

$$Y_i = 1 \ if \ y_i^* > 0$$

$$Y_i = 0 \ if \ y_i^* \leq 0 \tag{5.8}$$

If ε_i is assumed to be normally distributed with a mean zero and a constant variance equal to 100 ($\varepsilon_i \sim N(0,1)$), then the probability that the beneficiary drops out of the project is given by:

$$\begin{aligned} \Pr(Y_i = 1|X_i' &= \Pr(y_i^* > 0|X_i') \\ &= Pr\ (\beta_0 + X_i'\beta + \varepsilon_i > 0|X_i') \\ &= Pr\ [\varepsilon_i > -(\beta_0 + X_i'\beta)|X_i'] \\ &= 1 - F[-(\beta_0 + X_i'\beta)] \\ &= F(\beta_0 + X_i'\beta) \end{aligned} \tag{5.9}$$

where F(.) is the standard normal cumulative distribution function for the random variable r, with values lying between 0 and 1. $X_i'\beta$ is a vector of independent variables such that $X_i'\beta = \beta_1X_1 + \beta_2X_2 + \cdots + \beta_kX_k$

The β parameters are estimated using maximum likelihood estimation. Suppose the density function of $Y_i|X_i'$ is given by:

$$f(Y_i|X_i';\beta) = [\ F(X_i'\beta)]^{Y_i}[\ 1 - \ F(X_i'\beta)]^{1-Y_i}, Y_i = 0,1. \tag{5.10}$$

The log-likelihood function for each observation i is then given by the equations (5.11) below:

$$\ell_i(\beta) = Y_i log\ [\,F(X_i'\beta)] + (1 - Y_i)\log[1 - \ F(X_i'\beta)] \quad (5.11)$$

Marginal effects denote the effect a unit or small change in one of the continuous explanatory variables, say X_k, has on the dependent variable , that is $\frac{\partial p(X)}{\partial X_k} = f(\beta_0 + X_i'\beta)\beta_k.\, f(.)$ is the probability density function, satisfying the condition that $f(r) > 0$ for all r.

The average marginal effects (AME) method, where discrete or partial changes are averaged for each variable over all observations is used in this study to compute the marginal effects.

Generally the AME for the k^th independent variable is given by:

$$AME_k = \frac{1}{n}\sum_{i=1}^{n}\{F(\beta_i + \beta x^k) - \ F(\beta x^k)\} \quad (5.12)$$

βx^k gives the value of the linear combination of the β parameters and the explanatory variables (x) for the k^th observation.

For a continuous variable,x_1 the AME are given by:

$$AME_{x_1} = \beta_1\,\frac{1}{n}\sum_{i=1}^{n} f(\beta x^k) \quad (5.13)$$

The marginal effect for dummy variables for the effect of changing from 1 to 0 ceteris paribus is given by equation (5.14) for a dummy variable x_2.

$$AME_{x_2} = \frac{1}{n}\sum_{i=1}^{n}\{F(\beta x^k | x_2^k = 1) - F(\beta x^k | x_2^k = 0)\} \quad (5.14)$$

(Bartus, 2005; Cameron and Trivedi, 2010; Maddala, 1983; Wooldridge, 2000)

5.3.1 The data

This research uses data from the 2013 Smallholder Drip Irrigation Survey, conducted by the author and a team of 4 research assistants from January to March 2013. The beneficiaries[36] of the Smallholder Drip Irrigation project implemented by Plan International from 2003-2007 were interviewed in Mutoko and Mutasa districts of Zimbabwe. Approximately 806 households in the 2 areas benefited from this scheme. 200 households were targeted for the interviews and 170[37] households were interviewed successfully.

A questionnaire was administered to the project beneficiary in each household. In the event that the project beneficiary was absent, their spouse or adult children or an elderly relative were interviewed instead provided they were also involved in using the drip kit. If the beneficiary was absent and those present were not involved in using the drip kit, the household was not interviewed. The questionnaire collected information on household demography, drip irrigation related issues, cropping, marketing, income, expenditure, health, food security and remittances. Details of the survey are presented in the preceding chapter, Chapter 4.

[36] The terms beneficiary, household and smallholder farmer will be used interchangeably and all refer to a beneficiary who received a smallholder drip irrigation kit from Plan international.
[37] A total of 110 households were visited in each area. The response rate for Mutasa was 73.87%. 82 questionnaires were administered and 28 beneficiaries were not available (9 beneficiaries were deceased and the homestead has been abandoned, 2 beneficiaries were ill, 3 had relocated and 19 others were not at home). The response rate for Mutoko was 80%. 88 questionnaires were administered and 22 beneficiaries were not available (4 were deceased and the rest were not at home).

5.3.2 The variables

The dependent variable

The dependent variable *dropoutA* is a dummy variable which takes the value 1 if the beneficiary dropped out within 6 years of embarking on the project and 0 otherwise. Beneficiaries received the drip irrigation kit in different years from 2003 to 2007. The number of years a beneficiary was involved in the project was standardised to 6 years, which is the maximum number of years (inclusive of adoption year) a beneficiary who received the kit last in 2007 could remain in the project by the time of the interview. Beneficiaries who dropped out within this 6 year period are then considered as drop outs in the construction of *dropoutA*, the dependent variable.

The explanatory variables

The main variables of interest include *earlyadopt*, a dummy variable indicating that the beneficiary received their drip irrigation kit from Plan international in 2003. The researchers believe that timing in the receipt of the kit matters. Beneficiaries who received the drip kits at the start of the project (2003) are expected to have the added advantage of having support from the donor organisation for a longer time. This, the researchers believe will induce them to use the drip kit for a greater duration compared to their counterparts. Other literature also suggests that timing in adoption is important (Alcon et al., 2011; Läpple and van Rensburg, 2011).

Other main explanatory variables include the ease with which beneficiaries accesses drip irrigation water, represented by the variable *irrigwatertap*, a dummy variable indicating that the beneficiary gets their water for irrigation from a tap. This is mainly municipal tap water. The distance of the water source from the garden (*distancefromgdn*) in meters is also included as it contributes to ease of access to water. Beneficiaries whose water source is nearer to the garden are expected to remain in the project longer compared to their counterparts.

As the beneficiaries are assumed to be rational in their decision making, the dummy variable *yieldincgdn* indicating whether or not the beneficiary household realised an increase in garden crop yields during the period they used drip irrigation is included as a main variable. All dummy variables take the value 1 for the characteristic mentioned above and 0 otherwise. These main[38] explanatory variables are have also been identified by researchers such as Kulecho and Weatherhead (2005) and Mugabe et al. (2008) among others as being important in influencing dropout decisions.

Individual crop yield[39] increases are also incorporated as explanatory variables under the cropping section. These include yield increases in leafy vegetables (*leafyvegyldinc*), tomatoes (*tomatoyldinc*), onions (*onionyldinc*), beans (*beansyldinc*) as well as the yield increases of two major field crops maize (*maizeyldinc*) and groundnuts (*gnutyldinc*). For the garden and field crops, only the top five and two crops respectively in terms of the number of beneficiary households who grew them were selected. All the yield variables are dummy variables take the value 1 if an increase was realised in the crop mentioned above and 0 otherwise.

In terms of training[40], bookkeeping (*bookkeep*), marketing (*marketing*), permaculture (*permaculture*), master farmer (*masterfarmer*) and cropping (*croping*) training dummy variables are included if the beneficiary received the training. These trainings were not conducted directly by Plan International but by other stakeholders also assisted. Training such as marketing and bookkeeping were part of the trainings Plan International encouraged, given

[38] *earlyadopt* from the General information section, Q12; *irrigwatertap* and *distancefromgdn* from Section A ,Q12b and Q13ii respectively; *yieldincgdn* from Section C, Q9 in the questionnaire.
[39] Crop yield variables are constructed from the information obtained in Section C, Q9 of the questionnaire.
[40] Training variables are constructed from information from Section B, Q1a of the questionnaire

that the project was aimed at also encouraging marketing of surplus crops. Other training such as the Master Farmer training have been going on for quite a long period and are conducted by the Department of Agriculture and Rural Extension Services (AREX). Training on cropping included training on different crop enterprises regardless of whether they were directly linked to drip irrigation or not. All the training dummy variables take the value 1 if the beneficiary received the relevant training and 0 otherwise.

The three major problems[41] faced by the beneficiary households in using drip irrigation are represented by the dummy variables *waterprob*, *noprofitprob*, *labourinputprob*. These variables indicate that beneficiaries faced water related problems (including water shortages, difficulties in filling the tank and the water source being too far away), failed to realise any profit from using drip irrigation and experienced input and labour shortages respectively. The dummy variables take the value 1 if the beneficiary experienced the problem mentioned above and 0 otherwise.

Beneficiary[42] characteristics include the beneficiary's age (*benefage*) which is a continuous variable and dummy variables for education (*benefprimarylev*), marital status (*benefmarried*), gender (*benefmale*), main occupation (*benefarmer*) and group membership status (*benefgrpmember*). Group membership is specifically for farming or business related associations or groups. The dummy variables take the value 1 if the beneficiary attained primary school education and below, is married, has farming as their main occupation and is a member of a group that is agriculturally or business related and 0 otherwise.

[41] Variables representing problems faced by smallholder farmers in using drip irrigation are constructed from Section B, Q13 of the questionnaire.
[42] Beneficiary characteristics are constructed from the General information section, Q2; Section A,Q2, Q4, Q6, Q7,Q9 and Section B, Q24.

Household characteristics are also included as explanatory variables. These include continuous variables such as the number of members in each household (*hhdmembers*), the number of children below the age of 5 in each household (*childbelow5*) and the size of land the household owns (*landsize*). The number of family members in a household affects the amount of labour available for drip irrigation, since the enterprise is dependent on family labour. Households with more family members are thus expected to remain in the project for longer as they are less likely to face labour shortage problems. More household members also mean that the household can be more flexible in terms of allocating labour for different activities. The variable *childbelow5* is included to account for care of children and carrying out other household chores, which takes away time from working in the garden. The presence of more children below the age of 5 in a household places additional demands on the available adult time and thus affects whether or not the household continue with drip irrigation. The size of the land (*landsize*) owned by a household affects the household's allocation of resources especially in terms of labour. It is more likely that households who have more arable land require more labour to work the non-irrigated land and thus may have less labour to work in the garden (drip irrigated).

Dummy variables include *remittance*, indicating that the household received remittance from within and outside Zimbabwe, *orphan* denoting that the household looked after an orphan in the last 12 months and *chronillmember* indicating the presence of a chronically ill member in the household. Receipt of remittances can influence a beneficiary's decision to drop out of the project. This can occur in two ways. Beneficiaries receiving remittances from within or outside Zimbabwe may decide to drop out of the project as they will have the income to purchase the food they need. On the other hand, beneficiaries receiving remittances may opt to remain in the drip irrigation project as they are in a better position to purchase the required inputs (such as seeds and labour) as well as any replacement parts needed for their kits compared to those who do not receive remittances. The project was aimed at households looking after orphans as well as households looking after chronically ill members (*chronillmember*), so whether or not a household was looking after orphans (*orphan*) is controlled for to explore whether or not the targeting criteria was appropriate.

Location specific effects of the beneficiary's household are controlled for using the dummy variable *mutasa*, which takes the value 1 if the beneficiary resides in Mutasa and 0 if the beneficiary resides in Mutoko. The dummy variable *fdsecbelowaverage* represents a subjective valuation by the beneficiary of the level of improvements realised in the consumption of garden crops as a result of the using drip irrigation. Assuming that beneficiaries are rational in their decision making, it is expected that households who did not get an increase in their garden crop consumption or whose increase was below average are more likely to drop out compared to those who got an improvement which is above average.

Differences in household wealth status will be controlled for using the variables *middle* and *rich.* These variables take the value 1 if the household's wealth status is average and if the household is rich respectively and 0 otherwise. The variables are constructed for the wealth index using principal component analysis (PCA). Construction of the wealth index is fully described in section 5.3.3 below. Although all the households targeted are in the rural area and are all generally classified as poor households, the information collected showed that some households are better off than others in terms of wealth. The variables representing the wealth status of the household are included to explore whether wealth status has an impact on the likelihood of dropping out.

The variables are described in Table 5.6. For continuous variables, the mean and standard deviation is reported whereas the number and the percentage of observations in each category is reported for all dummy variables. The variables are introduced separately into the model in order to determine whether their impact on the probability of dropping out of the drip irrigation project. 6 models will be estimated with the following explanatory variables:

Model 1- main variables

Model 2- main and crop yield variables

Model 3- main, crop yield and training variables

Model 4- main, crop yield, training and problems faced variables

Model 5- main, crop yield, training, problems faced and beneficiary characteristics

Model 6- main, crop yield, training, problems faced, beneficiary and household characteristics

5.3.3 Measuring wealth

In order to come up with a single wealth index for the households in this study, the Principal Component Analysis (PCA) method is used. This method is a multivariate statistical technique that reduces a large number of seemingly correlated variables to uncorrelated elements or components. Correlated asset variables (including continuous as well as dummy variables) are used at the initial stage and they are weighted and combined linearly through PCA to give rise several elements or principal components (Vyas &Kumaranayake, 2006).

Asset based information is preferable compared to income and consumption based information as it does not suffer much from recall bias, seasonality and measurement error (Mckenzie, 2005). In spite of having all these advantages, using asset based information also has limitations in that it fails to take into account the differences in the value of the assets in question. There is also the challenge of having enough categories of asset variables to enable heterogeneity across the units to be captured effectively. Research however has shown that the PCA method, although not so well-defined does provide realistic approximations of wealth ranks (Filmer & Pritchett, 2001; McKenzie, 2005).

Following the approach used in Measure Demographic and Health Surveys (DHS), information was collected through the questionnaire on access to utilities and infrastructure, housing characteristics and durable asset ownership (section A, Q12-28 in the questionnaire). The information was used to create variables under three categories as summarised in Table 5.1 below. These variables were then used to create the wealth index in Stata (Rutstein & Johnson, 2004; Rutstein, 2008).

Table 5.1: Variables used to create the wealth index

Category	Variables
Access to utilities and infrastructure	• Drinking water source • Type of toilet used by the household • Household's main source of light • Household's main cooking fuel
Household characteristics	• Organisation of dwellings • Floor, roof and wall type • Total number of rooms in the house • Number of rooms used for sleeping in the house
Durable assets	• Household owns electricity, solar power, a radio, television, a landline phone, a refrigerator, an ox-drawn cart, a mobile phone, a bicycle, a motorcycle and or a car • Livestock ownership – cattle, goats, pigs, sheep, poultry, donkeys, other livestock • Size of land owned by the household

PCA operates under the assumption that variations in asset variables are as a result of a household's standard of living. The method assumes that the element that accounts for the most variance among the different linear groupings of the asset variables (principal component 1) is the one that best describes a household's wealth status (Filmer and Pritchett, 2001; Howe, Hargreaves & Huttly, 2008; McKenzie, 2005).

Generally the principal component (PC) for a given set of variables ($X_1, X_2 \ldots X_n$) is given by a linear grouping of all the variables, with each variable being weighted by different weighting factors ($\alpha_i{}'s$) as shown in equation (5.15) below.

$$PC_1 = \alpha_{11}\tilde{x}_1 + \alpha_{12}\tilde{x}_2 + \cdots \alpha_{1n}\tilde{x}_n$$

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$$PC_m = \alpha_{m1}\tilde{x}_1 + \alpha_{m2}\tilde{x}_2 + \cdots \alpha_{mn}\tilde{x}_n \qquad (5.15)$$

where $\tilde{x}_i = \frac{x_i - \bar{x}}{s_i}$ is the standardised asset variable with a mean equal to zero and a variance equal to λ and $\alpha_{i1}, \alpha_{i2} \ldots . \alpha_{in}$ are the different weighting[43] factors for the original asset variables. $\bar{x}$ is the mean of the variable in question and s_i is the standard deviation. $i = 1,2 \ldots n$ and λ is the largest eigenvalue for the correlation matrix of X. For dummy variables, the ratio between the weighting factor and the standard deviation represents the effect of a change in the asset variable from 0 to 1 on the principal element (Vyas and Kumaranayake, 2006).

All the resultant PC's are given in order of the variance, with PC1 being the component that accounts for the most variation in the initial asset variables. The subsequent PC's are not

[43] Assets with large differences in their distribution among the units under consideration are given greater weights. Assets owned by everyone or no-one that are lacking variation in terms of ownership have lower or no weights at all (McKenzie, 2005).

correlated with the preceding PC's and account for less variation than the preceding PC (McKenzie, 2005; Vyas and Kumaranayake, 2006). The first results give all the PC's and the eigenvalue for each PC is also given. PC's with an eigenvalue >1 are retained and used to generate the overall wealth index.

Following the method by McKenzie (2005), four separate wealth indices wealthUI, wealthHC, wealthDA and wealthAll are created for this study. These indices are based on utilities and infrastructure (UI), housing characteristics (HC), durable assets (DA) and all the three categories combined (All) respectively. 14, 14, 19 and 47 variables are used to generate the first PC's for the 4 indices and 7, 7, 6 and 18 components are retained and used to generate the overall wealth indices for each category respectively. The overall index (All) is divided into equal terciles representing poor, middle level and rich households respectively[44].

A choice of the best wealth index is made using clumping and truncation rules. Clumping occurs when the wealth index scores fail to follow a normal distribution. Truncation occurs when the wealth index scores are skewed (Krefis et al., 2010). A good wealth index avoids clustering of households and has the wealth indices spread out over a wide range so as to be able to give a clear picture of which group belongs to which wealth class. Problems of truncation and clumping can be addressed by using more variables to create the index (Howe et al., 2008; Vyas and Kumaranayake, 2006). The PCA results are presented in section 5.5.3.

[44] The categories poor, middle and rich simply represent households in the lowest 33%, middle 33% and top 33% of the wealth index. The division is similar to that used by Filmer and Pritchett (2001).

5.4 Duration analysis

In addition to investigating the factors that affect a beneficiary's decision to drop out from the smallholder drip irrigation project, an analysis will be done to account for timing effects on drop out decisions by smallholder farmers. This type of analysis is known as survival or duration analysis (Läpple and van Rensburg, 2011). Duration analysis has been used by researchers such as Alcon et al. (2011), D'Emden et al. (2006) and Läpple (2010) to investigate agriculture related issues such as adoption of organic farming, conservation tillage and drip irrigation technology. Studies have also used duration analysis to analyse the welfare impact from agriculture (Carletto, Kirk, Winters & Davis, 2010). Duration analysis is important in this study as it will help establish how long a beneficiary lasts in the project before they drop out. The results of this analysis can assist organisations who implement smallholder drip irrigation projects as well as policy makers in deciding whether or not to continue with this type of intervention or to channel their efforts elsewhere.

Duration analysis is mainly concerned with determining the risk or hazard that an event will occur in the next subsequent period, conditional on the event not having occurred yet at the time that the subject is observed (Cleves, Gould & Gutierrez, 2010). In this research duration analysis will determine the chances that a beneficiary will discontinue the use of drip irrigation or drop out in the next year, given that the beneficiary was still using drip irrigation in the previous year, for each of the 10 years (2003-2013) under study. In addition, duration analysis will be used to compare time-to-event for different groups of beneficiaries using characteristics such as age groups, gender and location. The influence of covariates on the length of the adoption period will also be examined.

Beneficiaries are all observed from the starting time (when they received the drip irrigation kit and began using it) to the time of failure (when they stopped using the drip kit). The starting time varies from 2003 to 2007 and time of failure also varies as beneficiaries began using the kit and dropped out at different times respectively. The duration (T), which is also the survival time, therefore takes the values 1-10 years and the failure (F) takes the values 1 if the beneficiary drops out within the observation period and 0 otherwise. The beneficiaries who do not drop out within the observation period are right censored because the duration they last in the project, though unknown, is greater that the observation time (Cleves et al., 2010; Kleinbaum and Klein, 2005).

Two important outcome functions of survival analysis are the survival $S(t)$ and hazard functions $h(t)$. The hazard function $h(t)$ is the conditional probability that a beneficiary who is still using drip irrigation at time t stops using it in the next interval and is given by equation (5.16) below:

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \leq T < t + \Delta t | T \geq t)}{\Delta t}$$

$$= \lim_{\Delta t \to 0} \frac{\mathrm{F}(t + \Delta t) - F(t)}{\Delta t(1 - F(t))} = \frac{f(t)}{S(t)} \qquad (5.16)$$

where Δt is the next short interval in which the beneficiary can choose to drop out, $f(t)$ is the continuous density function and $F(t)$ is the cumulative density function The survival function $S(t)$ on the other hand is the probability that T exceeds the specific time t. This is, in other words, the probability that the beneficiary continues to use the drip kit beyond time t. $S(t)$ is given by the equation below.

$$S(t) = \exp\left\{-\int_0^t H(s)ds\right\}$$

$$= 1 - F(t)$$

$$= \Pr(T \geq t) \quad (5.17)$$

(Alcon et al., 2011; Kleinbaum and Klein, 2005).

Specification of for the hazard function $h(t)$ is separated into the baseline part $h_0(t, \theta)$, common to all individuals, and the part that is determined by the covariates, $\exp(X, \beta)$ (allowing for heterogeneity in responses). This is shown in equation (5.18) below:

$$h(t, X, \theta, \beta) = h_0(t, \theta)\exp(X, \beta) \quad (5.18)$$

X is a vector of explanatory variables, β is the unknown parameter vector for X and the independent baseline hazard function is $h_0(t, \theta)$. The hazard function, commonly known as the proportional hazard can either be modelled by non-parametric, parametric or semi-parametric methods (Alcon et al., 2011). Following work by Alcon et al. (2011), Burton et al. (2003) and Dadi et al. (2004), all the three formulations are employed in this research to identify the determinants of the length of the adoption period. This will allow a choice to be made of the most appropriate model to represent the data in use. The methods are discussed in detail below.

5.4.1 Non- parametric models

Non-parametric methods make very few assumptions about the survivor function and the form of the hazard function. In this case, the assumptions made are that survival chances are the same regardless of when the beneficiary received their kit and that dropping out occurs in the year specified. Non-parametric methods are advantageous as they allow the data to form its own patterns. The estimators are easy to calculate and interpret. The main drawback of non-parametric models is that they do not incorporate covariates. Estimates of the non-parametric model can be used however to compare across different groups of explanatory variables such as age, education and gender, past a certain time (Brown, 2012; Cleves et al., 2010; Goel, Khanna & Kishore, 2010).

The Kaplan-Meier (KM) method is the non-parametric method that is used in this research. KM method approximates a survival function which measures the probability that one will survive past a certain time (t_j). This probability is known as the survival estimate, $\hat{S}(t)$. The survival estimate is based on partial information for the beneficiaries as some beneficiaries were still using the drip kit at the time the survey was conducted. In the presence of ordered failure times(t_j) such that $t_{(1)} \leq t_{(2)} \dots \dots \leq t_{(n)}$, the KM estimator of $\hat{S}(t)$ is given by :

$$\hat{S}(t) = \hat{S}\left(t_{(j-1)}\right) \; x \, \Pr(T > t_{(j)} | T \geq t_{(j)}) \qquad (5.19)$$

which is the probability of not experiencing the failure event up to the previous failure time, ($t_{(j-1)}$) multiplied by the conditional probability of lasting past time $t_{(j)}$ provided one has lasted up to time $t_{(j)}$. The KM estimator accounts for right censored observations (those who have not yet experienced the failure at the time of observation) in estimating $\hat{S}(t)$ (Cleves et al., 2010, Mills, 2011; Rabe-Hesketh & Everitt, 2007).

5.4.2 Testing the difference between two or more survivor functions

The survivor function $\hat{S}(t)$ is estimated according to districts, gender, age groups and according to the year the beneficiaries received their kit. The log rank test is the main test that is used to determine whether there is a significant difference in survivor functions between groups. Other variations of the log rank test; the Flemington-Harrington, Wilcoxon-Breslow, Tarone-Ware and Peto tests will also be used to verify the results.

All the above tests are based on the null hypothesis (H_0) that the survivor functions for the different groups (e.g. males versus female) are equal against the alternative (H_1) of no equality. All the tests are constructed on the Chi-square (χ^2) distribution with 1 degree of freedom (df) if there are 2 survivor curves being compared and *G*-1 df for more than 2 groups. *G* here represents the number of survivor curves being compared. The tests are described in detail in the section below (Kleinbaum and Klein, 2005; Knoke, 2011).

The Log rank test

The log rank weighted test statistic is given by the equation below:

$$\log rank\ \ statistic = \sum_j (r_{ij} - e_{ij}\ ) = \frac{\left(\sum_j w(t_j)(r_{ij} - e_{ij})\right)^2}{var(\sum_j w(t_j)(r_{ij} - e_{ij})} \qquad (5.20)$$

where $w(t_j)$ is the weight at failure time j (Kleinbaum and Klein, 2005; Knoke , 2011).

The Wilcoxon test

The Wilcoxon test gives more weight to earlier failure times and uses the number of subjects at risk at time j , n_j as a weighting factor for the j^{th} failure time.

The Tarone-Ware test

Similar to the Wilcoxon test, the Tarone-Ware tests also gives more weight to earlier failure times and uses the square root of the number of individuals at risk at time j , $\sqrt{n_j}$ as a weighting factor for the j^{th} failure time.

The Flemington-Harrington test

The Flemington-Harrington test is a more variable test that allows one to choose whether to focus on earlier or later failure times. The j^th failure time in this case is weighted by the survival estimate from the KM for all groups, $\hat{S}(t_{j-1})^p[1-\hat{S}(t_{j-1})^q]$. When $p=1$ and $q=0$ or $p=0$ and $q=1$, then the Flemington-Harrington test lends more weight to earlier and later failure times respectively[45]. When both p and q are equal to 0, the Flemington- Harrington test is equivalent to the log-rank test (Kleinbaum and Klein, 2005).

The Peto test

The Peto test is akin to the Flemington-Harrington test in that it weighs the j^th failure time using the survival estimates. The difference is that the Peto test uses the combined survival estimate $\tilde{S}(t_j)$ for all the groups which is similar but not equal to the KM survival estimate used by the Flemington-Harrington test (Kleinbaum and Klein, 2005 ; Knoke , 2011).

5.4.3 Parametric methods

Parametric methods assume that the baseline hazard $h_0(t)$ varies according to a specific functional form with time. Parametric methods are advantageous in that it is simple to incorporate explanatory variables in these models. The results also generate a value for $h_0(t)$ which allows one to compute specific rates. In addition, parametric methods smooth "noisy' data, making the analysis more flexible and robust. This also makes the identification of patterns within the data easier. The main limitation of parametric methods is that they impose the most structure on the data. This gives rise to the need to confirm and ensure that the imposed distribution tallies with the actual data (Alcon et al., 2011; Brown, 2012; Läpple, 2010).

[45] p and q values are chosen by the researcher depending on whether they want to give more weight to earlier or later failure times (Kleinbaum and Klein, 2005).

According to Alcon et al. (2011), the most common parametric methods used are based on the exponential and Weibull models. In the exponential model, $h_0(t)$ is constant over time. For the Weibull model, $h_0(t)$ can either be monotonically increasing or decreasing over time. The only variation in these models comes from the inclusion of covariates. The hazard and survivor functions for the exponential model are given by:

$$h(t) = \lambda \tag{5.21}$$

$$S(t) = exp\ (-\lambda\ ) \tag{5.22}$$

where λ is the time independent constant and $\lambda > 0$. The hazard and survivor functions for the Weibull distribution are given by:

$$h(t) = \lambda p t^{p-1} \tag{5.23}$$

$$S(t) = exp\ (-\lambda\ t^{p}) \tag{5.24}$$

If p>1 (or p<1) then $h_0(t)$ increases (decreases) over time. When p=1, the Weibull model becomes an exponential model (Alcon et al., 2011; Cleves et al., 2010; Läpple, 2010).

5.4.4 Goodness of fit tests for parametric models

The appropriateness of the functional form of the Exponential and Weibull models will be measured using and the Akaike information criterion (AIC). The AIC utilises the log likelihood value and is used to evaluate between nested and non-nested models. The AIC information criterion is given by:

$$AIC = -2(\log\ \ L) + 2\ (c + p + 1) \tag{5.25}$$

where c and p are the number of explanatory variables and structural parameters in the model respectively. When comparing between models, the model with a lower AIC is preferred over one with a higher AIC (Mills, 2011).

5.4.5 Semi-parametric models

Under semi-parametric models for survival analysis, the hazard function is decomposed into two parts, the baseline hazard and the exponential effect of the covariates.

The unstratified Cox model, known as the proportional hazards (PH) model is used in this study. The PH assumption arises from the fact that the baseline hazard, which is always positive, is influenced only by time and not by the covariates. The exponential effects of the covariates[46] on the other hand are not affected by time. The hazard and survival functions for the Cox model at time t are thus given as:

$$h(t,X) = h_0(t)e^{\sum_{i=1}^{n}\beta_i X_i} \tag{5.26}$$

$$S(t,X) = [S_0(t)]^{e^{\sum_{i=1}^{n}\beta_i X_i}} \tag{5.27}$$

where $h_0(t)$ is the baseline hazard and $e^{\sum_{i=1}^{n}\beta_i X_i}$ is the exponential of the sum of the product of all the coefficients (β) and the explanatory variables (X) where $X = X_1, X_2 \ldots \ldots, X_n$. The Cox model is based on the assumption that $h_0(t)$ is unspecified, unlike the exponential and Weibull models where $h_0(t)$ is constant or monotonic over time respectively. Thus the Cox model is semi-parametric in that $h_0(t)$ is unspecified whereas the covariates are parameterised through β. The advantage of using the Cox model lies in the fact that this model is suitable when one is not entirely certain about the functional form of the data in question, which is often the case. The Cox model gives a good approximation of the correct

[46] Time dependent covariates can also be used in an extended Cox model which will not be a PH model (Kleinbaum & Klein, 2005).

parametric form of the data as well as reliable estimates of the coefficients of the covariates, hazard ratios and survival curves. If the data follows an exponential or Weibull form, Cox model results will generally be similar to results obtained from estimating the parametric models (Cleves et al., 2010; Kleinbaum & Klein, 2005).

Assuming that the data allows two subjects to fail at the same time, this study will estimate the Cox model using Breslow and Efron's methods for ties. These two methods differ mainly by the way they treat estimate the second failure for tied[47] failures (e.g. two farmers both dropping out in year 2). Given that we have two subjects (A_1 and A_2) who experience the failure within the same year and A_1 experiences the failure event before A_2, then the Breslow method gives the impact on the likelihood of dropping out as: $A_{12} + A_{21} = \frac{2r_1r_2}{(r_1+r_2+r_3)^2}$ where A_{12} and A_{21} simply signify that A_1 experience the failure event first before A_2 who experiences it after A_1 but in the same time period (t=2). $r_1 + r_2 + r_3$ is the risk set (subjects who have not yet experienced the failure) at each time period (t=1, 2,3). The sequence here of events does not matter as both observations in all failure periods have a common denominator. This approximation is suitable for data with fewer failures in the risk set relative to the overall size of the risk set.

The Efron method, changes to the risk set due to past failures are accounted for by using the average of the sets as a denominator for the second risk set. Considering the 2 failures occurring at t=2 in the above explanation the impact on the likelihood of dropping out is given by: $A_{12} + A_{21} = \frac{2r_1r_2}{(r_1+r_2+r_3)\{\frac{1}{2}(r_1+r_2)+r_3\}}$.

[47] Tied failures assume that if two subjects experience the failure event in the same time period, say both farmers drop out of the smallholder drip irrigation project in year 2, they do not drop out at the exact same time. Considering this, Breslow and Efron's methods assume that the farmer who drops out second cannot have the same risk or hazard as the farmer who drops out first. So they correct for this.

The Efron method is thus more precise than the Breslow method. In both these methods, the effects of the covariates are constant for all subjects but the baseline hazards differ according to the groups of ties (Cleves et al., 2010; Public Policy 604).

5.4.6 Goodness of fit tests for the Cox models

5.4.6.1 Testing the PH assumption

The PH assumption will be tested for the Cox models using Schoenfeld's global test for the null hypothesis that the slope of the residuals versus the duration is flat (i.e equal to 0 or horizontal). Failure to reject H_0 indicates that the PH assumption is valid. The Schoenfeld residuals for dropping out at time t are given by:

$$U_i(t) = X_i(t) - \bar{X}(t) \quad (5.28)$$

where $X_i(t)$ is the vector of covariates, i is the subject and $\bar{X}(t)$ is the weighted average of the explanatory variables over the risk set at time t for across all subjects and

$\bar{X}(t) = \frac{\sum_j^n X_j(t) Y_j(t) \exp(\hat{\beta}' X_j(t))}{\sum_j^n Y_j(t) \exp(\hat{\beta}' X_j(t))}$. $Y_i(t)$ is a dummy variable represented by the value 1 if the subject is at risk and 0 otherwise and $\hat{\beta}$ are the estimated regression coefficients for the explanatory variables. In addition to using the results of the global test, a graphical representation of the Schoenfeld residuals will also be used to allow the detection of other types of non-proportionality that cannot be detected by the Schoenfeld test but are easily visible in a graph. If the PH assumption is not violated, the Schoenfeld residuals for each covariate should form a horizontal line (Abeysekera and Sooriyarachchi, 2009; UCLA, n.d).

If the global test indicates that the PH assumption is violated, the individual explanatory variables will be examined to identify the variable contributing to the violation of the PH assumption. The identified variables will then be tested for time dependence implied by the violation of the PH assumption. A new Cox model with all the covariates and including time interaction effects of the variables that have violated the PH assumption using Stata's *tvc* and *texp* functions will be estimated. The *tvc* command specifies the independent variables which violate the PH assumption and thus vary with time. The *texp* command specifies the functional form of the time variable that will be used to interact with the variables identified by *tvc*. In this study, three specifications of time used are the linear, log and exponential forms (UCLA, n.d).

The likelihood ratio (LR) test will be used to collectively test the PH assumption for all the time varying independent variables. The LR test- statistic below:

$$LR = 2(\mathcal{L}_{UR} - \mathcal{L}_{R}) \tag{5.29}$$

where $\mathcal{L}_{UR}$ is the log-likelihood of the unrestricted Cox model (containing all the explanatory variables including the time interaction variables) and $\mathcal{L}_{R}$ is the log-likelihood of the restricted Cox model (containing all the covariates without the interaction variables). The LR test follows the χ^2 distribution with degrees of freedom (df) equal to the difference between the number of independent variables in the unrestricted and restricted models. In order for the PH assumption to hold, the time varying covariates must not be significant in the unrestricted model (Abeysekera and Sooriyarachchi, 2009; Jones, 2005; Rabe-Hesketh and Everitt, 2007; UCLA, n.d; Wooldridge, 2000).

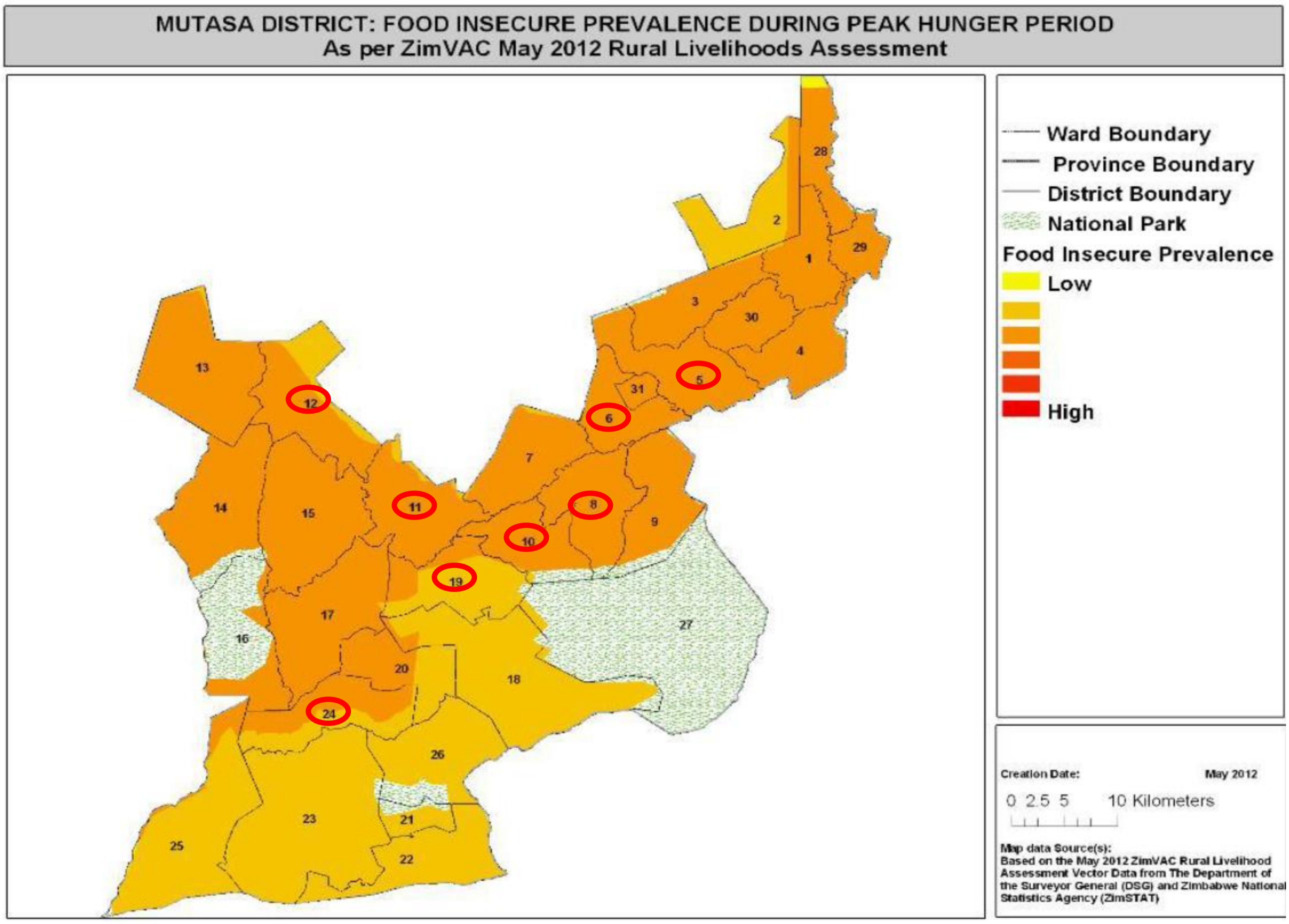
5.4.6.2 Overall goodness of fit for the model

The Cox-Snell residuals (CS) will be used to evaluate the fit and non-linearity of the Cox model as well as the fit of the exponential and Weibull models. The CS residuals will be estimated in Stata 12, using the *stset*, *mgale* and predict *CS* commands. If the approximated KM or Nelson-Aalen cumulative hazard function follows the 45° line then the model fits the data well (UCLA, n.d). In this study, the Nelson-Aalen cumulative hazard will be used.

5.5 Results and discussion

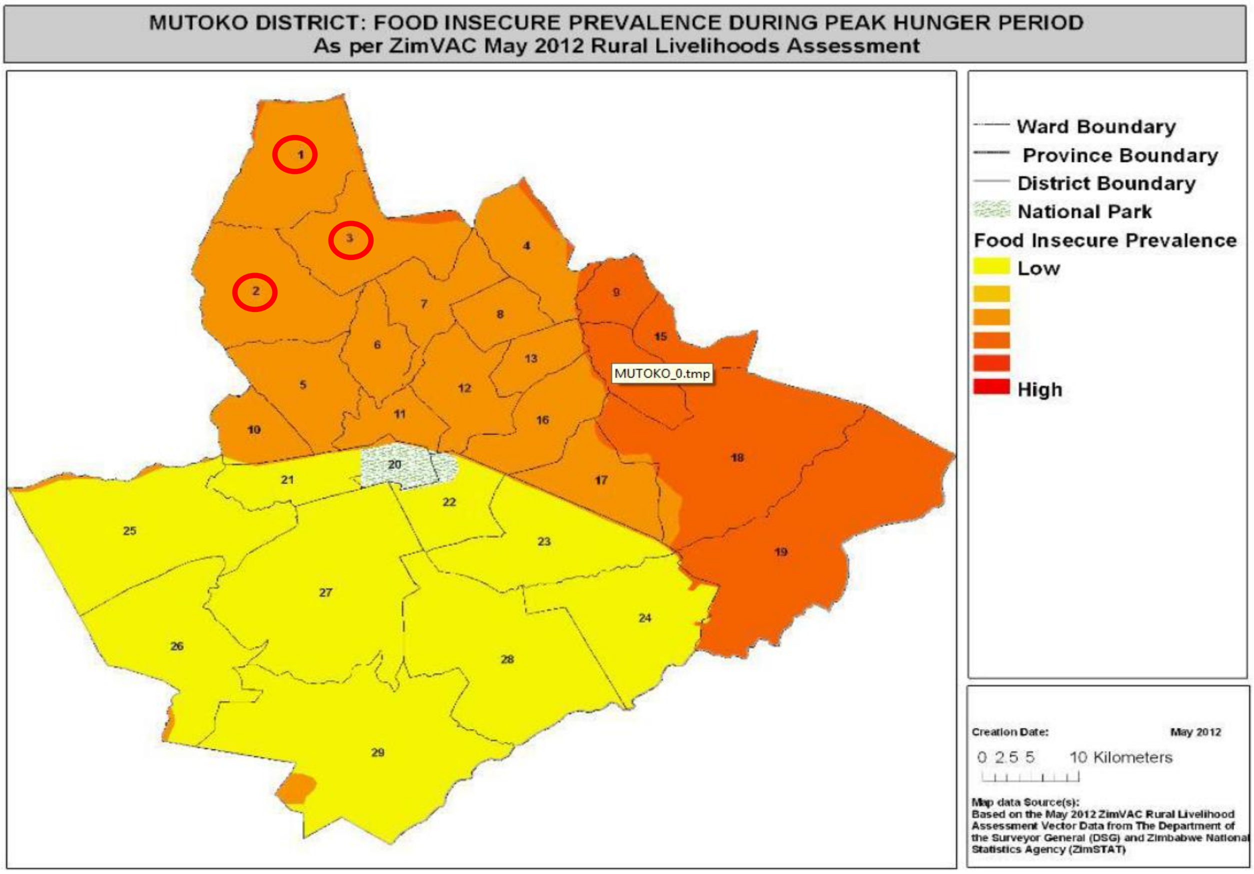
The results below are for smallholder drip irrigation farmers in Mutasa and Mutoko districts of Zimbabwe. 8 out of a total of 14 wards that benefited from the smallholder drip irrigation program through Plan International in Mutasa district were chosen for the survey. Only 3 wards were selected in Mutoko district because Plan International implemented the project in these 3 wards only. Figure 5.2 and Figure 5.3 below shows the location and prevalence of food insecurity in the wards sampled in Mutasa and Mutoko districts.

Figure 5.2: Mutasa map showing the wards and levels of food insecurity



Source: ZimVac, 2012

Figure 5.3: Mutoko map showing the wards and levels of food insecurity



Source: ZimVac, 2012

More information on Mutasa and Mutoko districts is in Chapter 4, section 4.3.1.

5.5.1 General descriptive analysis

A total of 170 beneficiaries were interviewed. 48% and 52% were from Mutasa and Mutoko districts respectively. Table 5.2 below show that in Mutasa district, the largest numbers of beneficiaries interviewed were from livelihood zones 2 and 4 (38% and 27% respectively).

Table 5.2: Beneficiaries distribution Mutasa district

Ward	Natural Farming Region[48]	Frequency	Percentage
Sadziwa (12)	Natural region IIb	16	19%
Gondenyakudyara (24), Sanyamandwe (11)	Natural region IIb, moderately affected by mid-season droughts	31	38%
Doweguru (19)	Natural region IIb. Low temperatures with frost incidents	8	10%
Samanga A(6), Sahumani(8), Samaringa (10)	Natural region 1 with high temperatures	22	27%
Muparutsa (5)	Natural region 1, fast growing area	5	6%
Total		**82**	**100%**

**Ward number in parenthesis*

For Mutoko district, approximately half (47%) of the beneficiaries interviewed were from Charehwa A ward and the least number of beneficiaries interviewed were from Charehwa B ward as shown in Table 5.3 below.

Table 5.3: Beneficiaries distribution Mutoko district

Ward	Natural Farming Region	Frequency	Percentage
Charehwa A (3)	Natural farming region III	41	47%
Charehwa B (1)	Natural farming region III	19	21%
Chindenga (2)	Natural farming region III	28	32%
Total		**88**	**100%**

**Ward number in parenthesis*

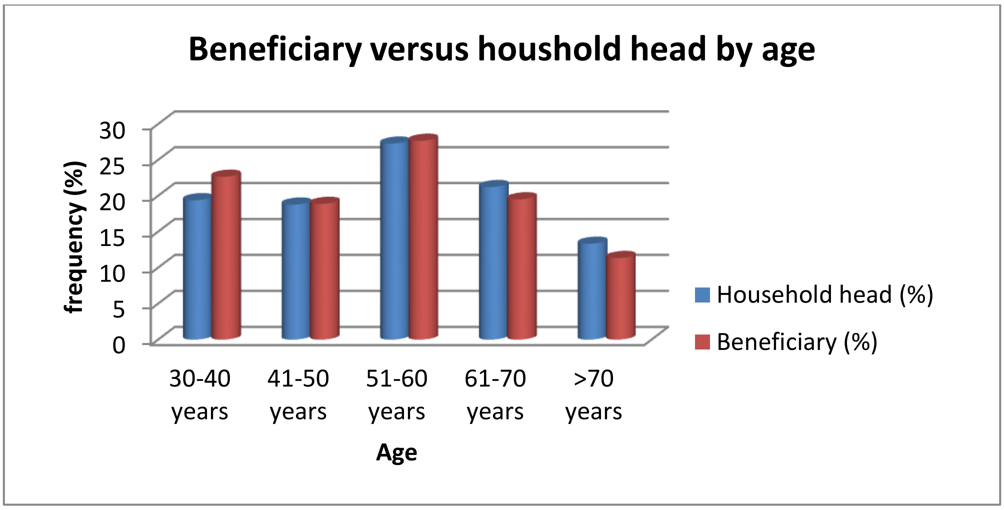
[48] As indicated in section 4.2, Zimbabwe is divided into 5 different natural farming regions or ecological zones based mainly on the amount of annual rainfall each area receives, the vegetation and the soil type.

64% of the interviewees were the household heads and 33% were spouses of the household heads. All the beneficiaries interviewed used the smallholder drip irrigation kit at some point and approximately 12% are still using the drip kit to date.

- **Household head and beneficiary characteristics**

The age of the household head ranges from 30 to 103 years. This is also the same age range for the beneficiary which is expected given that an estimated 71% of the beneficiaries are also the household head. Figure 5.4 shows that there is an almost even distribution of household heads and beneficiaries in each age category. The most common age range of the household heads and beneficiaries is between 51 and 60 years old. This is the expected age range given that the project targeted widows and household looking after orphans (which tended to be households managed by elderly relations). In addition, many people move to their rural homes when they become elderly.

Figure 5.4: Distribution of household heads and beneficiaries according to age



In terms of gender, an estimated 28% of the households are female headed whilst 72% are headed by males. An almost equal number of females and males benefited from the smallholder drip irrigation project (46% female and 54% male). All the household heads and beneficiaries in the sample have been married. 69% and 72% of the household heads and beneficiaries are currently married, 1% and 2% are currently divorced and 30% and 26% are widowed respectively.

Distribution in terms of education levels of both the household heads and beneficiaries are fairly similar, with a large number having completed primary level education (51% of the household heads and 53% of the beneficiaries). Less than 3% of the household heads and beneficiaries in the sample completed tertiary education as shown in Table 5.4 below.

Table 5.4: Completed education levels of household heads and beneficiaries

Completed education level	**Household head (%)**	**Beneficiary (%)**
none	5%	5%
primary	51%	53%
secondary	42%	40%
tertiary	2%	2%
Total	100%	100%

Most of the household heads (75%) and beneficiaries (82%) have farming as their main occupation.

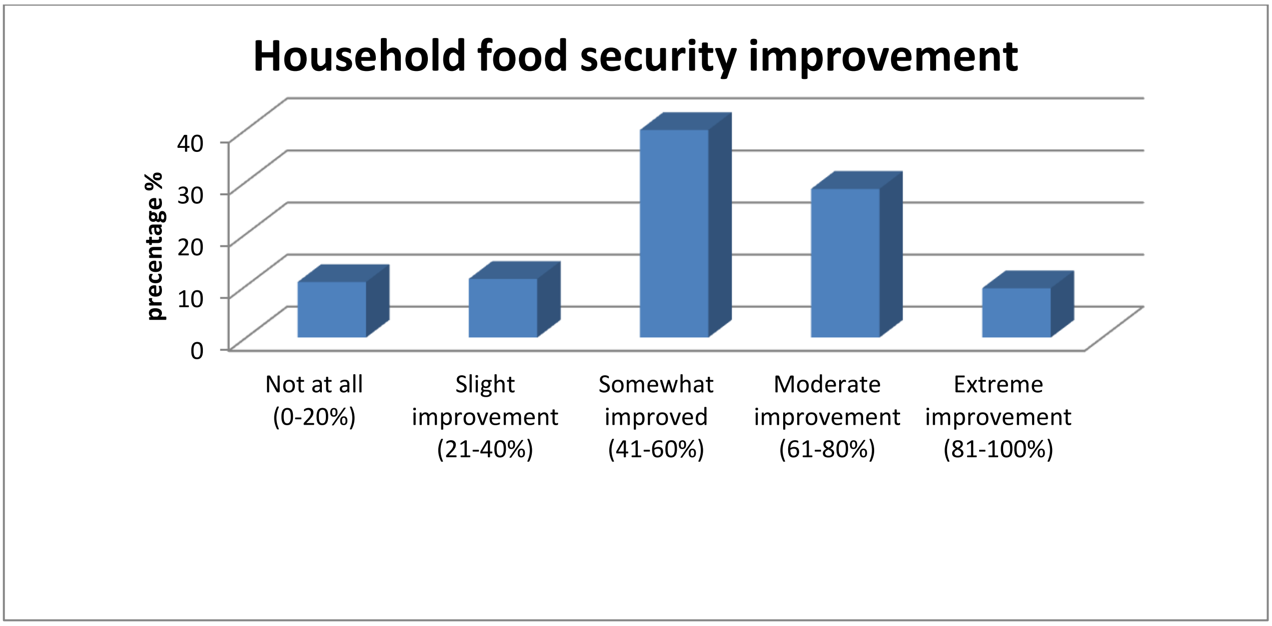
- **Self-rating of drip irrigation knowledge**

Generally the beneficiaries have grasped the concept of drip irrigation with 91% indicating that they rate the knowledge they possess to be average or better. Only 7% of the beneficiaries professed to have below average knowledge of drip irrigation respectively. 2% of the beneficiaries failed to rate their knowledge of drip irrigation.

- **Food security status**

Beneficiaries were asked to give a self-rating of how much their household food security improved during the time they were using drip irrigation compared to before , based on their consumption of irrigated crops. A Likert scale was used to enable the beneficiaries to place their food security improvement in one of 5 categories. For ease of explanation, each category represented 20%. Beneficiaries whose food security did not improve or who realised a very small improvement were in the nothing or very small improvement category (0-20%). The other 4 categories followed on from this as shown in Figure 5.5 below.

Figure 5.5: Changes to the household food security status[49] of beneficiaries



Overall, 40% of the beneficiaries indicated that their food security status somewhat improved after they began using the drip kit. However approximately 11% indicated that there was

[49] All the beneficiaries whose household consumption of garden crops (food security) worsened during the time they used drip irrigation compared to before are included in the “not at all’ category for 0-20% improvement.

hardly any improvement in their household food security. Other general descriptive statistics are provided in Appendix C1.

5.5.2 Descriptive analysis for dropouts

88% of the beneficiaries dropped out of the drip irrigation project. Dropouts by district indicate that there were more dropouts in Mutoko (93%) than Mutasa (82%) districts. A higher proportion of male beneficiaries dropped out compared to female beneficiaries, as shown in Table 5.5 below. Research has shown that in agriculture, cropping practices are divided according to gender. Males tend to focus on cash crops whilst females tend to focus on subsistence crops (Kooman, 1993; Kumar 1987; Randolf, 1988 cited in Doss, 1999). This means that males are more likely to drop out of smallholder drip irrigation at a faster rate than women especially if they fail to realise the expected profits.

Table 5.5: Dropouts by gender

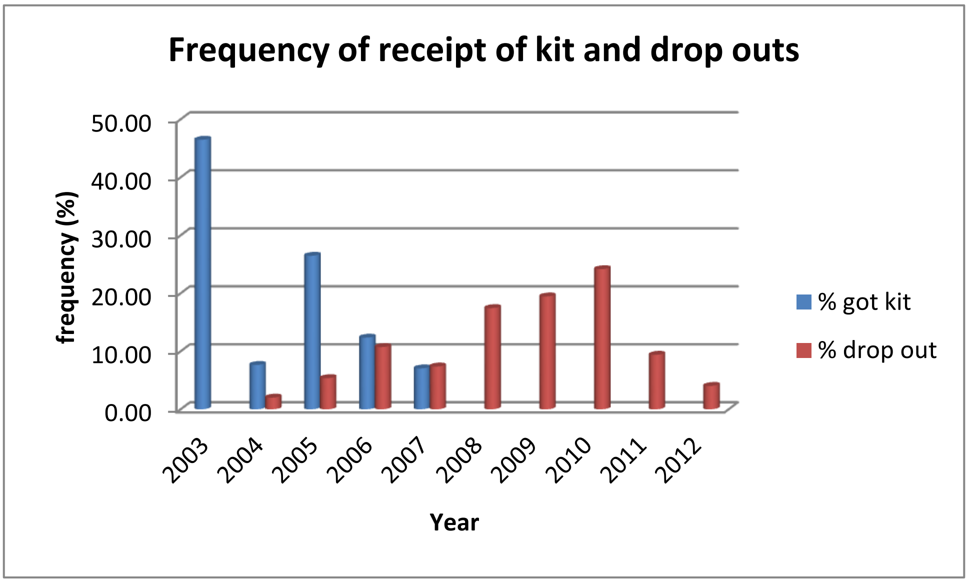
	dropout		
gender	**yes**	**no**	**total**
female	83%	17%	100%
male	91%	9%	100%
total	**88%**	**12.%**	**100%**

Slightly more beneficiaries with primary education and below (88%) dropped out of the drip irrigation project compared to those with secondary education and above (84%).

Figure 5.6 below shows the distribution of dropouts according to the year the beneficiaries received the kit and the year they stopped using the kit. The information shows that almost half of the beneficiaries received the drip kit in 2003 (46%) and only 7% received the kit in

2007. Most of the beneficiaries dropped out of the project between 2008 and 2010 (61%). This could have been as a result of the poor economic environment in Zimbabwe around 2008 (Richardson, 2013). In addition, food was scarce and most food had to be imported. The local Zimbabwean currency was no longer a match for foreign currency and thus a lot of people had to migrate in order to make a living. Harvests were also poor due to erratic rainfall and all impacted negatively on the drip irrigation project. Water shortages meant farmers has to travel longer distances to fetch water thus making the project less viable. In 2009, however, Zimbabwe adopted the US dollar as its official currency (Richardson, 2013). This may have prompted the drop outs in 2010 as alternative forms of employment offered better returns than market gardening. Dropout rates were lowest in the early years of the project life (e.g. 2% dropped out in 2004).

Figure 5.6: Year the beneficiary received the kit and dropped out of the project



More descriptive statistics are presented in Table 5.6 in below and in Appendix C1.

Table 5.6: Descriptive statistics

Continuous variables		**mean**	**std.dev**
distancefromgdn	distance of irrigation water source from the garden	108.61	235.89
benefage	age of the beneficiary	53.75	13.37
hhdmembers	number of household members	6.31	3.31
childbelow5	number of children below the age of 5	0.64	0.90
landsize	size of land owned by the household	2.05	2.07
Dummy variables		**frequency**	**%**
Main			
dropout6year	beneficiary dropped out of the project within a 6 year period	128	75%
dropout	beneficiary dropped out of the project between 2003 and 2013	149	88%
earlyadopt	early adopter, received the kit in 2003 or 2004	92	54%
irrigwatertap	beneficiary uses tap, borehole, well or spring water for irrigation	62	36%
yieldincgdn	yields of garden crops increased during the drip irrigation phase	142	84%
Cropping			
leafyvegyldinc	yields of leafy vegetables increased during the drip irrigation phase	86	51%
tomatoyldinc	yields of tomatoes increased during the drip irrigation phase	96	56%
onionyldinc	yields of onion increased during the drip irrigation phase	71	42%
beansyldinc	yields of beans increased during the drip irrigation phase	72	42%
maizeyldinc	yields of maize increased during the drip irrigation phase	64	38%
gnutyldinc	yields of ground nuts increased during the drip irrigation phase	40	24%
Training			
bookkeep	beneficiary received training in book keeping	49	29%
marketing	beneficiary received training in marketing	32	19%
permaculture	beneficiary received training in permaculture	66	39%
masterfarmer	beneficiary received master farmer training	100	60%
croping	beneficiary received training on cropping practices	20	12%
Problems			
waterprob	water shortage problems, water source too far an problems filling the tank	101	59%
noprofitprob	problems poor markets and no profit	45	26%
labourinputprob	problems with accessing labour and acquiring inputs	57	34%
Beneficiary characteristics			
benefmale	beneficiary is male	92	54%
benefprimarylev	beneficiary has primary level and below education	93	58%
benefmarried	beneficiary is married	124	73%
benefarmer	beneficiary's main occupation is farming	127	75%
benefgrpmember	beneficiary is a group member	110	65%
Household			
remittance	received remittances from within and outside Zimbabwe	64	38%
orphan	beneficiary household looked after orphans last year	59	35%
chronillmember	member of the household suffers from chronic illness	65	38%
mutasa	beneficiary is from Mutasa district	82	48%
fdsecbelowaverage	beneficiary subjectively rates the improvement in their food security status to below average (<40%)	104	62%
middle	beneficiary is from a household in the middle 33% of the wealth index	56	33%
rich	beneficiary is from a household in the top 33% of the wealth index	56	33%

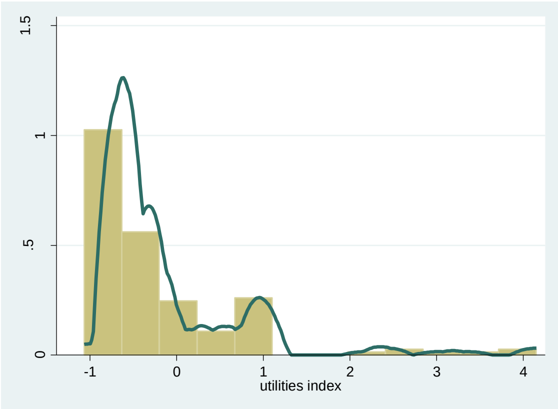
5.5.3 Wealth index results

Table 5.7: Principal component and summary statistics for asset indicators

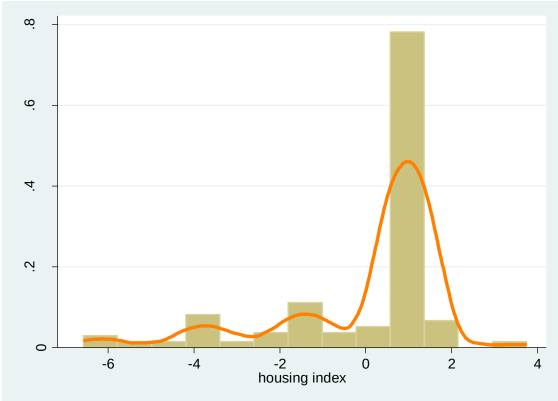
	scoring factors for PC1				summary statistics		rescaled overall	Means for each class		
utilities	**utilities**	**housing**	**durables**	**overall**	**mean**	**std.dev**	**index**	**poor**	**middle**	**rich**
pipedwtr	0.461			0.117	0.041	0.199	0.587	0.018	0.018	0.089
muntapwtr	-0.319			0.017	0.806	0.397	0.043	0.719	0.839	0.857
borholwell	0.098			-0.073	0.088	0.284	-0.257	0.175	0.054	0.036
flushtoil	0.030			-0.038	0.029	0.169	-0.223	0.053	0.018	0.018
pittoil	0.025			0.081	0.929	0.257	0.315	0.860	0.946	0.982
notoilet	-0.058			-0.072	0.041	0.199	-0.362	0.088	0.036	0.000
sharetoilet	-0.011			0.020	0.153	0.361	0.056	0.088	0.250	0.125
lghtelectric	0.362			0.238	0.082	0.276	0.864	0.000	0.000	0.250
solarlght	-0.046			0.122	0.159	0.367	0.332	0.018	0.089	0.375
keroslmplght	-0.201			-0.143	0.512	0.501	-0.285	0.667	0.625	0.250
candlelght	0.032			-0.016	0.124	0.330	-0.047	0.105	0.179	0.089
otherlght	-0.001			-0.104	0.118	0.323	-0.322	0.211	0.107	0.036
cookelectric	0.517			0.106	0.012	0.108	0.982	0.000	0.000	0.036
ckfirewdoth	-0.480			-0.106	0.982	0.132	-0.804	1.000	1.000	0.964
housing characteristics										
singledwel		0.049		-0.018	0.047	0.212	-0.082	0.053	0.089	0.000
severaldwel		0.004		0.052	0.929	0.257	0.201	0.895	0.911	1.000
roomimprohse		-0.086		-0.068	0.018	0.132	-0.518	0.053	0.000	0.000
earthsndwd		-0.384		-0.252	0.159	0.367	-0.686	0.474	0.000	0.000
cementiles		0.376		0.251	0.818	0.387	0.649	0.491	0.982	1.000
floorother		-0.023		-0.029	0.018	0.132	-0.220	0.035	0.018	0.000
rfthatchwd		-0.425		-0.274	0.153	0.361	-0.758	0.456	0.000	0.000
roofasbest		0.420		0.264	0.835	0.372	0.711	0.544	1.000	0.982
roofother		-0.005		0.024	0.006	0.077	0.309	0.000	0.000	0.018
nobamstnwall		-0.304		-0.161	0.047	0.212	-0.756	0.140	0.000	0.000
wallbricks		0.337		0.209	0.894	0.309	0.677	0.702	1.000	1.000
wallother		-0.163		-0.128	0.053	0.225	-0.569	0.158	0.000	0.000
rooms		0.254		0.223	5.077	2.517	0.088	3.789	4.661	6.804
sleeprms		0.217		0.167	2.817	1.285	0.130	2.333	2.643	3.482
durable assets										
electricty			0.295	0.238	0.088	0.284	0.838	0.000	0.000	0.250
solar			0.205	0.145	0.598	0.492	0.295	0.298	0.679	0.821
radio			0.225	0.107	0.627	0.485	0.220	0.456	0.607	0.821
televisn			0.358	0.253	0.343	0.476	0.532	0.088	0.161	0.786
hmephne			0.307	0.160	0.018	0.132	1.207	0.000	0.000	0.054
refrigeratr			0.330	0.212	0.053	0.225	0.940	0.000	0.000	0.161
oxdrwncrt			0.221	0.137	0.259	0.439	0.313	0.053	0.304	0.429
mobilphne			0.116	0.117	0.906	0.293	0.400	0.772	0.964	0.982
bicycl			0.172	0.093	0.406	0.493	0.188	0.316	0.357	0.554
motorcycl			0.014	0.025	0.006	0.077	0.321	0.000	0.000	0.018
car			0.266	0.139	0.029	0.169	0.822	0.000	0.000	0.089
cattle			0.310	0.193	2.953	3.269	0.059	1.368	2.696	4.875
pigs			0.329	0.167	0.641	2.051	0.081	0.228	0.554	1.161
goats			0.135	0.052	2.806	2.612	0.020	2.351	2.321	3.804
sheep			0.143	0.058	0.429	2.081	0.028	0.228	0.214	0.857
poultry			0.274	0.192	13.565	22.069	0.009	5.263	7.946	26.089
donkey			0.048	0.013	0.076	0.462	0.028	0.070	0.036	0.125
otherlvst			0.046	0.058	0.606	3.062	0.019	0.140	0.321	1.375
landsize			0.056	0.044	2.047	2.072	0.021	2.074	1.730	2.369
Eigen value for PC1	2.66	3.836	3.313	5.538						
Share of variance for PC1	0.19	0.274	0.174	0.118						
Number of variables used	14	14	19	47						

Figure 5.7: Histogram and kernel densities for the distribution of asset indicators

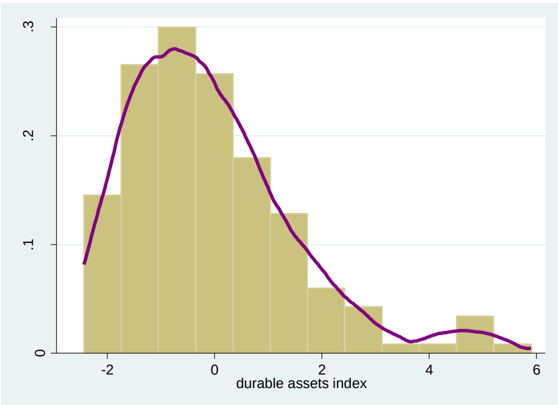
a. Distribution of utilities index



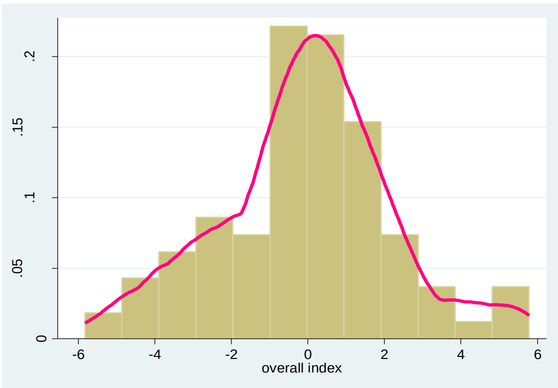
b. Distribution of housing index



c. Distribution of durable assets index



d. Distribution of overall index



5.5.3.1 Discussion of wealth index

As indicated in section 5.3.3, the Principal Component Analysis (PCA) method is used to generate a single wealth index for the households. Information from access to utility and infrastructure, household characteristics and durable asset variables is combined and weighted via PCA to generate several principal components. The first principal component is then used to generate the asset index (Filmer and Pritchett, 2001; McKenzie, 2005). The results are presented in Table 5.7 above. All the factors are fully described in Appendix C2.

Overall the results given in Table 5.7 are consistent over all the 4 indices for the relevant factors for the first principal component (PC1). Results from the overall index show that under the utilities section, scoring factors for piped drinking water and drinking water from a tap all contribute positively towards a household's wealth status. However the scoring factor for borehole water is negative which is also expected. In terms of the type of sanitary facilities available, scoring factors for both flushing toilets and no toilet facilities are negative which is unexpected. This however is due to the unreliable water supply in the rural areas which renders a pit toilet more effective (positive effect exhibited) than a flushing toilet, as discussed in Chapter 2 (section 2.7.2). Scoring factors for light sources and cooking fuel all exhibit the expected positive effect for better light and cooking fuel (electricity and solar) and negative effect for alternative sources such as candles, kerosene lamps and firewood.

For the housing characteristics category, roofing, walling and flooring materials of higher quality such as asbestos, bricks and cement all have positive scoring factors and lesser quality materials like thatch and earth have negative scoring factors as expected. The total number of rooms' available, number of rooms used for sleeping and the buildings being organised as several dwellings also have positive scoring factors as expected. All durable assets have positive scoring factors. All these results suggest that indeed PC1 gives a measure of the wealth of the household.

Based on the rescaled overall index (Table 5.7), cooking fuel, roofing, wall and flooring materials appear to have the greatest influence on the wealth index. In line with Filmer and Pritchett (2001) and McKenzie (2005)'s interpretations, the rescaled overall index represents a change from 0 to 1 in the variable such that for instance a household that owns a car has a higher asset index by 0.822 compared to a household that does not own a car. The highest negative contributor to the asset index is using firewood for cooking (-0.804) followed by having a thatched roof (-0.758), having a house with no walls (-0.756) and having a floor made of earth or wood (-0.686). The largest positive contributor is having a landline phone (1.207) followed by cooking with electricity (0.982) and owning a refrigerator (0.940). This shows that the greatest defining factor for wealth in the rural areas are the housing characteristics as evidenced by the PC1 for the housing characteristics alone, contributing the largest share of variation (0.274) compared to the other PC1's (utilities 0.190 ; durable assets 0.174). For the overall index, PC1 contributes only 0.118 of the variation. The correlation between the utilities, housing and durable asset indices with the overall index is 0.368, 0.789 and 0.801 respectively.

Results from Figure 5.7 show that when clumping (the wealth index scores are do not follow a normal distribution) and truncation (the wealth index scores are skewed) are considered, the best index is the overall index, which includes all the indicators. This index has a wider range than all the other indices and although clumping is evident, it is far less than that of the other three indicators. The distribution of the index here appears to be more normally distributed compared to all the other indices. The utilities and housing indices show clear evidence of clumping at lower and higher levels respectively. Truncation at higher levels (that is above 2) is also evident in both measures, suggesting that these indices might not contain all the necessary data required to differentiate between the households. There is also evidence of positive and negative skewness respectively. Although the durable assets index is much smoother compared to all the other indices, it covers a smaller range compared to the overall index and there is evidence of truncation at both lower and upper levels. In addition the durable assets index shows slight positive skewness. This indicates that using this index will not comprehensively differentiate between the households. The overall index is thus used to construct the wealth variables used in all the regressions in this study.

The households are grouped into 3 separate categories[50] (poor, middle and rich) based on the value of their overall wealth index. The cut off points for the categories are as follows:

Table 5.8: Cut-off points for the wealth categories

wealth class	min	max	no. of observations	percentage
poor	-5.824	-0.500	57	34%
middle	-0.453	0.848	56	33%
rich	0.852	9.427	56	33%

Using the analysis by Filmer and Pritchett[51] (2001), clear distinctions can be made for households in each class so the overall wealth index constructed for this study is quite consistent. From the results in Table 5.7, showing the means for the poor, middle level and rich households it is clear that the wealth index is driven by differences across the households in housing characteristics and durable asset ownership. For instance, 49% of the poor households have floors made of tiles and cement compared to 98% of the households classified as rich. 98% of the rich households tend to have asbestors roof as opposed to 54% of the poor households. None of the rich households have earth or wooden floors and thatched

[50] The households have just been divided into three equal portions using the wealth index. This follows the grouping by Filmer and Pritchett (2001) and the main difference is that Filmer and Pritchett's grouped the households as the poorest 40%, middle 40% and the top 20% whereas in this case each category comprises of 33% of the total households.

[51] Filmer and Pritchett (2001) tested the reliability of the wealth index by looking at coherence among the means of the different assets used to generate the wealth indices. They also checked for robustness of their final choice of wealth index by comparing the percentage of households classified in each wealth category across the different wealth indices. Clear differences between the poorest and richest groups and similar percentages across each wealth class indicate that the wealth index is reliable.

roofs. In terms of durable asset ownership, a clear distinction is there between poor and rich households pertaining to assets such as radios (46% versus 82% respectively) and televisions (9% versus 79% respectively). Clear distinctions between poor and rich households are evident in the number of cattle and poultry a household owns with rich households owning 5 cattle and 26 poultry on average compared to 1 cow and 5 poultry for poor households.

A comparison across all the four wealth indices (Table 5.9) shows that the classifications produced by the indices are very similar. The classification based on durable assets actually yields the same results as that based all assets.

Table 5.9: Classification of the poorest 33% using various indices

wealth class	**all**	**utilities**	**housing**	**durables**
poor	34%	44%	36%	34%
middle	33%	25%	39%	33%
rich	33%	32%	25%	33%
Total	100%	100%	100%	100%

However, the reliability of the overall index is compromised by the fact that distinctions between the middle level and rich households are not consistently apparent. For instance none of the middle level or rich households has earth and or wooden floors or thatched roofs. A similar percentage have tiled roofs (98% versus 100% respectively) and household in these two categories own more or less the same number of cattle (3 versus 5 on average for middle level and rich households respectively). This is a challenge that has been identified in other research of trying to distinguish wealth levels between rural households only or urban households only (Rutstein, 2008).

Despite this limitation, the wealth index constructed is sufficient for this research.

5.6 Empirical results

This section presents the results for the factors that lead to dropouts among beneficiaries of the smallholder drip irrigation project in Zimbabwe.

Tables 5.10a-5.11b give results of six Probit models which are estimated to identify the determinants of dropout decisions for smallholder farmers. Model 1 includes only those explanatory variables that are thought to be the major variables influencing drip irrigation dropout decisions. As indicated in section 5.3.2, the main variables influencing dropout decisions by smallholder drip irrigation farmers are timing of adoption (*earlyadopt*), access to water variables (*irrgwatertap* and *distancefromgdn*) as well as an outcome variable for yield increases realised by the farmer or beneficiary (*yieldincgdn*). These variables have been chosen based on other research which has indicated that timing of adoption and water access issues are important (Alcon et al., 2011; Kulecho and Weatherhead, 2005; Läpple and van Rensburg, 2011; Mugabe et al., 2008).The yield variable is also included as a main variable as it is assumed that smallholder farmers are rational as understood by economists in their decision making. So it is expected that beneficiaries who realise a yield increase (profit) in garden crops will remain in the project.

Models 2-6 include yield increase variables for individual crops, trainings received, problems faced and beneficiary and household characteristics respectively. Each category of variables is added to the model separately in order to determine the influence they have on the major variables (Model 1). As the goal of this research is to identify the determinants of dropout decisions in smallholder farmers, the discussion of the results will mainly focus on Model 6 (more comprehensive) and refer occasionally to the other models. Discussion will be based on the marginal effects (Tables 5.11a and 5.11b) as they give both the direction and magnitude of resultant changes expected in the probability of dropping out for a unit change in the explanatory variable for continuous variables and for a change from 0 to 1 for dummy variables.

Table 5.10a: Determinants of dropouts for smallholder drip irrigation famers

Dependent variable: Dropout (within a 6 year period)

	Model 1		**Model 2**		**Model 3**	
	coef	**se**	**coef**	**se**	**coef**	**se**
main variables						
earlyadopt	-0.415*	(0.217)	-0.397*	(0.225)	-0.400*	(0.240)
irrigwatertap	0.014	(0.228)	0.019	(0.235)	0.019	(0.248)
distancefromgdn	-0.001	(0.000)	-0.001	(0.000)	-0.001	(0.000)
yieldincgdn	-0.264	(0.317)				
yield increase per crop						
leafyvegyldinc			-0.543**	(0.253)	-0.559**	(0.270)
tomatoyldinc			-0.103	(0.257)	-0.140	(0.271)
onionyldinc			-0.002	(0.244)	-0.045	(0.253)
beansyldinc			-0.065	(0.245)	0.042	(0.255)
maizeyldinc			0.009	(0.262)	-0.070	(0.277)
gnutyldinc			0.314	(0.310)	0.371	(0.319)
training						
bookkeep					-0.548**	(0.262)
marketing					0.713**	(0.360)
permaculture					0.050	(0.247)
masterfarmer					0.210	(0.244)
croping					0.263	(0.391)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmemb						
household characteristics						
chronillmember						
orphan						
childrenbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembers						
remittance						
middle						
rich						
constant	1.197***	(0.336)	1.290***	(0.271)	1.207***	(0.331)
observations	165		165		165	

Standard errors in parentheses

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

Table 5.10b: Determinants of dropouts for smallholder drip irrigation famers

Dependent variable: Dropout (within a 6 year period)

	Model 4		**Model 5**		**Model 6**	
	coef	**se**	**coef**	**se**	**coef**	**se**
main variables						
earlyadopt	-0.440*	(0.244)	-0.561**	(0.264)	-0.478*	(0.290)
irrigwatertap	-0.023	(0.251)	-0.117	(0.273)	-0.070	(0.323)
distancefromgdn	-0.001	(0.001)	-0.001	(0.001)	-0.001	(0.001)
yieldincgdn						
yield increase per crop						
leafyvegyldinc	-0.609**	(0.277)	-0.505*	(0.297)	-0.555	(0.344)
tomatoyldinc	-0.176	(0.281)	-0.094	(0.300)	-0.149	(0.336)
onionyldinc	0.030	(0.260)	0.085	(0.274)	0.168	(0.312)
beansyldinc	0.162	(0.266)	0.239	(0.280)	0.233	(0.341)
maizeyldinc	0.043	(0.285)	0.070	(0.315)	0.142	(0.367)
gnutyldinc	0.243	(0.330)	0.360	(0.354)	0.793*	(0.445)
training						
bookkeep	-0.534**	(0.269)	-0.553*	(0.285)	-0.722**	(0.308)
marketing	0.706*	(0.372)	0.604	(0.386)	1.004**	(0.459)
permaculture	-0.025	(0.257)	-0.020	(0.272)	-0.050	(0.301)
masterfarmer	0.227	(0.251)	0.299	(0.271)	0.390	(0.307)
croping	0.076	(0.402)	0.129	(0.423)	0.227	(0.491)
problems faced						
waterprob	0.565**	(0.255)	0.503*	(0.269)	0.631**	(0.295)
labourinputprob	0.114	(0.276)	0.090	(0.284)	0.195	(0.320)
noprofitprob	0.037	(0.299)	0.009	(0.313)	-0.036	(0.376)
beneficiary characteristics						
benefmale			0.259	(0.290)	0.478	(0.359)
benefage			0.013	(0.013)	0.025	(0.017)
benefprimarylev			-0.084	(0.301)	-0.340	(0.349)
benefmarried			-0.138	(0.344)	-0.027	(0.383)
benefarmer			-0.257	(0.340)	-0.359	(0.381)
benefgrpmemb			0.131	(0.273)	0.036	(0.295)
household characteristics						
chronillmember					0.850**	(0.354)
orphan					-0.206	(0.308)
childrenbelow5					-0.256	(0.224)
fdsecbelowaverage					0.249	(0.305)
mutasa					-0.035	(0.379)
landsize					-0.039	(0.077)
hhdmembers					0.031	(0.060)
remittance					-0.043	(0.341)
middle					-0.613	(0.402)
rich					-0.868**	(0.391)
constant	0.894**	(0.372)	0.206	(0.805)	-0.361	(1.039)
observations	165		154		152	

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

Table 5.11a: Marginal effects for determinants of dropouts for smallholder drip irrigation famers

Dependent variable - dropoutA (within a 6 year period)

	Model 1		**Model 2**		**Model 3**	
	margins	**se**	**margins**	**se**	**margins**	**se**
main variables						
earlyadopt	-0.125*	(0.064)	-0.114*	(0.063)	-0.108*	(0.063)
irrigwatertap	0.004	(0.069)	0.006	(0.067)	0.005	(0.067)
distancefromgdn	-0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)
yieldincgdn	-0.079	(0.095)				
yield increase per crop						
leafyvegyldinc			-0.156**	(0.070)	-0.151**	(0.071)
tomatoyldinc			-0.029	(0.074)	-0.038	(0.073)
onionyldinc			-0.001	(0.070)	-0.012	(0.068)
beansyldinc			-0.019	(0.070)	0.011	(0.069)
maizeyldinc			0.002	(0.075)	-0.019	(0.075)
gnutyldinc			0.090	(0.088)	0.100	(0.086)
training						
bookkeep					-0.148**	(0.068)
marketing					0.193**	(0.094)
permaculture					0.014	(0.067)
masterfarmer					0.057	(0.065)
croping					0.071	(0.105)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmemb						
household characteristics						
chronillmember						
orphan						
childrenbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembers						
remittance						
middle						
rich						
observations	165		165		165	

Standard errors in parentheses

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

Table 5.11b: Marginal effects for determinants of dropouts for smallholder drip irrigation

Dependent variable - dropoutA (within a 6 year period)

	Model 4		**Model 5**		**Model 6**	
	margins	**se**	**margins**	**se**	**margins**	**se**
main variables						
earlyadopt	-0.115*	(0.062)	-0.147**	(0.066)	-0.115*	(0.068)
irrigwatertap	-0.006	(0.066)	-0.031	(0.071)	-0.017	(0.078)
distancefromgdn	-0.000*	(0.000)	-0.000	(0.000)	-0.000	(0.000)
yieldincgdn						
yield increase per crop						
leafyvegyldinc	-0.159**	(0.070)	-0.132*	(0.076)	-0.134*	(0.081)
tomatoyldinc	-0.046	(0.073)	-0.025	(0.078)	-0.036	(0.081)
onionyldinc	0.008	(0.068)	0.022	(0.072)	0.040	(0.075)
beansyldinc	0.043	(0.069)	0.063	(0.073)	0.056	(0.082)
maizeyldinc	0.011	(0.075)	0.018	(0.082)	0.034	(0.088)
gnutyldinc	0.064	(0.086)	0.094	(0.092)	0.191*	(0.104)
training						
bookkeep	-0.140**	(0.068)	-0.145**	(0.072)	-0.174**	(0.070)
marketing	0.185*	(0.095)	0.158	(0.099)	0.242**	(0.106)
permaculture	-0.006	(0.067)	-0.005	(0.071)	-0.012	(0.073)
masterfarmer	0.060	(0.065)	0.078	(0.070)	0.094	(0.073)
croping	0.020	(0.105)	0.034	(0.111)	0.055	(0.118)
problems faced						
waterprob	0.148**	(0.065)	0.132*	(0.068)	0.152**	(0.068)
labourinputprob	0.030	(0.072)	0.023	(0.074)	0.047	(0.077)
noprofitprob	0.010	(0.078)	0.002	(0.082)	-0.009	(0.091)
beneficiary characteristics						
benefmale			0.068	(0.076)	0.115	(0.085)
benefage			0.003	(0.003)	0.006	(0.004)
benefprimarylev			-0.022	(0.079)	-0.082	(0.084)
benefmarried			-0.036	(0.090)	-0.007	(0.092)
benefarmer			-0.067	(0.088)	-0.087	(0.091)
benefgrpmemb			0.034	(0.071)	0.009	(0.071)
household characteristics						
chronillmember					0.205**	(0.080)
orphan					-0.050	(0.074)
childrenbelow5					-0.062	(0.053)
fdsecbelowaverage					0.060	(0.073)
mutasa					-0.008	(0.091)
landsize					-0.009	(0.018)
hhdmembers					0.007	(0.014)
remittance					-0.010	(0.082)
middle					-0.148	(0.095)
rich					-0.209**	(0.090)
observations	165		154		152	

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

5.6.1 Discussion of the determinants of dropouts for smallholder drip irrigation

The discussion will focus on results of Model 6, which controls for yield, training, problems faced, beneficiary and household related variables in addition to the main variables. The associated marginal effects (Table 5.11b) will be used.

Main variables

The results indicate that early adopters (*earlyadopt*) are less likely to drop out of the drip irrigation project compared to late adopters. In fact given two beneficiaries whose only difference is the time that they received the kit, the chances that the beneficiary who received the kit in 2003 is going to stop using the kit are 0.115 lower compared to those of a beneficiary who received the kit from 2004 to 2007. This is in line with our expectations because during the project inception phase, the donor organisation and the government were heavily involved in the project and support was readily available for the farmers. Belder et al. (2007)'s study also revealed that extension and donor support is an important aspect in the success of smallholder drip irrigation.

Water source and distance to the garden from the water source (*irrigwatertap* and *distancefromgdn* respectively) do not have a significant influence on dropout rates, which is unexpected. Other studies though have indicated that distance of the water source from the garden matters and that beneficiaries whose water source is far from the garden are more likely to drop out (Belder et al., 2007).

Yield increase variables[52]

The results indicate that a lack of overall yield increases in garden crops when using drip irrigation (*yieldincgdn*) is not necessarily the driver of dropout rates in the smallholder drip irrigation project (Table 5.11, Model 1). Rather crop yields on certain specific crops seem to matter most. Beneficiaries who recorded increases in leafy vegetable yields (*leafyvegyldinc*) are 13.4 percentage points less likely to drop out of the project compared to those who do not realise a yield increase, all other things being equal (Table 5.11b, Model 6). This result is encouraging as one of the expected outcomes of the project was that household realise yield increases in vegetables and obtain extra food and income from selling surplus produce. This is expected to keep them motivated and encourage them to continue with the project which is evident from this result. Yield increases in other garden crops (*tomatoyldinc, onionyldinc, beansyldinc*) do not influence dropout rates significantly.

The results also indicate that yield increases realised in rainfed crops, although these crops are not irrigated also have an impact on dropout rates. All things being equal, a beneficiary who realised an increase in groundnut yields (*gnutyldinc*) is 19.1 percentage points more likely to drop out of the project compared to one whose yields do not increase ceteris paribus. This result is significant when all other variables are controlled for (Model 6).

Groundnuts are a competitive crop when compared to market gardening. This is because groundnuts can be sold off either as raw groundnuts or processed into peanut butter to generate income for the family. Compared to drip irrigated crops such as leafy vegetables, groundnuts are high value crops. Thus the opportunity cost of engaging in drip irrigation for a

[52] Yield increases in garden and field crops are a comparison between the base year (the year before the beneficiary began using the kit) and a year in which the beneficiary was using the kit (2006-2007 for beneficiaries who dropped out after 2007 and the year before a beneficiary dropped out for those who dropped out before 2007).

household growing groundnut is high especially in terms of labour use. So households who have an increase in groundnut yields can afford to drop out of the project as they have an alternative source of income which they can use to purchase the vegetables they need. Van Averbeke and Khosa (2007)'s results show that rainfed crops are especially important for improving food security for extremely poor households.

Training

Training in bookkeeping reduces a beneficiary's chance of dropping out of the project by 0.174 compared to a beneficiary who did not receive the training ceteris paribus. Bookkeeping was one of the accompanying trainings that Plan International initiated for the people who were set to benefit from the project. This training included teaching farmers how to keep records of their garden enterprises, not only in terms of income received but also of the cropping details (planting dates, quantities planted and harvested). This positive result thus supports Plan International's initiative of training farmers in bookkeeping. Training in marketing (*marketing*) however failed to yield the expected results. A beneficiary who received marketing training is 0.242 percentage points more likely to drop out compared to one who did not receive marketing training if they have the same main, yield increase, training, problems faced, beneficiary and household characteristics.

The marketing result is rather unexpected as one of the objectives was to encourage smallholder households to market their surplus. Beneficiaries may have become discouraged when they failed to market their crops or failed to realise the profit they expected and dropped out as a result. Master Farmer training (*masterfarmer*), training in cropping (*croping*) and in permaculture (*permaculture*) do not have much effect on dropout possibilities in this case. This is unexpected as one would expect master farmers to be more resilient and thus less likely to drop out. The use of permaculture was also being promoted and is relatively new so probably it is too early for the impact to have taken effect.

Problems faced

Studies have shown that the key factor that influences dropout rates from smallholder drip irrigation project is water problems (Belder et al., 2007; Kulecho and Weatherhead, Moyo et al., 2006; Mugabe et al., 2008). Results from Table 5.11b, Model 6 for *waterprob* reveal that indeed, all things being equal, a beneficiary who experiences water problems (including water shortages and difficulties in filling the tank with water) is 15.2 percentage points more likely to drop out compared to one who does not experience water challenges. Input acquisition problems and failure to realise profits do not have a major influence on dropout rates. The merits of smallholder drip irrigation are meant to include it being a labour saving technology and also a technology that allows efficient application of inputs such as fertilisers (Polak and Sivanappan, 1998 as cited in Kay, 2001; Postel et al., 2001). Based on these attributes, one would expect labour and input acquisition problems not to have a notable impact on dropout rates as indicated by the results. However Belder et al. (2007) and Maisiri et al. (2005)'s studies showed that smallholder drip irrigation technology is not labour saving but rather more labour is required to fill up the containers with water. Using this result, one would then expect *labourinputprob* to have a significant positive effect. In this case, the positive effect is there but is not significant. Not realising any profit (*noprofitprob)* exhibits the expected negative impact on dropout rates even though the result is not significant. This is because the main objective of the project was to increase the amount of food available to the household firstly via direct consumption of their produce and secondly via procurement of other food items using income from selling surplus produce (Pemba, 2004). The goal of food self-sufficiency thus overrides that of monetary profitability in the sense of this project. This can probably explain why *noprofitprob* does not have a significant impact on dropout rates.

Beneficiary characteristics

All the beneficiary characteristics (gender, age, education level, marital status, being a master farmer and belonging to an agricultural or income generating related group) controlled for in this study have little influence on dropout rates. This is unexpected as one would expect factors like gender, age and education levels to at least have some impact. Past studies have indicated that drip irrigation is more favourable towards women (Upadhyay, Samad & Giordano, 2005). Women in Nepal benefited more than men in terms of labour participation as approximately 88% of the tasks in the vegetable gardens were carried out by women. Smallholder drip irrigation also proved to be advantageous in terms of reducing the time and effort women spent fetching water and irrigating gardens. This enabled women to have more time to allocate to other household chores. In addition smallholder drip irrigation also provided women with a new or an additional source of income, as most of the women tended to farm for subsistence purposes only. This is possibly evident in the results as male beneficiaries are more likely to drop out of the project compared to their female counterparts, all things being equal. The result though is not statistically significant.

Although the result is not statistically significant, the older a beneficiary is, the more likely they are to drop out of the project, ceteris paribus. The positive relationship is expected as the nature of the smallholder drip irrigation project makes it rather challenging for elderly people to manage as they need to lift water into the tank. In addition to this, studies have revealed that younger people are able to adopt new agricultural technology at a faster pace than older people as they are more flexible (Belder et al., 2007; Carletto et al., 2010; Kay, 2001). This implies that older beneficiaries will most likely prefer their traditional watering systems as opposed to the new drip irrigation method.

A beneficiary who has attained primary level education or less is less likely to drop out of the project compared to a beneficiary who has attained a higher level of education. This is plausible as higher education means the opportunity cost of time spent irrigating is high, given that one is more likely to have other better income generating opportunities. All other beneficiary related factors such as marital status (*benefmarried*), having farming as one's main occupation (*beneffarmer*) and or belonging to an agriculture or business related group (*benefgrpmember*) have no substantial effect on dropout rates.

Household characteristics

A beneficiary from a household with a chronically ill member (*chronillmember*) has significantly higher chances of dropping out from the project of 0.205 on average, compared to a beneficiary from a household without a chronically ill member ceteris paribus. Based on the finding that the labour requirements of drip irrigation are high, the household's labour resources will have to be distributed between caring for the chronically ill and manning the drip irrigation project (Belder et al., 2007; Mugabe et al., 2008). Drip irrigation is likely to lose out in this case.

Wealth has a notable negative impact on dropout rates with a rich household (in the top 33% of the wealth index) being 20.9 percentage points less likely to drop out compared to a poor household (in the bottom 33% of the wealth index) , all other things being equal. Generally it is assumed that the initial capital outlay of smallholder drip irrigation kits, even though they have been modified to be of low cost, is still too expensive for some poor farmers (IWMI, 2006; Merrey et al., 2006). In this study, all the beneficiaries were given a drip irrigation kit by Plan International and so avoided the initial capital outlay. This result however suggests that there are other hidden costs involved in smallholder drip irrigation that poor households are unable to meet. Furthermore, this result is consistent with the conclusions made by Merrey et al. (2008) in their study that smallholder drip kits are not suitable as a support measure for the 'poorest of the poor'.

No other household factors have a significant impact on a beneficiary's dropout chances.

5.6.2 Does consumption matter in drop out decisions?

From the results in Tables 5.10a - 5.11b, it is evident that overall yield increase in garden crops (grown using drip irrigation) does not have a notable influence on dropout rates. Rather, yield increases in individual crops such as leafy vegetables are the ones that matter.

A yield increase however does not necessarily result in an increase in household consumption as households have a choice between consumption and selling their produce. Given that the main aim of the project was to improve household food security through increasing the consumption of vegetables, it stands to reason that an increase in consumption rather than yield may be a more relevant measure in this case. In addition, poor households are more likely to measure whether their food needs are met from total food consumption rather than total food yield.

This section presents results based on an increase in consumption levels rather than yield levels during the drip irrigation period. The results seek to address the following questions:

i. Does an increase in consumption during the drip irrigation period matter in determining dropout rates for smallholder farmers?

ii. What effect, if any does dropping out of the drip irrigation project have on overall household consumption in the subsequent period (2011-2012)?

Question i is of interest in this study as the project was mainly aimed at increasing the consumption of vegetables by the household in a bid to improve their food security levels. Question ii has important implications in that it can shed light on whether or not smallholder drip irrigation is important in the attainment of household food security in the long term. The IWMI (2006) in their study suggested that smallholder drip irrigation has potential as a long-term measure to address food insecurity. A negative relationship between consumption and dropping out will indicate that smallholder drip irrigation has an impact on household food security and vice versa.

The results are presented in Tables 5.12a - 5.13b and Tables 5.14 and 5.15 below for question i and question ii respectively.

5.6.2.1 Household consumption and dropout rates for smallholder drip irrigation

Tables 5.12a - 5.13b below present the results of the influence of consumption on the probability that a beneficiary will dropout from the drip irrigation project. The results presented in these two tables are similar to those presented in Tables 5.10a - 5.11b on the determinants of dropouts for smallholder drip irrigation farmers. The only difference is that the yield related factors (*yieldincgdn*, *leafyvegyldinc*, *tomatoyldinc*, *onionyldinc*, *beansyldinc*, *maizeyldinc* and *gnutyldinc* for overall, leafy vegetable, tomato, onion, beans, maize and groundnut yield increases respectively) are replaced by consumption[53] increase related factors (*consumpincgdn*, *leafyvegconsumpinc*, *tomatoconsumpinc*, *onionconsumpinc*, *beansconsumpinc, maizeconsumpinc* and *gnutconsumpinc* for overall, leafy vegetable, tomato, onion, beans, maize and groundnut yield increases respectively) . Consumption related, training, problems faced, beneficiary and household factors are introduced separately into the model in order to determine their effect on the main variables.

The discussion below is based on the results presented in Tables 5.13a and 5.13b, showing the marginal effects of a unit change of each determinant on smallholder drip irrigation dropout rates. Similarly to the discussion in section 5.6.1, the discussion will focus on Model 6, which controls for all the relevant factors. Where necessary, reference will be made to the other models.

[53] All the consumption variables are dummy variables taking the value 1 if the household indicated that consumption of the specific crop mentioned increased during the drip irrigation period.

Table 5.12a: Household consumption as a determinant of dropout rates for smallholder drip irrigation farmers

Dependent variable: Dropout (within a 6 year period)

	Model 1		Model 2		Model 3	
	coef	se	coef	se	coef	se
main variables						
earlyadopt	-0.405*	(0.218)	-0.466**	(0.229)	-0.481**	(0.240)
irrigwatertap	0.009	(0.228)	-0.003	(0.232)	-0.006	(0.245)
distancefromgdn	-0.001	(0.000)	-0.001	(0.000)	-0.001	(0.000)
consumpincgdn	-0.172	(0.234)				
yield increase per crop						
vegconsumpinc			-0.435	(0.312)	-0.302	(0.320)
tomatconsumpinc			0.470	(0.312)	0.406	(0.323)
onionconsumpinc			-0.020	(0.290)	-0.099	(0.300)
beanconsumpinc			-0.207	(0.281)	-0.217	(0.306)
maizeconsumpinc			-0.178	(0.326)	-0.311	(0.351)
gnutconsumpinc			0.492	(0.359)	0.627	(0.383)
training						
bookkeep					-0.523**	(0.265)
marketing					0.663*	(0.349)
permaculture					0.034	(0.246)
masterfarmer					0.190	(0.248)
croping					0.350	(0.410)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmemb						
household characteristics						
chronillmember						
orphan						
childrenbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembers						
remittance						
middle						
rich						
constant	1.083***	(0.246)	1.068***	(0.222)	0.995***	(0.290)
observations	165		165		165	

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

Table 5.12b: Household consumption as a determinant of dropout rates for smallholder drip irrigation farmers

Dependent variable: Dropout (within a 6 year period)

	Model 4		**Model 5**		**Model 6**	
	coef	**se**	**coef**	**se**	**coef**	**se**
main variables						
earlyadopt	-0.499**	(0.243)	-0.592**	(0.264)	-0.533*	(0.288)
irrigwatertap	-0.017	(0.247)	-0.119	(0.271)	-0.072	(0.329)
distancefromgdn	-0.001*	(0.001)	-0.001	(0.001)	-0.001	(0.001)
consumpincgdn						
yield increase per crop						
vegconsumpinc	-0.284	(0.334)	-0.338	(0.370)	-0.078	(0.427)
tomatconsumpinc	0.353	(0.332)	0.155	(0.372)	-0.005	(0.424)
onionconsumpinc	-0.075	(0.306)	0.080	(0.352)	0.069	(0.410)
beanconsumpinc	-0.167	(0.310)	0.042	(0.334)	-0.026	(0.391)
maizeconsumpinc	-0.234	(0.360)	-0.308	(0.387)	-0.456	(0.429)
gnutconsumpinc	0.572	(0.388)	0.776*	(0.427)	1.170**	(0.511)
training						
bookkeep	-0.517*	(0.271)	-0.602**	(0.290)	- 0.843***	(0.315)
marketing	0.685*	(0.360)	0.565	(0.381)	0.908**	(0.440)
permaculture	-0.037	(0.255)	-0.057	(0.272)	-0.120	(0.299)
masterfarmer	0.211	(0.253)	0.242	(0.275)	0.280	(0.307)
croping	0.211	(0.420)	0.166	(0.444)	0.295	(0.522)
problems faced						
waterprob	0.451*	(0.243)	0.380	(0.260)	0.454	(0.283)
labourinputprob	-0.030	(0.274)	-0.035	(0.285)	0.128	(0.319)
noprofitprob	0.180	(0.291)	0.093	(0.309)	-0.037	(0.357)
beneficiary characteristics						
benefmale			0.249	(0.292)	0.420	(0.352)
benefage			0.008	(0.012)	0.014	(0.015)
benefprimarylev			-0.029	(0.304)	-0.211	(0.340)
benefmarried			-0.152	(0.339)	-0.124	(0.378)
benefarmer			-0.377	(0.339)	-0.527	(0.372)
benefgrpmemb			0.343	(0.260)	0.305	(0.284)
household characteristics						
chronillmember					0.853**	(0.355)
orphan					-0.190	(0.314)
childrenbelow5					-0.181	(0.216)
fdsecbelowaverage					0.225	(0.310)
mutasa					-0.192	(0.355)
landsize					-0.024	(0.076)
hhdmembers					0.031	(0.059)
remittance					0.006	(0.338)
middle					-0.490	(0.381)
rich					-0.687*	(0.369)
constant	0.740**	(0.341)	0.519	(0.777)	0.348	(0.920)
observations	165		154		152	

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

Table 5.13a: Marginal effects for consumption as a determinant of dropout rates smallholder drip irrigation farmers

Dependent variable - dropoutA (within a 6 year period)

	Model 1		**Model 2**		**Model 3**	
	margins	**se**	**margins**	**se**	**margins**	**se**
main variables						
earlyadopt	-0.122*	(0.064)	-0.136**	(0.065)	-0.133**	(0.065)
irrigwatertap	0.003	(0.069)	-0.001	(0.067)	-0.002	(0.068)
distancefromgdn	-0.000	(0.000)	-0.000*	(0.000)	-0.000	(0.000)
consumpincgdn	-0.052	(0.070)				
yield increase per crop						
vegconsumpinc			-0.127	(0.090)	-0.084	(0.088)
tomatconsumpinc			0.137	(0.089)	0.113	(0.089)
onionconsumpinc			-0.006	(0.084)	-0.028	(0.083)
beanconsumpinc			-0.060	(0.081)	-0.060	(0.084)
maizeconsumpinc			-0.052	(0.095)	-0.086	(0.097)
gnutconsumpinc			0.143	(0.103)	0.174*	(0.104)
training						
bookkeep					-0.145**	(0.071)
marketing					0.184*	(0.095)
permaculture					0.010	(0.068)
masterfarmer					0.053	(0.068)
croping					0.097	(0.113)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmemb						
household characteristics						
chronillmember						
orphan						
childrenbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembers						
remittance						
middle						
rich						
observations	165		165		165	

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

Table 5.13b: Marginal effects for consumption as a determinant of dropout rates smallholder drip irrigation farmers

Dependent variable - dropoutA (within a 6 year period)

	Model 4		**Model 5**		**Model 6**	
	margins	**se**	**margins**	**se**	**margins**	**se**
main variables						
earlyadopt	-0.135**	(0.064)	-0.156**	(0.067)	-0.130*	(0.068)
irrigwatertap	-0.005	(0.067)	-0.032	(0.072)	-0.018	(0.080)
distancefromgdn	-0.000*	(0.000)	-0.000	(0.000)	-0.000	(0.000)
consumpincgdn						
yield increase per crop						
vegconsumpinc	-0.077	(0.090)	-0.089	(0.097)	-0.019	(0.104)
tomatconsumpinc	0.095	(0.089)	0.041	(0.098)	-0.001	(0.103)
onionconsumpinc	-0.020	(0.083)	0.021	(0.093)	0.017	(0.100)
beanconsumpinc	-0.045	(0.084)	0.011	(0.088)	-0.006	(0.095)
maizeconsumpinc	-0.063	(0.097)	-0.081	(0.102)	-0.111	(0.104)
gnutconsumpinc	0.155	(0.103)	0.205*	(0.110)	0.286**	(0.118)
training						
bookkeep	-0.140**	(0.071)	-0.159**	(0.074)	-0.206***	(0.072)
marketing	0.185*	(0.095)	0.149	(0.099)	0.222**	(0.103)
permaculture	-0.010	(0.069)	-0.015	(0.072)	-0.029	(0.073)
masterfarmer	0.057	(0.068)	0.064	(0.072)	0.068	(0.074)
croping	0.057	(0.113)	0.044	(0.117)	0.072	(0.127)
problems faced						
waterprob	0.122*	(0.064)	0.100	(0.068)	0.111	(0.068)
labourinputprob	-0.008	(0.074)	-0.009	(0.075)	0.031	(0.078)
noprofitprob	0.049	(0.078)	0.025	(0.082)	-0.009	(0.087)
beneficiary characteristics						
benefmale			0.066	(0.077)	0.102	(0.085)
benefage			0.002	(0.003)	0.003	(0.004)
benefprimarylev			-0.008	(0.080)	-0.051	(0.083)
benefmarried			-0.040	(0.090)	-0.030	(0.092)
benefarmer			-0.100	(0.088)	-0.129	(0.089)
benefgrpmemb			0.091	(0.068)	0.074	(0.069)
household characteristics						
chronillmember					0.208**	(0.081)
orphan					-0.046	(0.076)
childrenbelow5					-0.044	(0.052)
fdsecbelowaverage					0.055	(0.075)
mutasa					-0.047	(0.086)
landsize					-0.006	(0.018)
hhdmembers					0.008	(0.014)
remittance					0.001	(0.083)
middle					-0.120	(0.092)
rich					-0.168*	(0.087)
observations	165		154		152	

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

Discussion: Impact of consumption on dropout rates for smallholder drip irrigation farmers

Table 5.13 results show that overall increase in consumption of garden crops (*consumpincgdn*) during the drip irrigation phase does not influence dropout rates. Rather increase in the consumption of specific garden crops influence dropout rates. This is similar to the results based on the increase in yields. Whilst a beneficiary whose household consumption of leafy vegetables increased (*leafyvegconsumpinc*) during the drip irrigation period is less likely to drop out of the drip irrigation project compared to one whose consumption did not change or decreased ceteris paribus, this result is not significant unlike that of a yield increase in leafy vegetables.

However, increase in the consumption of groundnuts (*gnutconsumpinc*) significantly increases a beneficiary's chances of dropping out of the project. A beneficiary whose groundnut consumption increased during the drip irrigation phase is 28.6 percentage points more likely to drop out of the drip irrigation project compared to their counterpart, all things being equal. This effect is consistent with that of an increase in the yields of groundnuts (Table 5.11, model 6). Nevertheless one would hardly expect an increase in the consumption of groundnuts to have a positive influence on the likelihood of dropping out. Groundnuts are not substitutes for garden crops like leafy vegetables and tomatoes. Groundnuts though can be used to substitute a whole meal when they are prepared together with dried maize corn in a meal commonly known as *mutakura*. *Mutakura* replaces the usual meal of sadza (thick porridge made from maize flour, which is the staple food) and vegetables or beans. So it can be possible for a household whose consumption of groundnuts increased during the drip irrigation phase to be less reliant on garden crops and more likely to drop out. Overall, it is more likely that the positive influence of an increase in groundnut consumption on the likelihood of dropping out is through an increase in the yield of groundnuts rather than an increase in the consumption of groundnuts as discussed in section 5.6.1.

Increases in the consumption of other crops (tomatoes, onions, beans and maize) do not have a statistically significant impact on beneficiary drop out chances.

On the whole, early adopters (*earlyadopt*) still are less likely to drop out of the drip irrigation project. Beneficiaries who receiving training in bookkeeping (*bookkeep*) and those coming from a rich household (*wealth rich*) are still less likely to drop out of the project compared to their counterparts, all things being equal. Beneficiaries who received training in marketing (*marketing*) and those who come from a household with a chronically ill member (*chronillmember*) are more likely to drop out of the drip irrigation project, all things being equal. These results are consistent with those obtained when a yield increase is used (Table 5.11b, Model 6).

5.6.3 Impact of dropping out on overall household consumption of garden crops in 2011-2012 cropping season

The results in section 5.6.2.1 show that an overall increase in the consumption of garden crops during the drip irrigation phase does not have a notable impact on the likelihood that a beneficiary will drop out of the smallholder drip irrigation project. The results presented in this section (Tables 5.14 and 5.15 below) show whether dropping out of the project had any effect on household consumption of garden crops, up to 5 years after the benefactors withdrew from the project.

Table 5.14: The impact of dropping out on future household consumption

Dependent variable : Consumption of garden crops increased in 2011-2012 season

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
main								
dropout	-0.006	-0.302	0.068	(0.335)	0.202	(0.357)	0.119	(0.377)
earlydropA	0.112	(0.214)	0.224	(0.239)	0.107	(0.251)	0.252	(0.271)
yld3incgdn			1.531***	(0.221)	1.563***	(0.236)	1.737***	(0.263)
beneficiary								
benefmale					-0.394	(0.256)	-0.421	(0.281)
benefage					-0.003	(0.009)	-0.006	(0.010)
bmarried					0.254	(0.296)	0.310	(0.312)
household								
foodaid							0.979***	(0.356)
hhdmembs							-0.006	(0.046)
childrenbelow5							0.046	(0.180)
chronillmember							0.368	(0.245)
middle							-0.020	(0.306)
rich							0.292	(0.313)
constant	-0.06	(0.274)	-1.065***	(0.340)	-1.038	(0.662)	-1.362*	(0.755)
observations	170		170		159		159	

Standard errors in parentheses

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

Table 5.15: Marginal effects for the impact of dropping out on future household consumption

Dependent variable : Consumption of garden crops increased in 2011-2012 season

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	marginal effect	**se**	**marginal effect**	**se**	**marginal effect**	**se**	**marginal effect**	**se**
main variables								
dropout	-0.003	(0.120)	0.020	(0.101)	0.059	(0.105)	0.032	(0.103)
earlydropA	0.045	(0.085)	0.068	(0.072)	0.031	(0.074)	0.069	(0.074)
yld3incgdn			0.462***	(0.031)	0.460***	(0.035)	0.473***	(0.037)
beneficiary characteristics								
benefmale					-0.116	-0.074	-0.115	(0.075)
benefage					-0.001	(0.003)	-0.002	(0.003)
bmarried					0.075	(0.087)	0.084	(0.084)
household characteristics								
foodaid							0.267***	(0.091)
hhdmembs							-0.002	(0.013)
childrenbelow5							0.012	(0.049)
chronillmember							0.100	(0.066)
middlev							-0.006	(0.083)
rich							0.080	(0.085)
observations	170		170		159		159	

Standard errors in parentheses

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

The dependent variable is whether or not a household's consumption of garden crops increased in the cropping season preceding the interview (2011-2012) compared to the time the household was using drip irrigation. Dropping out (*dropout*) is the main variable of interest here and overall yield, beneficiary and household variables are also controlled for. The variable *dropout* is a dummy variable which takes the value 1 if the beneficiary has dropped out of the project and 0 otherwise. The discussion will mostly be based on model 5, which controls for all the factors and on the marginal effects (Table 5.15) which give both the direction and magnitude of the effect of dropping out on consumption in the 2011-2012 cropping season.

The results in Table 5.15 show that dropping out of the project increases the chances of a household realising an increase in future consumption by 0.032 compared to their consumption during the drip irrigation phase compared to continuing with drip irrigation ceteris paribus. For early dropouts (those who drop out within the first 3 years), the probability of realising an increase in future household consumption is higher by 0.101 compared to late dropouts and those who are still using drip irrigation, all other factors being equal. Based on the direction of effect, this result suggests that those who drop out are better off in terms of household consumption and hence food security.

However, on the whole, the results show that the effect of dropping out (*dropout*) of the smallholder drip irrigation project as well as whether the beneficiary drops out early or not (*earlydropout*) is not significant. Moyo et al., (2006)'s results revealed that in the short-term smallholder drip irrigation has no impact, especially when introduced in emergency situations. Moyo et al., (2006) concluded that smallholder drip irrigation has potential to contribute positively to the alleviation of food insecurity in the long-term. The results of this study however show that over a ten year period, participation in smallholder drip irrigation for farmers in Mutasa and Mutoko still has no statistically significant impact on alleviating household food security. As this study is based on a small sample, more analysis needs to be conducted at a larger scale in order to determine the robustness of this result.

Instead, the results show that future increase in household consumption in this case depends on whether the household realised a yield increase in garden crops in 2011-2012 (*afterdripyieldincgdn*) and whether the household received food aid (*foodaid*) or not. As expected, a household which got an increase in garden crop yields in 2011-2012 is 47.3 percentage points more likely to realise an increase in consumption of garden crops compared to a household whose garden crop yields remain the same or decreased ceteris paribus. Similarly a household which received food aid is 26.7 percentage points more likely to realise an increase in household consumption compared to a household which does not get food aid, all other factors being equal.

These results suggest that dropping out of the smallholder drip irrigation does not have a notable impact on a household's food consumption after controlling for whether or not the beneficiary has dropped out, yield increases, beneficiary and household characteristics. This implies that the channel through which household food security improves is from yield increases rather than the method used to attain these yield increases (drip irrigation). The objective of this project was mainly to improve household food security through increasing a household's consumption of garden crops.

In addition, these results could also be due to the simplicity of the dependent variable used. One could argue that the dependent variable (overall increase in the consumption of garden crops) used is imprecise. The variable is a dummy variable with the value 1 for a household which indicated that their consumption in any one of the garden crops (leafy vegetables, tomatoes, onions, beans, peas, butternut, and cucumber) increased in 2011-2012 cropping season. Use of other more precise food security variables such as the coping strategies and dietary diversity indices might improve the results.

5.6.4 Impact of dropping out on overall household garden crop yields in 2011-2012 cropping season

From the discussion in section 5.6.3, it is evident that dropping out of the smallholder drip irrigation project does not have a significant impact on household consumption of garden crops. Following the suggestion that the impact of smallholder drip irrigation could be via other avenues, this section explores the impact of dropping out on future yield increases realised by a household in garden crops.

The dependent variable is whether or not a household's yield of garden crops increased in the cropping season preceding the interview (2011-2012) compared to the time the household was using drip irrigation. Similar to section 5.6.3, dropping out (*dropout*) and *earlydropout* are still the main variables of interest here and are proxies for smallholder drip irrigation. In addition, overall consumption increase in 2011-2012, beneficiary and household variables are also controlled for. It is expected that there will be a negative relationship between the main variables (*dropout* and *earlydropout*) and the probability that a household realises an increase in garden crop yield in 2011-2012 compared to the period during which they were using drip irrigation.

The discussion will mostly be based on model 5, which controls for all the factors and on the marginal effects (Table 5.17) which give both the direction and magnitude of the effect of dropping out on consumption in the 2011-2012 cropping season.

Table 5.16: The impact of dropping out on future garden crop yields

Dependent variable : Yield of garden crops increased in 2011-2012 season compared to the drip irrigation period

	Model 1		Model 2		Model 3		Model 4	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
main variables								
dropout	-0.104	(0.307)	-0.139	(0.343)	-0.032	(0.352)	0.025	(0.375)
earlydropout	-0.106	(0.214)	-0.220	(0.240)	-0.264	(0.255)	-0.300	(0.274)
futureconsumpincgdn			1.523***	(0.220)	1.550***	(0.234)	1.715***	(0.261)
beneficiary characteristics								
benefmale					0.200	(0.261)	0.193	(0.288)
benefage					-0.014	(0.009)	-0.018*	(0.010)
benefmarried					0.027	(0.298)	-0.026	(0.318)
household characteristics								
foodaid							-0.813**	(0.362)
hhdmembs							0.015	(0.048)
childrenbelow5							-0.012	(0.189)
chronillmember							-0.243	(0.251)
middle							0.471	(0.303)
rich							0.516*	(0.310)
constant	0.303	(0.278)	-0.312	(0.320)	0.274	(0.629)	0.170	(0.715)
observations	170		170		159		159	

Standard errors in parentheses

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

Table 5.17: Marginal effects for the impact of dropping out on future garden crop yields

Dependent variable : Yield of garden crops increased in 2011-2012 season compared to the drip irrigation period

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	marginal effect	**se**	**marginal effect**	**se**	**marginal effect**	**se**	**marginal effect**	**se**
main variables								
dropout	-0.041	-0.12	-0.041	(0.101)	-0.009	(0.101)	0.007	(0.099)
earlydropout	-0.042	(0.084)	-0.065	(0.071)	-0.075	(0.072)	-0.079	(0.072)
futureconsumpincgdn			0.450***	(0.030)	0.443***	(0.033)	0.454***	(0.037)
beneficiary characteristics								
benefmale					0.057	(0.074)	0.051	(0.076)
benefage					-0.004*	(0.003)	-0.005*	(0.003)
benefmarried					0.008	(0.085)	-0.007	(0.084)
household characteristics								
foodaid							-0.215**	(0.093)
hhdmembs							0.004	(0.013)
Chuldrenbelow5							-0.003	(0.050)
chronillmember							-0.064	(0.066)
middle							0.125	(0.079)
rich							0.137*	(0.080)
observations	170		170		159		159	

Standard errors in parentheses

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

Table 5.17 results show that dropping out of the project (*dropout*) does not have a significant effect on the chances of the beneficiary household realising a yield increase in future garden crop yields. Dropping out of the project early (*earlydropout*) on the overall reduces the chances of the beneficiary household realising an increase in garden crop yields in the future by 0.079 compared to households who drop out late (after more than 3 years). However, this result is also not significant.

In spite of the lack of significance in this result, the direction of effect tallies with Moyo et al. (2006)'s conclusion that smallholder drip irrigation has no impact in the short-term but in the long-term. Households which drop out early (within 3 years of using the project) may not have yet had the chance to realise the benefits of participating in the project and hence their future food security (measured through an increase in future garden crop yields) is not likely to improve. This can possibly explain the negative relationship between the probability of experiencing a future increase in garden crop yields and *earlydropout.* On the other hand, households who stay longer than 3 years are more likely to realise the benefits of drip irrigation and probably maximise on them such that after they dropout, dropping out will not matter much in terms of yield increases in garden crops. This can possibly explain the positive effect of dropout and the small magnitude of effect.

5.7 Duration analysis results

Having established the factors that affect the chances of beneficiaries dropping out from the smallholder drip irrigation project, there is need to establish what factors have an effect on the duration that a beneficiary is likely to remain in the project, before they drop out.

The results presented in this section are for the non-parametric, parametric and semi-parametric models. As indicated in section 5.4, these models differ in the way the baseline hazard function ($h_0(t)$) is treated. The non-parametric model presents survival estimates according to different categories such as age and gender. The parametric models assume that $h_0(t)$ follows a specific distribution, whilst the semi-parametric models allow the data to determine the functional form of $h_0(t)$. The results presented in each section are for the Kaplan Meier (KM), exponential, Weibull and Cox models. As indicated in section 5.4, duration analysis of great importance in this case as it is pivotal in addressing the question of when a beneficiary drops out of the project

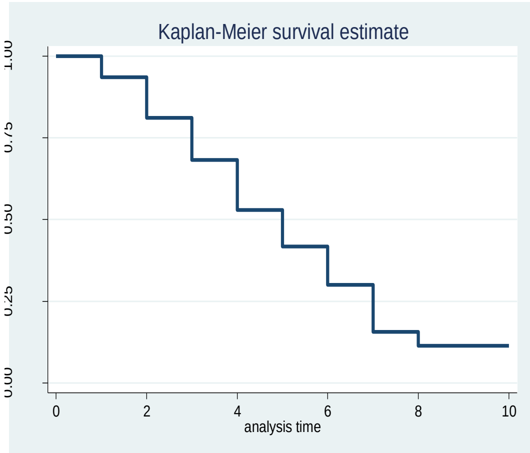
As indicated in section 5.4.1, the KM survival functions estimates are based on partial information as some beneficiaries had not dropped out at the time the survey was conducted. For the exponential, Weibull and Cox models, hazard ratios are reported for each covariate. A hazard ratio of 1 indicates that the covariate has no effect of the conditional probability of the beneficiary dropping out at time *t*. A hazard ratio <1 or >1 indicates that the covariate has a negative or positive effect on the duration a beneficiary lasts in the project respectively (D'Emden, 2006).

For the parametric and semi-parametric models, 6 models similar to those estimated in the previous section are estimated. Models 1- 6 include the main variables, yield increase variables for individual crops, trainings received, problems faced and beneficiary and household characteristics respectively. The results discussed will be based on Model 6 which contains all the possible factors thought to affect the instantaneous probability that a beneficiary stops using drip irrigation at time $t+1$ provide the beneficiary is still using the drip kit at time t.

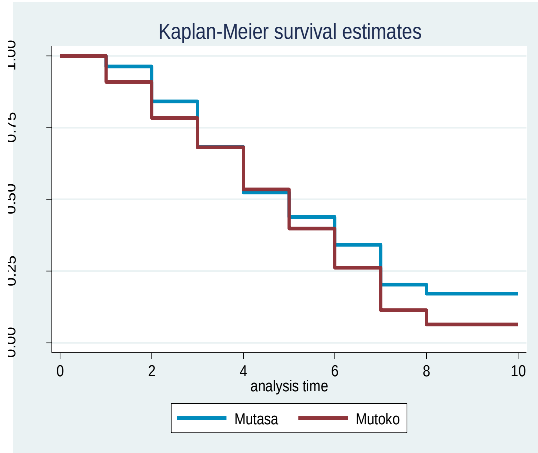
5.7.1 Non-parametric model results

Figure 5.8: KM survival estimates for various variables

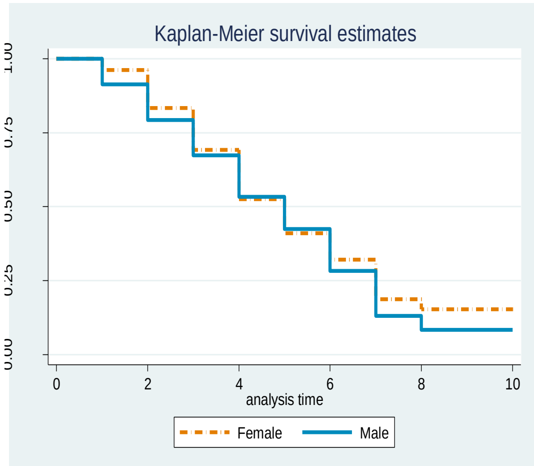
a. All beneficiaries



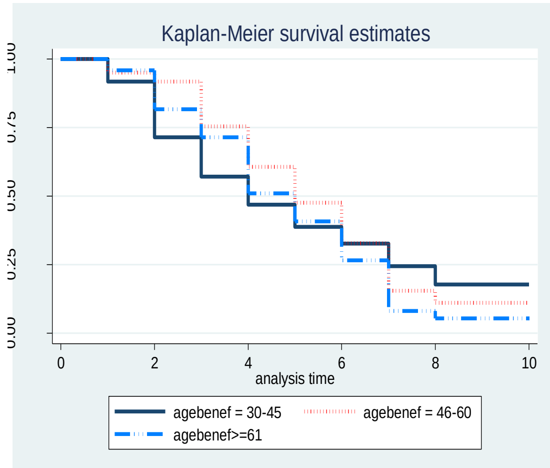
b. District



c. Gender



d. Beneficiary's age



e. Adoption year

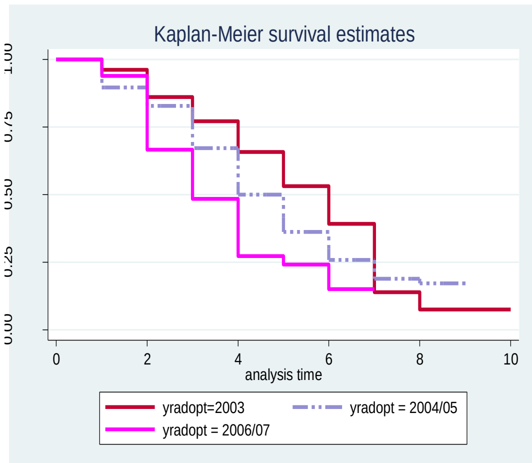


Table 5.18: Results for the significance of differences between the KM survival curves

Test	district		gender		age		adoption year	
	χ^2	pr>χ^2	χ^2	pr> χ^2	χ^2	pr>χ2	χ^2	pr>χ2
earlier failure more weight								
Flemington-Harrington (p=1;q=0)	0.930	0.336	0.320	0.574	1.870	0.392	10.350	0.006***
Wilcoxon-Breslow	0.900	0.643	0.310	0.581	1.880	0.390	10.440	0.005***
Taron-Ware	1.370	0.242	0.440	0.505	1.260	0.532	8.550	0.014**
later failure more weight								
Flemington-Harrington (p=0;q=1)	3.810	0.051*	1.230	0.268	5.240	0.073*	1.450	0.485
same as log- rank test								
Flemington-Harrington (p=0;q=0)	2.250	0.134	0.740	0.388	1.250	0.535	5.810	0.055*
Log-rank	2.250	0.134	0.740	0.388	1.250	0.535	5.810	0.055*
same as KM estimate								
Peto-Peto-Prentice	0.860	0.355	0.310	0.578	2.340	0.311	10.840	0.004***

All test are for one degree of freedom
****** p<0.01, ** p<0.05, * p<0.1*

5.7.1.1 Discussion of KM results

The KM survival functions (Figure 5.8a – 5.8e) all show the percentages of households who are yet to drop out of the smallholder drip irrigation project at time (*t*) for each year of the 10 year period under observation. Overall Figure 5.8a shows that an estimated 12% of the farmers were still using drip irrigation at the time the survey was conducted. Dropouts occurred within the first year of having received the kit as shown by the vertical drop for year 1. The largest number of drop outs occurred between the end of year 3 and year 4 and between the end of year 6 and year 7, with approximately 15% of the farmers dropping out in each period.

Dropping out also begins in the first time period in each district (Figure 5.8b), with slightly lower rates in Mutasa (3.7%) than in Mutoko (9.1%). Overall more farmers dropped out of Mutoko district (only 6.3% were still involved in the project in 2013) than Mutasa (17.1% still using the kit in 2013). The largest dropouts (ranging between 14% and 15%) for Mutoko were experienced between year 3 and year 7 of survival. For Mutasa, the largest dropout rates were slightly higher (between 15% and 16%) and occurred between the year 2 and year 4 and year 6 and year 7. The survival rates for both districts are similar in the 3rd and 4th years. From the 4th year onwards, Mutoko district experienced a rapid decline in survival rates compared to Mutasa which experienced a more gradual drop in survival rates. These results are reflected in the significance of the Flemington-Harrington test (Table 5.18) which places more weight on later failures (FHL). The FHL results indicate that the differences between survival rates in Mutoko and Mutasa are significant in the later years (p-value 0.051). All the other test results reported in Table 5.18, which place emphasise on earlier failures and the log-rank and Peto-Peto Prentice tests show that the differences between survival rates in the districts are not statistically significant.

Figure 5.8c which shows the survival rates based on the gender of the beneficiary gives similar results to those given by stratification at the district level. Dropping out begins in the 1st year of adoption. Overall female beneficiaries (15.3%) have higher survival rates compared to male beneficiaries (8.3%). Survival rates are similar for both males and females in the 4th and 5th years. Males' dropout at a faster rate (survival rates fall from 0.283 to 0.083) compared to females (survival rates fall from 0.321 to 0.153) from the 6th to the 8th year of using drip irrigation. The largest dropout rates for males and females (between 12% and 16.8%) occur between year 1 and year 4 of being involved in the project. In addition males also experience high dropout rates between the end of year 5 and year 7 whilst females experience high dropout rates between the end of year 6 and year 7 of surviving in the project. All the tests in Table 5.18, under gender however indicate that the differences in the survival rates of males and females are not significant.

Survival rates appear to vary between age categories (Figure 5.8d). The highest dropout rates experienced in one year for the 3 age categories (30-45; 46-60 and 61and above) varies between 14.3% and 20.4%. Overall, young beneficiaries (30-45 years old) have higher survival chances compared to the middle aged (46-60 years) and the elderly (61 and above) (17.8% compared to 11.1% and 5.4% surviving up to the 8th year respectively). Younger beneficiaries are less likely to drop out in the later years of the project life (7th year onwards) with the largest dropout rates being realised in the first 3 years. Middle aged beneficiaries on the other hand, do better in the early years (from year 2 to year 7) with the largest dropouts occurring in the 6th and 7th year. Elderly beneficiaries like the middle aged beneficiaries have lower survival rates from the 7th year onwards as depicted by the survival curves in Figure 5d. The differences between the survival rates are only significant at the 10% level if later years are accorded more weight as shown by the Flemington-Harrington test results in Table 5.18. All other tests are insignificant.

Beneficiaries who received their kits late (2006/07) had all dropped out by the end of the 7th year as shown in Figure 5.8e above whereas 7.6% of the early adopters (got the kit in 2003) survived up to the 8th year. Beneficiaries who received the drip kit in 2004/05 had the highest survival rates with 17.2% surviving up to year 8. For the early adopters (got the kit in 2003), the largest dropout rates are experienced in the 7th year of surviving the project where approximately 25% of those still using drip irrigation discontinued its use. The rest of the dropout rates during each year for the 10 year period vary between 4% and 13.9 %. For middle level adapters (got kit in 2004/05), the largest dropout rates are experienced between the end of year 3 and year 4 of surviving the project (17.2%) followed closely by the periods between the end of year 2 and year 3 and between the end of year 4 and year 5 (15.5% and 13.8% respectively). Late adopters (got kit 2006/07) experience the largest dropout rates between the 1st and 2nd year of using the kit (27.3%), followed by the period between the end of year 3 and year 4 (21.2%). The dropout rates for all the other years are quite low (range between 3% and 9%).

The tests for differences in survival rates between beneficiaries based on the year the beneficiary adopted the project are highly significant when earlier failures are given more weight compares to later failures as shown by the results in Table 5.18. All the three tests for earlier failures, the Flemington-Harrington, the Wilcoxon-Breslow and the Taron-Ware test results are all significant, mostly at the 1% level. The Peto-Peto Prentice test is also significant at the 1% level whilst the log rank test is significant at the 10% level.

5.7.2 Parametric and semi-parametric model results

This section presents the results (Tables 5.19a to 5.22b) for models that seek to identify the factors that influence the time a beneficiary lasts in the smallholder drip irrigation project from these methods. The results are presented as hazard ratios, where a hazard ratio >1 indicates that the factor increases a beneficiary's risk of dropping out from the project and thus reduces the duration they use drip irrigation. A hazard ratio of <1 reduces the risk of dropping out and increases the duration of using the drip kit.

Two parametric (exponential and Weibull) and two semi-parametric methods (Cox Breslow and Cox Efron) are used in this study and 6 models are estimated for each method. Similar to the method used in identifying factors that affect the probability of dropping out of the drip irrigation project (section 5.6), each group of variables are added to the model separately in order to determine their effect on the main variables. The variable categories are yield increase per crop; training and problems faced variables as well as variables representing the characteristics of the beneficiary and the household they reside in.

Firstly, for all the 4 methods the results show that the distance of the water source from the garden (*distancefromgdn*) has no impact on the conditional probability that a beneficiary will drop out at a specific time, *t* given that they would have survived to that time (hereafter referred to as the probability or the hazard or likelihood of dropping out, following D'Emden et al., 2006). The variables *irrigwatertap*, *leafyvegyldinc*, *tomatoyldinc*, *mzeyldinc*, *bookkeep*, *masterfarmer*, *croping*, *benefprimarylev*, *benefgrpmember*, *chronillmember*, *childbelow5*, *landsize*, *wealthmiddlev* and *wealthrich* have a negative impact on the hazard in all the 4 methods, implying that the expected duration will increase. On the other hand, the variables *earlyadopt*, *onionyldinc*, *beansyldinc*, *gnutyldinc*, *marketing*, *permaculture*, *waterprob*, *benefmale*, *benefage*, *benefmarried*, *benefarmer*, *hhdmembers*, *mutasa* and *remittance* have a positive effect on the hazard, implying that the expected duration will increase. The effect of *noprofitprob*, *labourinputprob*, *orphan* and *fdsecbelowaverage* varies according to the method used.

The factors are discussed further in section 5.7.2.1 below.

Table 5.19a: Exponential model results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 1		Model 2		Model 3	
	haz.ratio	**se**	**haz.ratio**	**se**	**haz.ratio**	**se**
main variables						
earlyadopt	0.905	(0.153)	0.902	(0.155)	0.939	(0.165)
irrigwatertap	1.052	(0.182)	1.068	(0.187)	1.078	(0.196)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn	0.818	(0.181)				
yield increase per crop						
leafyvegyldinc			0.722*	(0.136)	0.725*	(0.141)
tomatoyldinc			0.833	(0.160)	0.827	(0.162)
onionyldinc			1.098	(0.206)	1.071	(0.207)
beansyldinc			0.972	(0.180)	1.003	(0.190)
maizeyldinc			0.835	(0.163)	0.828	(0.164)
gnutyldinc			1.346	(0.290)	1.360	(0.295)
training						
bookkeep					0.831	(0.164)
mrkting					1.295	(0.291)
permacltr					1.082	(0.195)
msterfrmer					0.888	(0.162)
croping					0.925	(0.267)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmember						
household characteristics						
chronillmember						
orphan						
chnbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembs						
remittance						
wealthmiddlev						
wealthrich						
constant	0.218***	(0.050)	0.233***	(0.043)	0.241***	(0.057)
log-likelihood	-197.733		-194.194		-192.972	
AIC	405.465		408.387		415.944	
observations	165		165		165	

Standard errors (seEform)in parentheses

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

Table 5.19b: Exponential model results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 4		Model 5		Model 6	
	haz.ratio	**se**	**haz.ratio**	**se**	**haz.ratio**	**se**
main variables						
earlyadopt	0.925	(0.164)	0.877	(0.167)	0.907	(0.183)
irrigwatertap	1.077	(0.199)	1.038	(0.209)	0.986	(0.221)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn						
yield increase per crop						
leafyvegyldinc	0.701*	(0.141)	0.688*	(0.150)	0.694	(0.161)
tomatoyldinc	0.831	(0.164)	0.825	(0.173)	0.794	(0.175)
onionyldinc	1.135	(0.227)	1.122	(0.235)	1.133	(0.252)
beansyldinc	1.081	(0.217)	1.163	(0.245)	1.201	(0.287)
maizeyldinc	0.850	(0.169)	0.865	(0.186)	0.904	(0.212)
gnutyldinc	1.302	(0.287)	1.403	(0.324)	1.545	(0.417)
training						
bookkeep	0.848	(0.171)	0.833	(0.179)	0.820	(0.183)
mrkting	1.305	(0.298)	1.271	(0.313)	1.362	(0.354)
permacltr	1.026	(0.191)	1.062	(0.206)	1.105	(0.232)
msterfrmer	0.865	(0.160)	0.903	(0.179)	0.965	(0.207)
croping	0.817	(0.245)	0.872	(0.268)	0.874	(0.297)
problems faced						
waterprob	1.458**	(0.272)	1.456*	(0.286)	1.531**	(0.321)
labourinputprob	1.017	(0.199)	0.982	(0.198)	0.999	(0.220)
noprofitprob	1.067	(0.227)	1.047	(0.238)	0.977	(0.239)
beneficiary characteristics						
benefmale			1.054	(0.237)	1.104	(0.275)
benefage			1.007	(0.009)	1.010	(0.010)
benefprimarylev			1.001	(0.210)	0.980	(0.209)
benefmarried			1.045	(0.264)	1.002	(0.268)
benefarmer			1.070	(0.243)	1.033	(0.242)
benefgrpmember			0.936	(0.194)	0.954	(0.210)
household characteristics						
chronillmember					0.991	(0.206)
orphan					1.003	(0.210)
chnbelow5					0.905	(0.147)
fdsecbelowaverage					1.086	(0.227)
mutasa					1.032	(0.270)
landsize					0.982	(0.052)
hhdmembs					1.034	(0.047)
remittance					1.053	(0.228)
wealthmiddlev					0.731	(0.186)
wealthrich					0.681	(0.180)
constant	0.192***	(0.052)	0.120***	(0.065)	0.098***	(0.064)
log-likelihood	-190.716		-176.532		-172.578	
AIC	417.432		401.063		413.673	
observations	165		154		152	

Standard errors (seEform) in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table 5.20a: Weibull model results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 1		Model 2		Model 3	
	haz.ratio	**se**	**haz.ratio**	**se**	**haz.ratio**	**se**
main variables						
earlyadopt	0.772	(0.132)	0.749*	(0.132)	0.787	(0.142)
irrigwatertap	1.071	(0.186)	1.101	(0.196)	1.129	(0.211)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn	0.733	(0.164)				
yield increase per crop						
leafyvegyldinc			0.636**	(0.118)	0.635**	(0.125)
tomatoyldinc			0.755	(0.145)	0.736	(0.147)
onionyldinc			1.083	(0.198)	1.038	(0.202)
beansyldinc			0.955	(0.177)	1.004	(0.190)
maizeyldinc			0.831	(0.158)	0.825	(0.159)
gnutyldinc			1.517*	(0.323)	1.530**	(0.329)
training						
bookkeep					0.736	(0.147)
mrkting					1.667**	(0.381)
permacltr					1.148	(0.212)
msterfrmer					0.870	(0.161)
croping					0.907	(0.268)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmember						
household characteristics						
chronillmember						
orphan						
chnbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembs						
remittance						
wealthmiddlev						
wealthrich						
ln_p	1.996***	(0.138)	2.069***	(0.142)	2.128***	(0.147)
constant	0.044***	(0.014)	0.043***	(0.013)	0.040***	(0.014)
log-likelihood	-160.398		-153.16		-149.473	
AIC	332.797		328.32		330.946	
observations	165		165		165	

Standard errors (seEform) in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table 5.20b: Weibull model results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 4		Model 5		Model 6	
	haz.ratio	se	haz.ratio	se	haz.ratio	se
main variables						
earlyadopt	0.739	(0.136)	0.661**	(0.132)	0.695*	(0.150)
irrigwatertap	1.138	(0.216)	1.031	(0.218)	0.898	(0.222)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn						
yield increase per crop						
leafyvegyldinc	0.596**	(0.121)	0.553***	(0.125)	0.541**	(0.131)
tomatoyldinc	0.756	(0.151)	0.728	(0.157)	0.660*	(0.154)
onionyldinc	1.141	(0.235)	1.158	(0.253)	1.160	(0.281)
beansyldinc	1.105	(0.222)	1.269	(0.269)	1.384	(0.349)
maizeyldinc	0.846	(0.163)	0.872	(0.186)	0.930	(0.221)
gnutyldinc	1.420	(0.311)	1.624**	(0.382)	2.005**	(0.590)
training						
bookkeep	0.762	(0.155)	0.719	(0.158)	0.709	(0.165)
mrkting	1.704**	(0.400)	1.680**	(0.430)	1.952**	(0.545)
permacltr	1.031	(0.198)	1.094	(0.221)	1.231	(0.277)
msterfrmer	0.829	(0.159)	0.866	(0.183)	0.922	(0.213)
croping	0.706	(0.221)	0.799	(0.256)	0.792	(0.289)
problems faced						
waterprob	1.831***	(0.352)	1.825***	(0.375)	2.021***	(0.457)
labourinputprob	1.029	(0.202)	0.961	(0.198)	0.998	(0.236)
noprofitprob	1.143	(0.252)	1.108	(0.261)	0.993	(0.258)
beneficiary characteristics						
benefmale			1.011	(0.232)	1.124	(0.287)
benefage			1.012	(0.009)	1.018*	(0.011)
benefprimarylev			1.008	(0.222)	0.980	(0.217)
benefmarried			1.083	(0.285)	1.013	(0.284)
benefarmer			1.074	(0.250)	1.028	(0.250)
benefgrpmember			0.818	(0.174)	0.879	(0.209)
household characteristics						
chronillmember					0.974	(0.214)
orphan					0.874	(0.201)
chnbelow5					0.826	(0.156)
fdsecbelowaverage					1.069	(0.232)
mutasa					1.136	(0.300)
landsize					0.953	(0.053)
hhdmembs					1.071	(0.055)
remittance					1.077	(0.253)
wealthmiddlev					0.624*	(0.171)
wealthrich					0.519**	(0.149)
ln_p	2.211***	(0.154)	2.279***	(0.165)	2.315***	(0.168)
constant	0.025***	(0.010)	0.012***	(0.008)	0.007***	(0.006)
log-likelihood	-143.701		-129.999		-124.954	
AIC	325.403		309.999		319.907	
observations	165		154		152	

Standard errors (seEform) in parentheses

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

Table 5.21a: Cox model (Breslow) results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 1		Model 2		Model 3	
	haz.ratio	**se**	**haz.ratio**	**se**	**haz.ratio**	**se**
main variables						
earlyadopt	0.857	(0.146)	0.836	(0.146)	0.881	(0.158)
irrigwatertap	1.071	(0.186)	1.087	(0.192)	1.114	(0.204)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn	0.741	(0.166)				
yield increase per crop						
leafyvegyldinc			0.660**	(0.124)	0.651**	(0.128)
tomatoyldinc			0.793	(0.152)	0.778	(0.154)
onionyldinc			1.076	(0.198)	1.043	(0.202)
beansyldinc			0.920	(0.170)	0.963	(0.182)
maizeyldinc			0.838	(0.160)	0.832	(0.160)
gnutyldinc			1.393	(0.296)	1.401	(0.301)
training						
bookkeep					0.719*	(0.144)
mrkting					1.510*	(0.344)
permacltr					1.101	(0.201)
msterfrmer					0.899	(0.165)
croping					0.905	(0.264)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmember						
household characteristics						
chronillmember						
orphan						
chnbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembs						
remittance						
wealthmiddlev						
wealthrich						
$\chi 2$	8.56		7.98		17.77	
PH test (prob $>\chi 2$)	0.073		0.537		0.217	
df	4		9		14	
log-likelihood	-650.075		-644.508		-641.637	
AIC	1308.151		13.7.016		1311.274	
observations	165		165		165	

Standard errors (seEform) in parentheses

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

Table 5.21b: Cox model (Breslow) results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 4		Model 5		Model 6	
	haz.ratio	se	haz.ratio	se	haz.ratio	se
main variables						
earlyadopt	0.837	(0.152)	0.774	(0.153)	0.804	(0.169)
irrigwatertap	1.111	(0.208)	1.044	(0.216)	0.925	(0.219)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn						
yield increase per crop						
leafyvegyldinc	0.622**	(0.127)	0.593**	(0.133)	0.571**	(0.137)
tomatoyldinc	0.785	(0.157)	0.756	(0.161)	0.694	(0.159)
onionyldinc	1.131	(0.230)	1.138	(0.243)	1.145	(0.266)
beansyldinc	1.056	(0.212)	1.179	(0.250)	1.277	(0.317)
maizeyldinc	0.858	(0.166)	0.880	(0.188)	0.927	(0.217)
gnutyldinc	1.313	(0.289)	1.447	(0.339)	1.719*	(0.489)
training						
bookkeep	0.747	(0.152)	0.722	(0.158)	0.713	(0.165)
mrkting	1.540*	(0.358)	1.483	(0.375)	1.727**	(0.470)
permacltr	1.025	(0.194)	1.071	(0.212)	1.185	(0.257)
msterfrmer	0.866	(0.164)	0.892	(0.185)	0.945	(0.212)
croping	0.762	(0.233)	0.831	(0.261)	0.839	(0.295)
problems faced						
waterprob	1.642***	(0.316)	1.636**	(0.331)	1.781***	(0.392)
labourinputprob	1.043	(0.206)	0.998	(0.206)	1.052	(0.244)
noprofitprob	1.097	(0.240)	1.061	(0.247)	0.937	(0.239)
beneficiary characteristics						
benefmale			1.036	(0.236)	1.145	(0.287)
benefage			1.010	(0.009)	1.016	(0.010)
benefprimarylev			1.010	(0.218)	0.981	(0.214)
benefmarried			1.115	(0.291)	1.023	(0.282)
benefarmer			1.082	(0.252)	1.039	(0.250)
benefgrpmember			0.887	(0.188)	0.940	(0.217)
household characteristics						
chronillmember					0.990	(0.214)
orphan					0.840	(0.188)
chnbelow5					0.848	(0.151)
fdsecbelowaverage					1.032	(0.221)
mutasa					1.102	(0.291)
landsize					0.950	(0.052)
hhdmembs					1.067	(0.052)
remittance					1.052	(0.239)
wealthmiddlev					0.640*	(0.170)
wealthrich					0.565**	(0.158)
$\chi 2$	16.99		24.2		41.27	
PH test (prob >$\chi 2$)	0.455		0.393		0.153	
df	17		23		33	
log-likelihood	-637.847		-583.815		-570.167	
AIC	1309.694		1213.631		1206.333	
observations	165		154		152	

Standard errors (seEform) in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table 5.22a: Cox model (Efron) results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 1		Model 2		Model 3	
	haz.ratio	se	haz.ratio	se	haz.ratio	se
main variables						
earlyadopt	0.869	(0.149)	0.841	(0.147)	0.886	(0.159)
irrigwatertap	1.091	(0.189)	1.114	(0.197)	1.143	(0.212)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn	0.699	(0.157)				
yield increase per crop						
leafyvegyldinc			0.632**	(0.118)	0.623**	(0.123)
tomatoyldinc			0.773	(0.149)	0.745	(0.149)
onionyldinc			1.061	(0.194)	1.026	(0.199)
beansyldinc			0.899	(0.166)	0.945	(0.178)
maizeyldinc			0.822	(0.156)	0.819	(0.157)
gnutyldinc			1.448*	(0.308)	1.461*	(0.314)
training						
bookkeep					0.694*	(0.139)
mrkting					1.635**	(0.374)
permacltr					1.151	(0.212)
msterfrmer					0.904	(0.168)
croping					0.917	(0.270)
problems faced						
waterprob						
labourinputprob						
noprofitprob						
beneficiary characteristics						
benefmale						
benefage						
benefprimarylev						
benefmarried						
benefarmer						
benefgrpmember						
household characteristics						
chronillmember						
orphan						
chnbelow5						
fdsecbelowaverage						
mutasa						
landsize						
hhdmembs						
remittance						
wealthmiddlev						
wealthrich						
$\chi 2$	11.64		10.6		23.22	
PH test (prob >$\chi 2$)	0.02		0.304		0.507	
df	4		9		14	
log-likelihood	-631.862		-624.877		-621.067	
AIC	1271.724		1267.755		1270.134	
observations	165		165		165	

Standard errors (seEform) in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table 5.22b: Cox model (Efron) results for the determinants of the duration smallholder farmers last in drip irrigation

	Model 4		Model 5		Model 6	
	haz.ratio	se	haz.ratio	se	haz.ratio	se
main variables						
earlyadopt	0.831	(0.152)	0.759	(0.151)	0.796	(0.170)
irrigwatertap	1.144	(0.216)	1.055	(0.221)	0.908	(0.222)
distancefromgdn	1.000	(0.000)	1.000	(0.000)	1.000	(0.000)
yieldincgdn						
yield increase per crop						
leafyvegyldinc	0.585***	(0.120)	0.546***	(0.124)	0.525***	(0.128)
tomatoyldinc	0.755	(0.152)	0.723	(0.156)	0.652*	(0.152)
onionyldinc	1.127	(0.232)	1.142	(0.247)	1.141	(0.273)
beansyldinc	1.051	(0.211)	1.205	(0.256)	1.310	(0.331)
maizeyldinc	0.844	(0.161)	0.872	(0.186)	0.918	(0.216)
gnutyldinc	1.349	(0.297)	1.516*	(0.358)	1.874**	(0.548)
training						
bookkeep	0.725	(0.148)	0.689*	(0.152)	0.673*	(0.158)
mrkting	1.682**	(0.395)	1.612*	(0.413)	1.930**	(0.538)
permacltr	1.052	(0.201)	1.105	(0.222)	1.245	(0.274)
msterfrmer	0.867	(0.167)	0.895	(0.190)	0.950	(0.219)
croping	0.738	(0.229)	0.828	(0.264)	0.830	(0.299)
problems faced						
waterprob	1.811***	(0.353)	1.793***	(0.369)	1.994***	(0.452)
labourinputprob	1.050	(0.208)	0.998	(0.207)	1.042	(0.247)
noprofitprob	1.131	(0.250)	1.088	(0.256)	0.954	(0.248)
beneficiary characteristics						
benefmale			1.050	(0.241)	1.178	(0.299)
benefage			1.013	(0.009)	1.019*	(0.011)
benefprimarylev			0.999	(0.220)	0.971	(0.215)
benefmarried			1.116	(0.293)	1.015	(0.284)
benefarmer			1.113	(0.261)	1.068	(0.261)
benefgrpmember			0.848	(0.181)	0.921	(0.218)
household characteristics						
chronillmember					1.005	(0.221)
orphan					0.816	(0.187)
chnbelow5					0.811	(0.151)
fdsecbelowaverage					1.039	(0.225)
mutasa					1.125	(0.298)
landsize					0.947	(0.053)
hhdmembs					1.081	(0.055)
remittance					1.076	(0.251)
wealthmiddlev					0.613*	(0.166)
wealthrich					0.521**	(0.149)
$\chi 2$	23.23		33.29		56.92	
PH test (prob $>\chi 2$)	0.142		0.076		0.006	
df	17		23		33	
log-likelihood	-615.66		-562.688		-548.469	
AIC	1265.32		1171.376		1162.938	
observations	165		154		152	

Standard errors (seEform) in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

5.7.2.1 Discussion of exponential, Weibull and Cox results

In this section, all the results discussed will be based on Model 6 for each method. For the parametric models (exponential and Weibull), the Weibull results (Tables 5.20a and 5.20b) will be used in this discussion. The log-likelihood and AIC results indicate that the Weibull method is preferred to the exponential method as it has a higher log-likelihood (-124.954 compared to -172.578 for the exponential for method) and a lower AIC value (319.907 versus 413.673 for the exponential method) (Mills, 2011). Intuitively, using the Weibull model also makes sense as it is highly improbable that the assumption of the exponential model of a constant baseline hazard over 10 years holds given that this project is highly dependent on weather patterns which fluctuate with time. In addition, the results for the exponential model (Tables 5.19a and 5.19b) indicate that only *waterprob* and *leafyvegyldinc* have a significant impact on the likelihood of dropping out and hence the duration beneficiary survives in the project.

For the semi-parametric method (Cox Breslow and Cox Efron) the Cox Breslow results (Tables 5.21a and 5.21b) will be used for this analysis. The results from both the Breslow and Efron methods for the covariates are similar as shown in Tables 5.21a - 5.22b. However, the Breslow method is more suitable as the results indicate that it does not violate the proportional hazard (PH) assumption, upon which it is based. The p-values for the χ^2 tests from the Schoenfeld global test for proportional hazards is above $\alpha=0.10$ for 5 of the 6 models estimated. For Model 6, which will be used in the discussion, the p-value for the χ^2 test is 0.153.

Main variables

The Weibull (Table 5.20b) model results indicate that a beneficiary who received the kit in 2003 (*earlyadopt*) has a lower hazard by about 30% compared to one who received the kit later ceteris paribus. Thus an early adopter is expected to last longer in the project compared to a late adopter. This result is similar to that obtained in the model for the propensity to dropout (Tables 5.11a and 5.11b). Although the Cox Breslow model results (Tables 5.21a and 5.21b) also indicate that an early adopter has a lower hazard of dropping out of the drip irrigation program, the result is not significant. All other main variables have no statistically significant impact on the duration a beneficiary lasts in the project.

Yield increase variables

The Weibull and Cox Breslow results indicate that a yield increase in vegetables (*leafyvegyldinc*) reduces the hazard of dropping out by approximately 43-46%. In addition, the Weibull results indicate that a yield increase in tomatoes (*tomatoyldinc*) lowers the hazard by approximately 34%. The hazard for beneficiaries who realise a yield increase in groundnuts is approximately 2 times greater (2.005 and 1.719 for the Weibull and Breslow methods respectively) than that of beneficiaries with no yield increase in groundnuts. Thus beneficiaries who realise a yield increase in vegetable and tomato yields are more likely to continue with the project for longer, whilst those who realise a yield increase in groundnuts (*gnutyldinc*) are likely to drop out earlier. These results are expected and consistent yet again with those from the propensity to drop out model (Tables 5.11a and 5.11b).

Training

Receipt of marketing training (*mrkting*) increases a beneficiary's instantaneous probability of dropping out of the project by 73%- 95% according to the results of Tables 5.20a - 5.21b.

This result in itself is unexpected as one would expect a beneficiary trained in marketing to last longer in the project. However, as discussed under the results for the determinants of a beneficiary's propensity to drop out (section 5.6.1), this result is plausible as increasing household consumption was the main objective of this project.

Problems faced

Beneficiaries who experience water related problems (*waterprob*) have a conditional probability of dropping out which is approximately 2 times more than that of beneficiaries who do not experience water related problems ceteris paribus. This result is consistent for both methods and similar to the Probit model results.

Beneficiary characteristics

A unit increase in a beneficiary's age (*benefage*) is expected to increase the risk of dropping out by about 2% (Table 5.20b). This implies that younger beneficiaries are more likely to last longer in the project compared to older ones which is expected. This result is only significant for the Weibull model and not the Cox Breslow method. Results from the marginal propensity to dropout model (Table 5.11b) though indicate that age is not a major factor in determining whether on drops out or not. All other beneficiary characteristics have no substantial influence on the risk of dropping out and hence the duration one lasts in the project.

Household characteristics

Among the household variables, only wealth class has a significant effect on the duration a beneficiary lasts in the project. Results from Tables 5.20a - 5.21b shows that the instantaneous probability of dropping out is 36-48% lower for households in the middle level and rich wealth classes compared to that of poor households, all things being equal. Thus richer household last longer in the project compared to poor ones. This result is contrary to the expectations and is consistent with that obtained via the Probit model.

For the Probit and duration methods, the results indicate that *earlyadopt*, *leafyvegyldinc*, *gnutyldinc*, *bookkeep*, *marketing*, *waterprob*, and *wealthrich* have a significant impact on drop out chances and the duration a beneficiary lasts in the project. In addition, the Probit results indicate that *chronillmember* also has a significant influence on the probability of dropping out only. On the other hand *tomatoyldinc*, *benefage* and *wealthmiddlelevel* have a notable impact on the duration one lasts in the project only.

5.7.3 Goodness of fit tests

For the parametric models, the goodness of fit statistics based on the log-likelihood test and the Akaike criterion (AIC) indicate that the Weibull model is preferred to the exponential model (section 5.4.3). As mentioned earlier, the Weibull method has a higher log-likelihood (-124.954 compared to -172.578) and a lower AIC value (319.907 versus 413.673) than the exponential method thus rendering it more suitable for the analysis.

The Cox models are all based on the proportional hazard (PH) assumption. This assumption assumes that the baseline hazard varies with time. If this assumption fails, then the resultant model gives incorrect estimates. Schoenfeld's global test is performed on each of the 6 models to test for any violations of the PH assumption. The Schoenfeld global test results in Table 5.21 (χ^2, PHtest (prob > χ^2)) indicate that for the Cox model estimated using Breslow's method for accounting for ties, there is no evidence of a violation of the proportional hazards (PH) assumption for 5 of the 6 models estimated. The p-values for the χ^2 tests range from 0.153 for model 2 to 0.537 for model 3, which is above α=0.10. Model 1 though based in only the main factors violated the PH assumption. For the Efron method (Table 5.22a and 5.22b) however, the global test results are varied, with models 2, 3, 4 and 5 and models 1 and 6 indicating that there is no evidence and there is evidence of the violation of the PH assumption respectively. The test for the more comprehensive model (Model 6) in particular indicates that the χ^2 test (0.006) is significant at the 1% level.

Violation of the PH assumption generally indicates the presence of time- varying covariates in the model (Abeysekera and Sooriyarachchi, 2009; Jones, 2005; Rabe-Hesketh and Everitt, 2007). In order to identify these factors, the Schoenfeld global test results for each variable are estimated. As indicated above, the Cox Breslow results are used as they do not violate the PH assumption.

5.7.4 Overall goodness of fit test

The Cox-Snell results for model fit in Figure 5.9 below clearly show that for the parametric models (Figure 5.9a and 5.9b), the Weibull model (Figure 5.9b) is the preferred model as the hazard function closely follows the 45° line. This is reinforced by the log-likelihood and AIC tests which also favour the Weibull model as indicated in section 5.7.3above.

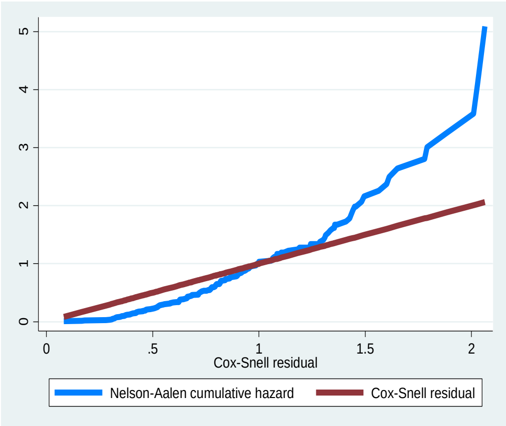
For the semi-parametric model, the Breslow method, Figure 5.9c is better than the Efron method (Figure 5.9d) as the hazard function follows the 45° line better. However, graphical comparisons alone are not sufficient (Abeysekera and Sooriyarachchi, 2009). The results from the PH test (Tables 5.21b and 5.22b for Model 6) also confirm that for the semi-parametric models, the Breslow method is the better method here. The hazard function follows the 45° line closely for lower values and deviates for higher values. This is to be expected in the presence of censored data.

So the Weibull and Cox Breslow methods (Figure 5.9b and 5.9c) are the best models. The results discussed in section 5.7.3 above are thus appropriate as the Cox Breslow does not violate the PH assumption.

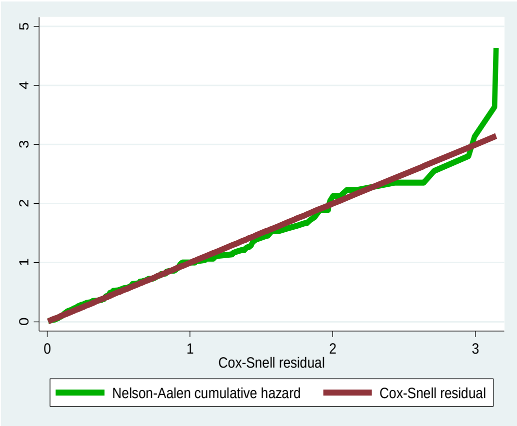
From the two methods shown to be the best, the Cox Breslow method is more suited to this data than the Weibull method. This is because the Cox Breslow method allows the baseline hazard function to vary with time and this gives room for the data to determine its own structure. The Weibull method on the other hand imposes more structure as the baseline hazard has to be monotonically increasing.

Figure 5.9: Cox-Snell plots[54] for goodness of fit

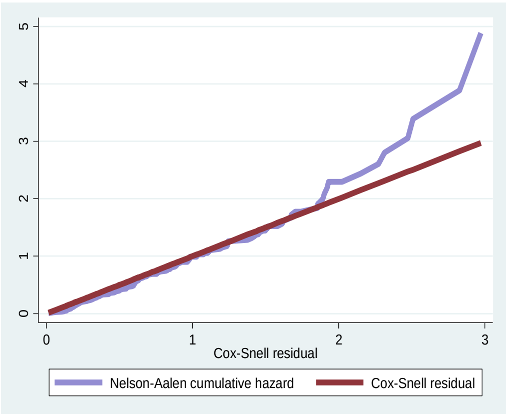
a. Exponential model



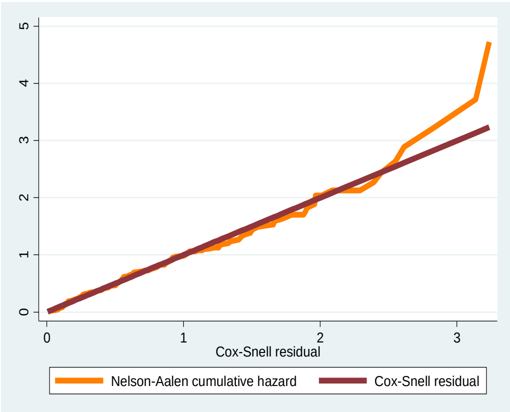
b. Weibull model



c. Cox Breslow model



d. Cox Efron model



[54] Deviations from the 45° line at higher values are normal in the due to the presence of censored data

5.8 Conclusion

The objective of this research was to establish the factors that significantly influence dropout rates in smallholder drip irrigation projects. In addition, the factors that influence the length of time that a beneficiary survives in the smallholder drip irrigation project are also identified.

Overall, the main findings reveal that receiving the drip kit early significantly reduces chances of dropping out, as well as increasing the duration a beneficiary lasts in the project.

Other relevant training also influences beneficiary dropout rates. Receipt of training in book keeping is beneficial as it has a negative effect on drop out probabilities. Contrary to this receipt of training in marketing has a positive effect on drop out probabilities. Training in marketing also substantially reduces the number of years a beneficiary uses drip irrigation.

Of the crops grown under irrigation, only leafy vegetable yield increases during the drip irrigation period significantly reduces and increases a beneficiary's probability of dropping out and the number of years they last in the project respectively. Yield increases in tomatoes on the other hand have a significant impact on the duration a beneficiary lasts in the project. Realising yield increases during the drip irrigation period in rain fed crops such as groundnuts notably increases the tendency to drop out of the project. Groundnut yield increases also notably reduce the duration a beneficiary lasts in the drip irrigation project.

Experiencing water problems including water shortages, the water source being too far and problems with filling up the tank with water, substantially increases a beneficiary's chance of dropping out of the project. Furthermore, experiencing water problems reduces the length of time a beneficiary lasts in the project.

Some beneficiary and household characteristics also have a notable impact on duration a beneficiary lasts in the project. An increase in a beneficiary's age reduces the number of years the beneficiary uses drip irrigation. Beneficiaries from households with a chronically ill member are more likely to drop out of the project. Conversely, beneficiaries from rich households (as classified by the wealth index) are less likely to drop out from the project. Household wealth increases the number of years a beneficiary uses drip irrigation before dropping out. These findings shed more light on the avenues which donors, the government and other interested stakeholders can use to encourage beneficiaries to continue with the smallholder drip irrigation project.

From the results, it is evident that water problems play a major role in increasing dropout rates. Policies and programs addressing the issue of access to water such as drilling of boreholes will go a long way in addressing water shortage problems as well as ensuring that the water source is in close proximity to the gardens. In Mutasa, some farmers interviewed indicated that promises to drill boreholes to improve water access made at the inception of the project had failed to materialise. Thus they had no choice but to drop out of the project. Introduction of technologies such as the use treadle pumps will greatly assist households looking after chronically ill members as well as elderly beneficiaries who are part of the target population by making it easier for them to fill the buckets or drums for irrigation. Treadle pumps have been successfully used by smallholder farmers in the neighbouring Malawi, Tanzania and Kenya (Mangisoni, 2008 as cited in Domenech and Ringler, 2013). In Zimbabwe use of the treadle pump has been limited by shortages of pumps in the market (Kay, 2001). Ensuring that there is a reliable water source in close proximity to the garden will also reduce the time one has to use to fetch water and thus motivate households looking after chronically ill members to continue with the project. They will be able to manage to look after the chronically ill as well as mind the garden without having to source additional labour.

Implementing agencies also need to assess the training needs of the target community in order to provide relevant and timely training. Associated training such as bookkeeping is important as this will allow the beneficiary to keep track of the costs and benefits associated with drip irrigation. This will assist the beneficiaries with their decision making process. Training in marketing in this case proved to increase the probability of beneficiaries dropping out of the project. This could have been due to the fact that some beneficiaries overestimated the expected returns of the project such that when they failed to realise these returns, they were discouraged and dropped out. In areas such as Mutoko, where market gardening was already rife, glut in the available markets meant that farmers failed to realise the profits they expected and thus were discouraged. Other farmers did not attempt to sell any surplus at all as the markets in both areas were few and quite far away. The major markets for the Mutasa and Mutoko farmers are Sakubva musika in Mutare and Mbare market in Harare.

In addressing the issue of food security through promoting irrigated vegetable gardens, it is important to note that rain fed crops also play a major role in determining food security. Hence rain fed crops grown by the beneficiary's household also impact on whether or not they will continue with the smallholder drip irrigation project. Good yields in competing crops such as groundnuts increase chances of beneficiaries dropping out as the opportunity cost of growing vegetables is high, especially in terms of labour use. Thus an assessment needs to be made before implementing the project in an area to assess whether the project is likely to be beneficial or not in the face of competition. Choice of crops grown under irrigation and the area to allocate to each crop is also important. Leafy vegetables appear to be the most beneficial crop in terms of encouraging farmers to continue with drip irrigation.

Early adoption of the project is beneficial in reducing project dropout rates. Timely dissemination of project technology will go a long way in encouraging farmers to continue with drip irrigation. Farmers who received the drip kits at the inception phase (2003) were less likely to drop out and were more likely to last longer in the project. This is probably because they benefited immensely from the amount of support available from the donor organisation and other government departments, which decreased as the project life increased. Efforts to disseminate project technology at the inception phase to as many beneficiaries as possible should be considered in the future for all capacity building projects in order to improve their impact on the targeted community.

Targeting of the projects still needs to be improved. Despite the fact that the project was aiming to promote females among other beneficiaries, there were more male than female beneficiaries in this project. This tends to be common in patrilineal societies. Improvements in targeting also need to consider household wealth status. Although the project was aimed at poor vulnerable households (especially those with a member suffering from chronic illness and those looking after orphans), it is actually those households that are better off that were more likely to continue with the project. This shows that it is important to assess the requirements of project at hand in order to determine whether poor households are able to afford the project. The main issue in the adoption of drip irrigation by smallholder farmers has been the high costs associated with the procurement of the drip kit (FAO SAPR, 2000; Kay, 2001). In this project, all the beneficiaries were given drip kits courtesy of USAID and Plan International so the initial capital outlay costs were removed. However the results suggest that maintenance costs associated with smallholder drip irrigation may have been too high for poor households. Therefore there is need to put in place measures that will assist smallholder drip irrigation farmers in order to ensure that sustainability for poorer households.

The following conclusions are drawn from information collected by the questionnaires to which a small number of the beneficiaries responded as well as from responses that were follow up questions (merely to satisfy the curiosity of the principal researcher) to answers for other questions and as such were not documented.

Interviews with the beneficiaries also revealed that they were motivated mainly through the interest that was shown by the donor organisation in their progress. Competitions such as field days for the beneficiaries and the extension services provided, motivated the beneficiaries to continue with the project. Thus it is important for all stakeholders involved to work together to ensure that even after the project benefactors withdraw, farmers continue to receive the extension support they need to continue with the project. This can be achieved for instance through collaboration with the government as emphasised by Merrey et al. (2008). Government agricultural extension departments already have permanent extension workers in most areas and these if incorporated at the onset of the project will be able to take over the full responsibility of providing support once the benefactors withdraw.

Security issues also need to be considered as beneficiaries indicated that one of the major threats they faced was theft of the irrigation equipment. As a result, they had to carry the kit to and from the garden each day. This increased the amount of labour required to ferry and assemble the kit and also the amount of time spent in the garden. Beneficiaries had to stay in the garden the entire time the drip kit was operating, especially if the garden was far away from their homestead. This defeated the whole purpose of the drip kit. The main idea is that the beneficiary just fills the tank with water and goes to do other duties, whilst the drip kit waters the garden. Drip irrigation compared to hand watering thus presented higher opportunity costs in terms of labour and time required.

Considerations should be made of the suitability of the kit in terms of the size of garden it can irrigate. Mutoko farmers especially indicated that the kit was too small for their gardens (approximately 92% of the beneficiaries who indicated that they dropped out because the kit was too small were from Mutoko district). Before the introduction of the smallholder drip irrigation kit, farmers in Mutoko were already involved in market gardening on a larger scale. The drip kit was only able to irrigate a $100m^2$ garden, which was insufficient for the farmers. It was more laborious to move the kit from one part of the garden to the other. As a result beneficiaries' abandoned drip irrigation and continued with their previous methods of watering. This raises the issue of involving intended beneficiaries in all phases of the project, from project choice to project evaluation (participatory approach). Using a participatory approach before implementing the smallholder drip irrigation project in Mutoko, perhaps would have brought to light the issue of the drip kit being too small and appropriate measures would have been taken so as to improve project uptake rates.

It is important to note that this capacity building project is different from other forms of assistance the beneficiaries have been used to. Most assistance in the past has been based on beneficiaries receiving actual food so they did not have to contribute anything in the past. In order to prepare beneficiaries for this shift, training for transformation was conducted. Despite this, the response from most of the beneficiaries during the interviews indicated that they failed to grasp the concept. In particular, beneficiaries were asked what their intentions were in the future with regards to drip irrigation (Appendix B1, section B: Q16). Most of the beneficiaries who had dropped out indicated that though they would like to begin using drip irrigation again, their actions were dependent upon whether Plan international would provide them with new drip kits to replace the damaged ones. This implied that they failed to grasp that they were responsible for all other repairs and replacements that were required after receiving the initial kit. As such it is important that training for transformation be done over a period of time with refresher courses being offered. This will give the beneficiaries time to change their way of operating and become more independent. After all it takes quite a while for one's mindset to change.

The need to evaluate projects from the point of view of the farmer cannot be overlooked. Farmers' expectations, realisations and views with regards to the project have to be incorporated in the evaluations as they provide insight into areas that worked well and those that require improvements. Most of the evaluation reports available in organisations are for the benefit of the donor organisation itself and their sponsors. These tend to mainly focus on the administrative side of the project and the measureable outcomes are in terms of the number of kits distributed and number of gardens established. These measures unfortunately do not give a complete picture of how the project fared and whether or not the intended benefits were realised by the targeted population. Moreover, it is necessary that organisations implementing projects, in addition to baseline, within project and end of project evaluations, also conduct evaluations a few years after the project time has lapsed. This is especially relevant for capacity building projects in order to ensure that the goal of sustainability and development embedded in these projects is met.

It will be wise for future projects to consider using the participatory approach from choosing the type of intervention required right through to implementing and evaluating the technology.

Merits of involving farmers in different stages of a project have been highlighted by different research. These include dissemination of more suitable technologies to farmers, greater economic impact and better project uptake and continuance rates. Moreover, farmer participation also has positive spill over effects outside the project, in that it encourages community work and creates a platform for setting up priorities and practices in a better way (Johnston, Lilja & Ashby, 2003; Weinstein & Sandman, 2002).

The results in this study are only based on two districts, Mutoko and Mutasa where the beneficiaries benefited from the smallholder drip irrigation scheme under Plan International. As indicated in Chapter 4, section 4.0, the smallholder drip irrigation project was implemented by USAID via 30 NGO's. It would be worthwhile to survey a wider sample of beneficiaries to include some from different districts who benefited under other NGO so as to establish whether there are any differences in terms of the way NGO's rolled out the project to beneficiaries. Such differences provide a learning platform which will help improve on existing and better future projects. Some work has been done in this area howbeit using small samples. More evaluations still need to be carried out, with special emphasis on issues such as training, early adoption, wealth status and the impact of rain-fed crops which have been flagged by this research as being drivers of dropout rates among smallholder drip irrigation farmers. This will shed more light and add value to the conclusions drawn.

CHAPTER 6

Can smallholder drip irrigation improve food security at the household level? The case of home nutrition gardens in Mutasa and Mutoko districts in Zimbabwe.

"Policies aimed at enhancing agricultural productivity and increasing food availability, especially when smallholders are targeted, can achieve hunger reduction even where poverty is widespread"

José Graziano da Silva, Kanayo F. Nwanze, Ertharin Cousin
Heads of FAO, IFAD and WFP (Reliefweb, 2013)

6.0 Introduction

Food security is a basic human right. According to The World Food Summit of 1996, food security is "*when all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life"* (Pinstrup-Anderson, 2009*)*.

Although the number of people suffering from chronic hunger has decreased, an estimated 842 million people worldwide experienced chronic hunger during 2011-2013. In Sub-Saharan Africa, approximately 24.8% of the population are hungry (Reliefweb, 2013). Most of the hungry population consist of poor smallholder families, who reside in the rural and marginal areas. Progress towards the attainment of Millennium Development Goal (MDG) 1 of halving the hungry population by 2015 in Sub-Saharan Africa has been limited so far. The heads of the Food and Agricultural Organisation (FAO), the International Fund for Agricultural Development (IFAD) and the World Food Program (WFP) have pointed out that there is still a chance for countries lagging behind to meet their MDG1 targets. This, they emphasised can be achieved through the promotion of nutrition-sensitive interventions and policies aimed at increasing food availability and the income of the poor in rural areas (Reliefweb, 2013).

Realisation of the lack of sustainability in humanitarian assistance provided to vulnerable people in the form of food aid led to the introduction and promotion of capacity building strategies (Mutambara, Satambara & Masvongo, 2013). Having the capability to obtain the food needed by its members renders a household food secure (Pinstrup-Anderson, 2009). Capacity building strategies aim to improve the aptitude of individuals and the community by equipping them with food skills designed to enable them to feed themselves without relying from external sources and hand outs (FSN, 2012).

The establishment of home nutrition gardens has been promoted in Sub-Saharan Africa as nutrition focused capacity building strategy for improving household food availability and income. Nutrition home gardens are advantageous in that they provide additional nutritious food and increased food diversity for the household and thus contribute to addressing malnutrition issues (CAPSA, 2013; Mutambara et al., 2013). Moreover surplus produce from home nutrition gardens can be sold to generate income.

Alongside home nutrition gardens, other interventions aimed at ensuring the success of the home nutrition gardens such as the use of low cost drip irrigation systems and treadle pumps have also been introduced and promoted (Kay, 2001). In Zimbabwe, a country mainly dependent on rain fed agriculture, the use of low cost drip irrigation systems in home gardens has been widely promoted. Belder et al. (2007) highlights that over 70,000 drip kits were distributed to smallholder farming households in various districts in Zimbabwe through different non-governmental organisations (NGO's) and donors. The main objective of the program was to encourage households to establish nutrition gardens to enable them to get direct access to vegetables as well as to generate income from selling surplus crops. Households which benefited from the program received a drip kit sufficient to irrigate gardens of various sizes (from as small as $13m^2$, Schmidt and Vorster, 1995).

Studies have been carried out to assess various aspects of the home nutritional gardens. However there is very little literature pertaining to whether the program's main objective of improving household food security was achieved in Zimbabwe (Mutambara et al., 2013). Evidence suggests that for households in Nyanga North district, adoption of home nutrition gardens led to an improvement in household nutritional status. The frequency of being underweight in children below the age of 5 was reduced and incidences of chronic illness among adults also decreased (Mutambara et al., 2013).

On the other hand, Mugabe et al. (2008) in their study failed to come to a conclusion as to whether the use of drip irrigation by smallholder households in home gardening in Gweru and Bikita districts in Zimbabwe led to improvements in household food security. This was because they obtained conflicting results on the impact of different wellbeing measures such as changes in the availability of food and ability of a household to pay fees before and after participation in the program. Their results were not consistent within and between adopters (those who were still using the kit), disadopters (those who had used the kit at one point in time but had stopped) and non-adopters (those who had never used the kit before).

From the above findings, it is evident that smallholder households in different districts have experienced different levels of improvement in their food security from using drip irrigation in their home nutrition gardens. The objective of this research is to find out whether food security improved for households who participated in the smallholder drip irrigation project in Mutasa and Mutoko districts in Zimbabwe. The findings of this study are important for purposes of promoting and improving smallholder drip irrigation programs in Zimbabwe through highlighting areas that need to be addressed in order to make the program a success.

6.1 Literature review

Different agricultural interventions have been implemented worldwide, in a bid to improve household nutritional status and thus alleviate food insecurity. A comparison between home garden interventions and other agricultural interventions suggested that home garden interventions result in better nutritional outcomes than other interventions such as livestock enterprises and cash crops. The nutritional outcomes mainly assessed include agricultural yields, dietary intake of vegetables and fruit, anthropometric measures such as stunting and underweight, biochemical or clinical measures such as anaemia, serum retinol (vitamin A) increase in children and changes in the incidence of morbidity and mortality (Berti, Krasevec & FitzGerald, 2004). As such, home nutrition gardens have been widely promoted in developing countries especially among poor rural households as a way to improve their nutrition through increasing micronutrient intake (CAPSA, 2013).

Home nutritional gardens have many benefits. In addition to direct benefits such as improved access for all members to an adequate, affordable and nutritious diet, home nutritional gardens also reduce the risk of diet-related diseases and improve health outcomes. As such home gardens contribute to mitigating different aspects of malnutrition ranging from undernutrition to obesity. Home gardens also increase dietary diversity in households and help to supplement seasonal availability of other foods produced (FAO, 2005).

6.1.1 Household improvement

A systematic review of the different agricultural interventions targeted at improving the nutritional status of children revealed that households that have home gardens realised an increase in the consumption of fruits and vegetables (Masset, Haddad, Cornelius & Isaza-Castro, 2012). CAPSA (2013) also find that in South-East Asia, growing vegetables, pulses and root crops which are rich in protein, energy and micronutrients improves household nutrition. Exploring the impact of nutrition gardens on the nutritional status for households in Nyanga North district, Zimbabwe, Mutambara et al. (2013) found that there were statistically significant differences for household nutritional status as a result of adopting nutritional gardening. Involvement in nutritional gardening was found to reduce the frequency of being underweight and malnourished in children under 5 years of age. In adults, participation in home gardening reduced the incidence of illness.

6.1.2 Vitamin A in children

Home nutrition gardens have also been found to be especially beneficial in improving vitamin A intake in children. CAPSA (2013) find that in South-East Asia, participation in home gardening led to an increase vitamin A intake in children and this helped to lessen red night blindness as well as improve growth and development. Similarly, Faber, Phungala, Venter, Dhansay and Benade (2003) in their study find that home garden programs aimed at increasing the production of yellow and dark green leafy vegetables in Ndunakazi village, South Africa also improved vitamin A intake in children between 2 and 5 years old. On the contrary, Schmidt and Vorster (1995) concluded that for children aged between 6 and 13 years in Slough village, South Africa, participation by their households in home nutrition gardens had no significant nutritional benefit to them in terms of improvements in vitamin A (serum retinol) levels.

6.1.3 Additional measures or interventions

Accompanying home nutrition gardens with other complementary interventions has proved to be beneficial in terms of improving nutritional outcomes. According to Berti et al. (2004)'s review, promoting nutritional education and addressing gender issues alongside home gardening proved to have a positive impact on nutritional outcomes. In addition, investment in other forms of capital (social, financial, physical and natural) also enhances the positive impact of home gardening and other agricultural interventions on nutritional outcomes. For households in rural South African, evidence shows that income plays a very important role in determining food security, thus adding weight to the need to invest in financial capital (van Averbeke and Khosa, 2007).

6.1.4 Drip irrigation

Measures aimed at improving water access in home gardening projects such as the promotion of smallholder drip irrigation can also ensure that nutritional outcomes are improved, especially in arid areas. Merrey et al. (2008) point out that it is possible to improve household food security for poor and rural households in Southern Africa through the use of smallholder drip irrigation kits. However they indicate that there is need to provide relevant support including spare parts, training, technical advice on inputs and market access for farmers to ensure sustainability. They also conclude that smallholder drip irrigation is an unsuitable intervention for the ultra-poor.

Moreover, van Averbeke and Khosa (2007) conclude from studying 10 households using drip irrigation on a $32m^2$ gardens in Limpopo valley, South Africa that vegetable production at the household level can possibly increase levels of vitamin A and C in the diets of the poor.

Nevertheless vegetable production failed to increase protein levels in very poor households and did not appear to have any impact on iron levels for all households.

Furthermore, Moyo et al. (2006)'s study draws attention to the fact that smallholder drip irrigation can only be sustainable as a long-term measure for addressing food insecurity. Drawing on evidence from Gwanda and Beitbridge districts in Zimbabwe, they emphasise on the need to ensure that there are reliable water sources available near the proposed gardens in order for drip irrigation to succeed.

Evidence form Mugabe et al. (2008)'s study indicated that for smallholder farmers in Gweru and Bikita districts in Zimbabwe, the impact of drip irrigated home gardens was difficult to determine. In this study, 3 groups of people were assessed namely: adopters (those who were still using the kit), disadopters (those who had used the kit at one point in time but had stopped) and non-adopters (those who had never used the kit before). This is because although there were differences in terms of improvements realised in food availability and other measures such as the ability to pay fees between the three groups these differences were not consistent nor were they significant. For instance, before the adoption of drip irrigation, 38.5% of the adopters in Gweru and 50% of the dis-adopters indicated that they did not have enough food to meet their family requirements. After the drip irrigation program, food availability improved for both groups. 83.4% of the adopters and 63.6% of the dis-adopters indicated that they now had enough food to meet their requirements. A similar result was also obtained for Bikita district. In terms of the ability to pay fees, more dis-adopters in both districts reported that they were able to pay fees compared to adopters in both district which is rather contrary to the expectations (22.7% versus 11.1% in Gweru and 38.5% versus 24.1% in Bikita districts).

6.1.5 Measuring improvement

With regards to measuring the impact of home nutrition gardens on food security, Masset et al. (2012) suggest that holistic measures such as the dietary diversity index be used instead of crop specific measures. In their review of the impact of different agricultural interventions on household nutrition, they concluded that crop specific measures alone fail to account for substitution effects in terms of consumption. This is corroborated by the results found by Bushanuka et al. (2005). Their findings revealed that for households that participated in the home gardening project, there was a trade-off between the consumption of vegetables, rice and fish which increased and that of pulses which decreased during the program. In addition van Averbeke and Khosa (2007) found that for rural South African households, dry land crops are an integral part of household nutrition and without these crops, household nutrition declines. Using a holistic measure such as the dietary diversity index will allow these integrations to be captured in assessing improvements in household nutrition through home nutrition gardens.

6.1.6 This research

This study is aimed at finding out whether participation in smallholder drip irrigation led to long-term improvements in food security for households in Mutasa and Mutoko districts in Zimbabwe. Previous research in Zimbabwe has faced challenges on trying to answer this question mainly due to somewhat unclear results obtained for various household wellbeing measures (Mugabe et al., 2008). Other studies however have indicated that smallholder drip irrigation has had a positive impact on household food security (Merrey et al., 2008; van Averbeke and Khosa, 2007). As such, it is important that this question be answered for different groups of people as variation in the results suggest that no two groups are the same.

Following Masset et al. (2012)'s suggestion, conventional measures of food security (number of coping strategies (CS), the coping strategies index (CSI) and the dietary diversity score (DDS[55]) will be used to determine whether smallholder drip irrigation (represented by whether or not the beneficiary dropped out of the project) led to improvements in household food security.

In order for smallholder drip irrigation to have an effect, it is expected that dropping out of the drip irrigation project will result in an increase in the number of coping strategies used and a decrease in the dietary diversity score. Other drip irrigation and food related variables as well as variables representing beneficiary and household characteristics are also controlled for.

6.2 Methods and procedures

6.2.1 The theoretical framework

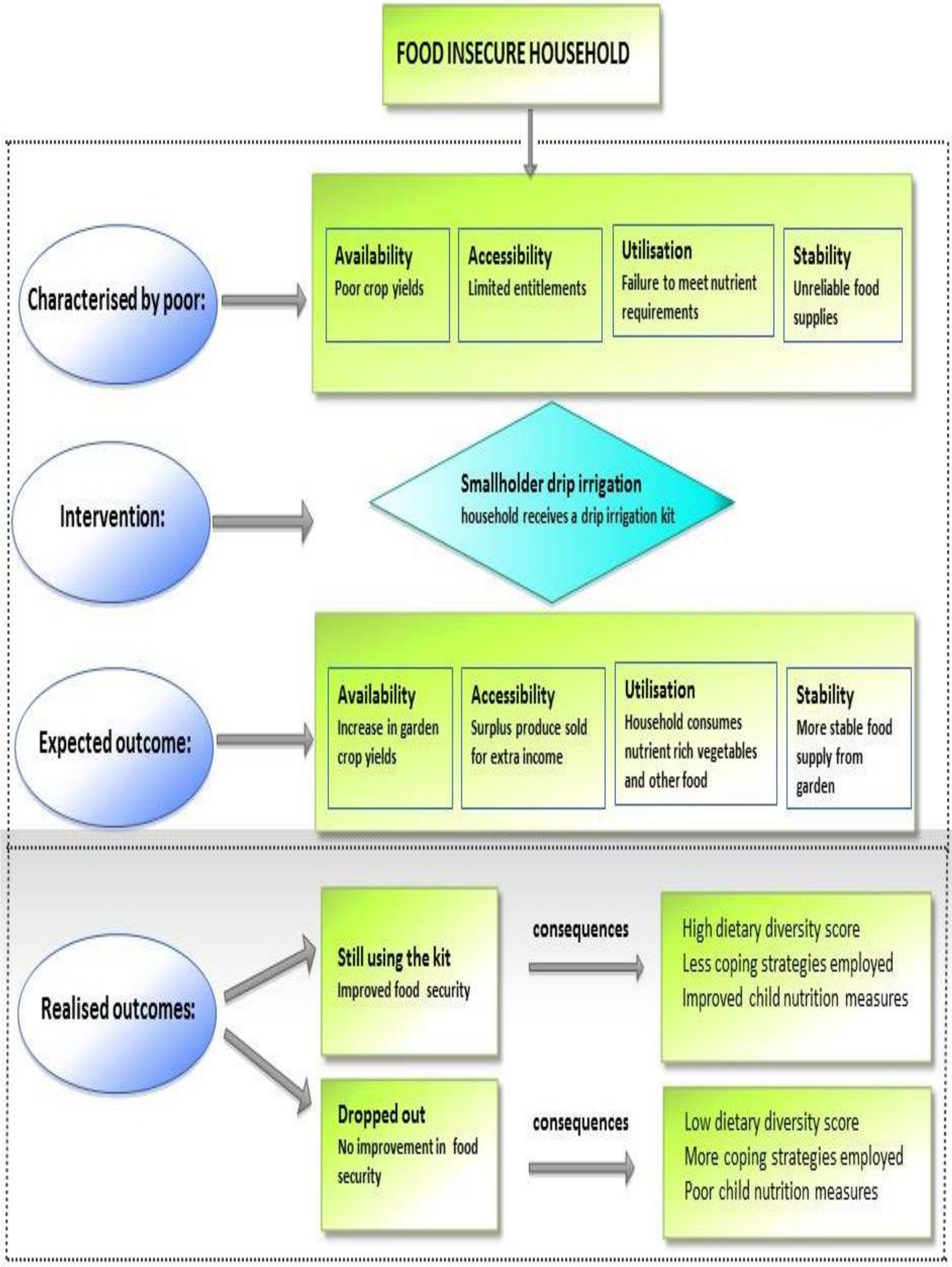
According to Maxwell (1996), food security consists of 3 chief components namely availability, accessibility and utilisation. In order for a household to be food secure, the household has to have the capacity to obtain the food needed by all its members (Pinstrup-Anderson, 2009). This means that the household has to either produce all its own food or to have the means to purchase the food it requires but cannot produce. This food has to be sufficient to meet the nutritional requirements of each household member. Vulnerable households are households that are unable to produce their own food and have limited capacity to purchase the food that they require. Interventions thus have to be introduced in a bid to improve the availability, accessibility and utilisation of food for these households. One such intervention is the home nutrition garden project.

[55] The DDS is a composite measure and includes all food categories a household consumed in the previous day.

Participants in the home nutrition garden project are expected to supplement their yields through vegetable production. Household consumption is expected to increase as they will now be able to afford garden crops. Their nutrition is also expected to increase as vegetables are a good source of micronutrients such as vitamin A, which are often lacking in the diets of the poor (Faber et al., 2003). Smallholder drip irrigation enhances the productivity of home nutrition gardens especially in places where water shortages are being faced, by using water more efficiently in crop production. Under drip irrigation, the water is applied directly on the plant unlike conventional water systems such as the use of buckets and sprinklers, which apply water to the whole field. The use of drip irrigation also allows households to produce garden crops outside the rainy season (Brouwer et.al., 1988; Moyo et al., 2006; Postel et al., 2001).

If participating households continue in the drip irrigation program, their food security is expected to improve as all the 3 aspects of food security are addressed. Dropping out of the project is expected to have a negative impact on the households causing them to remain as food insecure as they were before using drip irrigation or to be worse off. This is summarised in Figure 6.1 below.

Figure 6.1: Smallholder drip irrigation in the attainment of food security



Source: Own model

6.2.2 The data

This research uses data from the 2013 Smallholder Drip Irrigation Survey, conducted in Zimbabwe by the author and a team of 4 research assistants from January to March 2013. The beneficiaries[56] of the smallholder drip irrigation project implemented by Plan International from 2003-2007 in Mutoko and Mutasa districts of Zimbabwe were interviewed. A total of about 806 households benefited from this scheme. 200 households were targeted for the interviews and 170 households were successfully interviewed. In Mutasa the project was implemented in 14 wards and only 8 wards were selected based on representativeness and practicality in terms of reaching the wards. In Mutoko the project was implemented in 3 wards and all the wards are represented in the sample. Beneficiaries were chosen randomly from a combined list provided by Plan International for the wards selected for each district. The survey was approved and funded by Monash University, Australia. Approval and logistical support was also obtained from Plan International –Zimbabwe and the local leaders in Mutasa and Mutoko districts.

A questionnaire was administered to the project beneficiary in each household. In the event that the project beneficiary was absent, their spouse or an adult child or an elderly relative were interviewed instead provided they were also involved in using the drip kit. If the beneficiary was absent and those present were not involved in using the drip kit, the household was not interviewed. The questionnaire collected information on household demography, drip irrigation related issues, cropping, marketing, income, expenditure, health, food security and remittances. The response rate was 73.87% and 80% for Mutasa and Mutoko districts respectively.

[56] The terms beneficiary and smallholder farmer will be used interchangeably and all refer to a beneficiary who received a smallholder drip irrigation kit from Plan International.

Details of the survey, including an overview of the study areas are presented in Chapter 3.

6.3 Data analysis

The data is analysed using the ordinary least squares (OLS) method to show the relationship between household food security and smallholder drip irrigation as discussed below.

6.3.1 The main empirical specification

The main model assumes that there is a linear relationship between household food security (represented by three different measures[57]: the number of coping strategies, the coping strategies index and the dietary diversity score) and smallholder drip irrigation (represented by whether or not the beneficiary dropped out of the drip irrigation project and the interval that elapsed before they dropped out, *dropout* and *dropoutearly* respectively).

The model is represented by equation 6.1 below:

$$Foodsecurity_i = \beta_0 + \beta_1 dropout_i + \beta_2 earlydropA_i + X_i'\gamma + \varepsilon_i \qquad (6.1)$$

where X_i' is a 1x k vector of independent variables comprising of food related, drip irrigation related, beneficiary and household characteristics defined in section 6.3.3 and Table 6.4 below. All unobservable factors that have an impact on household food security are represented by the error term, ε_i and β_0 is the constant (Studenmund, 2010; Wooldridge, 2000).

[57] Following the recommendation by Masset et al., (2012), holistic measures of food security such as the dietary diversity index are used as dependent variables as opposed to crop specific measures to account for substitution effects.

6.3.2 The dependent variables

As indicated in section 6.1.2, three dependent variables are used as proxies of food security (number of coping strategies, the coping strategies index and the dietary diversity score) in this study. These variables are conventional proxies for food security that have been identified and used by other researchers (Drescher, Thiele & Mensink, 2007; Kennedy, Pedro, Seghieri, Nantel & Brouwer, 2007; Maxwell et al., 2003; Regasa, 2011).

i. The number of coping strategies (CS)

A coping strategy is the action one adopts to instantly address sudden and erratic changes to food supply (FAO, 1997 as cited in Masendeke and Shoko, 2014). In order to identify the coping strategies used by each household, respondents were asked the following question (Appendix C1, section E: Q10):

"In the past 30 days, if there have been times when you did not have enough to food or money to buy food, how often has your household had to use….. (a specific strategy indicated in Table 6.1 below)":

All the strategies a household used were added together to get the final number of coping strategies used. The number of strategies used by each household ranged between 0 and 9. A higher number of coping strategies shows that the household is more food insecure (Regasa, 2011).

ii. **The coping strategies index (CSI)**

The CSI is an improvement on the number of coping strategies in that it accounts for the frequency and severity of the coping strategy used.

Conventionally, focus group discussions are carried out in areas under study and participants are asked to identify and rank these strategies in terms of severity as coping strategies are location specific. In this case, there were no focus group discussions conducted. Three sets of severity weights are thus used.

The first one is based on the general categorisation of coping strategies presented by Maxwell et al. (2003). Under this method, the consumption coping strategies are grouped in terms of type and the severity of each group of strategies is determined as shown in Table 6.1 below.

Table 6.1: List of household coping strategies

Category	Specific strategy	Weights
1. Dietary change	a. Rely on less preferred and less expensive foods	1
2. Increase short term household food availability	a. Borrow food or rely on help from a friend or relative b. Purchase food on credit c. Gather wild fruit, hunt or harvest immature crops d. Consume seed stock held for the next season.	2
3. Decrease numbers of people	a. Send household members to eat elsewhere b. Send household members to beg	3
4. Rationing strategies	a. Limit portion size at meal times b. Restrict consumption by adults in order for small children to eat c. Feed working members at the expense of non-working members d. Ration the money you have and buy prepared food e. Reduce the number of meals eaten per day f. Skip entire days without eating	4

Source: Maxwell et al. (2003)

The coping strategies are weighted according to the category they fall into, with the most severe strategy (category 4) receiving the highest weighting as shown the Table 6.1.

The second set of severity weights is based on the reduced coping strategy index developed by Maxwell and Caldwell (2008). Maxwell and Caldwell (2008) draw attention to the existence of 5 standard coping strategies that are common to households anywhere and they present the severity weights for each strategy as shown in Table 6.2. The 5 standard coping strategies identified are used to develop the "reduced or comparative coping strategies index".

Table 6.2: Household coping strategies for the reduced coping strategies index

Coping strategy used in the 30 days preceding the survey	Severity Weight
1. Rely on less preferred and less expensive foods	1.0
2. Borrow food or rely on help from a friend or relative	2.0
3. Limit portion size at meal times	1.0
4. Reduce the number of meals eaten per day	1.0
5. Restrict consumption by adults in order for small children to eat	3.0

Source: Maxwell and Caldwell (2008)

Using the reduced CSI means some of the information on other coping strategies is disregarded. Despite this limitation, the reduced CSI is suitable for use in this study, firstly because the index is mainly used for comparison in different settings. Since there are two areas under study, Mutasa and Mutoko, the reduced coping strategies index will allow uniformity between the two areas and thus the measures obtained will be consistent for both areas. Secondly, the reduced CSI is employed to provide a measure of household food security which can be used to determine whether the use of smallholder drip irrigation improves or worsens a household's food security. Given that Maxwell and Caldwell (2008) argue that the reduced CSI accurately reflects a household's food security status, the use of the reduced CSI is thus suitable in this case.

The third set of severity weights is derived from the number of households who indicated that they used the strategy in question in the survey. This weighting is based on the assumption that least severe strategies are commonly used whilst the most severe strategies are least used as pointed out by Maxwell et al. (1999). This method is unorthodox and is based mainly on culture, intuition and also from the reactions of the different respondents when they were being interviewed. The coping strategies used and their weighting are presented in Table 6.3 below:

Table 6.3: Household coping strategies for smallholder drip irrigation farmers in Mutasa and Mutoko

Coping strategy used in the 30 days preceding the survey	% of households using the strategy	Weight
1. Rely on less preferred and less expensive foods	41%	1
2. Purchase food on credit	31%	2
3. Borrow food or rely on help from a friend or relative	30%	3
4. Limit portion size at meal times	22%	4
5. Reduce the number of meals eaten per day	22%	5
6. Consume seed stock held for the next season.	17%	6
7. Restrict consumption by adults in order for small children to eat	12%	7
8. Skip entire days without eating	12%	8
9. Ration the money you have and buy prepared food	9%	9
10. Send household members to beg	7%	10
11. Feed working members at the expense of non-working members	7%	11
12. Send household members to eat elsewhere	5%	12

Source: Own classification based on popularity of use.

From Table 6.3 above, the commonly used coping strategy is relying on less preferred and less expensive food, which is similar to the classification by Maxwell et al. (2003). The least used strategy and hence the one that is used in severe cases of food insecurity is sending children to eat with neighbours. This is probably due to the culture of the people in Zimbabwe. Children are not encouraged to eat food from neighbours as it is considered to be a shameful thing. This is also true of begging, which happens as the very last resort and is practiced by ultra-poor people. None of the households in Mutasa and Mutoko indicated that they gathered wild fruit, hunted or harvested immature crops as a coping strategy in the 30 days preceding the survey. The weights indicated in Table 6.3 are used to construct another CSI which is compared to that constructed using Maxwell et al. (2003) and Maxwell and Caldwell (2008)'s weights.

In order to weight the frequency of use, the respondent's response to the question (Appendix C1, section E: Q10) : *"In the past 30 days, if there have been times when you did not have enough to food or money to buy food, how often has your household had to use each strategy in Table 6.1 above"* was used. The interviewees had to respond by indicating their frequency using the responses in Table 6.4 below:

Table 6.4: Weights for the frequency of use of various coping strategies.

Frequency of use responses	**Weigh**ts
All the time (everyday)	7
Pretty often (3-6 days / week)	4.5
Once in a while (1-2 days /week)	1.5
Hardly at all (<1 day/ week)	0.5
Never (0 days/ week)	0

The frequency of use responses are weighted by using the mid-points[58] of each category shown in Table 6.4 above

The coping strategies index for a specific household i (CSI_i) is then given by :

$$CSI_i = \sum_{j=1}^{n} S_{wj} F_{wj}$$

where S_{wj} is the severity weight and F_{wj} is the frequency weight for the coping strategy j used by the household i and n is the total number of coping strategies used by the household which varies between 0 and 9.

iii. The dietary diversity score (DDS)

The DDS simply consists of the total number of food groups a household eats in a day. The member of the household being interviewed was asked to indicate the food the household ate the previous day (section E, Q9 in Appendix C1). This food is classified according to groups. The number of groups varies according to the method followed (Drescher et al., 2007; Kennedy et al., 2007). In this study, 13 groups namely: cereal; white tubers and roots; dark green vegetables; other vegetables and tubers; legumes, nuts and seeds; meat; eggs; fish; fruits; milk and milk products; oils and fats; sweets and spices, condiments and beverages were used. Drescher et al. (2007) points out that it is generally accepted that the higher the dietary diversity score, the healthier the household is. A healthier household in this case implies a more food secure household.

The proxies for food security in this case can be improved in future in order to improve the results. The data used in this study is based on interviews that were conducted in February

[58] These are the severity weights suggested by Maxwell et al. (2003).

and March 2013. This is the pre-harvest period and it is the period where households are mostly vulnerable to food insecurity (Ignowski, 2012). As such, one would expect households to use more coping strategies and to have a low dietary diversity score at this time compared to the rest of the year. Had the survey been conducted around June and July or October to September, the number of coping strategies and the dietary diversity scores would be different. Perhaps increasing the recall period of coping strategies used to 1 year may improve the results, despite increasing bias due to a longer recall period. For the dietary diversity score, conducting interviews on the household in the three different periods (planting season, pre-harvest and post-harvest seasons) would also improve the analysis.

6.3.3 The explanatory variables

The main variables of interest are *dropout* and *earlydropout*, dummy variables taking the value 1 if the beneficiary has stopped using drip irrigation and if the beneficiary stopped using drip irrigation within the first 3 years. These variables are proxies for smallholder drip irrigation. Assuming that smallholder drip irrigation is important in the attainment of household food security, it is expected that there be a positive relationship between *dropout* and *earlydropout* and the number of coping strategies and a negative relationship between *dropout* and *earlydropout* and the dietary diversity score.

Other drip irrigation related variables include decision making factors (*familydecidecrp*, *maledecidecrp* and *femaledecidecrp* which is the base category) indicating whether the family decides together or the male head of the household or an adult female household member who is ether the head or spouse decides which crops to grow respectively. Decision on which crops to sell is also included and is represented by *familydecidesell* , *maledecidesell* and *femaledecidesel*l (base category) denoting that the family decides together or the male household head decides or an adult female member decides which crops to sell and the quantity to sell. The decision making factors are important as research has shown that male farmers are more likely to decide to grow cash as opposed to food crops. Research has shown that females firstly consider family consumption before they decide what to sell as they are directly involved in food preparation. Males on the other hand tend to more income minded. These differences impact on household food security (Doss, 1999; Holmboe-Ottesen and Wandel, 1991).

The beneficiary's self-rating on their level of knowledge in drip irrigation is also included. It is expected that beneficiaries who believe that their knowledge of drip irrigation is poor will most likely be more food insecure compared to their counterparts if drip irrigation has an effect. This is because poor knowledge of drip irrigation can result in poor implementation of the project by the beneficiaries and this result in poor food security outcomes.

Food related variables include *consumpincgdn* and *foodaid*, dummy variables taking the value 1 if the household realised an increase in the consumption of garden crops in 2011-2012[59] and if the household received food aid in the 12 months preceding the survey. The beneficiary's personal valuation of how much their household food security increases as a result of drip irrigation is represented by the dummy variable *fdsecbelowaverage*. *fdsecbelowaverage* takes the value 1 if the household's improvement in food security during the drip irrigation period was below average. If drip irrigation is not important in the attainment of household food security, one would expect the household with below average food security improvement to be better off after they dropped out and to use less coping strategies in the 12 months preceding the interview. Their dietary diversity index is expected to be higher.

[59] 2011-2012 was the last cropping season before the survey was conducted.

Beneficiary characteristics including the beneficiary's gender (*benefmale*), education level (*benefprimarylev*), marital status (*benefmarried*) and whether or not they belong to an agriculturally or business related group (*benefgrpmemb*) are also included. All these variables are dummy variables taking the value 1 if the beneficiary is male, has attained primary level education or below, is married and belongs to a group respectively and 0 otherwise. The age of the beneficiary (*benefage*) is also included as a continuous variable.

Household characteristics controlled for include *drinkwatertap,* a dummy variable taking the value 1 if the household's drinking water comes from a municipality tap and 0 otherwise. Other dummy variables include *familydecidespnd* and *maledecidespnd* indicating that the family or an adult male member (mainly the household head) respectively decides how to spend the disposable income the household receives from various sources. Whether or not the household received remittances from within and outside Zimbabwe in the 12 months preceding the survey is represented by remittance and the presence of a chronically ill member in the household is represented by the variable *chronillmember*. The variables *wealthtertile2* and *wealthtertile3* for a household in the middle and top tertiles respectively represent the socio-economic status of the household. The wealth index variable was constructed using the principal component analysis (PCA) and is described fully in section 5.3.4. All the dummy variables take the value 1 for the specific characteristic mentioned and 0 otherwise. Continuous variables such as the number of members in each household (*hhdmembs*), the number of children below the age of 5 in each household (*chnbelow5*) and any other income the household received in the 12 months preceding the survey (*otherincome*) are also included as control variables. Previous research has shown that these factors are important in determining food security (Garret & Ruel, 1999; Gundersen, Kuku & Kelly, 2007; Ignowski, 2012).

6.4 Results and discussion

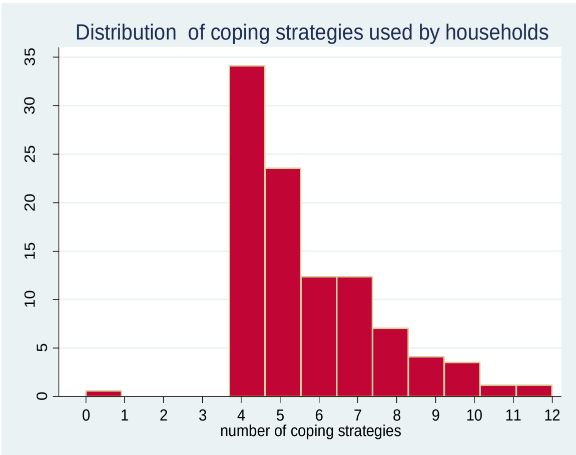
6.4.1 General descriptive analysis

A total of 170 beneficiaries were interviewed. 48% and 52% were from Mutasa and Mutoko districts respectively. 88% of the beneficiaries had dropped out of the project at the time the survey was conducted.

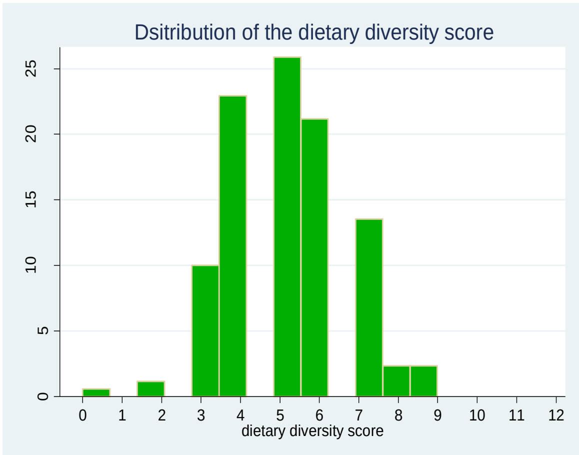
The number of coping strategies used by a household ranged from 4 to 12 whilst the dietary diversity score showed that households consume between 1 and 9 food groups a day. Most households (34% and 26% respectively) used 4 coping strategies in the 12 months preceding the household and consumed food from 5 different groups in the day preceding the survey. The distributions are shown in Figure 6.2 below.

Figure 6.2: Distribution of the number of coping strategies and dietary diversity score

a. Number of coping strategies



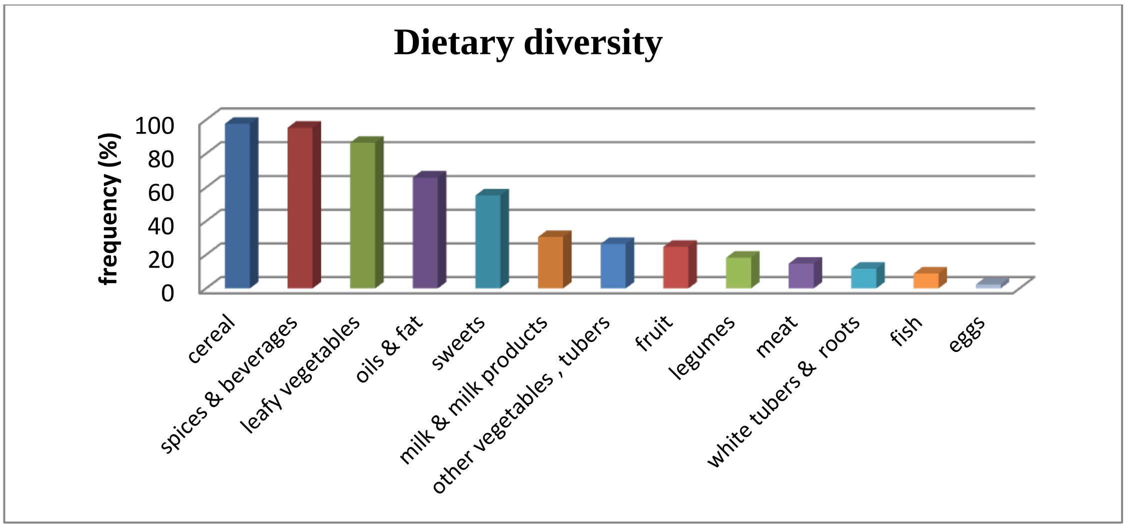
b. Dietary diversity score



- **Food security**

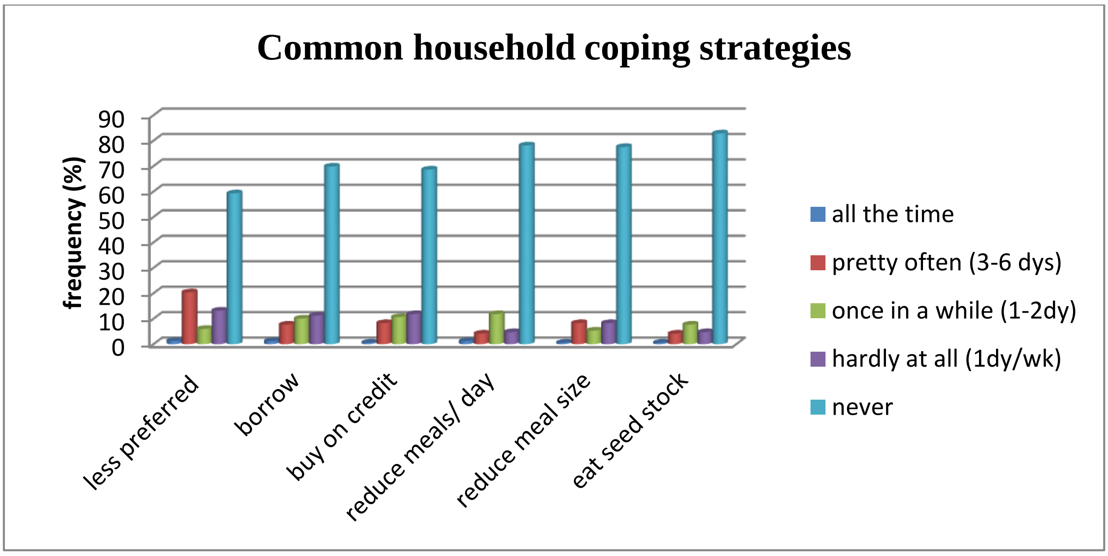
13% of the beneficiaries indicated that they had gone without enough food for some days in the last 30 days. 99% of the households eat at least 2 meals a day. In terms of dietary diversity, a majority of the households ate food from the cereal group (98%), spices and beverages group, mainly salt (95%) and the dark green leafy vegetables group (87%) on the day before the interview. Meat (15%), fish (9%) and eggs (2%) consumption was very low for most households as shown in Figure 6.3 below.

Figure 6.3: Food consumed by the household on the day before the interview



The most common coping strategies used by households is eating less preferred but more affordable foods (41%), borrowing food from neighbours (30%) and buying food on credit (31%). The frequency with which the household used these strategies in the last 30 days before the interview is shown in Figure 6.4 below.

Figure 6.4: Common household coping strategies for Mutasa and Mutoko beneficiaries



Other coping strategies such as gathering wild fruit or harvesting immature crops (15%) , skipping entire days without eating (12%) and sending household members to eat away (5%) are also used to a lesser extent. Overall, approximately 54.7% of the households used at least one coping strategy in the month preceding the interview.

More variables are described in Table 6.5 below.

Table 6.5: Descriptive statistics

Variable name	Description		
Continous variables		**mean**	**std.dev**
CSnumb	number of coping strategies used	5.71	1.95
lnCSindex	log of the coping strategies index	2.60	0.82
dietdivscore	dietary diversity score	5.15	1.49
benefage	beneficiary's age	53.75	13.37
hhdmembs	number of members in the household	6.31	3.31
otherincome	other income received by the household excluding remittances and income from garden crops	213.92	471.47
chnbelow5	number of children below 5 years residing in the household	0.64	0.90
Dummy variabes		**frequency**	**percentage**
main			
dropout	beneficiary dropped out of the project	149	88%
earlydropout	beneficiary dropped out within the first 3 years using the kit	54	32%
food related			
consumpincgdn	consumption of garden crops increased in 2011-2012 season compared to the time the beneficiary was using the kit	83	49%
foodaid	beneficiary received food aid in the 12 months preceding the survey	22	13%
fdsecbelowaverage	household's improvement in food security from using drip irrigation was below average	104	62%
drip irrigation related			
familydecidecrp	family decides which crops to grow in the garden	76	41%
maledecidecrp	an adult male household member decides which garden crops to grow	52	28%
femaledecidecrp	an adult female household member decides which garden crops to grow	56	30%
familydecidesell	family decides which crops to sell from their garden	31	22%
maledecidesell	an adult male member alone decides which crops to sell from the garden	49	35%
femaledecidesell	an adult female member alone decides which crops to sell from the garden	62	44%
poordripknowledge	beneficiary rates their knowledge of drip irrigation to be poor	70	42%
beneficiary characteristics			
benefmale	beneficiary is male	92	54%
benefprimarylev	beneficiary attained primary level education	85	50%
benefmarried	beneficiary is married	124	73%
benefgroupmemb	beneficiary is a member of a farming or business related group	110	65%
household characteristics			
drinkwatertap	the household's drinking water source is municipality tap water	137	81%
familydecidespend	family decide how to spend their income together	62	38%
maledecidespend	adult male member makes spending decisions in the household	47	28%
femaledecidespend	adult female member makes spending decisions in the household	56	34%
chronillmember	household has a chronically ill member	65	38%
remittance	household received remittances from within and outside Zimbabwe in the last 12 months	64	38%
wealthtertile1	household is in wealth tertile 1	57	34%
wealthtertile2	household is in wealth tertile 2	56	33%
wealthtertile3	household is in wealth tertile 3	56	33%

The base variables are *femaledecidecrp, femaledecidesell, femaledecidespend* and *wealthquintile1*

6.5 Empirical results

This section presents the results of the influence of drip irrigation on household food security. As specified in section 6.3.2, the number of coping strategies (CS), coping strategies indices (*CSI, reducedCSI and newCSI*) and the dietary diversity score (DDS) are used as proxies for household food security. The CSI and reduced CSI are constructed using the general weights for severity as reported by Maxwell et al. (2003) and Maxwell and Caldwell (2008) respectively. For the *newCSI*, the severity weights are based on the popularity of the coping strategy used as indicated by the survey results. The most commonly and least commonly used measures have the lowest and highest severity weights respectively. For the coping strategies indices, the natural log of the CSI is used (*lnCSI, lnreducedCSI* and *lnnewCSI*). The number of coping strategies used and the dietary diversity score are imply the sum total of the strategies and food groups identified by the household respectively.

The results test the hypothesis that participation by households in the smallholder drip irrigation project led to an improvement in their household food security. If this is the case, then the main variables *dropout* and *dropoutearly* are expected to be positively associated with the coping strategies and negatively associated with the dietary diversity measures respectively. *dropout* and *dropoutearly* are take the value 1 if a beneficiary has dropped out of the drip irrigation project and if the beneficiary dropped out within the first 3 years of being in the project. 5 models are estimated for each dependent variable with Model 1 including only the main variables (*dropout, dropoutearly*) and other drip , food, beneficiary and household related factors are controlled for in Models 2 to 5.

All results discussed are based on Model 5 for each dependent variable, unless otherwise stated. This is because Model 5 is an all-inclusive model where all the factors believed to influence household food security are controlled for in the regression. The results of whether or not drip irrigation is an important intervention in improving household food security for smallholder farmers are presented in Tables 6.6- 6.10 below.

Tables 6.6-6.9 below are based on the coping strategies measures (number of coping strategies for Table 6.6 and three variations of the coping strategies index in Tables 6.7, 6.8 and 6.9. Overall, all the results are consistent and very similar for all the 4 dependent variables. This implies that just counting the number of coping strategies and accounting for the severity and frequency of use of the coping strategies in this case makes no difference to the effect of drip irrigation on household food security. As such, the discussion below will be based only on the number of coping strategies used (Table 6.6) and the dietary diversity score (Table 6.10).

Table 6.6: Impact of smallholder drip irrigation on household food security (as defined by the number of strategies)

Dependent variable: Number of coping strategies used (csnumb)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	coef	se	coef	se	coef	se	coef	se	coef	se
main										
dropout	-0.192	(0.461)	-0.312	(0.466)	-0.591	(0.467)	-0.340	(0.457)	-0.529	(0.458)
earlydropout	0.954***	(0.326)	0.995***	(0.330)	1.063***	(0.334)	0.789**	(0.325)	0.760**	(0.334)
food related										
consumpincgdn			0.394	(0.299)	0.421	(0.292)	0.260	(0.289)	0.355	(0.290)
foodaid			0.633	(0.445)	0.570	(0.441)	0.591	(0.415)	0.377	(0.428)
fdsecbelowaverage			0.244	(0.306)	0.299	(0.317)	0.238	(0.314)	0.258	(0.311)
drip irrigation related										
familydecidecrp					0.079	(0.341)	0.286	(0.340)	0.495	(0.493)
maledecidecrp					0.301	(0.443)	0.382	(0.438)	0.345	(0.448)
familydecidesell					-0.332	(0.429)	0.002	(0.423)	-0.195	(0.460)
maledecidesell					0.851*	(0.501)	0.826*	(0.481)	0.788*	(0.473)
poordripknowledge					0.577*	(0.309)	0.744**	(0.303)	0.684**	(0.305)
beneficiary characteristics										
benefmale							-0.419	(0.376)	-0.361	(0.384)
benefage							-0.035***	(0.013)	-0.026**	(0.013)
benefprimarylev							-0.064	(0.325)	-0.243	(0.327)
benefmarried							-0.591	(0.370)	-0.589	(0.415)
benefgrpmemb							-0.100	(0.307)	-0.025	(0.308)
household characteristics										
drinkwatertap									0.023	(0.362)
familydecidespnd									-0.375	(0.435)
maledecidespnd									-0.531	(0.652)
chronillmember									0.404	(0.308)
chnbelow5									-0.230	(0.216)
hhdmembs									0.163***	(0.056)
otherincome									-0.000	(0.000)
remittance									-0.255	(0.311)
wealthtertile2									-0.338	(0.364)
wealthtertile3									-1.003**	(0.387)
constant	5.571***	(0.418)	5.226***	(0.473)	4.886***	(0.492)	7.285***	(0.847)	6.751***	(0.910)
observations	170		168		165		154		154	

Standard errors in parentheses

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

Table 6.7: Impact of smallholder drip irrigation on household food security (as defined by the coping strategies index[60])

Dependent variable: Log of coping strategies index(*lncsindex*)

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
main										
dropout	0.081	(0.196)	0.031	(0.198)	-0.067	(0.200)	-0.026	(0.202)	-0.130	(0.195)
earlydropout	0.306**	(0.138)	0.328**	(0.140)	0.346**	(0.143)	0.273*	(0.143)	0.254*	(0.142)
food related										
consumpincgdn			0.167	(0.127)	0.176	(0.125)	0.137	(0.127)	0.193	(0.123)
foodaid			0.274	(0.189)	0.227	(0.189)	0.253	(0.183)	0.175	(0.182)
fdsecbelowaverage			0.136	(0.130)	0.142	(0.136)	0.135	(0.138)	0.152	(0.132)
drip irrigation related										
familydecidecrp					0.025	(0.146)	0.054	(0.150)	0.029	(0.210)
maledecidecrp					-0.083	(0.190)	-0.119	(0.193)	-0.175	(0.190)
familydecidesell					-0.144	(0.184)	-0.051	(0.187)	-0.108	(0.196)
maledecidesell					0.456**	(0.214)	0.446**	(0.212)	0.434**	(0.201)
poordripknowledge					0.272**	(0.132)	0.317**	(0.134)	0.287**	(0.130)
beneficiary characteristics										
benefmale							0.047	(0.166)	0.058	(0.163)
benefage							-0.012**	(0.006)	-0.006	(0.006)
benefprimarylev							-0.050	(0.143)	-0.149	(0.139)
benefmarried							-0.230	(0.163)	-0.250	(0.177)
benefgrpmemb							-0.088	(0.135)	-0.056	(0.131)
household characteristics										
drinkwatertap									0.096	(0.154)
familydecidespnd									-0.158	(0.185)
maledecidespnd									-0.101	(0.277)
chronillmember									0.161	(0.131)
chnbelow5									-0.081	(0.092)
hhdmembs									0.080***	(0.024)
otherincome									-0.000	(0.000)
remittance									-0.174	(0.132)
wealthtertile2									-0.285*	(0.155)
wealthtertile3									-0.575***	(0.165)
constant	2.432***	(0.177)	2.268***	(0.201)	2.153***	(0.210)	2.968***	(0.373)	2.700***	(0.387)
observations	169		167		164		154		154	

Standard errors in parentheses

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

[60] Using severity weights used by Maxwell et al., 2003.

Table 6.8: Impact of smallholder drip irrigation and household food security (as defined by the reduced[61] coping strategies index)

Dependent variable: Reduced CSI (*reducedCSI*)

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
main										
dropout	0.051	(0.231)	-0.020	(0.232)	-0.097	(0.231)	-0.045	(0.238)	-0.227	(0.230)
earlydropout	0.476***	(0.163)	0.502***	-0.165	0.475***	(0.166)	0.397**	(0.169)	0.431**	(0.168)
food related										
consumpincgdn			0.227	(0.149)	0.233	(0.145)	0.228	(0.150)	0.267*	(0.146)
foodaid			0.309	(0.221)	0.263	(0.218)	0.275	(0.216)	0.248	(0.215)
fdsecbelowaverage			0.235	(0.153)	0.177	(0.157)	0.197	(0.163)	0.216	(0.156)
drip irrigation related										
familydecidecrp					0.066	(0.169)	0.099	(0.177)	-0.091	(0.248)
maledecidecrp					-0.086	(0.219)	-0.159	(0.227)	-0.272	(0.225)
familydecidesell					-0.048	(0.212)	0.037	(0.220)	0.097	(0.231)
maledecidesell					0.492**	(0.247)	0.492*	(0.250)	0.499**	(0.238)
poordripknowledge					0.509***	(0.153)	0.550***	(0.158)	0.519***	(0.153)
beneficiary characteristics										
benefmale							0.069	(0.195)	0.051	(0.193)
benefage							-0.010	(0.007)	-0.006	(0.007)
benefprimarylev							-0.067	(0.169)	-0.159	(0.164)
benefmarried							-0.230	(0.192)	-0.292	(0.209)
benefgrpmemb							-0.230	(0.160)	-0.202	(0.155)
household characteristics										
drinkwatertap									0.181	(0.182)
familydecidespnd									-0.108	(0.219)
maledecidespnd									0.220	(0.328)
chronilmember									0.141	(0.155)
chnbelow5									-0.183*	(0.109)
hhdmembs									0.102***	(0.028)
otherincome									-0.000	(0.000)
remittance									-0.325**	(0.156)
wealthtertile2									-0.156	(0.183)
wealthtertile3									-0.530***	(0.195)
constant	1.058***	(0.209)	0.812***	(0.236)	0.593**	(0.243)	1.385***	(0.440)	1.112**	(0.458)
observations	169		167		164		154		154	

Standard errors in parentheses

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

[61] Using only 5 common coping strategies as put forward by Maxwell and Caldwell (2008).

Table 6.9: Impact of smallholder drip irrigation and household food security (as defined by the new coping strategies index[62])

Dependent variable: Log of new coping strategies index(*lnnewcsindex*)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	coef	se	coef	se	coef	se	coef	se	coef	se
main										
dropout	0.000	(0.126)	-0.029	(0.127)	-0.095	(0.129)	-0.075	(0.127)	-0.123	(0.124)
earlydropout	0.172*	(0.089)	0.185**	(0.090)	0.204**	(0.092)	0.168*	(0.090)	0.159*	(0.090)
food related										
consumpincgdn			0.125	(0.082)	0.134*	(0.081)	0.097	(0.080)	0.124	(0.079)
foodaid			0.157	(0.121)	0.126	(0.121)	0.152	(0.115)	0.078	(0.116)
fdsecbelowaverage			0.097	(0.083)	0.106	(0.087)	0.098	(0.087)	0.114	(0.084)
drip irrigation related										
familydecidecrp					0.020	(0.094)	0.032	(0.095)	0.079	(0.134)
maledecidecrp					-0.092	(0.122)	-0.099	(0.122)	-0.113	(0.121)
familydecidesell					-0.124	(0.118)	-0.049	(0.118)	-0.103	(0.125)
maledecidesell					0.307**	(0.138)	0.306**	(0.134)	0.302**	(0.128)
poordripknowledge					0.158*	(0.085)	0.176**	(0.084)	0.164**	(0.083)
beneficiary characteristics										
benefmale							0.003	(0.104)	0.031	(0.104)
benefage							-0.008**	(0.004)	-0.005	(0.004)
benefprimarylev							0.003	(0.090)	-0.069	(0.089)
benefmarried							-0.126	(0.103)	-0.140	(0.113)
benefgrpmemb							-0.032	(0.085)	-0.028	(0.083)
household characteristics										
drinkwatertap									0.110	(0.098)
familydecidespnd									-0.082	(0.118)
maledecidespnd									-0.180	(0.177)
chronillmember									0.161*	(0.083)
chnbelow5									-0.038	(0.059)
hhdmembs									0.036**	(0.015)
otherincome									0.000	(0.000)
remittance									-0.112	(0.084)
wealthtertile2									-0.225**	(0.099)
wealthtertile3									-0.361***	(0.105)
constant	3.824***	(0.114)	3.706***	(0.129)	3.644***	(0.135)	4.186***	(0.235)	4.024***	(0.247)
observations	169		167		164		154		154	

Standard errors in parentheses

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

[62] Using severity weights determined by the frequency of occurrence of use of coping strategy by households in Mutasa and Mutoko districts.

Table 6.10: Impact of smallholder drip irrigation and household food security (as defined by the dietary diversity score)

Dependent variable: dietary diversity score (dietdscore)

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	coef	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**	**coef**	**se**
main										
dropout	0.305	(0.358)	0.269	(0.364)	0.397	(0.372)	0.324	(0.364)	0.393	(0.371)
earlydropout	-0.361	(0.253)	-0.350	(0.258)	-0.424	(0.266)	-0.288	(0.259)	-0.348	(0.271)
food related										
consumpincgdn			0.273	(0.233)	0.186	(0.232)	0.131	(0.230)	0.060	(0.235)
foodaid			0.179	(0.347)	0.202	(0.351)	0.189	(0.331)	0.175	(0.346)
fdsecbelowaverage			0.263	(0.239)	0.296	(0.252)	0.239	(0.250)	0.252	(0.252)
drip irrigation related										
familydecidecrp					-0.038	(0.271)	-0.190	(0.271)	0.042	(0.400)
maledecidecrp					0.222	(0.352)	0.136	(0.349)	0.250	(0.363)
familydecidesell					0.438	(0.342)	0.261	(0.337)	0.263	(0.373)
maledecidesell					-0.432	(0.399)	-0.545	(0.383)	-0.501	(0.383)
poordripknowledge					-0.492**	(0.245)	-0.395	(0.241)	-0.389	(0.247)
beneficiary characteristics										
benefmale							-0.035	(0.299)	-0.008	(0.311)
benefage							0.014	(0.010)	0.007	(0.011)
benefprimarylev							-0.311	(0.259)	-0.193	(0.265)
benefmarried							0.297	(0.295)	0.428	(0.336)
benefgrpmemb							0.429*	(0.245)	0.488*	(0.250)
household characteristics										
drinkwatertap									-0.441	(0.294)
familydecidespnd									-0.042	(0.352)
maledecidespnd									-0.381	(0.528)
chronillmember									0.223	(0.249)
chnbelow5									0.038	(0.175)
hhdmembs									-0.037	(0.045)
otherincome									-0.000*	(0.000)
remittance									0.282	(0.252)
wealthtertile2									0.146	(0.295)
wealthtertile3									0.718**	(0.314)
constant	5.000***	(0.324)	4.723***	(0.370)	4.879***	(0.391)	4.045***	(0.675)	4.322***	(0.737)
observations	170		168		165		154		154	

Standard errors in parentheses

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

6.5.1 Discussion: Smallholder drip irrigation and household food security

The chief objective of the smallholder drip irrigation project was to improve household food security for rural households in Mutasa and Mutoko district in Zimbabwe. The discussion below is centred on two measures of household food security (the number of coping strategies and the dietary diversity score) for which the results are presented in Table 6.6 and Table 6.10 above. Most of the discussion will focus on Model 5, which controls for food related, other drip irrigation related and beneficiary and household related characteristics.

Main variables

Overall, the results (Table 6.6) suggest that smallholder drip irrigation is important in improving household food security. Although dropping out of the drip irrigation project (*dropout*) seems to reduce the number of coping strategies a household uses, implying that smallholder drip irrigation is not effective, it is the duration one lasts in the project that really matters. Dropping out within the first 3 years of being involved in the project (*earlydropout*) results in a significant increase in the number of coping strategies a household uses. Considering two beneficiaries who have both dropped out, but one beneficiary dropped out early (within the first 3 years), the beneficiary who dropped out early uses 0.231 more coping strategies compared to their counterpart ceteris paribus. This implies that households which drop out of the project later acquire skills which assist them in improving their food base, compared to their counterparts who drop out earlier.

The influence of smallholder drip irrigation is evident through coping strategies measures only. When the dietary diversity score (Table 6.10) is used as a proxy for food security, smallholder drip irrigation becomes ineffective in the attainment of household food security.

This hints at the importance of choosing suitable proxies for household food security. This could also be due to the fact that the data used in this survey was collected in the January to March period, which is the pre-harvest season in Zimbabwe. During this time, household food security is at its lowest as most households will have run out of food and will be relying on food aid (FEWS NET, 2013; Ignowski, 2012). Dietary diversity is thus expected to be very low at this time.

Drip related variables

If an adult male member of the household is the sole decision maker on which garden crops to sell (*maledecidesell*), the household is likely to be more food insecure compared to households where adult female members decide. This is evidenced by an increase of 0.788 in the number of coping strategies used by a household where the male makes the selling decisions compared to a household where the female decides, all other things being equal. This is expected as evidence suggests that females, by virtue of being directly involved in producing and preparing food for the households, are more likely to be consumption oriented compared to males who focus more on income (Doss 1999; Holmboe-Ottesen and Wandel, 1991). The number of coping strategies used by household of a beneficiary who self-rates their knowledge of drip irrigation to be below average is 0.684 higher compared to those used by a household of a beneficiary with at least average knowledge in drip irrigation, ceteris paribus. This is expected as one expects beneficiaries with poor drip irrigation knowledge to be more likely to be poor implementers of the project and hence they fail to realise the benefits of the project in terms of improved food security. All other drip irrigation related variables have no significant effect on the number of coping strategies used by a household and hence on food security. None of the drip irrigation related variables have a statistically significant impact on the dietary diversity score.

Beneficiary and household characterisitics

Only the age of the beneficiary (*benefage*), the number of household members (*hhdmemb*) and the wealth status (*rich*) of the household have a notable impact on the number of coping strategies a household uses. Comparing two beneficiaries with the same main, food, drip, beneficiary and household related characteristics but with an age difference of 10 years, the number of coping strategies used by the older beneficiary is 0.26 lower than those used by the younger beneficiary. Assuming that the older you get, the more experienced you become, this result is plausible.

As expected, a household with an extra household member uses 0.163 more coping strategies compared their counterpart, all things being equal. A beneficiary from a household in the top tertile of the wealth class uses less coping strategies by 1.003 compared to one from a household in the bottom tertile, all other factors being the same. Given that more household members mean more mouths to feed and in food emergency situations, this implies that more people are vulnerable making the household more food insecure (use more coping strategies). Households in the top tertile are generally less vulnerable than households in the bottom tertile as they have more entitlements and options to source for food compared to their counterparts.

Belonging to a farming or business related group (benef*grpmemb*) has a positive impact on household food security through increasing the dietary diversity score of the household. Holding all other factors constant, the dietary diversity score for a household whose beneficiary is a group member is higher by 0.488 compared to that of a household whose beneficiary is not a group member. Belonging to a group in this instance suggests that members share and exchange their produce with each other and thus their dietary diversity increases and hence food security increases. Household socio-economic status, especially being rich has a similar effect on the dietary diversity score as on the number of coping strategies a household uses. A rich household's dietary diversity score increases by 0.718 compared to a poor household's dietary diversity score ceteris paribus. This is expected as better off households in rural areas are generally expected to be in a position to purchase more food from different groups (such as meat which is more expensive) compared to poorer households who have to rely on the basic food types available.

6.5.2 Robustness check: Using count models for the number of coping strategies (*csnumb*) used

One of the proxies used for food security is the number of coping strategies (*csnumb*). This variable simply adds up the number of coping strategies used by the family in the last 30 days to cope with food shortages as pointed out in section 6.3.2. Although the OLS model has been used to analyse the effects of smallholder drip irrigation on *csnumb*, count models can also be used. The Poisson model is thus employed to estimate these effects.

Under the Poisson model, the outcome variable (*csnumb* represented by y) is assumed to have an exponential conditional mean given by:

$$E(y|x) = \exp(x'\beta) \tag{6.2}$$

As the numbers of coping strategies used by a household are positive, the Poisson model specification ensures that the conditional mean estimated is also positive. Robust standard errors are estimated for this model in order to relax the assumption with regards to the conditional mean being correctly specified. The results from the Poisson model are presented in Table 6.11 below.

Table 6.11: Impact of smallholder drip irrigation on household food security (as defined by the number of coping strategies.

Dependent variable: Number of coping strategies used (*csnumb*)

	OLS model		**Poisson model**	
	coef	**se**	**coef**	**se**
main				
dropout	-0.529	(0.458)	-0.090	(0.073)
earlydropout	0.760**	(0.334)	0.118**	(0.048)
food related				
consumpincgdn	0.355	(0.290)	0.070	(0.048)
foodaid	0.377	(0.428)	0.059	(0.062)
fdsecbelowaverage	0.258	(0.311)	0.039	(0.045)
drip irrigation related				
familydecidecrp	0.495	(0.493)	0.092	(0.089)
maledecidecrp	0.345	(0.448)	0.065	(0.076)
familydecidesell	-0.195	(0.460)	-0.037	(0.081)
maledecidesell	0.788*	(0.473)	0.113	(0.072)
poordripknowledge	0.684**	(0.305)	0.112**	(0.052)
beneficiary characteristics				
benefmale	-0.361	(0.384)	-0.056	(0.065)
benefage	-0.026**	(0.013)	-0.005**	(0.002)
benefprimarylev	-0.243	(0.327)	-0.041	(0.054)
benefmarried	-0.589	(0.415)	-0.110	(0.068)
benefgrpmemb	-0.025	(0.308)	-0.004	(0.048)
household characteristics				
drinkwatertap	0.023	(0.362)	0.005	(0.051)
familydecidespnd	-0.375	(0.435)	-0.061	(0.074)
maledecidespnd	-0.531	(0.652)	-0.085	(0.112)
chronillmember	0.404	(0.308)	0.059	(0.057)
chnbelow5	-0.230	(0.216)	-0.037	(0.036)
hhdmembs	0.163***	(0.056)	0.027***	(0.007)
otherincome	-0.000	(0.000)	-0.000	(0.000)
remittance	-0.255	(0.311)	-0.033	(0.045)
wealthtertile2	-0.338	(0.364)	-0.045	(0.055)
wealthtertile3	-1.003**	(0.387)	-0.173***	(0.059)
constant	6.751***	(0.910)	1.911***	(0.138)
observations	154		154	

Standard errors in parentheses

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

Table 6.11 above shows a comparison between the OLS model results (for model 5 in Table 6.6) and the results obtained using the Poisson method which is more suitable for count data. As can be seen, the direction of impact for each of the variables is the same for both methods. The variables *earlydropout, poordripknowledge* and *hhdmembs* still have a significant positive impact on *csnumb* whilst *benefage* and *wealthtertile3* still have a significant negative impact on csnumb. The only difference is in the magnitude of the impact each variable has on *csnumb* and in the variable *maledecidesell,* which no longer has a significant impact on *csnumb*.

6.5.3 Robustness check: Does smallholder drip irrigation influence diversity in garden crops grown and consumed by rural households?

Using measures for overall household food security (dietary diversity), the results suggest that smallholder drip irrigation (denoted by *dropout* and *earlydropout*) has no significant impact on dietary diversity and hence food security for rural households.

The dietary diversity measure is constructed from 12 food groups (Appendix C1, section E:Q9). Of these groups, smallholder drip irrigation is concerned with crops that fall under the vegetables (dark green leafy vegetables and other vegetables and tubers with orange insides) and the legume, nuts and seeds groups, thought to be mainly vitamin A rich foods (Faber et al., 2003; Schmidt and Vorster, 1995).This contributes to food security by improving the intake of micronutrients. In order to ascertain whether indeed smallholder drip irrigation has an impact on household food security via dietary diversity in vegetables, two more explicit measures are constructed and used to represent household food security.

Firstly, using the responses from Q9 (Appendix C1, section E), a dummy variable (*consumveglegum*) is constructed for denoting whether the household consumed any food from the vegetable and legume group in the day preceding the interview. *consumveglegum* takes the value 1 if the household consumed any vegetables or legumes. Expectations are that if indeed smallholder drip irrigation has no statistically significant impact on household food security, then there will be a positive relationship between *consumveglegum* and the drip irrigation proxies, *dropout* and *earlydropout* and vice versa.

A second, slightly more diverse variable *veglegumnumb*, standing for the number of vegetable varieties a household grew in their garden and consumed in the last cropping season (2011-2012) is also constructed. The vegetables and legumes that will be used are those that farmers in Mutoko and Mutasa indicated that they grew under irrigation during the time they were involved in the project (Appendix C1, section C: Q5a). The variable is also based on other responses from the cropping section of the questionnaire (Appendix C1, section C: Q12-Q20). Using the logic used in the construction of the dietary diversity index, the author believes that the number of vegetables and legumes a household grow indicates the diversity in terms of garden crops. Assuming that a household cannot consume all their garden crops in the same day, this measure can account for a longer period of time compared to *consumveglegum* which accounts only for a day’s consumption.

Establishing the relationship between *veglegumnumb* and smallholder drip irrigation will provide a more specific conclusion to whether smallholder drip irrigation has merits in the improvement of household food security through increasing the diversity of vegetables consumed by the household. A negative relationship between *veglegumnumb* and *dropout* and *earlydropout* is expected for smallholder drip irrigation to matter.

Other variables, used in Model 5 of Tables 6.6 and 6.10 are controlled for. The results are presented in Table 6.12 below.

Table 6.12: Results based on vegetable and legume crops grown and consumed by smallholder households.

Dependent variable	consumed vegetables and or legumes in the day preceding the interview				number of vegetable varieties grown and consumed in 2011-2012	
	Model 1		Model		Model 3	
	coef	se	marginal effect	se	coef	se
main						
dropout	-0.526	(0.485)	-0.106	(0.097)	-0.524	(0.389)
earlydropout	0.667*	(0.348)	0.135**	(0.068)	0.279	(0.283)
food related						
consumpincgdn	0.344	(0.298)	0.070	(0.060)	0.729***	(0.246)
foodaid	0.508	(0.405)	0.103	(0.081)	-0.270	(0.362)
fdsecbelowaverage	0.202	(0.323)	0.041	(0.065)	0.008	(0.263)
drip irrigation related						
familydecidecrp	0.453	(0.476)	0.092	(0.096)	-0.215	(0.418)
maledecidecrp	-0.609	(0.491)	-0.123	(0.098)	-0.687*	(0.379)
familydecidesell	0.005	(0.451)	0.001	(0.091)	0.577	(0.390)
maledecidesell	0.465	(0.501)	0.094	(0.101)	-0.164	(0.401)
poordripknowledge	0.184	(0.311)	0.037	(0.063)	-0.009	(0.258)
beneficiary characteristics						
benefmale	0.177	(0.411)	0.036	(0.083)	-0.315	(0.326)
benefage	0.018	(0.013)	0.004	(0.003)	-0.003	-0.011
benefprimarylev	-0.314	(0.336)	-0.064	(0.067)	-0.464*	(0.277)
benefmarried	0.157	(0.432)	0.032	(0.087)	0.176	(0.352)
benefgrpmemb	0.730**	(0.373)	0.148**	(0.073)	-0.018	(0.261)
household characteristics						
drinkwatertap	-0.156	(0.380)	-0.032	(0.077)	0.387	(0.307)
familydecidespnd	-0.315	(0.473)	-0.064	(0.095)	-0.218	(0.368)
maledecidespnd	-0.793	(0.670)	-0.160	(0.134)	0.413	(0.553)
chronilmember	0.394	(0.321)	0.080	(0.064)	0.477*	(0.261)
chnbelow5	-0.15	(0.222)	-0.030	(0.045)	-0.221	(0.183)
hhdmembs	0.052	(0.060)	0.010	(0.012)	0.068	(0.047)
otherincome	0.000	(0.000)	-0.000	(0.000)	0.000	(0.000)
remittance	-0.034	(0.319)	-0.007	(0.065)	-0.453*	(0.263)
middlelevel	0.279	(0.418)	0.056	(0.084)	0.566*	(0.309)
rich	0.476	(0.438)	0.096	(0.088)	0.221	(0.328)
constant	-3.218***	(1.034)			2.776***	(0.771)
observations	154		154		154	

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

Based on the results in Table 6.12, Model 2 above, it is evident that a household whose beneficiary dropped out of the smallholder drip irrigation project is less likely to have consumed vegetables normally grown under irrigation in the day preceding the interview compared to a household whose beneficiary is still using the kit ceteris paribus. This effect however is not significant. Interestingly, comparing two beneficiaries who both dropped out but one dropped out early (within 3 years of using the project) and the other dropped out late, the chances that the household for the beneficiary who dropped out early consumed vegetables is significantly higher by 0.029, all things being equal. Although this result seems to suggest that smallholder drip irrigation is of little importance in increasing the consumption of vegetables, households could have just decided not to consume vegetables on that particular day. The magnitude of the effect itself is also small.

The results from Model 3, on the other hand suggest that smallholder drip irrigation may be important in increasing diversity in terms of garden crops grown under irrigation by the household. Both dropping out (*dropout*) and timing of dropping out (*earlydropout)* of the drip irrigation program have the potential to reduce the number of garden crop varieties a household grows. Even though this result is not statistically significant, it serves to draw attention to the fact that smallholder drip irrigation may matter in improving the diversity of garden crops grown and consumed by the household in the long-term.

6.6 Summary

This study set out to establish whether the main goal of the smallholder drip irrigation project of improving household food security for rural households in Mutasa and Mutoko districts in Zimbabwe was attained.

The results obtained show that overall smallholder drip irrigation has the potential to improve food security for smallholder rural farmers. However, the benefits are evident over the long term as dropping out of the project early (within the first 3 years) appears to worsen a household's food security. The impact of smallholder drip irrigation is mainly through its effect on the number of coping strategies a household uses. According to the results, smallholder drip irrigation does not have any notable effect on a household's dietary diversity, despite this being one of the expected outcomes of the project. The results also suggest however that smallholder drip irrigation has potential in improving household food security through increasing the number of different varieties of garden crops grown.

In addition, household selling decisions and the beneficiary's perception of the level of knowledge they possess on drip irrigation are also important in improving food security. Households where an adult male is the sole decision maker with regards to which garden crops to sell are more likely to be food insecure compared to households in which an adult female makes the decisions. Below average knowledge of drip irrigation results also has a negative impact on household food security. The age of the beneficiary and the number of household members have a positive and negative impact on smallholder household food security respectively. Household socio-economic status also plays a major role in the attainment of food security with rich households being more food secure than poorer households. Furthermore, belonging to a farming or business related group has been shown to be advantageous especially for increasing dietary diversity.

Implications of this study

These results suggest that smallholder drip irrigation does have potential to improve household food security. However in order for the benefits to be realised there is need for several measures to be taken by both the implementing organisations and the beneficiaries.

Firstly beneficiaries need to be made aware during the awareness raising and throughout the implementation phases that the benefits from drip irrigation take time to be realised. This will encourage them to be patient and not drop out early.

Secondly, the issue of training in drip irrigation operation and management is paramount. Although all the beneficiaries who were interviewed indicated that they received drip irrigation related training at some point during the project phase, their responses showed that they failed to grasp all the knowledge at one go. This suggests that in addition to training offered in the initial stages of the project, refresher courses also need to be offered to all beneficiaries so that their knowledge improves. Better knowledge will assist in boosting the beneficiaries' confidence in the project and motivate then to continue with the project.

Thirdly, beneficiaries should also be encouraged to establish relationships and learn from each other. This will provide a platform for those who are young and new to drip irrigation and home gardening to learn from those who have been involved for a while. It will also motivate them to continue in the project even when support from the implementing organisation is no longer available. Under the Plan International program, Lead Farmers were nominated and given some beneficiaries to look after. Promotion and continuation of such a program will greatly benefit household food security.

Fourthly, establishment and promotion of drip irrigation related groups in the community can go a long way in improving dietary diversity. Members of a gardening group can grow different crops and exchange. This will increase the varieties of vegetables the household consumes and hence improve household food security. In Mutasa, some beneficiaries interviewed indicated that they belonged to gardening groups. Some of these groups were actually assisted by Plan International in fencing off their gardens to reduce damage of crops by livestock. Promotion of such groups may indeed prove to be vital in the attainment of household food security.

Lastly, the importance of a household's socio-economic status in the attainment of food security for rural households is clear. The impact of wealth is evident in both the number of coping strategies used and in dietary diversity. Thus measures should be put in place to ensure that poor households build their long term wealth. Such measures can include programs like village microfinance groups. A few of the farmers interviewed in Mutasa indicated that they were members of microfinance groups. They highlighted that they benefited greatly especially in terms of input acquisition.

CHAPTER 7

Summary, policy implications and further research

7.0 Introduction

This thesis has two parts, one based on research into food security issues in Zimbabwe using Measure DHS data and the other uses data from the 2013 Smallholder Drip Irrigation Survey carried out by the author in 2 districts in Zimbabwe. This chapter will also present the implications of the results obtained on different policies aimed at improving food security issues in Zimbabwe. Areas of further research will also be highlighted.

7.1 Short-term versus long term child health

The first objective looked into whether there is an association between short and long term child health for children aged 0-59 months in Zimbabwe using the 2005/06 DHS data. Based on the assumption of a linear relationship existing between a child's the BMI z-score (proxy for short-term health) and their height z-score (proxy for long-term health) the ordinary least squares method was used to model this association. Potential sample selection bias and endogeneity were also controlled for as were other maternal, child and household related characteristics that may influence a child's health. In this study, long-term (height z-score) child health was taken to be health stock which can be used in the future to help a child cope with short-term (BMI z-score) health shocks such as food shortages. If indeed long-term health influences short-term health then the expectation was that there would be a positive relationship between a child's BMI z-score and their height z-score. This would mean that a child with a higher height z-score would have better health stock and thus be able to respond better to any short-term health shocks. On the other hand, a child whose height z-score is lower would have poor health stock and thus would respond poorly to a short-term health shock.

Contribution of this study

The relationship between a child's BMI z-score and height z-score has been analysed especially for developed countries such as the USA, for countries undergoing economic transitions such as Chile and for South Africa, a developing country whose economy is developing at a faster pace compared to other developing countries in Africa. In these studies, the emphasis has been on the relationship between height and obesity. This research focuses on a poor, developing country Zimbabwe, whose main challenge is that of having underweight children as opposed to overweight children. In addition, this research accounts for potential sample selection and endogeneity bias which have not been accounted for in previous studies.

Results

The results obtained showed that there is a negative association between a child's short-term (BMI z-score) and long-term (height z-score) health for Zimbabwean children under the age of 5. This relationship remains robust when other maternal, child and household characteristics are controlled for and when potential sample selection and endogeneity bias are accounted for. Using a different reference population (the 2006 WHO standard) to construct the z-scores also produces a significant negative relationship between the BMI z-score and the height z-score. The mechanism through which this negative association occurs is probably through upbringing factors such as intra-household food distribution. This suggestion stems from the results obtained by comparing Zimbabwean children with

Australian children. For Australia, a positive relationship was obtained between a child's BMI z-score and their height z-score. This alludes to the fact that there must be some factors that make children in Australia who are taller to have a higher BMI and those in Zimbabwe who are taller to have a lower BMI. The maternal fixed effects model results for Zimbabwe indicated that there is a significant negative relationship between a child's BMI z-score and their height z-score. So considering two children from the same mother, residing in the same household and with the same child characteristics except that one is taller than the other, the taller child is likely to be thinner compared to the shorter child on average. If the amount of food in the household is fixed and the food each child receives equal portions, if the food portion is just enough to satisfy the hunger of the shorter child, the taller child by virtue of having a bigger frame to feed will not get enough to eat and this will affect their BMI. This hints at intra-household food distribution being the mechanism through which the negative association arises.

Moreover results indicate that the presence of pit toilet facilities, the type of food household consumes, the duration of breastfeeding and the mother's marital status are also important in determining a child's health. For child survival, receipt of prenatal care by the mother during pregnancy plays an important role in improving a child's survival chances.

Policy implications

The results imply that children with better long-term health (higher height z-score) are more likely to have poorer short-term (lower BMI z-score) health. With regards to food security, this suggests that children who are suffering from chronic food insecurity (low height z-score) are more likely to be food secure in the short-term (higher BMI z-score). Currently, the BMI z-score (a BMI z-score of less than -2SD means the child is food insecure) is the common measure used to identify children and consequently households who are food insecure in emergency situations. For Zimbabwe, the ratio of underweight (low BMI z-score) to stunted (low height z-score) children is approximately 1:3. Targeting food insecure children and households using the BMI z-score thus implies that children and households already suffering from chronic food insecurity (height z-score below -2SD) are more likely to be left out. Targeting using the BMI z-score will select households with children who have better long-term health (taller) and poorer short –term health given the negative association between the two measures. This therefore suggests that it may be worthwhile to include the long-term measure (height z-score) as a tool for selecting children and households that receive food aid in emergencies.

Another important implication of these results on food security is that gleaned from the role of the mother's marital status in determining a child's health. Children whose mothers are widowed or divorced are more vulnerable to food insecurity compared to children whose mothers are married. Currently widows are included in the vulnerable population and thus are more likely to receive food aid. Divorced mothers on the other hand are not included. From the results obtained, it may be beneficial in terms of improving child and household food security to incorporate divorced mothers as part of the vulnerable population. The importance of appropriate sanitary facilities (in this case pit toilets as opposed to flushing toilets), given the current water shortages being experienced in Zimbabwe will also assist in improving child health and hence food security as would the inclusion of meat in children's diets. All these efforts however only work if the children are alive. In order to improve child survival chances, prenatal care for pregnant mothers is essential. Thus policies which encourage mothers to have prenatal check-ups will have a positive impact on child survival chances.

7.2 The role of maternal nutrition in determining child nutrition

The second objective was based on determining the role of maternal nutrition (denoted by the mother's BMI) on child nutrition (denoted by the child's BMI z-score) using the DHS data for Zimbabwe for 2005/06. Comparisons were also made using DHS data for Malawi for 2004. Initially, it is assumed that there is a linear relationship between the mother's BMI and a child's BMI, explored using the ordinary least squares (OLS) method. The mother's BMI in this case is assumed to have an indirect effect on a child's BMI as it is presumed to be an indicator of the household's overall nutrition choices. Potential simultaneity or endogeneity bias in the determination of the mother and child's BMI is also accounted for using instrumental variable (IV) regression in order to establish whether the mother's BMI has a direct impact on a child's BMI and hence nutrition. The general expectation is that there will be a positive relationship between a mother's nutrition and a child's nutrition given that they reside in the same household. Ascertaining whether or not maternal BMI has a direct impact on child BMI will also help in improving policies targeted at improving child health and nutrition.

Contribution of this study

There is limited research that has been conducted on the impact of maternal nutrition on child nutrition. Most studies conducted include the mother's BMI (proxy for maternal nutrition) as an explanatory variable in the child nutrition equation. Like Rahman et al. (1993)'s study using data from Bangladesh, this research assumes that there is a linear relationship between maternal BMI and child BMI. Unlike Rahman et al. (1993)'s study based on data from 2 hospitals and a clinic, this study uses a larger and more representative sample from Zimbabwe and also accounts for potential endogeneity or simultaneity bias which Rahman et al. (1993) and indeed other studies to the best of our knowledge did not account for.

Results

Overall the OLS results indicate that there is a robust positive relationship between a mother's BMI and a child's BMI as expected. This relationship is evident for Zimbabwe as well as for Malawi. This relationship is also evident across all the provinces in Zimbabwe. In addition, the IV results indicate that accounting for potential simultaneity or endogeneity bias in the determination of maternal BMI has a significant positive impact on a child's BMI for both countries. The results show that the magnitude of effect is higher for the direct compared to the indirect impact of maternal BMI on child BMI. This is unexpected as one would expect the magnitude of the direct effect (IV estimates) to be lower than that of the combined direct and indirect effect (OLS estimates). This result suggests that the indirect effect is either negative or small and insignificant or perhaps the instruments used for the mother's BMI are not appropriate. The first-stage IV regression results though shows that the instruments used (household wealth categories) are significant and strong. Other studies have found similar results for returns to education (Trostel et al., 2002).

The results also show that other factors such as maternal education and marital status, a child's size at birth, birth order, the incidence of diarrhoea in children and the presence of proper sanitary and drinking water facilities have an important role to play in shaping a child's nutrition. This is in line with what has already been established in other literature.

Policy implications

Obtaining a statistically significant relationship between maternal and child BMI for both the OLS and IV methods would mean that maternal BMI and hence nutrition has both a direct and indirect effect on child nutrition or BMI. For both Zimbabwe and Malawi, our results indicate that both the direct and indirect effect of maternal BMI on child BMI is significant.

In terms of policies, this result suggests that policies aimed at improving maternal nutrition will also improve child nutrition directly. Thus in addition to targeting overall household nutrition and child nutrition, improving the mother's nutrition in general will also benefit the child. Interventions aimed at women often tend to focus on pregnant and lactating mothers. This result brings to light that promoting maternal nutrition even for mothers who are not pregnant or lactating also has benefits for both the mother and her children.

Similar to the previous research on the association between short and long term child health, the results indicate that considering divorced and unmarried mothers in addition to widows in nutrition based programs will go a long way in improving child health and nutrition. In order for these policies to succeed there is need for mothers to be educated so they can fully comprehend and be better able to employ nutritional resources to benefit their households. This perhaps points to promoting policies aimed at educating the girl child as she will be a mother in the future as well as programs implemented to raise awareness among mothers on the benefits of good nutrition.

The results however indicate that when considering the provincial effect for Zimbabwe, only the OLS results are positive and significant with the exception of one out of the 10 provinces. This implies that maternal nutrition has an indirect impact on a child's nutrition through perhaps overall household nutrition. The direct effect seems not to be evident. However this could be due to the small sample size and thus further analysis is required to improve the results.

7.3 Why do smallholder farmers drop out of drip irrigation projects

The third objective uses data from the 2013 Smallholder Drip Irrigation survey conducted by the author in Mutasa and Mutoko districts of Zimbabwe to establish the factors that determine dropout rates in drip irrigation projects. In addition, factors that influence the duration a beneficiary lasts in the project are also identified. The details of the survey and the data are fully described in chapter 4.

The smallholder drip irrigation project was implemented on a relatively large scale in Zimbabwe by the USAID in conjunction with 30 NGO's. Reports show that over 70000 drip kits were distributed to smallholder households between 2002 and 2007 (Belder et al., (2007). Research so far has established that on the part of the implementing organisations, success has been largely dependent on logistical issues such as distributing the kits to farmers. Findings have showed that dropout rates from the project were very high.

Contribution of this study

This research looks into the factors that influence dropout rates for smallholder drip irrigation farmers in Zimbabwe. Previous research has only gone as far as indicating the reasons that beneficiaries have highlighted for dropping out. Our research explores these factors further using econometric methods and controls for other factors such as the yields realised by the household for field crops, other training received that is relevant to drip irrigation as well as beneficiary and household characteristics. Moreover we also explore the determinants of the length that farmers stay in the project. The results of this study are important especially for organisations implementing the projects as well as for informing future policies on projects aimed at alleviating food insecurity.

Results

Overall, the main findings reveal that receiving the drip kit early, realising a yield increase in leafy vegetables and household wealth significantly reduce chances of dropping out, as well as increase the duration a beneficiary lasts in the project. Realising a yield increase in groundnuts, receipt of training in marketing, experiencing water problems and the beneficiary's age on the other hand increase the likelihood of a beneficiary dropping out of the project and consequently reduce their length of use of drip irrigation. Beneficiaries looking after chronically ill members are more likely to drop out but this has no impact on the duration of stay in the project.

Policy implications

Given the merits of drip irrigation as a water saving technology and in light of the predictions that in the near future major water shortages are likely to be faced, these findings shed more light on the avenues which donors, the government and other interested stakeholders can use to encourage beneficiaries to continue with the smallholder drip irrigation project.

Early adoption of the project is beneficial in reducing project dropout rates as this will go a long way in encouraging farmers to continue with drip irrigation. Thus efforts to disseminate project technology at the inception phase to as many beneficiaries as possible should be considered in the future for all capacity building projects in order to improve their impact on the targeted community.

It is evident that water problems play a major role in increasing dropout rates. Policies and programs addressing the issue of access to water such as drilling of boreholes will go a long way in addressing water shortage problems as well as ensuring that the water source is in close proximity to the gardens. Introduction of technologies such as treadle pumps will greatly assist households looking after chronically ill members as well as elderly beneficiaries who are part of the target population by making it easier for them to fill the buckets or drums for irrigation.

Rainfed crops also play a major role in determining dropout rates from smallholder drip irrigation projects. Good yields in competing crops such as groundnuts increase chances of beneficiaries dropping out as the opportunity cost of growing vegetables is high, especially in terms of labour use. Thus an assessment needs to be made before implementing the project in an area to determine whether the project is likely to be beneficial or not taking into consideration the major rainfed crops grown in the area. Choice of crops grown under irrigation and the area to allocate to each crop is also important. Leafy vegetables appear to be the most beneficial crop in terms of encouraging farmers to continue with drip irrigation.

Targeting of the projects still needs to be improved. The general trend in patrilineal societies like Zimbabwe is that males tend to benefit more than females despite projects being targeted at females. So there is need to ensure that females benefit especially from projects targeted at them. In terms of the socio-economic status of targeted household, our results indicate that wealthier households were more likely to continue in the project compared to poorer households. Yet the project targeted poor and vulnerable households. There is thus need to ensure that the targeted population have the necessary resources to support them in the project. Our results suggest that the cost of maintaining the drip kits were too high for poor households, since initial capital outlay costs were covered by from Plan International, who donated the kits.

7.4 Can smallholder drip irrigation improve food security at the household level?

The fourth objective of this research was based on the data that the author collected in the 2013 Smallholder Drip Irrigation Survey conducted in Mutasa and Mutoko districts of Zimbabwe. The aim of this part of the research was to establish whether indeed smallholder drip irrigation in these 2 districts helped to improve household food security for the beneficiaries. Given the high dropout rates, it was necessary to find out whether the drip irrigation program achieved its main goal of improving household access and consumption of garden crops. Using various proxies for household food security (number of coping strategies, the coping strategies index and the dietary diversity score), the relationship between household food security and drip irrigation (represented by whether one dropped out of the project or not and the timing of dropping out) was explored. Other drip irrigation, food, beneficiary and household related factors are also controlled for in this study.

Contribution of this study

This study adds to the limited literature that is available for Zimbabwe on the merits of smallholder drip irrigation in improving household food insecurity. To date the available literature suggests that the impact of the drip irrigation program on household food security varied by district. This research explores the impact in Mutasa and Mutoko districts of Zimbabwe.

Results

For smallholder rural famers in Mutasa and Mutoko districts, the results indicate that drip irrigation has the potential to improve household food security. The results suggest that the benefits of smallholder drip irrigation in these two districts are evident in the long term as household food security worsened for those who dropped out early (within the first 3 years of using drip irrigation). The impact of the smallholder drip irrigation program for the households in Mutasa and Mutoko district was mainly evident through a reduction in the number of coping strategies a household uses. Although the project aimed at increasing food diversity in the household, the findings show that dropping out of the drip irrigation program did not have a significant effect on the dietary diversity scores.

Other factors including who decides how much of the garden produce to sell, a beneficiary's perception on how much they know about drip irrigation, the beneficiary's age and the number of household members are also important in improving household food security. Households where the male adults are the sole decision makers on how much garden produce to sell are more likely to be food insecure compared to households where adult females or spouses make the decision. This is consistent with available literature. Of interest is the result that households where the beneficiaries believe that they have below average knowledge of drip irrigation are more likely to be food insecure compared to households where beneficiaries think they have above average knowledge in drip irrigation. The household's socioeconomic status and belonging to a farming or business related group also proved to be important for food security.

Policy implications

Overall the results of this study show that there is potential in smallholder drip irrigation to alleviate household food insecurity for poor households. However in order for the full benefits of this program to be realised, several issues need to be addressed. These issues are mainly targeted at the organisations implementing the program.

Beneficiaries need to be made aware that the benefits from drip irrigation do not occur overnight so that they can embark on the project knowing that it will take time for them to realise the impact. Training in drip irrigation operation and management is also important and perhaps providing refresher training courses will go a long way in improving project uptake and hence project impact levels. As indicated in the results, beneficiaries who perceived that they has above average knowledge in drip kit operation and management fared better than their counterparts with below average knowledge. Encouraging beneficiaries to learn from each other and to form gardening and or business support groups will also go a long way in improving the duration of stay in the project. This is especially helpful in instances where resources are limited and it is not possible to have as many trained extension staff on the ground as required by the farmers. The drip irrigation program is mainly targeted at poor households. However the results indicate that poorer households are more likely to drop out compared to richer households. This implies that there are other costs beyond the initial capital outlay costs that households need to cover in order to continue with the project. It is thus important to provide a support base for poorer households before distributing the drip kits to them.

7.5 Lessons learnt from the 2013 Smallholder Drip Irrigation Survey

Ethics approval

The survey was a low risk survey so obtaining ethical clearance from Monash University was not difficult. Obtaining ethical clearance from Plan International which is the organisation that implemented the project was not burdensome. This is because an informal request had been logged about a year before the survey was conducted and the organisation had indicated that they were also interested in the results of the survey. Obtaining clearance from local authorities such as the District Administrators, the Rural Development Authority, the department of Agricultural and Rural Extension Services (AREX) and the Mechanisation department was also quite simple as appointments were made before hand to meet with the relevant personnel. For both districts, all the offices were located in close proximity to each other and thus the process was completed the same day. Having a staff member from Plan International to introduce and support the team in this instance proved to be very useful as Plan International is well known to all government departments. Obtaining clearance from the village headmen and chiefs also was made simpler by the Rural District Council who informed all the chiefs in their monthly meeting of the survey that was to take place.

Networking

Networking between the donor organisation and the local authorities was good at all levels. This was evidenced by the reception we received from the local authorities as we sought ethical clearance. In the villages, a favourable response was also received from the village headman and the chiefs. At the farmer level, networks exist and are fully operational between extension staff from the donor organisation and from local government bodies and the farmers. The extension worker to farmer ratio for Plan International personnel is quite low compared to that of government departments. So in areas where the Plan International extension staff was not available, extension staff from government departments like AREX was assisting the farmers in terms of drip irrigation. These networks proved to be very useful especially in assisting the enumerators with locating the households to be interviewed in the area. In Mutasa networking was much better than Mutoko as the households are in closer proximity to each other.

The major challenge was that of a high staff turnover at Plan International. This meant that the extension workers who had been involved in the implementation of this project had long gone and we had to rely on their records. For the farmers this proved to be detrimental as the new extension staff were not so well versed with the project and thus their level of support for it was quite different from that received from the original extension workers. All in all, support from the donor organisation proved to be invaluable in this research.

Organisational data

Record keeping at Plan International proved to be very good. In Mutasa district, we had to go to the archives to obtain the lists of the beneficiaries. This was made quite simple because the person responsible for filing the data in 2003 was still around in 2013 and thus knew exactly what we were looking for and where to obtain the information. For Mutoko this also proved to be the case and thus identification of the households to be interviewed was made easier. We were also able to ascertain the times at which beneficiaries received their kits using information contained in these files. The extension workers in the different wards also had records on who had received the kit and when they had received it.

Timing of the survey

Timing of the survey is important. Due to the upcoming elections that Zimbabwe was facing, the survey was conducted between January and March. This is the rainy season and as a result all the farmers were concentrating on field crop production. We thus failed to see any drip irrigation in action as farmers normally use the kit between May and November. The rains rendered some of the roads inaccessible by car and as such the enumerators had to walk long distances to get to the households they had to interview. The survey was conducted just before the election campaigns which enabled us to avoid clashes and misunderstandings with those campaigning.

7.6 Potential areas for further research

In terms of the association between long and short-term child health, it may be worthwhile to explore the issue of intra-household food distribution to determine whether it is the channel through which the negative association occurs. The DHS data used in this research has no information on this and thus we could not ascertain this in our study. Comparisons with other African countries facing similar challenges of undernutrition and stunting in children below the age of 5 may also be helpful in establishing whether the negative association is common for Africa. Lessons learnt from other countries will also be helpful for future policies aimed at improving child health.

The contribution of maternal nutrition to child nutrition can be further improved perhaps in terms of the identification variables for the instrumental variable regression. In this research household wealth categories were used as identifying variables for the mother's nutrition (represented by the BMI), based on evidence from other literature. Other literature suggests that household wealth has little significant impact on a child's BMI. Using other variables as instruments in this case, may lead to improvements in terms of the consistency in the direction of effect and magnitude of maternal nutrition on child nutrition. With regards to the provincial effect, further research may be carried out using larger sample sizes, in order to improve the results.

With regards to smallholder drip irrigation, this study is based only on data from two districts, Mutoko and Mutasa where the beneficiaries benefited from the smallholder drip irrigation scheme under Plan International. It would be worthwhile to survey a wider sample of beneficiaries to include some from the same as well as from different districts who benefited under other NGOs so as to establish whether there are any differences in terms of the way

NGOs rolled out the project to beneficiaries. Such differences provide a learning platform which will help improve on existing and better future projects. Some work has been done in this area howbeit using small samples. More evaluations still need to be carried out, with special emphasis on issues such as early adoption, wealth status and the impact of rain-fed crops which have been flagged by this research as being drivers of dropout rates among smallholder drip irrigation farmers. This will shed more light and add value to the conclusions drawn. Furthermore the entire yield data used in this research is retrospective. It is better to build in data collection at the baseline, during the implementation phase and when the project ends. It may also be worthwhile to extend this research to other African countries as literature suggests that the issue of high smallholder drip irrigation project dropout rates is not only confined to Zimbabwe.

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APPENDIX A: APPENDIX TO CHAPTER 2

Appendix A1: Background on Zimbabwe

Zimbabwe is a landlocked country in south central Africa, covering 390,580 square kilometres in extent. It is shares boundaries with Mozambique to the east, South Africa to the south, Botswana to the west and Zambia to the north *(Encyclopaedia of nations)*. At the moment, Zimbabwe's population is estimated to be 13,182 million. An estimated 38.6 % of this population resides in urban areas (CIA, 2014).

According to USAID (2010), the adult HIV prevalence rate is an estimated 13.6% and around 1.02 million people are affected by HIV and AIDS. WHO (2005) indicates that the HIV prevalence rate is higher (35%) in the large scale commercial farming areas, administrative centres, high growth areas outside cities and towns , state lands and in mining areas. The HIV prevalence rate in urban and rural areas is 28% and 21% respectively. The group that is mainly affected by HIV and Aids includes women involved in sex work, uniformed personnel and orphaned children.

Zimbabwe‘s provinces

Zimbabwe comprises of 8 provincial or administrative areas and two cities Harare and Bulawayo have also been accorded the status of an administrative province. As shown in Table A1 below, Matabeleland North and South, Mashonaland West, Masvingo and Midlands cover the largest areas. These provinces are mostly in agro ecological regions III, IV, and V which receive the least and most erratic annual rainfall. Most of the population dwells in Harare, which is the capital city (Law, 2010).

Table A1: Zimbabwe's provinces

Province	Area %	% Population	Agro-ecological region
Bulawayo	0.1	6	IV
Harare	0.2	15	IIA
Manicaland	9.3	13	I, IIA, IIB
Mashonaland Central	7.3	9	IIA, III, 1V
Mashonaland East	8.2	10	IIA, IIB
Mashonaland West	14.7	11	IIA, III, IV
Masvingo	14.5	11	III, IV, V
Matabeleland North	19.2	6	III, IV, V
Matabeleland South	13.9	6	IV, V
Midlands	12.6	13	III, IV, V
Total	**100**	**100**	

Source: Law (2010), OCHA (2009)

Zimbabwe's economy

In addition to agriculture which accounts for about 19.5% of the GDP and employs about 66% of the population, Zimbabwe's economy also relies on the industrial and services sector.

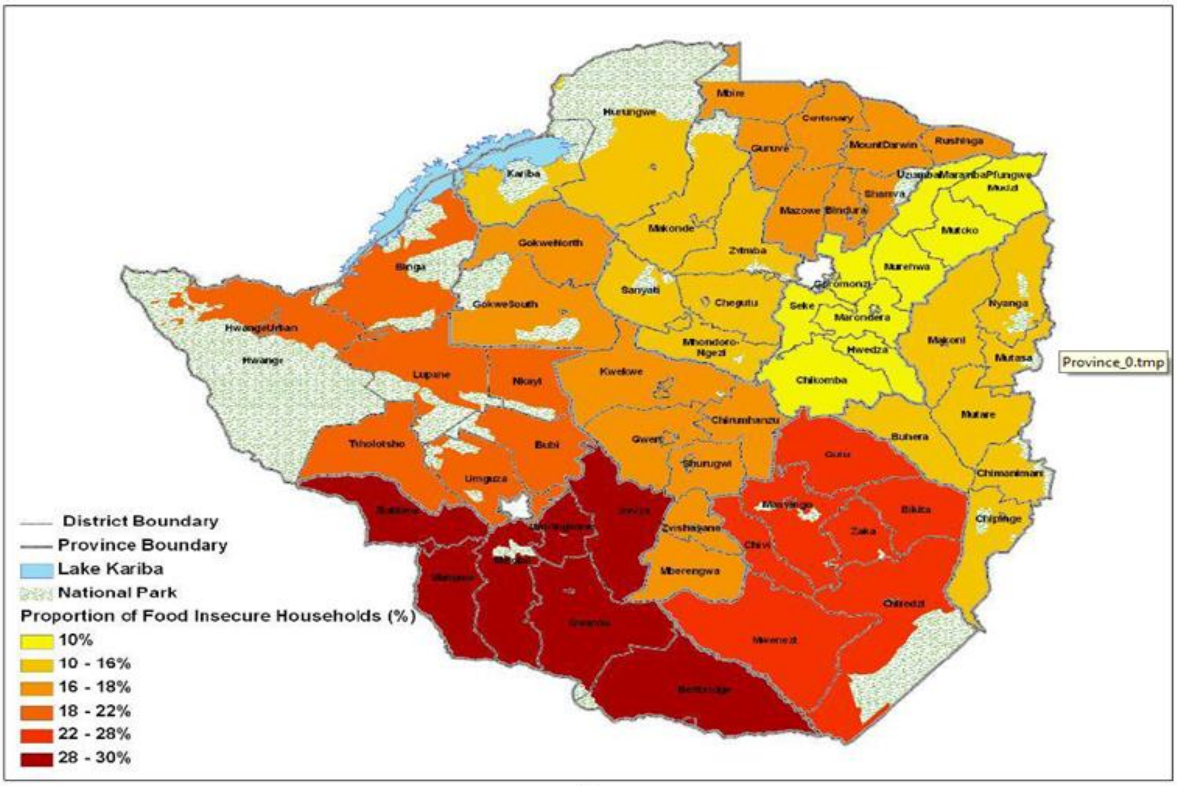
About 10% of the population are employed by the industrial sector, which accounts for about 25.1% of the GDP. The industrial sector includes the mining (mainly coal, gold, platinum, copper, metallic and non-metallic ores), steel, wood production, chemical, fertiliser, textile, and food and beverage production industries. The services industry accounted for around 54.6% of the GDP. This sector employs approximately 24% of the population. The overall GDP growth rate for 2012 was around 4.4. The unemployment rate is estimated to be 95% and the inflation is roughly 8.2% % (CIA, 2014).

In terms of trade, Zimbabwe exports platinum, cotton, tobacco, gold, ferro alloys and clothing and imports food, machinery and transport equipment, fuel, chemicals and other manufactured goods. Zimbabwe's main trade partners are South Africa, China and Japan. Trade also occurs with the Democratic Republic of Congo (DRC), Botswana, Zambia, Netherlands and the United Kingdom. The unemployment rate was estimated to be 95% in 2009 and 68% of Zimbabwe's population was living below the poverty datum line. Inflation in 2010 was 5.03% (Zimbabwe Economy, (2011)).

Zimbabwe's food security

Zimbabwe suffers especially from transitory food insecurity due to seasonality of production. The extent of food insecurity is shown in Figure A1 below.

Figure A1: Zimbabwe's provincial food insecurity prevalence map



Source: ZimVAC, 2012

Food insecurity is highest in the November to March period, which is the period between planting and harvesting. Harvests occur mainly at the end of March and the food insecurity situation improves until late October. The major challenge is in terms of accessibility as most poor household have very low income and very small resource endowments such as land and draft power for production. An estimated 75% of the communal households live in agro-ecological regions IV and V which receive very low and unreliable rainfall annually. Crop production in these areas is highly unreliable and this makes it difficult for the households to get sufficient food to meet their daily requirements (Mudimu). As a result, all communal areas suffer from varying levels of malnutrition, ranging from 10-15% to 20-25% for children between the ages of 1 and 5 years in low rainfall communal areas. Other areas such as Nyanga, Binga and some areas in Matabeleland province have malnutrition rates which are as high as 30-40% (Rukuni and Jayne (1995) in Mudimu).

APPENDIX B: APPENDIX TO CHAPTER 4

Appendix B1: Capacity building, food security and smallholder drip irrigation survey questionnaire

Monash University and Plan Zimbabwe

Your household was selected randomly from a list of the beneficiaries of PLAN Zimbabwe's smallholder drip irrigation project to which questions of the project will be asked. You ere not selected for any other reason other than this.

GENERAL INFORMATION

1.	Household ID: ________________________
2.	Name of the project beneficiary: ……………………………..……….
3.	District name :____________________ District code: __________
4.	Ward name: ____________________ Ward code: __________
5.	Village name :____________________Village code : __________
6a.	Interviewer's name : ……………………………………………………
6b.	Interviewer's ID :………………………………………………………….
7.	Team leader's name: …………………………………………………
8.	Date of interview.
9.	Main respondent's phone contact: ________________________
10.	Team leader's signature: ………………………………………………….. Date: Day ………… /Month ………………………. /Year ………………

8a. day	8b. month	8c. year

11.	Name of respondent: ____________________
11a.	Name of household head: ____________________
11b.	Respondent's relationship to household head: __________

1=Household head 2=Wife/husband 3= Biological child 4=Grand child	5= Father/ mother 6= Brother / sister 7 =Other (specify): ____________________

Project details

12.	When did you receive your drip irrigation kit from PLAN? …………….month …………year
12a.	Have you ever used your drip kit since you received it? Yes=1 No=2 ☐
12b.	Are you still using your drip kit? Yes=1 No=2 ☐

Consent form

Title: Capacity building, food security and smallholder drip irrigation

NOTE: This will remain with the Monash University researcher for their records

I agree to take part in the Monash University research project specified above. The project has been explained to me.

I understand that:	YES	NO
- **I will be asked to be interviewed by the researcher**	☐	☐
- **Unless I otherwise inform the researcher before the interview I agree to allow the interview to be audio-taped**	☐	☐

I know that my taking part is voluntary and I am free to decide when to withdraw before the interview begins without being punished in any way.

I am aware that the data collected will be used for a report but will not be used to identify me as an individual in any way.

I am aware that the information I give is private and cannot be traced back to me.

I am aware that data will be kept in a safe place and will be destroyed after 5 years.

Participant's name: ……………………………………………………….

Signature : …………………………………………………………………

Date: ………………………………………………………………………..

Interviewer's Name: ……………………………………………………..

Signature: ……………………………………………………………………

Date: …………………………………………………………………………….

Section A: Household Characteristics

A "household" comprises of all members within that residence, sharing the same resources and income. This includes domestic workers who have been resident in the house within the last 12 months.

Among the residents of the household, identify the household head and assign them PID1. Enter his or her name in the first row. Assign PID2 to the project beneficiary and enter their details. Household members include people who frequently travel away from the household such as children in boarding school. Ask the project beneficiary and or the household head this.

Household demography

1 **PID**	**2** **Name**	**3** **Sex** 1= male 2= female	**4** **Age** (completed years)	**5** **Relationship to household head** 1 = Head 2 = Wife/ husband 3= Son or daughter 4 = Grandchild 5 = Other (specify) 98= Don't know	**6** **Marital status** 1= Married or living together 2= Divorced or separated 3= Widowed 4= Never married and never cohabited	**7** **Education (highest level attained)** 1= None 2= Primary 3= Secondary 4= Tertiary 98= Don't know	**8** **Is (NAME) currently attending school?** 1= Yes 2=No	**9** **Main occupation** (last 12 months) (Occupation codes on the right)	**10** **Secondary occupation** (last 12 months**)** Occupation codes on the right)
1									
2									
3									
4									
5									
6									
7									
8									
9									

11. Do you look after any orphans?

Yes ☐ *(go to Q 11a)* No ☐ *(go to Q 12)*

11a. If yes, how many? ☐

Occupation code
1= Government junior posts (clerks, drivers, office orderly, extension workers)
2= Government middle level posts (officers, teachers, army staff)
3= Government senior posts (HOD, provincial & district officers)
4= Professional, technical , sales or managerial
5= Farmer
6= Self employed
7= Agriculture employee
8= Household and domestic services
9= Skilled manual (carpenter, tailor, mechanic)
10= Unskilled manual
11= Clergyman (pastor, church official)
12= Pupil or student
13= Not working
14= Other (specify)
99= Don't know

Household characteristics continued

12. What is the household's main drinking water source?
1= tap water
2= borehole or well
3= spring
4= rain water
5=dam, pond, lake, river, canal, irrigation channel
6=other (specify)

12a. Is this the water source you use for watering your garden?

1= Yes *(go to Q13)*
2= No (*go to Q12b)*

12b. What is your main water source for irrigating your garden*?(use Q12 codes)*
………………………

12c. Type of irrigation source
1= communal
2= private

13. How far is the water source from:
(use the standard)
i. the main dwelling?
…………..meters

ii. the garden
…………. meters

14. Do you pay for irrigation water?
Yes ☐ No ☐

(If No, go to Q15)

14b. If yes, how much do you pay per month?

US$ ………………

15. If you use a communal water source have you ever experienced any water sharing conflicts?
1= Yes
2= No

15b.What was the nature of this conflict?
……………………
……………………
……………………
…………
……………………
……………………
……………………
…………..
……………………..
……………………..
…………….
……………………..
……………….

16. What kind of toilet facilities do members of your household usually use?

1= flush toilet
2= pit toilet
3= no facility /bush / field
4=other (specify)

16a. Do you share this toilet facility with other households?

Yes ☐ No ☐

17. What is the MAIN source of lighting used by your household?

1= electricity
2= solar energy
3= paraffin lamp
4= candle
5= other (specify)

18. What type of fuel does your household mainly use for cooking?
1= electricity
2=gas
3= charcoal
4= firewood
5= other (specify)

19. How are the dwellings of this household organised?
1= single house
2= several separate structures
3= room in a larger dwelling
4= improvised house (temporary structure)
5= other (specify)

20. How many rooms including the kitchen, are there for this household *(exclude rooms not occupied by people e.g. garage, sheds, animal houses)*

21. How many rooms in this household are used for sleeping?

22. What material is the floor of the main dwelling made of?

1= earth, sand, dung
2= wooden planks, bamboo
3= wood, vinyl, ceramic tiles, cement, carpet
4=other (specify)

23. What material is the roof of the MAIN dwelling made of?

1= no roof
2= thatch, palm leaf
3=rustic material, wood planks, bamboo, cardboard
4= metal, asbestors, cement fibre, ceramic tiles, roofing shingles
5= other (specify)

24. What material are the outer walls of the MAIN dwelling made of?

1= no wall
2= cane, palm, trunks
3=bamboo with mud, stone with mud, plywood, reused wood
4= cement, stone with cement, bricks, wood planks
5= other (specify)

25. Does your household have:

		Yes	No
a	electricity		
b	solar power		
c	radio		
d	television		
e	landline phone		
f	refrigerator		

26. Does any member of your household own a:

		Yes	No
a	ox-drawn cart		
b	mobile phone		
c	bicycle		
d	motor cycle or scooter		
e	car or truck		

27. How many of the following animals does this household own?

cattle	pigs	goats	sheep	poultry	horses, donkeys, mules	other *(specify)*

28. Landholdings

a. Does any member of this household own agricultural land?	b. How much of the land is arable?
1=Yes 2=No	………. ha ……..unknown

Section B: Drip irrigation details

1. Did you receive any training organised through PLAN?

Yes ☐ *(fill the table below)* No ☐ *(go to Q2)*

	Which type of training did you receive?	**1a. Training received**	**1b When did you get the training?**
		1=Yes 2=No	1= before 2003 2=2003 3=2004 4=2005 5=after 2005
a	training for transformation		
b	book keeping		
c	drip kit operation and management		
d	using permaculture		
e	marketing		
f	master farmer training		
g	other (specify)		

2. Did you have an established vegetable garden before the drip irrigation project was implemented?

Yes ☐ *(go to Q2a)* No ☐ *(go to Q6)*

2a. What was the size of your vegetable garden before the project? ………………………………………ha

3. How were you watering your garden before the project?

irrigating ☐ rain fed ☐ by hand ☐ other ☐

4. After receiving the kit, did you make any changes to the garden in terms of size?

Yes ☐ No ☐ *(go to Q5)*

4a. What type of change did you make in terms of the size of the garden?

increased ☐ decreased ☐

5. Which crops were you growing before you received the drip kit?
(fill in the table below)

code	**crops grown** *(circle the code)*	**5a. How did the size of land allocated to the crop change after you received the kit** *(include new crops grown)***?** 1=stayed the same 2=increase 3= decrease 4= started growing crop
1	beans	
2	leafy vegetable	
3	cowpeas	
4	onions	
5	tomato	
6	carrots	
7	banana	
8	sugar cane	
9	yams *(madhumbe)*	
10	Sweet potato	
11	cassava	
12	other (specify	

(go to Q8)

6. When did you establish your garden?

a	< a month after receipt of drip kit	
b	1- 3 months after receipt of drip kit	
c	3-6 months after receipt of drip kit	
d	7-12 months after receipt of drip kit	
e	>1 year after receipt of kit	

7. What was the reason for your delay in starting the garden?
(*tick all that apply to you)*

a	lack of inputs (seed, fertiliser)	
b	shortage of labour to prepare the land	
c	did not know how to set up the equipment	
d	Other (specify)	

8. Have you used drip irrigation every year since the year you started?

Yes ☐ *(go to Q12)* No ☐ *(go to Q9)*

9. In which year did you first stop using the kit?

☐

9a. How many times did you stop using the kit after restarting again? ☐ times

Drip irrigation details continued

9b. Why did you stop using drip irrigation?

a	water shortages	
b	too difficult to fill up the tank	
c	marketing challenges	
d	project not as profitable as I expected	
e	labour shortages	
f	failure to replace equipment after it broke down	
i	Other (specify)	

9c. For how long did you stop using drip irrigation in the first instance?

1 year ☐ 2-3 years ☐ 4-5 years ☐ > 5years ☐

10. When did you start using drip irrigation again after stopping for the first time? ☐ year

11.Why did you start using drip irrigation again?

……………………………………………………………….
………………………………………………………………
……………………………………………………………….
………………………………………………………………
……………………………………………………………….
………………………………………………………………

12. Who carried out the following tasks in the garden in last cropping season?

1= all family members *5= children (<15)*
2= husband (adult male 15-49) *6= beneficiary*
3= wife (adult female 15-49) *7= drip kit coordinator/technical*
4= wife and children *8= other(specify*

a	land preparation	
b	deciding which crops to plant	
c	planting and weeding the crops	
d	fetching water for irrigation	
e	harvesting the crops	
f	deciding which crops to sell	
g	maintaining the irrigation system	
h	repairing the irrigation system	
i	purchasing new equipment	

13. Did you receive any other formal support with the drip irrigation apart from the drip irrigation kit and training?

Yes ☐ No ☐ *go to Q14)*

13a. If yes, which assistance did you receive and from whom?

	Support received	**Organisation** 1= Plan 2= Government 3=other (specify)
a	labour	
b	finance or monetary assistance	
c	inputs (seed , fertilisers)	
d	technical (advice on growing crops)	
e	marketing	
f	other (specify)	

14. How do you rate yourself in terms of your knowledge of drip irrigation?

1= extremely poor *(0-20%)* 4=above average *(61-80%)*
2= below average *(21-40%)* 5=excellent *(80-100%)*
3= average *(41-60%)*

☐

15. What problems have you faced using drip irrigation? (*tick all the problems that apply to you***)**

	Reason	1=Yes 2=No
a	water shortage	
b	water source is too far away	
c	difficulties in filling the bucket/ tank	
d	difficulty in maintaining the drip irrigation equipment (*clogging of pipes etc)*	
e	labour shortages (*no one to help with the planting and watering)*	
f	difficulty in obtaining inputs (seed, fertilisers)	
g	costs of the project higher than the benefits	
h	failure to replace drip kit (very expensive)	
i	failure to get drip irrigation kits & replacement parts locally	
j	difficulties in accessing extension services from Plan, agricultural extension officers & financial organisations	
k	difficulties in accessing markets	
l	not interested in the project anymore	
m	Other *(specify)*	

Drip irrigation details continued

16. What are your intentions in the future with regards to drip irrigation? *(tick where appropriate)*

code	What are your future intentions with regard to the project?	tick
1	start using drip irrigation again	
2	continue with the project at the same scale	
3	expand the area under drip irrigation	
4	reduce the area under drip irrigation	
5	drop out of the drip irrigation project	
6	other (specify)	

17. Overall how has your food security status and life improved as a result of being a beneficiary of the drip irrigation project?

code		tick
1	not at all *(0-20%)*	
2	slightly improved *(21-40%)*	
3	somewhat improved *(41-60%)*	
4	moderately improved *(61-80%)*	
5	extremely improved *(81-100%)*	

Repair and maintenance of drip kit *(last 5 years of using the kit, if less than then)*

18. Have you ever had to repair / replace your drip irrigation kit?

1 = yes ☐
2 = no
(if Yes go to Q19; if No go to Q24)

19. How many times have you repaired/ replaced the kit?

☐ times

20. Where did you obtain the parts from?

……………………..
……………………..
……………………….

21. How much did it cost you to repair/ replace the kit each time?

USD ………..

22. Who carries out the repair/ replacement and maintenance of your drip kit?

Self ☐
Friend ☐
Trained personnel ☐
Other ☐

23. Have you ever been trained or instructed on how to maintain your kit?

1 = yes ☐
2 = no

Group membership

24. Are you a member of any local farming or business related group or association?

Yes ☐ *(go to Q25)* No ☐ *(go to section C)*

25. Which local group do you belong to?

Name………………………………………………………………
Activity……………………………………………………………..

26. How long have you been a member of this local group? *(Use group name)*

…………….months …………years

27. What are the benefits of belonging to this group? *(tick where appropriate)*

code	Benefits	tick
1	able to access loans as a group	
2	input purchase in bulk	
3	group marketing contract	
4	support from group members	
5	Other (specify)	

28. What are the challenges or disadvantages (if any) of being a member of this local group? *(Use group name)*

………………………………………………………………
………………………………………………………………
………………………………………………………………
………………………………………………………………

Section C : Cropping activities

I would like to ask you questions pertaining to your cropping enterprise. I would like you to think back to the period just before you received the drip irrigation kit from Plan (2001-2002). In this period, a severe drought occurred and Plan joined WFP in distributing food in this area. (ask questions below for this period)

BEFORE THE PLAN SMALLHOLDER DRIP IRRIGATION PROJECT (Indicate cropping season ……………………………….)

1. Which crops did you grow the season just before the PLAN drip irrigation project? *(October 2002-September 2003)*	**Crops** (Codes and names on the right)		**2. What did you grow the crops for?** 1= food/ subsistence 2= for sale 3= both food & selling	**3. Did you sell any crops?** 1= Yes 2=No
	code	**crop**		
1a. Under irrigation?				
1b. Dry land crops? (depending on the rains)				

Crop code
01 maize
02 sorghum *(mapfunde)*
03 bulrush millet *(mhunga)*
04 finger millet *(rapoko/ njera/zviyo)*
05 groundnuts *(nzungu)*
06 round nuts *(nyimo)*
07 cassava
08 sunflower
09 beans
10 potatoes
11 leafy vegetables
12 peas
13 onions
14 tomatoes
15 carrots
16 sugar cane
17cowpeas *(nyemba)*
18 banana
19 other (specify)

Cropping activities continued

4. In which year did you finally stop using the drip kit? [ ] *(If before 2006, use their last cropping season as the reference period instead of 2006-2007 in Q below)*

I would like you to think back to the period 2006-2007/ last cropping season for those who completely dropped out before 2006. Define the period: 2006-2007 is the period when the bearer's cheques were still in use. This was the period just before the major food crisis (no food in supermarkets, price of food changed on an hourly basis) of 2008.

DURING THE PLAN SMALLHOLDER DRIP IRRIGATION PROJECT implementation (Oct 2006- Sept 2007 season / last cropping season ………………*(indicate the year here)***)**

5. Which crops did you grow during this period *[refer to period identified above]* (Oct 2006 – Sept 2007 or last cropping season)	**Crops** *(Codes and names on the right)*		**6. What did you grow the crops for?** 1= food 2= for sale 3= both food & selling	**7. Did you sell any crops?** 1= Yes 2=No	**8. How has the area allocated to each crop changed compared to 2002-2003?** 1=the same 2=increased 3= decreased 4= crop not grown anymore	**9. How have the crop yields changed compared to 2002-2003?** 1=the same 2=increased 3= decreased 4= crop not grown anymore	**10. How have the crop sales changed compared to 2002-2003?** 1=the same 2=increased 3= decreased 4= crop not grown anymore 5=N/A	**11. How has household consumption changed compared to 2002-2003?** 1=the same 2=increased 3= decreased 4= crop not grown anymore
	code	**crop**						
5a. Under irrigation?								
5b. Dry land crops? (relying on the rains)								

Crop code
01 maize
02 sorghum *(mapfunde)*
03 bulrush millet *(mhunga)*
04 finger millet *(rapoko/ njera/zviyo)*
05 groundnuts *(nzungu)*
06 round nuts *(nyimo)*
07 cassava
08 sunflower
09 beans
10 potatoes
11 leafy vegetables
12 peas
13 onions
14 tomatoes
15 carrots
16 sugar cane
17 cowpeas *(nyemba)*
18 banana
19 other *(specify)*

Cropping activities continued

Now I would like you to ask you questions pertaining to your most recent cropping season. If the respondent is still using the drip kit, use the default period. If the respondent indicated in Q4 that they dropped out of the project after 2006 but before 2011, the use their last cropping season using drip irrigation as a reference period.

Last planting season (Oct 2011- Sept 2012 season). *This is for all the beneficiaries regardless of whether they dropped out or they are still using the kit.*

12. Which crops did you grow during the period that PLAN had finished implementing the project? (October 2011–September 2012)	**Crops** *(Codes and names on the right)*		**13. Area planted to each crop**	**14. Total yield** **code for unit** 1=kilogram 2=50kg bag 3= 90 kg bag 4=bunch 5=basket (dengu) 6=basket (rusero) 7=bale 8=other(specify) **code for S/U** 1= shelled (S) 2= unshelled(U) 3= not applicable			**Conversion factor to kgs** *(e.g 1 bag of maize =90kg)*	**15. What did you grow the crops for?** 1= food 2= for sale 3= both food & selling	**16. Did you sell any crops?** 1= Yes 2=No	**17. How has the area allocated to each crop changed compared to the project period? (2006-2007)** 1=the same 2=increased 3= decreased 4= crop not grown anymore	**18. How have the crop yields changed compared to the project period? (2006-2007)** 1=the same 2=increased 3= decreased 4= crop not grown anymore	**19. How have the crop sales changed compared to the project period? (2006-2007)** 1=the same 2=increased 3= decreased 4= crop not grown anymore 5=N/A	**20. How has household consumption changed compared to the project period? (2006-2007)** 1=the same 2=increased 3= decreased 4= crop not grown anymore
	code	**crop**	**ha**	**quantity**	**units**	**S/U**							
12a. Under irrigation?													
12b. Dry land crops? (relying on the rains)													

Crop code
01 maize
02 sorghum *(mapfunde)*
03 bulrush millet *(mhunga)*
04 finger millet *(rapoko/ njera/zviyo)*
05 groundnuts *(nzungu)*
06 round nuts *(nyimo)*
07 cassava
08 sunflower
09 beans
10 potatoes
11 leafy vegetables
12 peas
13 onions
14 tomatoes
15 carrots
16 sugar cane
17 cowpeas
18 banana
19 other *(specify)*

Section D : Marketing, Income and Expenditure

I would like to find out more about the formal employment of your household members (this does not include farming activities mentioned in section C).

Code	**1. Name** *(obtain these from section A, p3 for all the people who are employed and use the same code)*	**2. How many months did NAME work in the last 12 months in their main job on average?**	**3. How many days did NAME work each week in these months on average?**	**4. How many hours did NAME work each day of the week on average?**	**5. How many months did NAME work in the last 12 months in their second job on average?**	**6. How many days did NAME work each week in these months on average?**	**7.How many hours did NAME work each day of the week on average?**

Other income generating activities

8.Did you engage in any other income generating activities besides formal employment and farming in the last 12 months?

1= Yes 2= No ☐

8a. If yes, which activities do you engage in?

…………………………………………………………………………………………..

………………………………………………………………………………………….

8b. How often did you engage in ACTIVITY NAME in the last 12 months?

…………………………… months

8c. On average how much income did you receive from these activities in the last 12 months? USD ………………………

9. In the last 12 months, has any member of your household received food or any other aid from relatives, the government or NGO's?

Yes ☐ No ☐ *(go to Q10)*

9a. Indicate which aid you received in the table below *(last 12 months).*

Aid type 1= food 2= school feeding 3= educational 4= medical 5= other(specify)		**Name of organisation** *(if received from a relative, write relative, otherwise specify the name of the organisation)*	**Assistance given to:** 1=entire household 2= child less than 5 3= child greater than 5 4=mother & child less than 5 5=elderly household member 6= other (specify)	**Total food received** 1= kg 2= ml 3=litres
code	**type**			

Marketing, Income and Expenditure continued

Marketing

10. Which type of market did you sell your crops to?

formal *(specify)* ………………………………………………
…………………………………………
Informal *(specify)* ………………………………………..
…………………………………………

11. Have you ever had any supply contracts to date?

Yes ☐ *(go to Q12)* No ☐ *(go to Q13)*

12. Which organisation did you have the contract with and for which crop ?

organisation……………………………………………..
crop …………………………………………………

13. How far is the market from your area?

………………kms

14. In the last 12 months, did you require transport to take your produce to the market? Yes ☐ No ☐

14a. If yes, how much did you pay to transport your produce in the last 12 months?

USD ………… …..

Livestock sales

15. Did you sell any livestock in the last 12 months? ☐

1=Yes 2=No *(go to Q17)*

16. If yes, which livestock did you sell? *(write the appropriate number of livestock)*

1= cattle ☐ 5= poultry ☐
2= pigs ☐ 6= horse, mule, donkey ☐
3=goats ☐ 7= other (specify) ☐
4= sheep ☐

16a. On average how much income did you receive from livestock sales in the last 12 months?

USD…………………………

17. Who in your household keeps or decides what to do with all the household earnings?

………………………………………………………

Expenditure

I would like to ask you about the goods your household used last month. Please tell me how your household obtained these goods (own production, purchased or through gifts and donations).

	18. Did you acquire any of the following for your household in the last month?	1=Yes 2=No	**19. How much did you spent on this?** *(Amount in USD)*	**20. Did you get any of these from your own production?** 1=Yes 2=No	**20a. How much would you have spent if you had purchased them?** *(Amount in USD)*	**21. Did you get any of the products from government, NGO's, relatives, friends?** 1=Yes 2=No	**21a. How much would you have spent if you had purchased them?** *(Amount in USD)*
	Item		**amount**		**amount**		
1	Food items						
2	Education related (school fees, uniforms, stationery)						
3	Bills (electricity, water, phone, rent)						
4	Transport costs (commuting, fuel costs, vehicle maintenance costs)						
5	Other non-food items *(fertilisers, clothes, pesticides, detergents, personal products such as soap)*						

22. What was your average total monthly expenditure last month?

USD ……………………..

23. Is this the amount of money you normally spent each month?

Yes ☐ No ☐ *(If No, specify amount normally spent each month)* **……………………………….**

Section E: Health and food security

Health : *I would like to ask you questions pertaining to the health of your household members?*

1. Does any member of your household suffer from chronic illness (hypertension (BP), TB, HIV/AIDS, diabetes, etc) Yes ☐ No ☐ *o to Q7)*

1a. How many members of your household are suffering from chronic illness at the moment? ☐

2. Who takes care of this person/ people if they require personal care?
1= adult member (15+ years) 2= child (less than 15 years old) ☐
3= elderly member (> 50 years)

3. Among the people suffering from the chronic illness, is one of them the household head?
Yes ☐ No ☐

4. Among the people suffering from chronic illness, was one of them the main bread winner before the illness? Yes ☐ No ☐

4a. Are they still the main bread winner? Yes ☐ No ☐

5. Did the person/ people suffering from chronic illness receive medical treatment in the last year? Yes ☐ No ☐

6. How much did you spent in medical costs for them in the last 12 months?
US$...............................

Food security
I would like to ask some questions pertaining to food consumed by your household.

7. During the last 30 days, has your household gone without enough food to eat on any day?
Yes ☐ No ☐

7b. If yes, for how many days did your household not have enough to eat? ☐

8. How many meals including breakfast are taken per day in your household? ☐

Dietary diversity

9. Please describe the foods (meals and snacks) that you or anyone else in your household ate yesterday during the day and at night, excluding foods purchased and eaten outside of the home.

	Food group	**Examples** *(* child is someone less than 5 years old)*	**Eaten by all members** 1=Yes, 2=No
a	Cereals	bread, sadza, porridge, millet sorghum, maize, rice, wheat , noodles, biscuits, cookies, or any food made from grains	
b	White tubers and roots	white potatoes, white yams (*madhumbe*), cassava (*mujumbuya*), any food from roots	
c	Dark green leafy vegetables	Rape, covo, spinach, tsunga, runi, cassava leaves, tomato, onion, eggplant, wild vegetables or any other leafy vegetables	
d	Other vegetables , tubers	Pumpkin, carrots, squash or sweet potatoes , sweet pepper (that are orange inside)	
e	Legumes, nuts and seeds	beans, peas, lentils, nuts, seeds, foods made from seeds	
f	Meat	liver, kidney*(itsvo)*, heart, tripe*(matumbu, maguru)*, gizzards *(zvihururu)*, other organ meats, beef, pork, lamb, goat, rabbit, wild game, chicken, duck, other birds	
g	Eggs	eggs	
h	Fish	fresh or dried fish, shellfish	
i	Fruits	ripe mangoes, rock melon, dried apricots, dried peaches, mazhanje, nzviru, masau, hubva, apples, grapes, guava, other fruits including wild fruits	
j	Milk and milk products	milk *(excluding formula and breast milk)*, cheese, yoghurt, other milk products	
k	Oils and fats	oils, fats or butter added to food or used for cooking	
l	Sweets	sugar, honey, sweetened soda or sugary foods e.g. chocolates, sweets or candies	
m	Spices, condiments, beverages	Spices (black pepper, salt, royco, maggi seasoning), condiments (soy sauce, hot sauce, tomato sauce), tea, alcohol	

Health and food security continued

I would like to ask you some questions relating the ways your household uses to guard against food shortages.

Coping strategy responses

10. In the last year have there been times when you did not have enough food or money to buy the food? 1=Yes 2= No ☐

	How often has your household had to:	**In the last 30 days** *(See response code in Box 3 on the right)*
a	Rely on less preferred and less expensive food?	
b	Borrow food or rely on help from a friend or relative?	
c	Purchase food on credit?	
d	Gather wild fruit, hunt or harvest immature crops?	
e	Consume seed stock for the next season?	
f	Send household members to eat elsewhere?	
g	Send household members to beg?	
h	Limit portion size at mealtimes?	
i	Restrict consumption by adults in order for small children to eat?	
j	Feed working members of the household at the expense of non-working members?	
k	Ration the money you have and buy prepared food?	
l	Reduce the number of meals eaten a day	
m	Skip entire days without eating	

Box 1
Last 30 days code
1 = all the time (everyday)
2 = pretty often (3-6 days/ week)
3 = once in a while (1-2 days/ week)
4 = hardly at all (<1 day / week)
5 = never (0 days/ week)

Adaptive strategies

11. In the past, if there have been times when you did not have enough food or money to buy food, how often has your household had to:		**In the last 30 days** *(See response code in Box 1 above)*
n	Avoid essential costs (e.g. health care and education costs) in order to buy food?	
o	Sell assets (e.g. livestock, household goods) in order to buy food?	
p	Migrate to find work so as to get money for food?	

Section F: Remittances

1. Did you receive any remittances from within Zimbabwe in the last 12 months? 1=Yes 2=No *(If No, go to Q7)*	**2.Who did you receive the money from?** *(list all the people you receive remittances from)* 1 =Parents 2= Husband 3=Wife 4= Son (biological) 5= Daughter (biological) 6=Brother or sister 7= other (specify)		**3. How often did you receive this money?** 1= monthly 2= once in 3 months 3= once in 6 months 4= once a year 5= other *(specify)*	**4.How much did you receive each period?** *(in US$)* 1= < 50 2= 50-100 3= 100-200 4= 200-500 5= > 500 6= other *(specify)*	**5.What is the occupation of the person sending you the money?** 1=student 2=part-time employee 3=full-time employee 4=self employed 5=other *(specify)*	**6.What did you use this money for?** 1=purchase food 2= pay school fees 3= sent to other relatives 4= farming 5= other *(specify)*
	code	**category**				

From outside Zimbabwe

7. Did you receive any remittances from outside Zimbabwe? 1=Yes 2=No *(If No, go to section F)*	**8. Who did you receive the money from?** *(list all the people you receive remittances from)* 1 =Parents 2= Husband 3=Wife 4= Son (biological) 5= Daughter (biological) 6=Brother or sister 7= other (specify)		**9. Which country does the sender reside in?**	**10. How long has the sender been residing in that country?** *(in years)*	**11. How often did you receive this money?** 1= monthly 2= once in 3 months 3= once in 6 months 4= once a year 5= other *(specify)*	**12. How much did you receive each period?** *(in US$)* 1= US$ 2= Rands 3=other *(specify)*	**13. How much cash did the sender send in total in the last 12 months?** 1= US$ 2= Rands 3=other *(specify*	**14. Why did the sender migrate to this country?** 1= academic / school 2= work 3= marriage 4=other *(specify)*	**15. What did you use this money for?** 1=purchase food 2= pay school fees 3= sent to other relatives 4= farming 5= other *(specify)*	**16. What is the marital status of the sender?** 1=single 2=married 3= divorced 4=widowed 5= single parent 6= other
	code	**category**								

Appendix B2: Ethics approval from Plan International, Zimbabwe

Plan Zimbabwe
Mutasa Program Unit
P. O. Box 190
1st & 5th Floors, Msasa House
75 Herbert Chitepo Street
Mutare
Zimbabwe

[redacted]
www.plan-international.org

Plan

3 January 2013

Professor Brett Inder
Building 11E
Econometrics & Business Statistics
Business and Economics
MONASH UNIVERSITY VIC 3800

Dear Professor Brett Inder,

Re: **Permission Letter for Capacity building, food security and smallholder drip irrigation survey**

Thank you for your request to recruit participants from Plan Zimbabwe for the above-named research.

I have read and understood the Explanatory Statement regarding the above mentioned research and hereby give permission for this research to be conducted.

I give permission for the database of Plan Zimbabwe's smallholder drip irrigation beneficiaries be used to select participants in the research.

Yours Sincerely,

[redacted]

Program Unit Manager- Mutasa District

National Organisations [illegible]

Program Countries [illegible]

Registered in the Republic of Zimbabwe as a Welfare Organisation, [illegible]

Appendix B3: Ethics approval from Monash University

MONASH University

Monash University Human Research Ethics Committee (MUHREC)
Research Office

Human Ethics Certificate of Approval

Date:	**4 February 2013**
Project Number:	**CF13/39 – 2013000015**
Project Title:	**Capacity building, food security and smallholder drip irrigation**
Chief Investigator:	**Prof Brett Inder**
Approved: From:	**4 February 2013 To: 4 February 2018**

Terms of approval
1. The Chief investigator is responsible for ensuring that permission letters are obtained, if relevant, and a copy forwarded to MUHREC before any data collection can occur at the specified organisation. **Failure to provide permission letters to MUHREC before data collection commences is in breach of the National Statement on Ethical Conduct in Human Research and the Australian Code for the Responsible Conduct of Research**.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash University letterhead and the Monash University complaints clause must contain your project number.
6. **Amendments to the approved project (including changes in personnel):** Requires the submission of a Request for Amendment form to MUHREC and must not begin without written approval from MUHREC. Substantial variations may require a new application.
7. **Future correspondence:** Please quote the project number and project title above in any further correspondence.
8. **Annual reports:** Continued approval of this project is dependent on the submission of an Annual Report. This is determined by the date of your letter of approval.
9. **Final report:** A Final Report should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected date of completion.
10. **Monitoring:** Projects may be subject to an audit or any other form of monitoring by MUHREC at any time.
11. **Retention and storage of data:** The Chief Investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.

[redacted]

Professor Ben Canny Chair, MUHREC
cc: Ms Miriam H. Marembo

Postal – Monash University, Vic 3800, Australia
Building 3E, Room 111, Clayton Campus, Wellington Road, Clayton
[redacted] www.monash.edu/research/ethics/human/index/html
ABN 12 377 614 012 CRICOS Provider #00008C

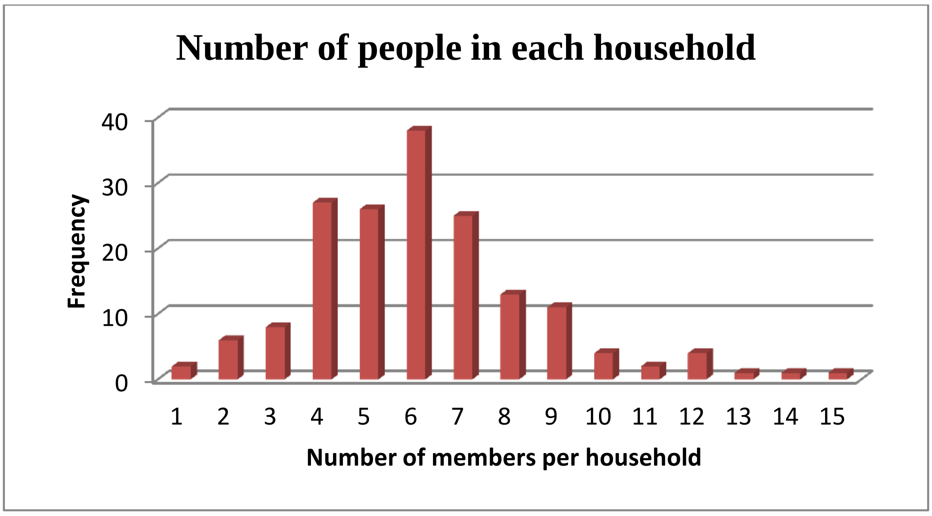
APPENDIX C: APPENDIX TO CHAPTER 5

Appendix C1: Descriptive Analysis

- **Other household characteristics**

On average, most of the households have between 4 (16%) and 6 (22.5%) members. Very few households have more than 10 members as shown in Figure C1 below.

Figure C1: Distribution of household members



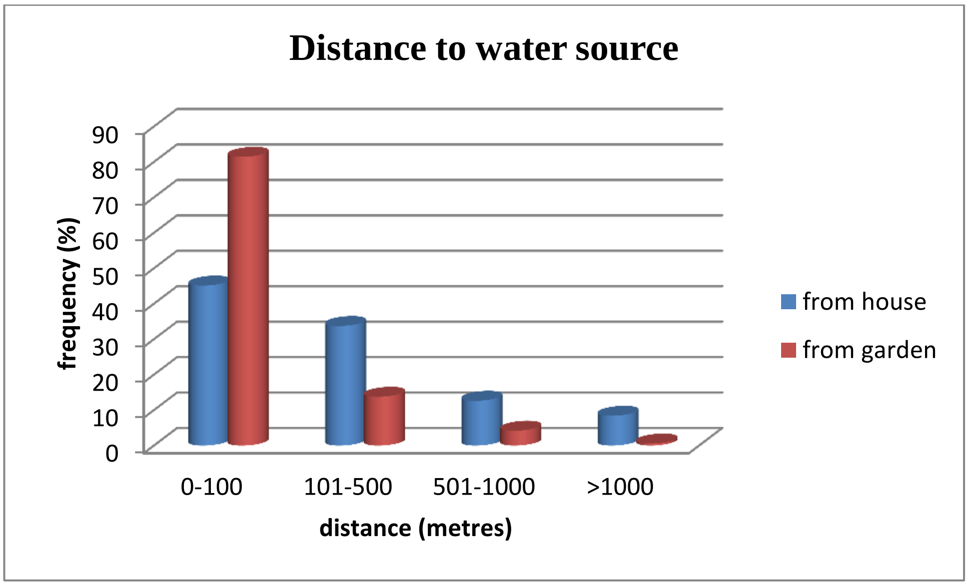
46.5% of the households have children under the age of 5 residing in them and the number per each household varies between 1 and 5 children. 34.9% of the households looked after orphans in the last 12 months with the majority of the households looking after 1 orphan (50.8%). Generally, the number of orphans in a household ranged between 1 and 7.

- **Water issues**

An estimated 80.6% of the households use boreholes or wells for their drinking water and 70.9% use water from dams and rivers for drip irrigation. 53% of these dams and rivers are communally owned whilst 46.4% have private dams within their fields. 11.8% of the beneficiaries have experienced water sharing conflicts especially towards the end of the dry season (August -October). The conflicts are mainly fuelled by the fact that water will be scarce in this period as the rivers will be drying up, an issue that was sighted by 70% of the beneficiaries who experienced water sharing challenges. Some of the conflicts include abuse of water sharing allocations whereby some individuals fail to adhere to the watering roster that they would have agreed upon as a group. Others just block the path to the water source if it is near their garden making it difficult for the rest of the group to access the water. Some individuals have also had their gardens destroyed as members pass through them to fetch water for their own gardens. Only 5.3% of the households pay for the water they use for irrigation and the amount paid ranges from US$2 to US$32 per month.

Figure C2 below shows that although a sizeable number of the households (45.1%) are located within 100m of the irrigation water source, even larger portions (81.5%) of the gardens are located within 100m of the irrigation water source. Very few households (8.4%) and gardens (0.6%) are located more than 1 km away from the irrigation water source.

Figure C2: Distance of the irrigation water source from the main dwelling and garden

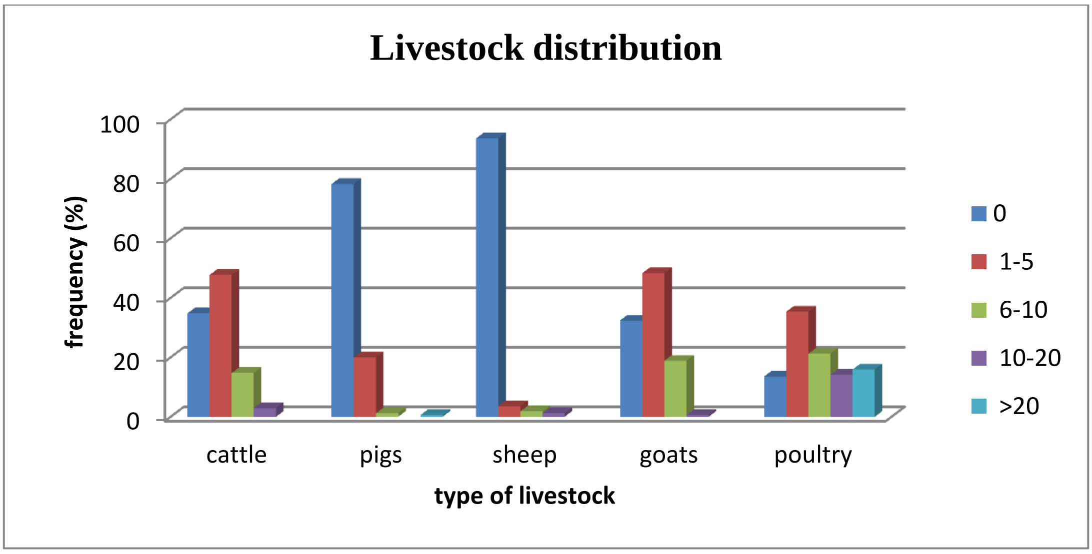


- **Other household characteristics**

The dwellings of most of the households (93.5%) are made up of several separate structures. The main material used for the walls (89.9%) is cement with stone, bricks or wood planks. Most of the floors are made of cement (82.3%) and roofing (84%) mainly comprises of asbestors or metal sheets. The most common sources of light are the paraffin lamp (51.5and solar energy (16%). Only 8.2% of the households use electricity as their main source of light and 12.4% use candles. Almost all the households (98.2%) use firewood for cooking. 93% of the households have Blair toilets and 84.7% do not share their toilet facility with other households.

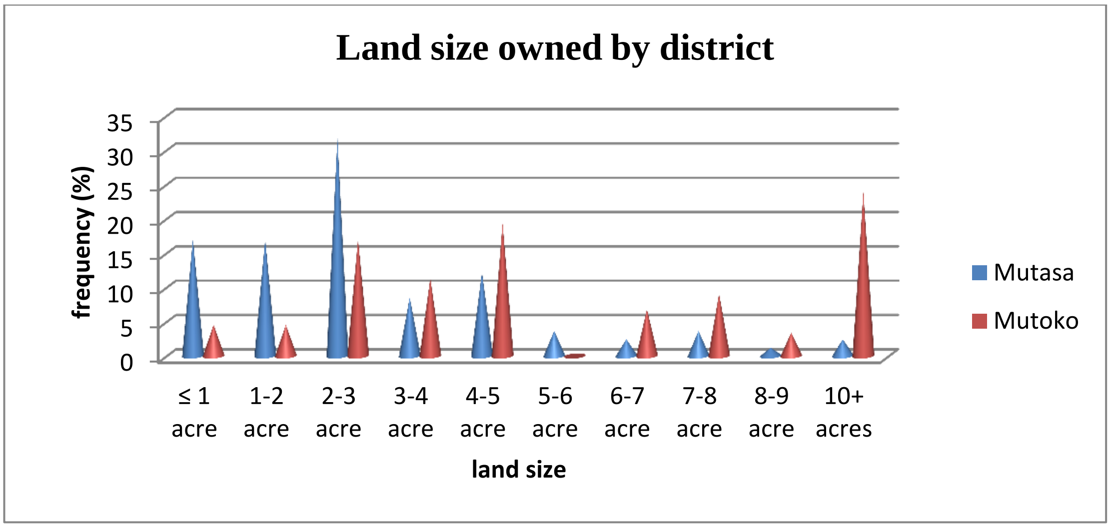
Overall, 86.5% of the households own poultry, 65.3% own cattle, 67.7% own goats, 21.8% own pigs, 6.5% own sheep3.5% own rabbits and 2.9% own donkeys. Distribution of livestock in terms of numbers owner is shown in Figure C3 below.

Figure C3: Number of livestock owned by categories.



All the households own land which varies in size. The majority of households in Mutasa district (31.7%) own between 2 and 3 acres (0.8-1.2 hectares) of land whilst in Mutoko district, the majority of households (23.9%) own 10 or more acres (≥ 4 hectares) of land. Distribution of land according to size is shown in Figure C4 below.

Figure C4: Distribution of size of land owned by district

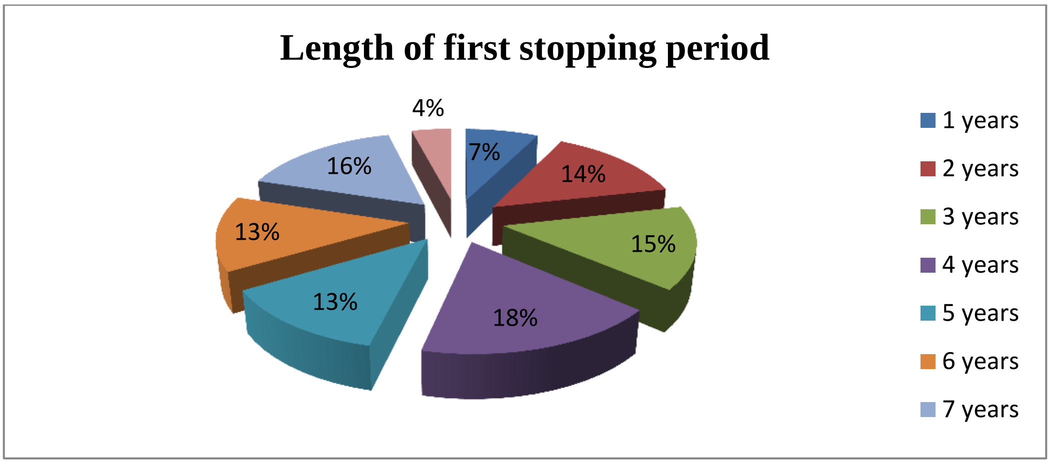


Smallholder drip irrigation characteristics

- **Drip irrigation usage**

87.7% of the beneficiaries stopped using drip irrigation at some point. Of the beneficiaries who dropped out of the project, 8.7% started using drip irrigation again after stopping for the first time whilst the remainder dropped out for good. Of the beneficiaries who stopped using the kit at some point (149), approximately one third continued to use the drip irrigation kits well beyond the project duration of 5 years (13% for 6 years, 16% for 7 years and 4% for 8 years) before stopping for the first time as shown in Figure C5 below. 13% managed to use the drip kits for exactly 5 years and only 4% continue to 8 years. 54% stopped using the drip kits before 5 years elapsed with the highest number (18%) dropping out after using the drip kit for 4 years.

Figure C5: Length of first stopping period



The highest number if drop outs was in 2010 (25.5%) followed by 2009 (15.7%) and the lowest number of dropouts was realised in 2004 and 2012 (both 2.6%) as shown in Table C1 below.

Table C1: Years that the beneficiaries finally dropped out of the drip irrigation project

year	frequency	percentage
2004	4	2.6%
2005	9	5.9%
2006	18	11.8%
2007	13	8.5%
2008	28	18.3%
2009	24	15.7%
2010	39	25.5%
2011	14	9.2%
2012	4	2.6%
Total	153	100%

- **Reasons for stopping**

Table C2 below indicates that the most common reason for dropping out of the drip irrigation project was water shortages (42.3%) , followed by failure to replace parts of the kit when they got damaged (19.5%) and difficulties in filling the tank (18.1%) a reason most common among the elderly. Only beneficiaries in Mutoko (8.1%) indicated that the drip kit was too small and too slow in dispensing water.

Table C2: why the beneficiary stopped using drip irrigation

reason	percentage
water shortages	42.3%
fail to replace kit	19.5%
difficult to fill tank	18.1%
damaged pipes	11.4%
not profitable	10.1%
kit too small and slow	8.1%
labour shortages	8.1%
kit maintenance	7.4%
damaged tanks	5.4%
lack of interest	4.7%
marketing challenges	3.4%
illness	3.4%
no extension services	2.7%
alternative method	2.0%
kit incomplete	2.0%
thieves	2.0%
beneficiary death	1.3%
other projects	0.7%
input acquisition problem	0.7%
relocation	0.7%

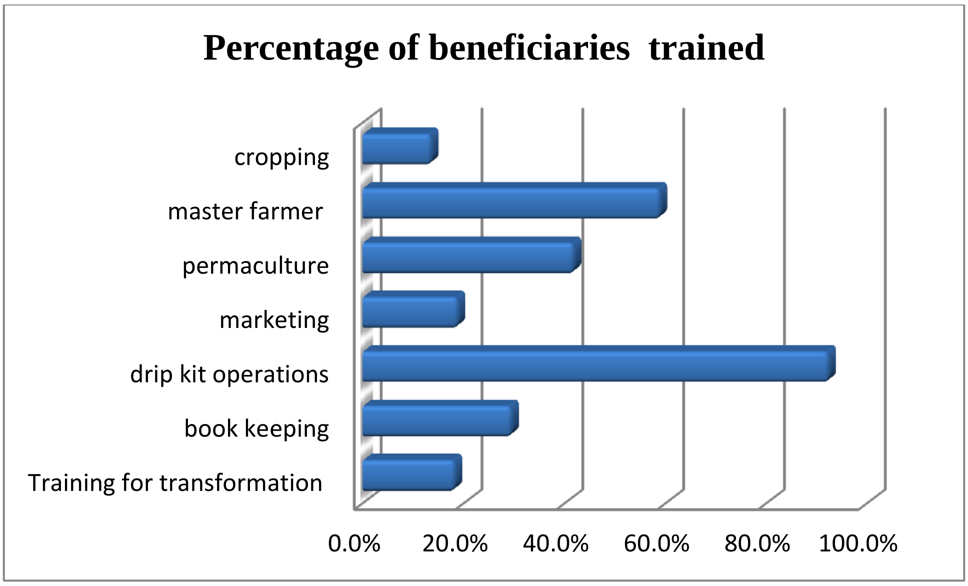
- **Formal support**

Approximately 51.8% of the beneficiaries received additional formal support from Plan and other stakeholders such as the government and organisations such as GTZ, CADS, Agritex, DUP and SAT. 50% of the beneficiaries received support in the form of inputs (seed and fertiliser) whilst 9.4%, 2.4%, and 1.8% received technical, financial and marketing support.

- **Training**

95.9% of the beneficiaries received training organised through Plan International and other stakeholders which was relevant to the smallholder drip irrigation program. Trainings included drip kit operation management (received by 92.4% of the beneficiaries), marketing of produce (received by 18.8% of the beneficiaries) and training for transformation (received by 18.2%) of the beneficiaries as shown in Figure C6 below.

Figure C6: Types of trainings received by the beneficiaries



- **Cropping**

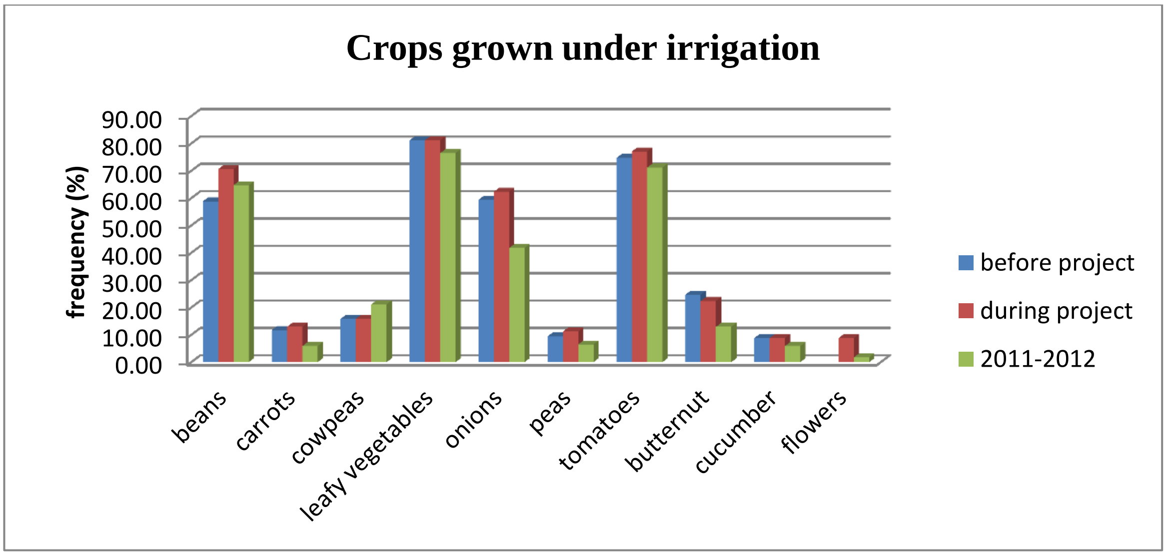
95.9% of the beneficiaries already had gardens before they benefited from the drip kits. 27.6% changed the size of their garden after receipt of the kit with 77.8% increasing and 22.2% decreasing the size of land allocated to gardening. The size of the gardens owned prior to the drip irrigation program ranged from 15m^2 (0.0015ha) to 2ha. 90.8% of the beneficiaries used buckets to water their gardens before receiving the drip kits.

Under irrigation

- **Crops grown**

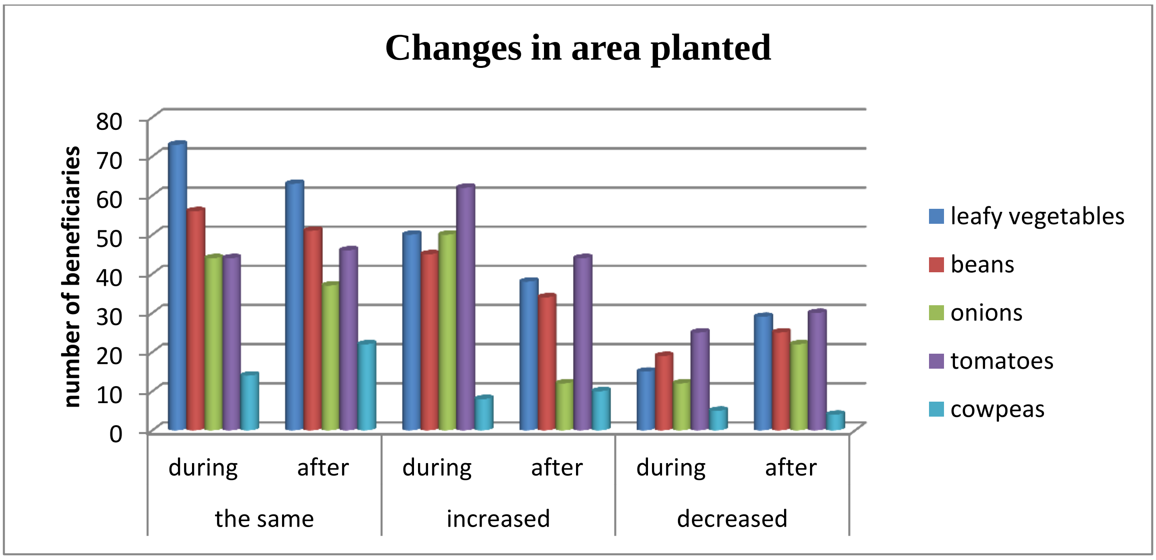
Most of the beneficiaries grew beans, leafy vegetables, onions and tomatoes throughout the three periods and the number hardly changed during these periods. Fewer beneficiaries also grew carrots, peas, butternuts and cucumbers. The number of beneficiaries growing these crops was high during the drip irrigation project implementation phase and after this there was a slight decline as shown in Figure C7 below. Flower production only began during the drip irrigation project phase (2003-2007) and declined sharply afterwards.

Figure C7: Irrigated crops grown before, during and after the drip irrigation project



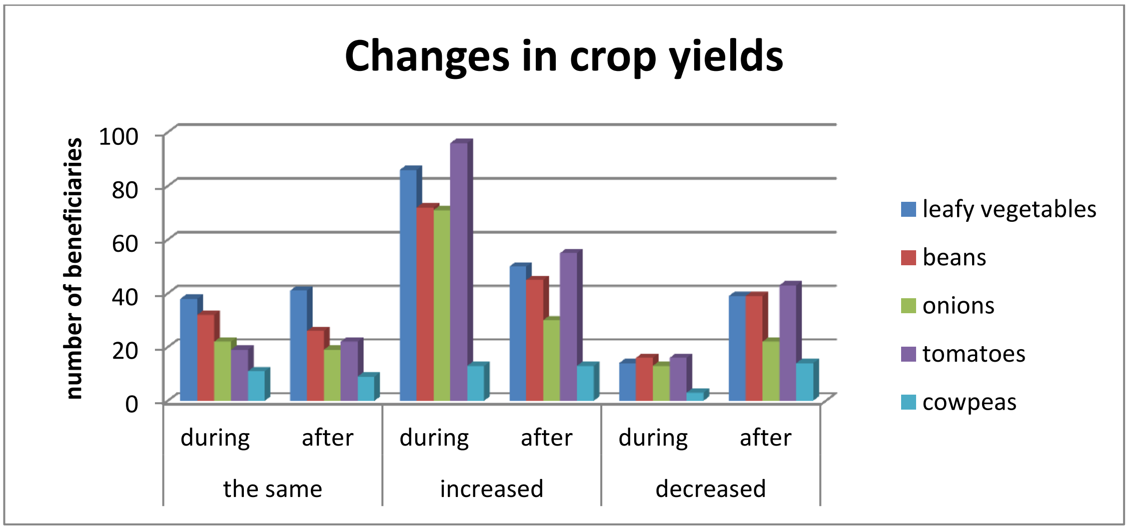
Other crops grown under irrigation by a small number of the beneficiaries (less than 6%) include bananas, sugarcane, yam, beetroot, chilli, garlic, green pepper, jam squash, okra and paprika. 3 beneficiaries also began growing herbs during the project period and they stopped once the project ended.

Figure C8: Area planted to the top 5 irrigated crops during and after the project



As shown in Figure C8 above, the area planted to vegetables remained the same for 73, increased for 50 and decreased for 15 beneficiaries during the project phase (2003-2007). After the project phase (2008 onwards), a sizeable number of beneficiaries (29) reduced the area planted to leafy vegetables. Beans production more or less followed the same trend. For onions and tomatoes, a larger number of beneficiaries increased the area planted to the crop (50 and 62 for onions and tomatoes respectively) during the project phase and a larger number reduced (22 and 30 for onions and tomatoes respectively) the area afterwards. For cowpeas during the project, a larger number of beneficiaries maintained the same area they allocated to the crop as before the project and reduced the area after the project.

Figure C9: Yield changes in the top 5 irrigated crops during and after the project



A noticeably larger number of beneficiaries reported an increase in tomato (96), leafy vegetable (86), beans (72) and onion (71) yields. After the project, a general decrease in yields was realised for all crops with the highest number of beneficiaries reporting a decrease in tomato (43), vegetable (39) and onion (22) yields. The number of farmers who reported having the same, increased and decreased cowpeas yields remained very low and almost constant during and after the project as shown in Figure C9 above.

Figure C10: Consumption changes in the top 5 irrigated crops during and after the project

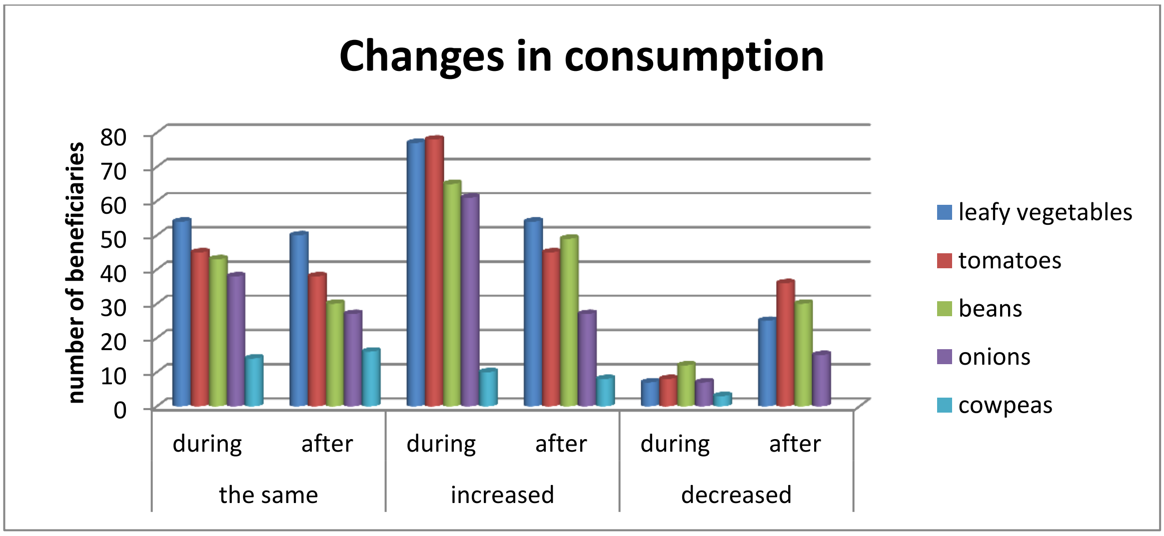
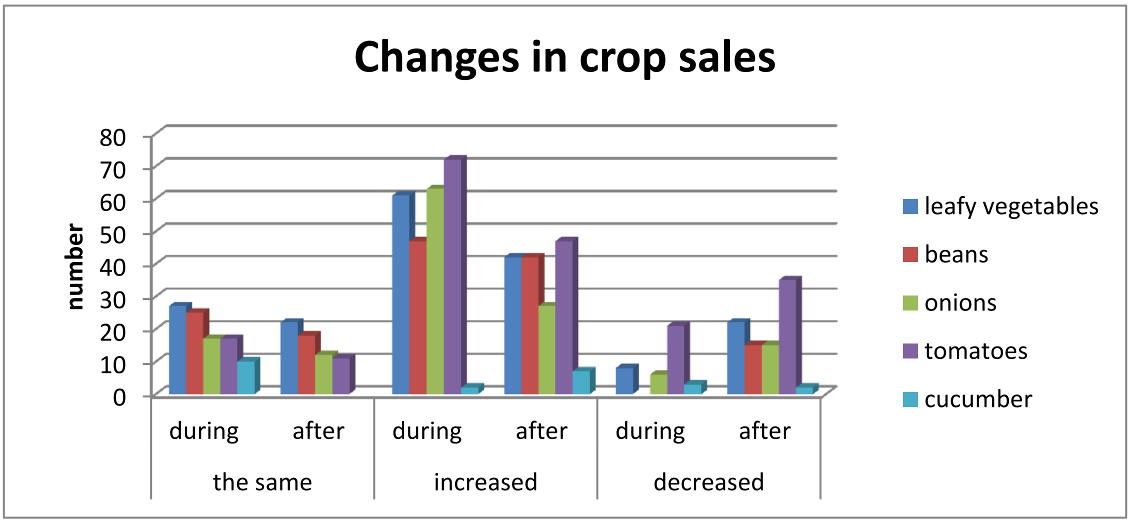


Figure C10 above shows that a large number of beneficiary households reported an increase in the consumption of leafy vegetables, tomatoes, beans and onions during the drip irrigation project phase and a decrease after the project. Cowpeas consumption was lowest in all periods.

Figure C11 below shows that a larger number of beneficiary households reported an increase in their sales for tomatoes, vegetables, onions and beans during the project phase and a decrease after. This is plausible given that the same trend was reported for crop area and yields. In terms of crop sales, more beneficiary households sold cucumbers than cowpeas.

Figure C11: Crop sale changes in the top 5 irrigated crops during and after the project

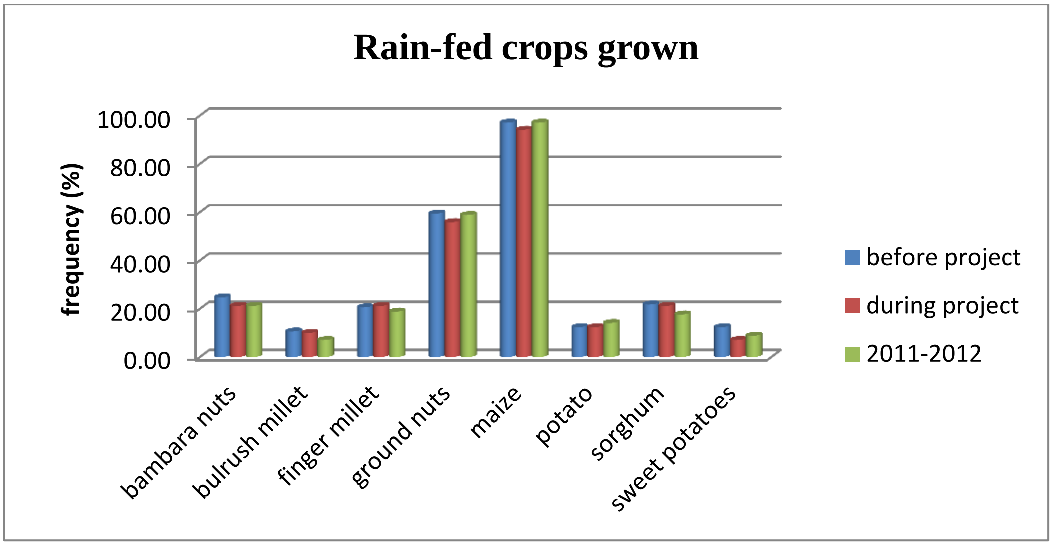


Dry land crops (rain-fed)

- **Crops grown**

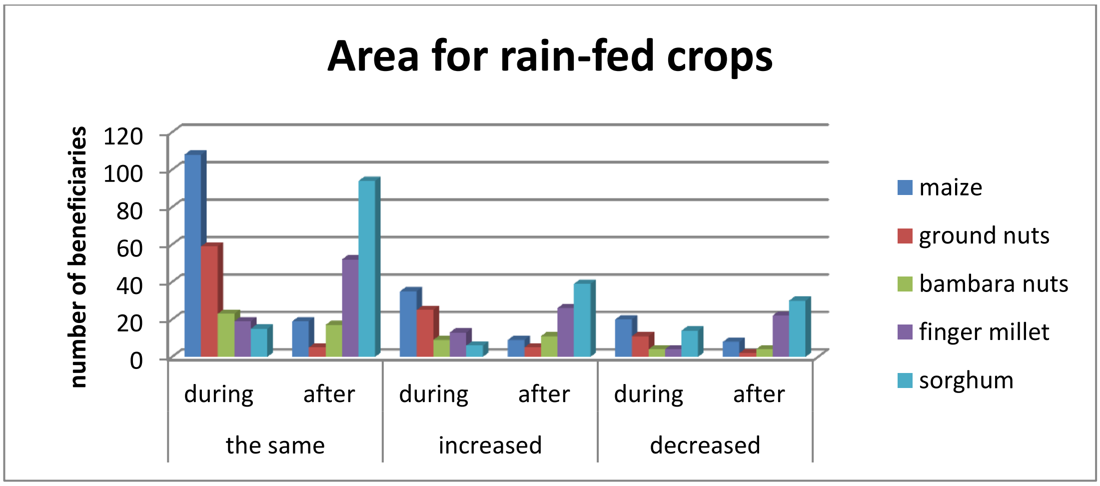
The main rain fed crops grown are maize and groundnuts. Bambara nuts, finger millet and sorghum were also grown during these 3 phases by fewer beneficiaries. The number of beneficiaries growing these crops remained fairly constant throughout all the phases as shown in Figure C12 below.

Figure C12: Rain-fed crops grown before, during and after the drip irrigation project



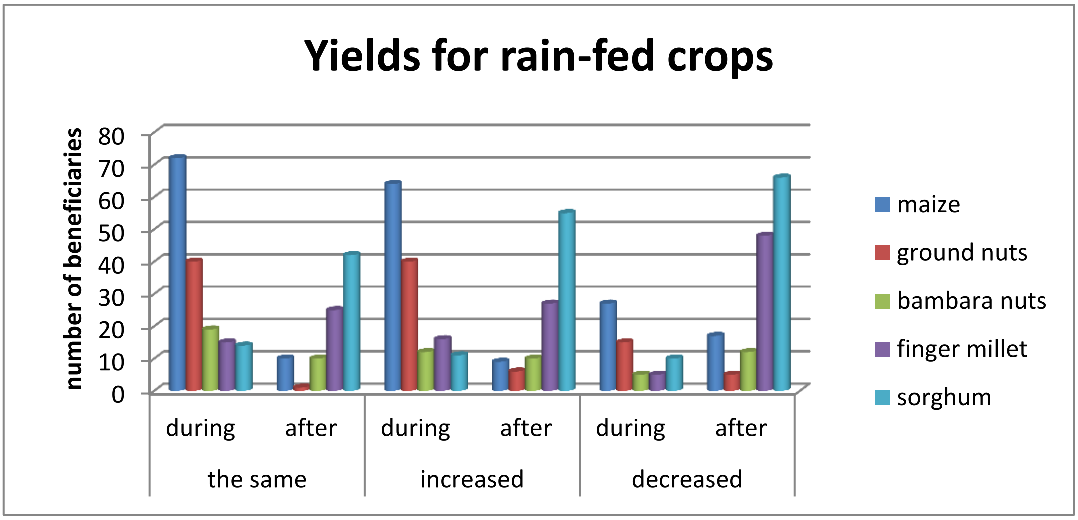
Other rain fed crops grown by a small number of the beneficiaries (less than 5.5%) include cowpeas, baby marrow, cassava, pumpkins, rice, soya beans, sunflower, tobacco and wheat.

Figure C13: Area planted to the top 5 rain-fed crops during and after the project



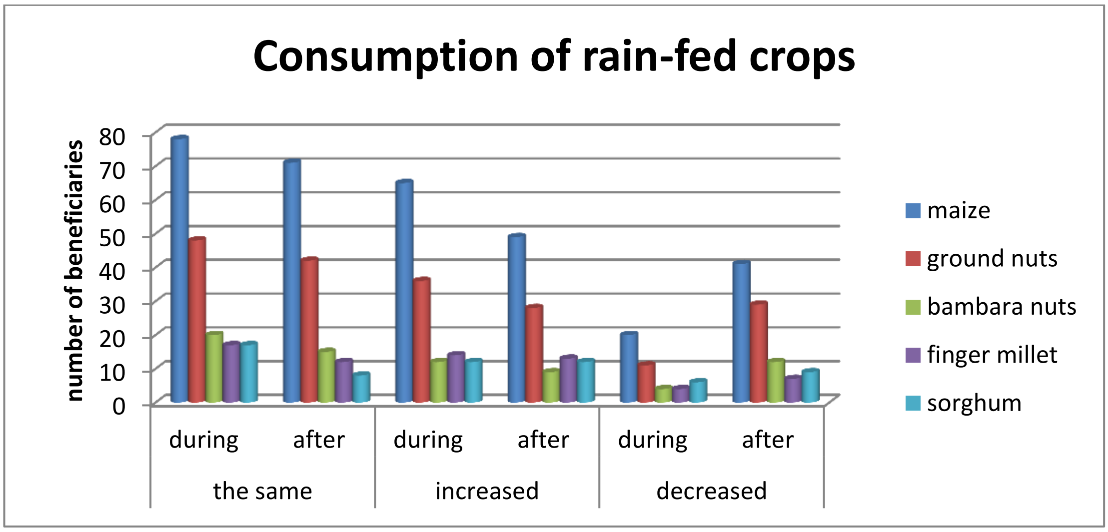
A larger number of households during the project allocated the same area of land to rain-fed crops as they had before and the cropping area decreased after the project for almost all crops. For sorghum, the number of beneficiary households after the project, who allocated the same amount of land as they had during the project increased. There was not much change in terms of the number of beneficiaries allocating the same, increased or decreased land portions to Bambara nuts as shown in Figure C13 above.

Figure C14: Yield changes in the top 5 rain-fed crops during and after the project



The number of households recording positive changes in all 3 yield categories (the same, increased and decreased) in sorghum and finger millet yields increased after the project compared to during the project whilst that of maize and groundnuts decreased (show in Figure C14 above).

Figure C15: Consumption changes in the top 5 rain-fed crops during and after the project



The fairly large number of beneficiary households reported an increase in the consumption of maize and groundnuts during the project phase and the number declined thereafter. For Bambara nuts, finger millet and sorghum, the numbers remained almost constant as shown in Figure C15 above.

Figure C16: Crop sale changes in the top 5 rain-fed crops during and after the project

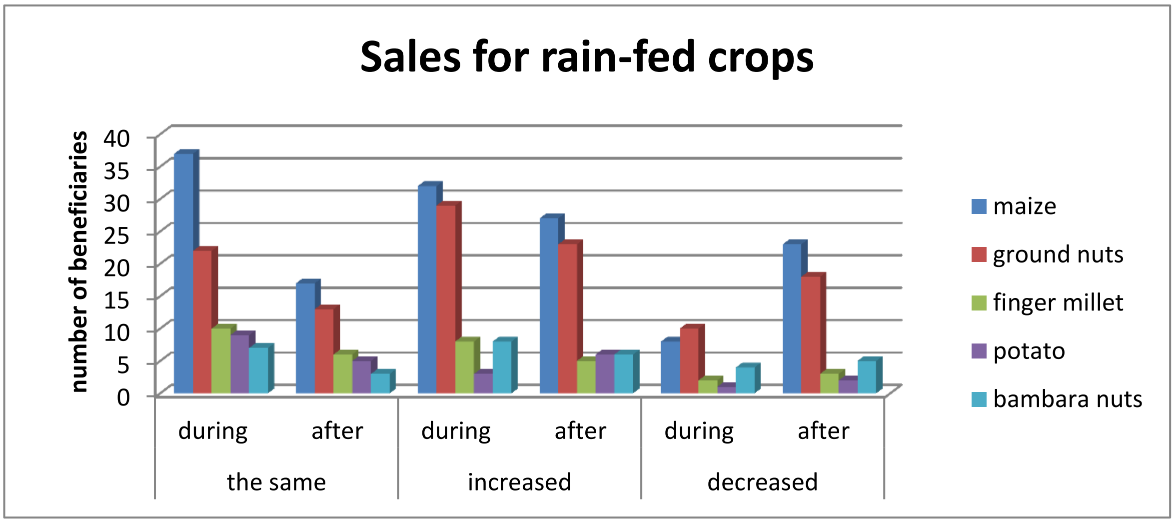


Figure C16 above shows that the number of beneficiaries who sold maize and groundnuts in all 3 categories remained high during the project and decreased slightly thereafter. Potatoes replace sorghum in the top 5 crops sold. The number reporting the same, increased and decreased sales in finger millet, potatoes and Bambara nuts remains low and constant throughout.

- **Future intentions**

69.8% intend to start using drip irrigation again provided the challenges they have are addresses. Chief among the challenges is the availability of new pipes, tanks and other parts required for the kit and availability of water and extension services. 17.8% have no intention of using drip irrigation again. 7.7% intend to continue with drip irrigation at the same scale whilst 4.7% intend to expand the area under drip irrigation.

- **Repairs to drip kit**

Only 3% of the beneficiaries made major repairs to their drip kit whereby they acquired a part for the kit. The beneficiaries spent at most US$65 on purchasing these parts.

- **Group membership**

64.7% of the beneficiaries indicated that they belong to farming or business related group. Period of membership varied from months to 51 years. 13.3% of the beneficiaries have been group members for 2 years and 10.5% have been group members for 10 years. 25.7% have been group members for more than 10 years. Benefit accrued by being a group member include moral support (41.7%), support in the form of group input purchases (16.5%), marketing produce as a group (10.6%) and accessing financial loans (4.7%).

- **Other income generating activities**

21.2% of the beneficiaries engaged in other income generating activities including occasional poultry production, peanut butter making, buying and selling of different goods, building and catering.

- **Receipt of other aid**

30% of the beneficiaries indicated that they received other aid in the last 12 months from Plan, other non-governmental organisations and the government. Of these beneficiaries, 12.9% received food aid, 14.1% received school fees for their children, 8.2% received inputs (mainly seeds, fertilisers, farming implements and input vouchers) and 0.6% received medical aid.

- **Marketing**

41.8% of the beneficiaries sold their produce at both formal and informal markets and 14.7% and 36.5% sold their produce at formal and informal markets only respectively. On average the beneficiaries travel for 116.4 km to the nearest market. Distance to the market by district however shows that the average distance travelled by beneficiaries in Mutasa to the market is 20.3km and the furthest distance travelled is 80km. For Mutoko, the average and furthest distances travelled are 179.6km and 272km respectively. 47.1% of the beneficiaries required transportation to the market in the last year and on average they paid US$ 230 for the year. 36.5% sold livestock in the last 12 months with 19.4%, 12.9%, 6.5% and 2.9% selling cattle, goats, poultry and pigs respectively. The amount of income realised from livestock sales averaged US$352 per household for the last 12 months, with households getting as little as US$20 and as much as US$2000.

- **Expenditure**

75.3% of the beneficiary households bought food in the last 30days, 68.2% paid education related costs and 68.8% purchased non-food items such as fertilisers and seeds. Approximately half (49.4%) of the beneficiary households used food from their own production and 8.8% receives food aid from NGO's, the government and other donor organisations in the last 30 days. Detailed expenditure is provided in Table C3 below.

Table C3: Beneficiaries' expenditure in the last 30 days

	number	percentage
Paid for		
food bought	128	75.3
education paid	116	68.2
bills	46	27.1
transport paid	67	39.4
non-food items bought	117	68.8
Own production		
food own	84	49.4
education own	3	1.76
non-food own	3	1.8
From donors[63]		
food NGO	15	8.8
education NGO	8	4.7
non-food NGO	8	4.7

On average beneficiary households each spent US$197.77 in the last month. The average normal monthly expenditure is US$88.32.

[63] Donors in this case refer to non-governmental organisations (NGO's), the government as well as relatives and friends who gave the beneficiary household goods they would have otherwise had to buy.

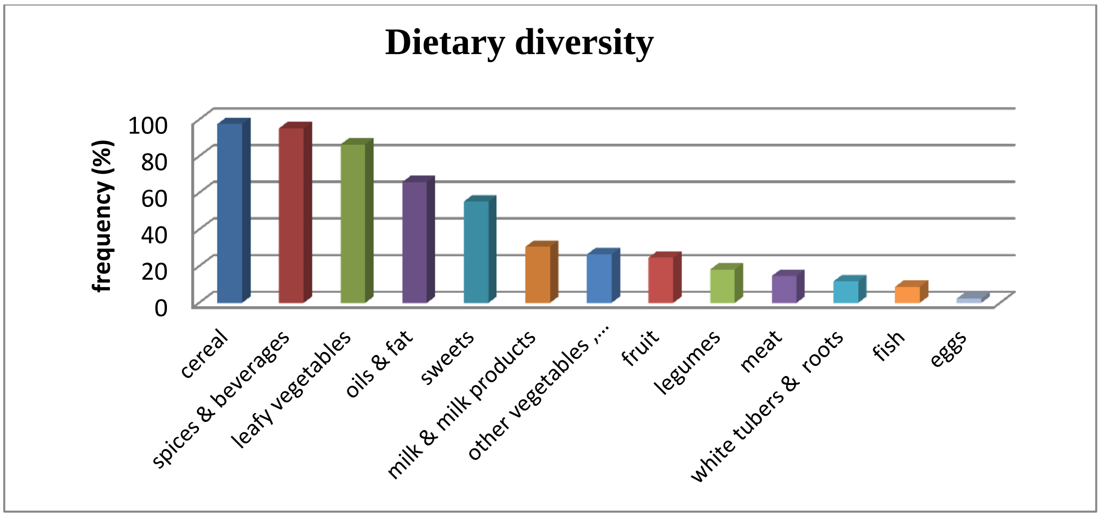
- **Health**

38.2% of the beneficiary households have between 1 and 3 members who suffer from chronic illness. 18.2%, 18.8% and 17.7% of the members suffering from chronic illness are household heads, main bread winners and are still the main breadwinners respectively. 34.1% of the chronically ill members received medical care in the last month at an average cost of US$115.57.

- **Food security**

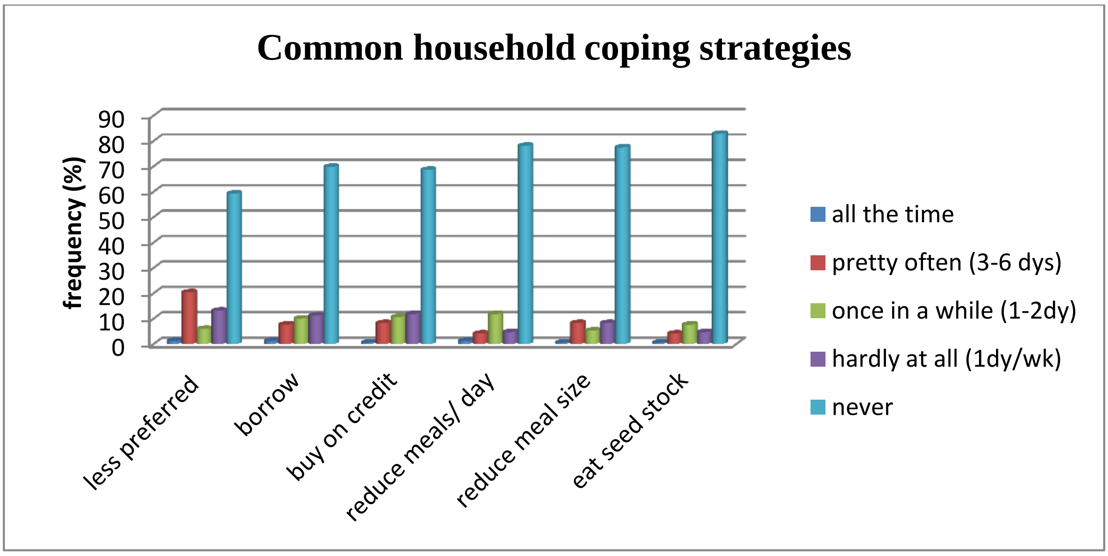
12.9% of the beneficiaries indicated that they had gone without enough food for some days in the last 30 days. Of these, 72.7% had gone without food for 5 or less days. 54.5%, 43.7% and 1.8% of the households eat 3, 2 and 1 meals a day. In terms of dietary diversity, a majority of the households ate food from the cereal group (97.7%), spices and beverages group, mainly salt (95.3%) and the dark green leafy vegetables group (86.5%) on the day before the interview. Meat (14.7%), fish (8.8%) and eggs (2.35%) consumption was very low for most households as shown in Figure C17 below

Figure C17: Food consumed by the household on the day before the interview



The most common coping strategies used by households is eating less preferred but more affordable foods (40.7%) , borrowing food from neighbours (30.2%) and buying food on credit (31.4%). The frequency with which the household used these strategies in the last 30 days before the interview is shown in Figure C18 below.

Figure C18: Common household coping strategies for Mutasa and Mutoko beneficiaries



Other coping strategies such as gathering wild fruit or harvesting immature crops (14.8%) , skipping entire days without eating (11.9%) and sending household members to eat away (4.7%) are also used to a lesser extent.

- **Remittances**

34.1% of the beneficiary households received remittances from within Zimbabwe, mostly from their children (48.3% and 32.8% from sons and daughters respectively) in the 12 months before the survey. Remittances are commonly received monthly (36.2%) or once in 3 months (27.6%). 61.8% of the beneficiaries received less than US$50 whilst 29.1% received between US$50 and US$100 in each period. 56.1% of the remittances are sent by people who are fully employed whilst 17.5% are from self-employed people. Remittances are mostly used to purchase food (56.1%) and to pay school fees (17.5%). 10%, 4.1% and 2.4% of the beneficiaries received remittances from 2, 3 and 4 different people respectively in the last year.

Only 8.2% of the beneficiaries received remittances from abroad mostly once a year (42.9%) in the 12 months before the survey. 84.6% of the senders are working abroad and 71.4% are married. Most of the remittances sent are used to purchase food (42.9%) and to pay fees (28.6%).

Appendix C2: PCA variables

Table C4: Description of PCA variables

variable	description
utilities	
tapwater	household's main drinking water source is tap water
boreholewellwater	household's main drinking water source is from a borehole or well
springwater	household's main drinking water source is a spring
flushtoil	household has a flushing toilet
pittoil	household has a pit toilet
notoilet	household has no toilet facilities
sharetoilet	household shares a toilet facility with other households
lightelectric	main source of light for the household is electricity
lightsolar	main source of light for the household is solar energy
lightkerosenelamp	main source of light for the household is a kerosene lamp
lightcandle	main source of light for the household are candles
lightother	household uses other sources of light such as torches
cookelectric	household mainly uses electricity for cooking
cookfirewoodother	household mainly uses firewood, gas and or charcoal for cooking
housing characteristics	
singledwelling	beneficiary's household is organised into a single dwelling
severaldwellings	beneficiary's household is organised into several dwellings
roominhouse	beneficiary resides in a room in a larger dwelling or impoverished house
floorearthsandwood	floor of the main dwelling is made of earth, san, dung, wooden planks or bamboo
floorcementtiles	floor of the main dwelling is made of cement, tiles, wood vinyl or carpet
floorothermaterial	floor of the main dwelling is made of other material
roofthatchwood	main dwelling has a roof made of thatch, palm leaf, rustic material, wood planks or bamboo
roofasbestors	main dwelling has a roof made of asbestors, metal, cement fibre, ceramic tiles or roofing shingles
roofothermaterial	main dwelling has a roof made of other material
wallnonebamboostone	main dwelling has no wall or a wall made of bamboo , cane, palm trunks or stone with mud
wallbricks	main dwelling has walls made of bricks or stone with cement, cement or wood planks
wallothermaterial	main dwelling has a wall made of other material
numberofrooms	number of rooms in the household including the kitchen
sleepingrooms	number of rooms in the household used for sleeping
durable assets	
electricty	household has electricity
solar	household has solar power
radio	household has a radio
television	household has a television
homehone	household has a landline phone
refridgerator	household has a refrigerator
oxdrawncart	household member owns an ox-drawn cart
mobilephone	household member owns a mobile phone
bicycle	household member owns a bicycle
motorcycle	household member owns a motorcycle
car	household member owns a car
cattle	number of cattle owned by the household
pigs	number of pigs owned by the household
goats	number of goats owned by the household
sheep	number of sheep owned by the household
poultry	number of poultry owned by the household
donkey	number of donkeys owned by the household
otherlivestock	number of other livestock owned by the household
landsize	size of arable land (hectares)

Appendix C3: Kaplan Mier survival estimates

Table C5: Kaplan Mier (KM) results overall and by district

	All=170			Mutasa =82			Mutoko = 88		
Time	Pc[64]	Pu[65]	se	Pc	Pu	se	Pc	Pu	se
1	0.935	0.935	0.019	0.963	0.963	0.021	0.909	0.909	0.031
2	0.868	0.812	0.030	0.873	0.842	0.040	0.863	0.784	0.044
3	0.841	0.682	0.036	0.812	0.683	0.051	0.870	0.682	0.050
4	0.776	0.529	0.038	0.768	0.524	0.055	0.783	0.534	0.053
5	0.789	0.418	0.038	0.837	0.439	0.055	0.745	0.398	0.052
6	0.718	0.300	0.035	0.778	0.342	0.052	0.657	0.261	0.047
7	0.520	0.156	0.028	0.593	0.202	0.045	0.435	0.114	0.034
8	0.727	0.114	0.025	0.846	0.171	0.043	0.556	0.063	0.027
9	1.000	0.114	0.025				1.000	0.063	0.027
10	1.000	0.114	0.025	1.000	0.171	0.043	1.000	0.063	0.027

Table C6: Kaplan Mier (KM) results by gender

	Female			Male		
Time	Pc	Pu	se	Pc	Pu	se
1	0.9615	0.9615	0.0218	0.913	0.913	0.0294
2	0.8667	0.8333	0.0422	0.869	0.7935	0.0422
3	0.8308	0.6923	0.0523	0.8493	0.6739	0.0489
4	0.7593	0.5256	0.0565	0.7903	0.5326	0.052
5	0.7805	0.4103	0.0557	0.7959	0.4239	0.0515
6	0.7813	0.3205	0.0528	0.6667	0.2826	0.0469
7	0.5833	0.187	0.0446	0.4615	0.1304	0.0351
8	0.8182	0.153	0.0425	0.6364	0.083	0.0293
9				1	0.083	0.0293
10	1	0.153	0.0425	1	0.083	0.0293

[64] Pc is the conditional probability that the farmer is still using the drip irrigation kit beyond time, t.
[65] Pu is the unconditional probability that the farmer continues using drip irrigation to a particular time, *t* (Cleves et al.,2010).

Table C7: Kaplan Mier (KM) results by year the beneficiary received the kit

	got kit 2003			got kit 2004/05			got kit 2006/07		
Time	**Pc**	**Pu**	**se**	**Pc**	**Pu**	**se**	**Pc**	**Pu**	**se**
1	0.962	0.962	0.022	0.897	0.897	0.040	0.000	0.939	0.042
2	0.895	0.861	0.039	0.923	0.828	0.050	0.103	0.667	0.082
3	0.897	0.772	0.047	0.813	0.672	0.062	0.172	0.485	0.087
4	0.852	0.658	0.053	0.744	0.500	0.066	0.328	0.273	0.078
5	0.808	0.532	0.056	0.724	0.362	0.063	0.500	0.242	0.075
6	0.738	0.392	0.055	0.714	0.259	0.058	0.638	0.152	0.062
7	0.355	0.139	0.039	0.733	0.190	0.052	0.741	0.152	0.062
8	0.545	0.076	0.030	0.909	0.172	0.050			
9				1.000	0.1724	0.050			
10	1.000	0.076	0.030						

Table C8: Kaplan Mier (KM) results by year the beneficiary's age

	beneficiary age :30-45			beneficiary age :46-60			beneficiary age :>=61		
Time	Pc	Pu	se	**Pc**	**Pu**	**se**	**Pc**	**Pu**	**se**
1	0.918	0.918	0.039	0.951	0.951	0.028	0.959	0.959	0.028
2	0.778	0.714	0.065	0.966	0.918	0.035	0.851	0.816	0.055
3	0.800	0.571	0.071	0.821	0.754	0.055	0.875	0.714	0.065
4	0.821	0.469	0.071	0.804	0.607	0.063	0.714	0.510	0.071
5	0.826	0.388	0.070	0.784	0.475	0.064	0.800	0.408	0.070
6	0.842	0.327	0.067	0.690	0.328	0.060	0.650	0.265	0.063
7	0.750	0.245	0.061	0.474	0.155	0.047	0.308	0.082	0.039
8	0.727	0.178	0.056	0.714	0.111	0.043	0.667	0.054	0.034
9				1.000	0.111	0.043			
10	1.000	0.178	0.056	1.000	0.111	0.043	1.000	0.054	0.034