Agricultural Productivity Growth and Its Impact on Household Poverty in Selected Villages in Rural Ethiopia

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A Thesis Submitted to the College of Development Studies Centre for Rural Development Studies in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Development Studies (Rural Livelihoods and Development)

Addis Ababa University
Addis Ababa, Ethiopia

May 2012

Addis Ababa University

School of Graduate Studies

This is to certify that the thesis prepared by Zewdu Ayalew Abro, entitled: *Agricultural Productivity Growth and Its Impact on Household Poverty in Selected Villages in Rural Ethiopia* and submitted in partial fulfillment of the requirements for the Degree of Master of Arts in Development Studies (Rural Livelihoods and Development) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Declaration

This is to certify that the thesis titled "*Agricultural Productivity Growth and Its Impact on Household Poverty in Selected Villages in Rural Ethiopia*" has been prepared solely by me under the supervision of Dr Bamlaku Alamirew in partial fulfillment of the requirements for the Degree of Master Arts in Development Studies (Rural Livelihoods and Development). This thesis has not been submitted for any Degree in any university; it is my original work.

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ABSTRACT

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Poverty is pervasive in rural Ethiopia. The Growth and Transformation Plan stipulated that increasing agricultural productivity of farmers is one entry point for poverty reduction. In this Regard, studying the sources of productivity growth and its implication for poverty reduction is very important for policy making. So far, studies in Ethiopia focused on productivity per se. Other studies on household poverty also paid more attention on the impact of productivity-enhancing factors such as roads and improved agricultural water management technologies on household poverty. However, studies on the impact of productivity growth on poverty reduction are limited. In an attempt to fill this gap, this study analyzed sources of agricultural productivity and its impact on household poverty. Stochastic Frontier Analysis (SFA) was employed to decompose the Malmquist Total Factor Productivity Index using the Ethiopian Rural Household Survey data. The results showed that agricultural TFP grew for the sample households. The analysis further showed that the main source of TFP growth was improvement in technical efficiency. The results also revealed that there is no growth in technology (the state of knowledge) of the farmers that significantly shifts the production frontier upward. Results of Two Stages Least Squares (2SLS) fixed effects regression also indicated that growth in technical efficiency reduces household poverty. Other productivity indicators, land and labor productivity, also reduces household poverty, albeit not as responsive as technical efficiency.

ACKNOWLEDGEMENTS

I would like to thank my advisor Bamlaku Alamirew (PhD) for his precious comments, suggestions and encouragement from the beginning up to the end of my research.

I also would like to thank Tewodros Tebekew, Getachew Ahmed Abegaz, Eyasu Tsehaye and Alekaw Kebede for their excellent assistance in developing my idea in the whole process of the research. I need also to very much appreciate the excellent assistance of Samuel Abera and Ermias Dessie while I was doing the data management in the ERHS data. Moreover, I need to thank Dagimawi Atnafu and Tesfaye Chanie for their excellent IT support.

I gratefully acknowledge the financial support from the Ethiopian Strategy Support Program II (ESSPII), a collaborative research program between the International Food Policy Research Institute (IFPRI) and the Ethiopian Development Research Institute (EDRI).

Many of the journal articles used in this thesis are made accessible by Gebeyehu Manie. He also greatly shaped my idea in the whole process of the research. He deserves great appreciations. I also thank Meron Assefa for her encouragement and she also supplied me some journal articles that was inaccessible to me and Gebeyehu. Yohanes Alemayehu not only supported me by printing books and articles but also strongly encouraged me to finish my education on time.

I am also grateful to several other people for their encouragement and support. I especially would like to thank Isaiase Abebe, Meron Zena, Tigist Worku, Lemlem Solomon, Bedilish Gebremedhin, Frehiwot Fantaw, Ibrahim Worku, Betelhem koru, Sinishaw Tamiru, Ermias Engeda, Ethiopia Abate, Rahel Derbe, Tsehay Ataklt, Fantu Nisrane (PhD), Fantu Guta (PhD), Tadele Ferede (PhD), Workneh Nigatu (PhD), Tigist Teferi, Mehari Zemelak, Alehegn Habtamu, Ali Hassen (PhD), Hailu Shiferaw, Getachew Yosef, Rahel Solomon, Zenaye Tekle, Yimer Tefera and Ayenew Derese.

Dedication

I dedicated this thesis for those people who have a greater stake in my life frontier.

To my father and my mother who gave me “something that they have never enjoyed; education” which is the foundation for my life frontier!

To W/ro Lakech Meshesha Hussein; shifted my life frontier considerably upward!

To Selamawit Aklilu; arrow of God!

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CHAPTER I

INTRODUCTION

1.1 Overview

Since recently, Ethiopia has been registering an impressive and sustained annual average 11.3 per cent economic growth for the last seven consecutive years. The same period witnessed an average growth rate of 10.3 per cent, 10.2 per cent and 13 per cent in value added of agriculture, industry and service, respectively (MOFED, 2010).

Agriculture is the foundation of the Ethiopian economy. It employs more than 80 per cent of the labor force (CSA, 2005). In the 1998 Ethiopian Fiscal Year (EFY), the sector contributed more than 48 per cent of the total value added to the nation's economy. Within the agriculture sector, crop production (both cereals and cash crops) accounts for more than 30 per cent of the agriculture value-added. The agriculture sector is the most labor intensive sector. The sector contributed 75.4 per cent of the value-added paid to labor in 2005/06. Moreover, it generates 90 per cent of export earnings and supplies about 70 per cent of the country's raw material for other sectors in the same period (EDRI, 2009).

As a source of consumption, "agricultural enterprises" remain to be the main source of income accounting 73 per cent and 63 per cent of the income earnings in rural areas in 1999/2000 and in 2004/05, respectively (MOFED, 2008). The agriculture sector determines the overall performance of the economy in terms of production and employment. As a result, poverty reduction policies need to recognize the central role of efficiency and productivity of the agriculture sector. With this backdrop, investigating the impact of changes in agricultural productivity on poverty in rural areas has immense policy relevance.

1.2 Problem Statement

The development strategy of Ethiopia emphasizes on poverty alleviation and sustainable economic growth. To achieve this objective, a series of three five years national development plans have been put in place since 2002 including the Growth and Transformation Plan (GTP) and the Plan for Accelerated and Sustained Development to End Poverty (PASDEP). These development plans are strongly integrated with the eight Millennium Development Goals (MDGs). For instance, increasing agricultural production and productivity through the use of modern inputs and enhanced extension services to reduce hunger and poverty (MDGs goal one) is one of the priorities of the GTP. Moreover, the plans succinctly articulate that agriculture is the engine of economic growth and the means to end poverty in the country on a sustainable basis through its forward and backward linkages with other sectors of the economy (MOFED, 2010; 2006; 2002).

As a result of such efforts and several other factors, the agriculture sector registered a 10.3 per cent growth rate per year for the period 2003/04 - 2009/10. Specifically, the crop production subsector grew by 13 per cent per year in the period under consideration.[1] A recent research using nationally representative production data by Alemayehu *et al.* (2011) indicated that the rise in the production of crops has been due to both growth in area and yields each accounting for 50 per cent of production growth.

In a study of fifteen villages in rural Ethiopia Fantu *et al.* (2011) and Fantu (2009) showed that most of the increase in output was attributable to increased use of traditional inputs. Besides, farmers' technical efficiency and Hicks-neutral technological change improved between 1994 and 2004 though a decline was witnessed in 2009. Ownership of two or more oxen and other livestock wealth, expansion of education and extension services were the main factors for gains in efficiency. On the other hand, labor shortage and drought adversely affected efficiency especially for female-headed households. Fantu (2011) also found growth in agricultural total factor productivity (TFP) by 4.5 per cent per year between 2004/5-2009/2010. These all justify the growth in the agriculture sector.

Nonetheless, poverty remains to be rather pervasive with official statistics indicating 29.6 per cent of the total population was living below the national poverty line in 2004/05. The statistics further shows that poverty was more prevalent in rural areas (30.4 per cent) than urban areas (25.7 per cent) (MOFED, 2008)). Moreover, millions of people are dependent on food aid. For instance, nearly 6.4 million, 4.9 million and 5.2 million people was food insecure demanding for food aid in 2008, 2009 and 2010, respectively. Approximately 2.8 million people

1 Ministry of Finance and Economic Development (MOFED) National Accounts data

require relief food assistance in 2011. Stimulating factors for widespread vulnerability to food insecurity are *inter alia* erratic rainfall, climate change and drought (DPPC, 2011; 2010). However, the main deriving forces for food insecurity and famine were the outcome of the country's long-run process of wrong policies, institutional and structural constraints (Getnet, 2007).

In fact, increase in production and productivity in agriculture directly affects the welfare of the bulk of the rural poor (Irz *et al.*, 2001). This suggests that quantitative analysis on the contribution of sources of productivity for human welfare is of great significance for the design of development policy (Hayami and Godo, 2005). In this regard, many cross-country studies indicated that increase in agricultural GDP per worker reduces poverty (Godoy and Dewbre, 2010; Christiaensen *et al.*, 2010; Christiaensen and Demery, 2007; Majid, 2004). Other studies also indicated that farm yields helps to reduce poverty (Ravallion and Datt, 2002 in India; Sarris *et al.*, 2006 in Tanzania, Minten and Barrett, 2005 in Madagascar).

In Ethiopia, most of the empirical works conducted so far have focused on technical efficiency *per se* without looking at the linkages that may exist between the growth in productivity and the reduction in poverty (Fantu, 2011; Fantu *et al.,* 2011; Fantu, 2009; Bamlaku, 2009). Others did not directly incorporate gains in agricultural productivity into their poverty analysis (Ayalneh, 2011; Ayalneh *et al.*, 2005; Ayalneh *et al.*, 2002; Bigsten and Abebe, 2004; Dercon and Krishnan, 2008; Bigsten *et al.*, 2003 and Islam and Abebe, 2007). Still others did only show the snapshot of the impact of productivity-enhancing factors such as land management practices on rural poverty by Bamlaku (2009) and fertilizer application by Dercon and Christiaensen (2005b) without estimating productivity gains directly.

From the above-mentioned studies, it is possible to observe that poverty-agricultural productivity nexus has not been very well studied. Very few studies tried to examine the impact of productivity growth for poverty reduction in Ethiopia. A micro level study of three agro-ecological zones in Eastern Gojam by Bamlaku (2010) showed the poverty-productivity linkages and found out that the two interact in a causal effect relationship. However, the study did not show the poverty mobility of farm households across time due to the cross-sectional nature of the data he used. Moreover, Dorosh and Thurlow (2009) and Dio and Pratt (2005) studied the impact of alternative growth options and agricultural growth on poverty reduction using computable general equilibrium (CGE) models. Both studies found that growth in agricultural productivity reduces poverty. However, the problem with the CGE models is that total factor productivity (TFP) growth is assumed to be exogenous like "*manna from heaven*". Thus, the models do not have the scope to analyze the sources of productivity growth which is the most important variables policy makers are particularly interested in. Therefore, this study sought to contribute to the existing literature by examining the source of productivity in subsistence agriculture in rural areas and then by showing the impact of agricultural productivity growth on poverty level of households.

1.3 Objective of the Study

The general objective of this study is to examine the impact of productivity growth on poverty level of households in rural areas. The specific objectives of this research are three-fold. These are to:

- analyze the sources of growth in productivity in rural Ethiopia and
- examine the impact of agricultural productivity on household poverty.

1.4 Significance of the Study

Rigorous analysis of the agricultural productivity-poverty nexus has a lot to contribute for policy making through evidence-based research. In this regard, the study provides empirical evidence on sources of productivity changes. It also gives insight on how total factor productivity growth contributes to poverty reduction in the study villages. On top of that, the study may provoke researchers' in the analysis of total factor productivity in all sectors of the economy.

1.5 Scope of the Study

The sampling frame to select the villages was strictly stratified in the main agro-ecological zones and sub-zones, and a minimum of one and a maximum of three villages per strata were selected (Dercon and Hoddinot, 2011). However, as Dercon and Hoddinot stated 15 of the thousands of villages were surveyed. This means that the panel is not representative for the country as a whole. As a result, the interpretation and generalization is limited to the study villages. The study does not examine determinants of agricultural productivity growth. It is limited to see the sources of productivity change and its implication for household welfare.

1.6 Organization of the Paper

The rest of the thesis is organized as follows. Chapter II reviews the theoretical and empirical literature and develops the conceptual framework of the study. Chapter III presents the data and the research methods. Chapter IV discusses results and discussion of the study. Finally, Chapter V deals with conclusion and policy implications.

CHAPTER II

REVIEW OF RELATED LITERATURE

The chapter reviews both the theoretical and empirical literature in Ethiopia and elsewhere which scaffold the assumptions used to develop the conceptual framework and hypothesis of the study.

2.1 The Impact of Agricultural Productivity Growth on Poverty Reduction

Productivity is a measure of performance of decision making units (DMUs)[2] at a given point in time. In contrast, productivity change is the movement in the performance of DMUs over time (Coelli *et al.*, 2005). In empirical literature, there are two widely used measures of change in productivity. The first method is the partial productivity measures which explain in terms of output per worker, output per hectare or output per hours worked. It is "partial" in the sense that it uses only parts of the inputs used for production. The use of partial productivity measures can potentially mislead and misrepresent the productivity of DMUs, as it does not make use of all the inputs (Coelli *et al.*, 2005). However, its main advantage is that it is simple and less data demanding.

The second method is the use of Total Factor Productivity (TFP) which considers the use of a number of factors of production. In this respect, TFP is a generalization

[2] Decision making units (DMUs) can be firms, farmers, individuals or countries; the term DMUs is widely used in the Data Envelopment analysis (DEA) literature.

of an index of output to a single input such as labor (Lovell, 1993). Measuring productivity growth by using TFP helps to avoid imputing gains to one factor while productivity gains are actually attributable to some other inputs. For instance, a gain in output resulting from a rise in capital or better management skills might be mistakenly attributed to labor, while the performance of labor is worsened in a given time (Cooper *et al.*, 2002). Therefore, TFP is more suitable to compare the change in efficiency and productivity across DMUs and for a given DMU over time (Coelli *et al.*, 2005). For this reason, this study opted to use TFP as measure of agricultural productivity. Productivity growth is thus the net change in output due to change in efficiency of DMUs and shifts in the production frontier (an indicator of technological change) over time (Grosskopf, 1993; Lovell, 1993).[3]

Productivity is at the heart of human beings effort as a way out of poverty (Lora and Pagés, 2010). This suggests that expanding productivity must be the epicenter of the debates in economic development because higher productivity pays the highest for the poor. Productivity growth accounted for about three fourths of the fourfold increase in real net national product per capita between 1889 and 1957 for the United States of America. Their capacity to supply more and more diverse economic goods enabled them to enhance future growth and strengthen their national income (Kendrick, 1961; Jorgenson, 1991; Denison, 1985).

In rural areas, many of the farming households in one way or another depend on agriculture. Over the last two decades, poverty has been fundamentally a rural

[3] More detailed treatment on total factor productivity and its decompositions are postponed to chapter III.

phenomenon (IFAD, 2010; WB, 2008; IFAD, 2001). Furthermore, between 1993 and 2002, more than 80 per cent of the worldwide reduction in rural poverty was due to improved conditions in rural areas suggesting that the rural economy is central for development (WB, 2008).

The ability of farmers to command over a wide range of commodities and services is mainly influenced by the income they have at their disposal. If increase in production is translated into higher income, they can also increase their bargaining power in the local development process and in any decision making process that have a tremendous impact over their life. Hence, in rural settings such as Ethiopia, raising the return from farming and agriculture-based resources through productivity increment is the first entry point and is the root cause for the crunch of low income. The empirical evidence in Asia and Latin America supports this thesis (Christiaensen and Demery, 2007).

In this regard, Irz *et al.* (2001) identified the following three major contributions of gains in agricultural productivity for poverty reduction (Similar arguments can be found in Schneider and Gugerty, 2011; WB, 2008; Christiaensen and Demery, 2007 and Johnston and Mellor, 1961).

First, raise in productivity directly increases production and higher profit for farmers. Two conditions affect the direct effect of productivity on the poor. Primarily, the extent to which the poor are engaged in farming determines the poverty-reducing effect of gains in productivity. Besides, high demand for agricultural inputs may push input prices up and a larger fall in output prices since higher supply might reduce the gross margin of producing farmers.

Second, gains in productivity and higher agricultural production is likely to boost the demand for farm labor as the amount of labor used per hectare rises due to either the expansion of cultivated land or the incidence of cropping increases. Third, net-food-buyers in rural areas could also be benefited from gains in agricultural productivity since the rise in aggregate food supply creates a downward pressure on food prices. The poverty-reducing effects of the gains in productivity in the farm sector are achieved if and only if the gain from reduced spending on food exceeds the loss from reduced wage income. In contrast, food-selling farmers gain only if productivity grows faster than prices fall.

Besides the farming sector, higher income in rural areas benefits the rest of the economy through different ways. First, it creates forward (labor and raw materials) and backward linkages by increasing the demand for industrial commodities for the industrial sector. Second, agricultural productivity also helps for the expansion of rural non-farm economy. Agricultural productivity growth raises incomes and thus increases the demand for non-farm products (Mellor and Johnston, 1984). However, growth in demand raises non-farm activity depends on whether these goods can be efficiently produced and supplied at the local level (Foster and Rosenzweig, 1988). Third, agricultural productivity enhances agricultural exports and generates foreign exchange earnings which augment the foreign exchange position of a country. Fourth, it raises aggregate supply and this in turn reduces prices of raw materials and food staples at the national level so that the urban poor might benefit. Finally, agricultural productivity growth helps to facilitate transfer of resources from agriculture to the rest of the economy in the form of taxation to finance industrial development.

As shown above, the pathways through which agricultural productivity reduces poverty are many and linked to each other. As a result, this study concentrates on the direct impact of agricultural productivity on the poor. In the following two sections, the empirical literature both in Ethiopia and elsewhere is reviewed.

2.2 Empirical Evidence from the Rest of the World

In the empirical literature, the most widely used explanatory variables to make causal inference in the poverty-productivity regression equations is agricultural value-added per labor and/or agricultural value-added per hectare. In this regard, Godoy and Dewbre (2010) in a cross-country analysis of pooled regression of panel data found that the estimated coefficient on agricultural GDP per worker was significantly higher than non-agricultural GDP per worker and remittance per capita. All the estimated coefficients were statistically significant with the expected signs. They found that a unit increase in agricultural GDP per worker reduces the percentage of the population living under the USD 2.00 per day poverty rate by nearly 0.14 per cent (for other cross-country analysis see also Christiaensen *et al.*, 2010; Christiaensen and Demery, 2007; Majid, 2004). In China, Ravallion and Chen (2005) found that economic growth (agricultural GDP per capita) in rural areas was far more important to poverty reduction than economic growth in urban areas.

Irz *et al.* (2001) specified a model for cross-section data by using land-labor ratio and agricultural value added per land as explanatory variables in cross country regressions. Both variables are statistically significant at 1 per cent level with the expected signs. They found that a 1 per cent increase in land-labor ratio reduces head count poverty by 0.82 per cent. In the same way, a 1 per cent improvement in value added per land reduces the percentage of the population living below USD 1.00 per day by 0.91 per cent. Moreover, they tested the sensitivity of the results employing different dataset. The results were entirely consistent with the previous result. As a result, the researchers concluded that agricultural growth driven by yield gains can provide effective way of fighting poverty (see also (Thirtle *et al.*, 2001; CSLS, 2003).

Using causal-chain regression models Thirtle *et al.* (2003) quantified the impact of research-led agricultural productivity growth on the incidence of poverty in developing countries. Their model involved in four equations. In the first equation, value added per unit of land was explained by research and development (R&D), fertilizer, labor and machinery per hectare, a land quality index and illiteracy. In the second equation, GDP per capita was explained by yields, land labor ratios, exports as a percentage of GDP and the percentage of the illiterate population. In the third equation, Gini coefficient was explained by value added per unit of land, GDP per capita, government expenditures as a percentage of GDP, the percentage of the population that is rural and a dummy variable for Latin America. Finally, they explained the poverty index using Gini, GDP per capita, exports, government expenditures and gross fixed investment. Results showed that a one per cent increase in yields reduces the number of people who live below $1 per day by more than six million. Results further reveal that 95 per cent of these were in Africa and Asia.

There are also country specific studies. Ravallion and Datt (2002) analyzed 20 household surveys for India's 15 major states for the period 1960-1994. The results showed that a unit increase in farm yields reduces head count poverty[4] by nearly 0.11 per cent. (for similar results see also Ravallion and Datt, 2002; Datt and Ravallion, 1998 for India, Sarris *et al.*, 2006 in Tanzania; Minten and Barrett, 2005 for Madagascar).

Attempt was also made by Thirtle *et al.* (2001) to see the impact of productivity measured by Total Factor Productivity (TFP) on poverty head count. They estimated three alternative models using head count poverty as a dependent variable and TFP index for model 1, technical progress for model 2 and efficiency change for model 3 as independent variable for nine Asian countries.[5] Model 1 and 3 are statistically significant at 5 per cent level. However, model 1 is statistically insignificant but it had its expected signs. They claimed a 1 per cent improvement in TFP reduces the USD 1.00 poverty head count by 1.3 per cent. Similarly, a 1 per cent increase in efficiency change reduces the USD 1.00 poverty head count by 2.04 per cent. They

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[4] The authors estimated the coefficients for all three Foster-Greer-Thorbecke classes of poverty measures, and the coefficients are highly significant. For the sake of space limitations, I do not want to present the details of the results. These details can be seen in the paper itself.

[5] The list of the countries were Bangladesh, China, Indonesia, Malaysia, Nepal, Pakistan, Sri Lanka and Thailand

concluded that agricultural productivity growth does appear to have a consistent and substantial impact on poverty. The poverty elasticity using different productivity measures were in between 0.62 and 1.3. The result is in line with the historical significance of productivity growth and technical progress in improving the standard of living of societies in advanced countries (Denison, 1985; Johnston and Mellor, 1961).

2.3 Evidence on the Impact of Agricultural Productivity on Poverty in Ethiopia

There are econometric works that attempted to link productivity with household welfare. Bamlaku (2010) examined links among poverty, land management strategies, and crop productivity as well as the technical efficiency level of farmers and identified the factors causing inefficiency. Using three stages least squares, he found that the poverty and productivity interact in a causal effect relationship. However, the study did not able to show the poverty mobility of farm households across time due to the cross sectional nature of the data it used.

Moreover, Getahun (2003) estimated the elasticity of poverty to growth in productivity, measured by per capita value-added of agricultural production, using household income consumption expenditure survey (HICES) of the Central Statistical Agency (CSA) of Ethiopia and the national agricultural GDP. He indicated that a 1 per cent growth in per capita agricultural value-added would lead to at least 0.24 per cent decline in poverty incidence.

Fertilizer application is one of the most important factors of production to increase agricultural productivity if it is used with other complementary inputs such as water. Dercon and Christiaensen (2005b) in Christiaensen and Demery (2007) studied the effect of fertilizer application on welfare and poverty among 1500 households in 15 villages across the four major regions of Ethiopia from 1994 to 1999. They found that per capita consumption (in adult equivalent) was 8.5 percentage points higher for households that use fertilizer as input in production. They estimated that the elasticity of consumption to fertilizer use (kilogram per hectare) is estimated to be 0.02. The result is robust because it controls for observable household characteristics, unobserved time-invariant heterogeneity across households and time variant village effects such as changes in relative prices and the provision of infrastructure. However, Fantu *et al.* (2011) and Fantu (2009) showed that fertilizer use is less responsive to output growth using the same data for 1994-2009 survey years. Not only fertilizer application but also improved land management practices are important to increase productivity and hence poverty. Bamlaku (2009) studied the causality between unsustainable land management practices on poverty in East Gojjam using simultaneous equation approach. Results show that poverty and unsustainable land management practices feed to each other in a cause and effect relationship.

In addition to the above-mentioned econometric works, the economy-wide effect of agricultural growth was studied by Dorosh and Thurlow (2009) and Dio and Pratt (2005) using computable general equilibrium (CGE) models. Dorosh and Thurlow (2009) analyzed the implications of accelerated agricultural growth on household incomes and poverty in Ethiopia using the 2005/06 Ethiopian Social Accounting Matrix (SAM) which was calibrated into a dynamic regional economy-wide CGE micro-simulation model. The authors simulated 5 alternative scenarios. The business-as-usual scenario was calibrated to production trends from 1998-2007. The finding showed that the incidence of poverty will decline from 40 per cent to 23 per cent during 2005-2015.

Dio and Pratt (2005) also employed a spatial economy-wide model of Ethiopia prepared by the IFPRI. They have made different scenarios' of growth options to see their impact on poverty incidence both within the agriculture and the non-agriculture sector. Under the business-as-usual scenario, the majority of the Ethiopian people's life will not improve by 2015. They argued that unless the current economic environment is improved, growth in agriculture, especially in cereal production, will contract compared to the population growth rate and the national poverty rate will increase from 44.4 per cent in 2003 to 45.7 per cent by 2015. The difference in the results is expected since the growth performance of the agriculture sector and the overall economy during the 1998-2007 far higher than that of 1992-2002. As noted in chapter I, the problem with the CGE models is that total factor productivity (TFP) growth is assumed to be exogenous. Thus, the models do not have the scope to analyze the drivers of productivity growth.

Thus far, attempt was made to review the impact of productivity and productivity enhancing factors such as fertilizer application and improved land management practices on household poverty. There are also many other studies that made more emphasis on the impact of village and other idiosyncratic factors on household poverty. Ayalneh (2011) analyzed the extent and determinants of rural household poverty in the eastern highlands of Ethiopia using ordered probit model. The study was particularly interested in the effects of location-specific and institutional factors in determining the probability of being poor. Results indicated that involvement in governance, social and production related networks were found to be strongly associated with the probability of a household being poor. They also found access to irrigated land and access to non-farm income reduces the probability of being poor. Besides, household wellbeing is negatively affected by household size, and positively affected by age of household head (for positive the impact of informal risk sharing strategies see Andinet, 2007). Ayalneh *et al.* (2005) also studied the determinants of rural poverty in three Woredas in East Harerge. They identified many individual, household and village level characteristics as determinants of the probability of being poor using binary logit model. They argued that rural poverty is strongly linked to entitlement failures understood as lack of household resource endowments to crucial assets such as land, human capital and oxen (see also Ayalneh *et al.*, 2002).

Dercon *et al.* (2011) explored chronic poverty and its link with consumption growth in 15 Ethiopian villages between 1994 and 2009. They indicated that consumption poverty declined between 1994 and 2004 but came to halt in 2009 mainly due to inflationary and location specific factors. As a result, movements in and out of poverty remained relatively large. They found that chronic poverty is associated with lack of physical assets, education, and 'remoteness' in terms of distance to towns or poor roads. Using a dynamic micro-level growth model they also found that factors driving growth such as extension or access to roads have similar impacts on chronically poor and non-chronically poor households. However, the chronic poor face a considerable growth handicap compared to the rest due to poor initial assets and remoteness (see also Dercon and Krishnan, 1998).

Moreover, Dercon, *et al.* (2008) also employed an instrumental variables model using Generalized Methods of Moments and controlling for household fixed effects to study the impact of road networks and increased access to agricultural extension services. They found that receiving at least one extension visit reduces headcount poverty by 9.8 percentage points and increases consumption growth by 7.1 per cent. Moreover, access to all-weather roads found to be reducing poverty by 6.9 percentage points and increases consumption growth by 16.3 per cent. The negative effects of different kinds of shocks including but not limited to rainfall, drought and illness on household consumption and poverty are studied by Dercon *et al.* (2005), Dercon (2004) and Dercon and Krishnan (2000). All studies unanimously found that these shocks are strongly negatively associated with lower levels of per capita consumption.

Islam and Abebe (2007) studied persistence of poverty in rural areas using latent class probit models using the Ethiopian Rural Household Survey (ERHS) and the Ethiopian Urban Household Survey (EUHS) data for urban areas for the period 1994-2000. The model allows for permanent household specific effect to control for household unobserved heterogeneity, serially correlated error component and state dependence component which controls for the effect of previous poverty status on the current poverty status. Results indicated that for both rural and urban areas each of these components is statistically significant. Urban households have a greater degree of true state dependence than the rural households. Rural households have a relatively lower risk of being poor due to permanent unobserved heterogeneity. The effect of time varying transitory shocks in poverty persistence was also stronger for urban households than the rural households. Besides, the increase in household size raises the risk of being poor while land size and producing cash crops (coffee and chat) has significant role for poverty alleviation in rural areas.

Bigsten and Abebe (2004) also studied the dynamics of income poverty by decomposing poverty into chronic and transient poverty (poverty decomposition) using the ERHS for rural and EUHS data for urban areas in Ethiopia covering the period 1994-97. Findings indicated that in rural areas, age of the head of the household, dependency ratio greatly affect the odds of moving into poverty. On the other hand, they found that cultivated land, education of the head of household, education of the wives, value of crop sales, type of crops planted and access to local markets significantly reduce vulnerability to poverty. In urban areas, household size, age of the head and region of residence (particularly the capital) increase the probability of being in poverty. Besides, occupation of the head of the household except for casual workers and education of head of the household were significant determinants of moving out of poverty. A similar study with identical results also found in Bigsten *et al.* (2003). However, Bigsten and Abebe (2004) decomposed changes in poverty into growth and redistribution components. Their findings indicated that economic growth reduces poverty but counteracted by worsening income distribution.

There are also studies that made more emphasis on policy related determinants of poverty. Mulubirhan and Calfat (2010) evaluated the impact of food aid on poverty reduction using the ERHS data for 1999 and 2004. Results showed that access to information, initial endowment, household characteristics, and shocks were the main determinants to escape from poverty. They claimed difference-in-differences matching and switching regression support the fact that participation in food-for-work (FFW) or free-food-distribution (FFD) increased welfare growth.

Like the aid-based and emergency-related government interventions, investment in improved agricultural water management technologies (AWMTs)) are also found to be essential for poverty reduction as well. Fistum *et al.* (2010) have conducted impact evaluation on the impact of AWMTs using data collected from a representative sample of 1,517 households from 29 Peasant Associations (PAs) in four regions of Ethiopia. Results indicated that the estimated average treatment effect (for users of low-cost AWMTs) on per capita income was significant and amounted to USD 82. They also showed that poverty incidence was 22 per cent lower among users of AWMTs compared to non-users. Besides, they found difference in poverty incidence by the type of technology farmers' used. Relative to rain-fed systems using deep well, river diversions and micro-dams have led to 50 per cent, 32 per cent and 25 per cent reduction in poverty incidence, respectively.

Even though it is difficult to compare the impact of aid-based and emergency-related government interventions to the use of AWMTs from these studies, it gives an indication that a coordinated effort to link the food-for-work program with investments on irrigation and water management technologies might help for escaping poverty.

Finally, Alemayehu *et al.* (2006) estimated fixed effects logit model for Ethiopia using the ERHS for rural and EUHS for urban areas to study the link between finance and poverty in Ethiopia. Findings showed that access to finance is an important factor in consumption smoothing and poverty reduction. They also found evidence for a poverty trap due to liquidity constraints that limits the ability of rural households from consumption smoothing. This study is also corroborated by a study on the impact of credit aceess on povery reduction in five major coffee growing areas in Oromia and SNNPR (Getachew, 2009).

To sum up, from the reviews so far, productivity-enhancing factors such as fertilizer application, improved land management practices as well as policy interventions like food-for-work, road networks, extension services and improving water management practices help in reducing poverty. Moreover, the econometric works of Bamlaku (2010) and Getahun (2003) and results of the CGE studies undertaken by Dorosh and Thurlow (2009) and Dio and Pratt (2005) undoubtedly articulate the importance of raising productivity to help households escape out of poverty.

2.4 Conceptual Framework and Hypotheses

The theory and the empirical evidence in Ethiopia and elsewhere clearly shows that rise in agricultural productivity have indeed poverty–reducing effect. Gains in productivity directly improve the living standards of the farming community in three main channels. First and most importantly, higher productivity, and hence higher volume of production, increases the availability and farmers' ability to command diversified agricultural commodities for their own consumption. In Ethiopia subsistence farmers spend substantial part of their production for household consumption. Consequently, higher agricultural productivity is likely to be easily translated to higher consumption and less poverty.

Second, improvement in productivity enables farmers to increase their marketable output. If price does not fall until it vanishes all the gross margins due to rise in productivity as agricultural supply increase, farmers obtain the higher pay off. This in turn enables them to increase the consumption of industrial commodities. Channels one and two jointly increase the ability of diversifying their food baskets and this in turn has nutritional implications for farmers. The third channel is that increase in agricultural productivity raises the demand for farm labor as the expansion of cultivated land and or the incidence of cropping increase. Off-farm employment rises which leads to higher income diversification for poor farmers. This reinforces the benefits of rural families via channels one and two. Agricultural laborers and net-food-buyers also benefit from higher production because of lower price of agricultural commodities.

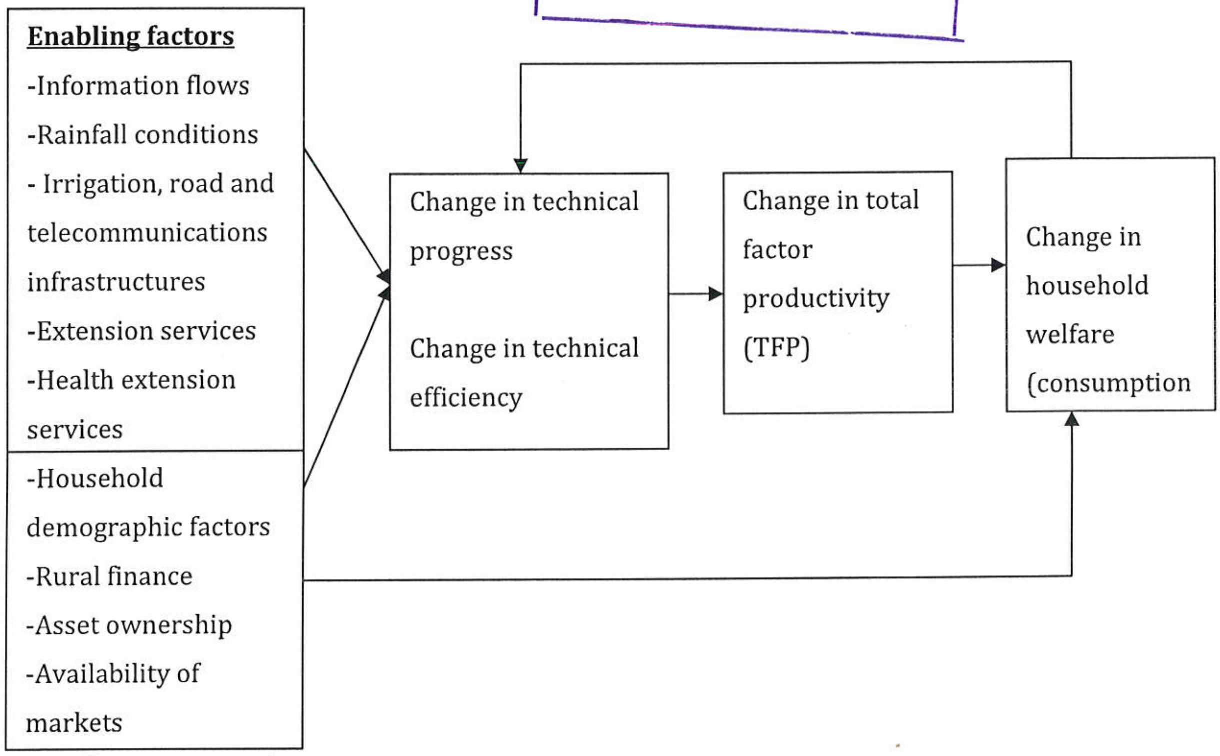
The literature review in Ethiopia and elsewhere clearly shows that increase in agricultural productivity reduces poverty. This study hypothesizes that agricultural productivity growth, measured by total factor productivity growth, helps to improve human welfare measured by household consumption (Figure 2.1).

Ultimately, the interaction of these channels improves the living standards of farmers. It is to mean that vulnerability to shocks (illness, weather shocks and natural disaster) can be minimized because farmers owns large amount of stocks of agricultural production and more likely to have more saving in cash at their disposal. With regard to health, the risk of illness could be prevented if farmers can have balanced diet and can diversify their food items.

Moreover, if all farmers are better off, their contribution for financing of development projects in terms of taxation and other contributions raises so that their say in local development process, decision making and political participation improves. As a result, the dimensions of poverty in terms of powerlessness and voicelessness are more likely to reduce.

Finally, once poverty starts to fall, it has a multiplier effect to increase another round of improvements in productivity and better living standards to the farming society. In other words, if productivity perpetuates overtime, it is more likely that better standard of living too perpetuates in the future.

All the formal rules and regulations, macroeconomic policies, cultures, religions, accessibility of infrastructures such as health, education, telecommunications etc and extension services determines the ways farmers respond to increase productivity. If all these factors are in favor of farming systems, farmers might easily adopt new technologies. They also efficiently use their available resources. As a result, productivity improvements are constrained by the local and national contexts in which farmers operate.



Source: Own representation

Figure2.1: Conceptual framework: the impact of agricultural productivity on household consumption.

CHAPTER III

DATA AND RESEARCH METHODS

In this chapter, an attempt is made to present the data and the research methods employed. The first two sections discuss the sources of the data, sampling design and the data cleaning process. Finally, the fourth section discusses the research methods.

3.1 The Ethiopian Rural Household (ERHS) Data

The ERHS is a panel dataset covering 15 villages in rural Ethiopia. The data collection started in 1989, when a team visited 6 farming villages in Central and Southern Ethiopia. In 1994, the survey was expanded to cover 15 villages across the four major regions of the country surveying 1500 households. An additional round was conducted in late 1994, with further rounds in 1995, 1997, 2004 and 2009 (Dercon and Hoddinott, 2011). The data have been made available by the Economics Department, Addis Ababa University, the Centre for the Study of African Economies (CSAE), University of Oxford and the International Food Policy Research Institute (IFPRI). Funding for data collection was provided by the Economic and Social Research Council (ESRC), the Swedish International Development Agency (SIDA) and the United States Agency for International Development (USAID); the preparation of the public release version of these data was supported, in part, by the World Bank. AAU, CSAE, IFPRI, ESRC, SIDA, USAID and the World Bank are not responsible for any errors in these data or for their use or interpretation.

representativeness. Therefore, inference and policy recommendations from the survey results should be done with care (Dercon and Hoddinott, 2011). The data also lags three years behind which might not represent the current reality on the ground in the study villages.

High rate of attrition might bias estimates. But attrition rate was very low. It was as low as 8.1 per cent between 1994 and 2009. Dercon and Hoddinott (2011) stated that attrition results were partly from site specific factors. For example, the extension of the Lalibela airport resulted in a loss of agricultural land in the village of Shumsheha. As a result, some of the sample households might depart their residence. Doma is a resettlement village and some households may have decided to return to their original villages. They also claimed that the use of panel fixed effects reduces such biases.

3.2 The Data Cleaning Process

This study uses only rounds 1994a[6], 1999, 2004 and 2009 out of the seven rounds. Two justifications can be given for the selection of these rounds. First, it gives equal time dimension easing the interpretation of results across the same time span. Second, the dataset in each survey period is huge. Effectively managing the data is a crucial factor to use only some of the survey rounds.

[6] The first and the second rounds were collected in the year 1994 (round 1 in 1994a and round 1994b).

The number of households surveyed in first round was 1,477, 1681/1452[7]in the fifth round, 1384 in the sixth round and 1577/1358[8] in the seventh round. The panel was created based on two criteria. On the one hand, households must have cultivated some plot of land and on the other hand, they have to have positive value of production. Without a positive value for these two variables, it is difficult to make further analysis. As aresult, all households with zero or missiong for these variables were removed. Finally, a balanced panel of 1007 consisting of 4028 observations was created.

The data cleaning process for most of the variables is straightforward. Nevertheless, further description is important for some of the variables. Aggregation of quantity of crops produced by farmers into value of production for all crops produced by farmers involves three steps. First, quantity produced measured by different local units of measurements were converted into a standard measure, kilogram. Village level conversion factors prepared by the International Food Policy Research Institute (IFPRI) were used.

In the second step, the quantity of production in kg was converted into value in Birr using village level prices collected during the survey. However, the ERHS data do not have price data for 1999. Based on recommendation from researchers who previously used this data, the 1997 ERHS price data was scaled up by village level inflation rate calculated from the IFPRI's village level price index. An alternative to

[7], [8] In 1999, three additional villages form higher agricultural potential areas - Oda Dawata, Bako Tibe and Somodo were surveyed. There was not sufficient funding to re-survey these villages in 2004 but re-surveyed in 2009.

this would be to use the Central Statistical Agency (CSA) zone level producer price data for aggregation. Aggregation was made using both sources of data for the purpose of comparisons.

Third, after aggregating the plot level nominal value of production into household level, the nominal value was deflated by the spatial price index.[9] The justification behind this task is that even though farmers produce a lot of crops, the data do not identify the input levels by crop type making multi/output-multi/input analysis difficult.

Just like the production data, many farmers reported their cultivated land using different local units of measurements. Plots cultivated by households measured by local units of measurements were converted into standard measure, hectare, using the IFPRI's conversion factor. Finally, the plot level information was aggregated into household level.

The amount of labor used is measured by a proxy variable by the number of household members between the age of 10 and 65 years converted to male adult equivalent units. The standard conversion factor where labor of an adult female and children are converted into adult male labor equivalent by 0.8 and 0.3 rates, respectively (Mahmud *et al.*, 2008). The use of family labor as proxy for labor use in agricultural production was due to inconsistency in the duration of labor use data across different rounds.

[9] The IFPRI calculated the spatial (village level) price Index from village specific prices collected during the survey time and using value of production shares of each village in 1994a as weights.

The value of farm capital is a self-reported value by farmers, which is the sum of the value of sickles, hoes and ploughs used for cultivation. Measuring farm capitals using self-reported values increases the risk of measurement errors in the data. An alternative would be to use the number of farm capitals (number of hoes, number of ploughs and number of sickles owned). However, this option assumes all the farm assets are homogenous among households. The use of self-reported values not only shows the difference in quantity of ownership but also shows differences in quality of the assets owned by farmers.

An index of land quality indicator using the information on farmers' self-reported slope and fertility of their plots was calculated (Fantu, 2009). To calculate the average land quality index, a value of 1 for a plot with flat slope *(meda),* 2 for hill slope and 3 higher hills was assigned for every household. Similarly, if the land is very fertile *(lem),* a value of 1 and 2 if fertile (*lem tef*) and 3 infertile (*tef*) was assigned. Then multiplying the slope and fertility indicator of the plots, a plot with a value of 1 will have the best land quality while 9 indicate the lowest quality. Other combinations of quality indicators are in between 1 and 9.

Water is a critical input in agricultural production. It was measured by the amount of rain recorded either in the study villages or their proximate meteorology stations depending on data availability. A dummy variable if the farmers use any kind of irrigation was also included. However, information was not collected for the 1994a and 2009 rounds. For 1994a the question if the farmer uses irrigation as modern input in the 1994b survey was used. For the 2009 round, whether farmers used water harvesting technologies was used as proxy. The use of these proxies might affect the results.

Alike the irrigation variable, information were not collected for participation in government extension program in the 1994a and 2009 rounds. A question that reflects the role of the extension system and development agents from the 1994b survey was used. The question was "Who or what influenced your decision to grow the crops?" For those farmers who were influenced by the extension agents on their decision for specific crops, it is assumed that they have participated in the extension program in 1994a. For the 2009 round, the number of extension visits was used as proxy for extension participation. Those farmers who received an extension visit of one or more times are classified as participants in the extension program.

Human capital was measured by the years of schooling for the head of the household. In the data not only formal education but also informal education including church/mosque education and adult literacy program were reported by heads of households. For those who attended informal educations and can read and write, 3 years of schooling was assumed. In some cases, the highest grade completed was not reported but their literacy status. If the head can read and write a letter, it was assumed he or she completed 3 years of schooling.

Finally, real consumption per capita is used in the determinants of poverty model.[10] Real consumption per capita calculated by the IFPRI is used. As stated in Dercon *et al.* (2011) consumption is defined as the sum of values of all food items, including

[10] The use of consumption expenditure rather than other indicators is justified in section 3.5.5.

purchased meals, and non-investment non-food items. Then, it is expressed in monthly per capita terms and deflated using the food price index for 1994. Livestock ownership in tropical livestock units (TLUs) calculated by the IFPRI was also directly used in the fixed effects regression.

Besides, the IFPRI calculated the spatial (village level) price Index from village specific prices collected during the survey time and using value of production shares of each village in 1994a as weights. This index served two purposes; on the one hand, it served as a regressor to control for the impact of inflationary pressures on consumption and on the other hand, it was used to deflate the nominal value of production as stated above.

As a final note, it is important to note that problem in unit conversion factors and the local measurement unit itself for both production and area cultivated data which might be a source of measurement error. As Fantu (2009) made it clear, few of the local units are easily comparable with standard units and the same local unit may translate into different standard units across peasant associations (PAs). Moreover, some of the local units do not even measure what is sought to be measured. For instance, a local unit used to measure area actually measures length, not area, and a local unit used to measure weight actually measures volume, not weight. To mitigate these problems, the IFPRI has made relentless effort in preparing units of measurement conversion factors for both quantity data and area cultivated.

It should also be acknowledged that the use of proxy such as the number of household members between the age of 10 and 65 years for labor use may affect the findings. The use of Stochastic Frontier Analysis (SFA) minimizes the risk of measurement errors which will be discussed in Section 3.5.3.

3.3 Research Methods

This subsection discusses the research methods of the study. The first two subsections highlights sources of productivity and the Malmquist Productivity Index which is supposed to serve as a benchmark for the other subsections. The next two subsections presents the Stochastic Frontier Model (SFA) and the empirical model. The fifth subsection presents the fixed effects method of estimating the impact of productivity on household poverty. Finally, the last section discusses a method to undertake simulations for alternative government interventions and estimations of the associated changes in poverty levels of households.

3.5.1 Sources of Productivity

As defined in Chapter II, productivity is a measure of performance of decision making units (DMUs) at a given point in time. In contrast, productivity change is the movement in the performance of DMUs over time (Coelli *et al.*, 2005). In the productivity and efficiency analysis literature three sources of productivity are identified (Färe *et al.*, 1994; Coelli *et al.*, 2005; Balk, 2001; see also Solow, 1987; Solow, 1957; Hayami and Godo, 2005 for technical progress broadly defined). First, productivity can be increased through more efficient use of the existing means of production. This is the gain in technical efficiency change which is the optimum allocation of the available stock of inputs to produce the maximum attainable amount of output. This is portrayed in the production frontier in Figure 2.1 below.

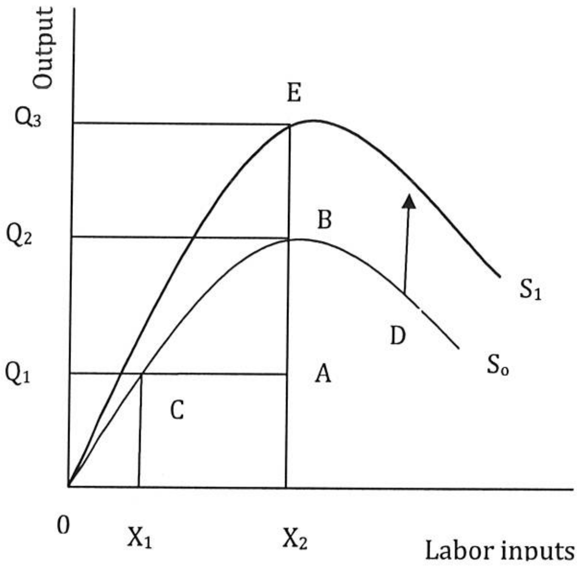


Figure 2.1: Measuring Sources of Productivity Change

3.5.2 The Malmquist Total Factor Productivity Index (TFP)

The focus of the preceding subsection has essentially been to show the snapshot of an appropriate framework to measure productivity and productivity change. This subsection describes how productivity and productivity changes are measured. In the presence of technical inefficiency and panel data, the Malmquist productivity index is used to calculate productivity growth (Grosskopf, 1993; Coelli *et al.*, 2005).

In this study, calculation of TFP is made using the output-oriented Malmquist TFP index proposed by Färe *et al.* (1994) and Caves *et al.* (1982a, 1982b). The index differs according to the orientation used.[11] In agriculture, it is usually assumed that farmers attempt to maximize output from a given set of inputs (Coelli and Rao,

11 "An output orientation of the Malmquist TFP index asks "by how much can output quantities be proportionally expanded without altering the input quantities used?" On the other hand, input orientation asks "by how much can input quantities be proportionally reduced without changing the output quantities produced?"" (Coelli *et al.* 2005 page 54).

2003). In fact, if the production technology exhibits constant returns to scale, both input and output orientations give equivalent measures of efficiency change and productivity change. Fantu (2009) tested for the type of returns to scale that existed among farmers in the data this study used. Besides, since many of the farmers have more or less similar agricultural factors of production, economies of size may not be a decision variable. Therefore, constant returns to scale are assumed.

The Malmquist TFP index measures change in productivity by comparing the observed outputs in period t and $t + 1$ with the maximum level of outputs that can be produced using x^t and x^{t+1} inputs for the two periods, operating under the reference technology. This method also decomposes the TFP growth into two mutually exclusive components: changes in technical efficiency and shifts in frontier or catch up (Färe *et al.*, 1994).

Following Färe *et al.* (1994), Coelli *et al.* (2005) and Grosskopf (1993), the production technology which consists of all the set of input and output vectors are assumed to satisfy certain axioms. If a firm is assumed to use N amounts of inputs (e.g., labor, machinery, raw materials), the main axioms are non-negativity (the value of the production technology is a finite non negative real number), weak essentiality (producing positive output is impossible without the use of at least one input), monotonicity (additional units of an input will not reduce output) and concavity (if the production function is continuously differentiable, concavity implies all marginal products are non-decreasing).

For each time period t=1,...,T, the production technology, S^t, models the transformation of inputs $x^t \in \Re^N_+$ into outputs $y^t \in \Re^M_+$. The feasible production technology can be defined in terms of the correspondence between the output set $P^t(x^t)$ which can be produced, and the input vector x^t:

$$S^t = \{ y^t \textit{ is obtainable from } x^t \}, t = 1, ...T$$

Since production is technically inefficient, defining a distance functions to take into account the discrepancy between the maximum attainable output for a given level of input and the observed output is important. Thus, the appropriate tool to consider inefficiency is the use of distance functions.

The output distance function for a given period *t* is defined as

$$D^t_0(x^t, y^t) = \inf\{\theta : (x^t, y^t / \theta) \in s^t\}$$

Inf represents the infimum function which calculates the minimum value of the function in the curly brackets. Note that $D^t_0(x^t, y^t) \leq 1$ if and only if $(x^t, y^t) \in s^t$. If $D^t_0(x^t, y^t) = 1$, y^t is located on the production possibility set. It follows from the definition of distance function in that it is homogenous of degree 1 and weakly monotonically decreasing in outputs. It is also invariant with respect to changes in units of measurement (Lovell, 1993). In addition, it is the reciprocal of Farrell's (1957) output-based measure of technical efficiency. This permits the decomposition of productivity change into two parts; one measuring changes in technical efficiency and the other captures the shift in the frontier.

To define the output-oriented Malmquist TFP index (OMTFPI), it requires defining distance functions with respect to two different time periods. That is,

$$D_0^t(x^{t+1}, y^{t+1}) = \inf\{\theta : (x^{t+1}, y^{t+1}/\theta) \in s^t\} \quad (1)$$

$$D_0^{t+1}(x^t, y^t) = \inf\{\theta : (x^t, y^t/\theta) \in s^{t+1}\} \quad (2)$$

The first distance function, in equation (1), measures the maximum proportional change in outputs required to make (x^{t+1}, y^{t+1}) feasible in relation to the technology in period *t*. Similarly, the second mixed-period distance function, in equation (2), measures the maximum proportional change in output required to make (x^t, y^t) feasible in relation to the technology at *t + 1*, which is $D_0^{t+1}(x^t, y^t)$. In both these mixed-period cases, the value of the distance function may exceed unity. This can occur if the observation being evaluated is not feasible in the other period.

The Malmquist Productivity Index can be defined relative to a single technology *t* as:

$$M_o^t = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad (3)$$

And for *t + 1* as

$$M_o^{t+1} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \quad (4)$$

It is easy to show that equation (3) and (4) are equal if and only if technical change is hicks neutral. If this is not true, the equations yield different productivity numbers since their reference technology might differ. In order to avoid imposing this restriction or choosing an arbitrary benchmark, the output-based Malmquist

In practice, the production technology in equation (1) remains unknown. Therefore, it has to be estimated from the data. There are two frequently used methods of estimating the efficient frontiers (s^t and s^{t+1}) and decomposition of output-oriented Malmquist productivity index in equation (6) (O'Donnell, 2011, Perelman, 1995; Grosskopf, 1993; Coelli *et al.*, 2005). The first widely used method is the linear programming approach known as Data Envelopment Analysis (DEA). The DEA is a non-parametric approach in which the envelopment of decision-making units (DMU) or farmers can be estimated to identify the "best practice" for each farmer. The efficient farmers are located on the frontier and the inefficient ones are enveloped by it. Estimation of production technology using DEA has many advantages. First, it is suitable for discrete data. This avoids approximation error introduced in the parametric models which presumes continuity. Second, it is not prone to specification error in the production function as well as distributional assumptions as it is the case in the stochastic frontier approach. Third, it does exactly envelop the data unlike the econometric model. DEA however, is not without problems. Its main weakness is that it is non-stochastic. As a result, it lumps data noise and inefficiency together and takes the combination as inefficiency. Moreover, it is impossible to test statistical hypothesis (Grosskopf, 1993; Lovell, 1993; Coelli *et al.*, 2005).

The second method is the stochastic frontier analysis (SFA). The main strength of this method is that it distinguishes the effect of data noise from the effects of inefficiency. It is also possible to make tests of statistical hypothesis. On the other hand, this approach is parametric in nature in that it confounds the effect of misspecification of functional form (of both technology and inefficiency) with inefficiency.

The inherent variability of agricultural production to exogenous shocks such as weather, pests and diseases forces agricultural economists to prefer the SFA (Coelli and Battese, 1996). Moreover, the authors claimed that farmers do not keep accurate records of all the factors of production and their production as a result of which measurement errors may occur. For these reasons, this study prefers the SFA rather than the DEA.

3.5.3 Stochastic Frontier Analysis (SFA)

Let's start using the following deterministic production frontier

$$y = f(x,t;\beta) * \exp\{-u\}, \tag{7}$$

Where y is the scalar output of a producer, $f(x,t;\beta)$ is the deterministic part of a stochastic production frontier with technology parameter vector β to be estimated, $x = (x_1,...,x_n) \geq 0$ is an input vector, t is a time trend serving as a proxy for technical change, and $u \geq 0$ represents output-oriented technical inefficiency. From this production frontier the rate of technical change can be measured as

$$\Delta TC = \frac{\partial \ln f(x,t;\beta)}{\partial t} \tag{8}$$

ΔTC has a value greater than, less than or equal zero as technical change shifts the production frontier up, leaves it unchanged, or shifts it down, respectively. $TC\Delta$ can be interpreted as outward shift in the production frontier over time. Similarly, the rate of change of technical efficiency (ΔTE) can also be measured by

$$\Delta TE = -\frac{\partial u}{\partial t} \tag{9}$$

ΔTE has a value greater than, less than or equal zero as technical inefficiency declines, remains unchanged, or increases through time, respectively. ΔTE can be interpreted as the rate at which a producer moves toward or away from the production frontier, which itself may be shifting through time (Kumbhakar and Lovell, 2000).

Estimation of the Malmquist Productivity Index developed in the previous section will be made using a parametric distance function. In order to estimate it, a functional form for the transformation function S^t is required (Fuentes *et al.*, 2001; Coelli and Perelman, 1999; Coelli *et al.*, 2005). The functions should be flexible to represent the production technology in that several restrictive functional forms can be statistically tested as explained in Kumbhakar and Hjalmarsson (1993). The translog production function is frequently used to achieve this purpose. Moreover, the translog does not impose any restrictions on returns to scale or substitution possibilities but susceptible to multicollinearity and degrees of freedom problems (Coelli, 1995). Despite these advantages of the translog production technology, the Cobb-Douglas (CD) production technology is chosen in this study.[12] The problem of the translog is that there are more parameters to estimate, and this may raise

[12] The CD can be thought of as a special case of the translog production technology by fixing the coefficients of its cross products to zero for example as specified in Fuentes et al. (2001).

econometric difficulties such as multi-collinearity (Coelli *et al.*, 2005). Moreover, interpretation of the cross-products of the translog is very difficult.

Following Coelli *et al.* (2005) and Fuentes *et al.* (2001) specification for the translog production function, define the Cobb-Douglas (CD) specification of the transformation function corresponds to a multi-output/multi-input technology with technical progress as follows.

$$\ln D_0^{\,t}(x^{i,t}, y^{i,t}) = \alpha_0 + \sum_{k=1}^{K} \alpha_k \ln x_k^{\,i,t} + \gamma_1 t + \frac{1}{2}\gamma_2 t^2 + \sum_{k=1}^{K} \eta_k \ln x_k^{\,i,t} t; t = 1,\ldots,T, i =,1,\ldots,N$$

$$= CD(x^{i,t}, y^{i,t} / y_m^{\,i,t}, t; \theta) \qquad (10)$$

Where $\hat{\theta} = [\hat{\alpha}, \hat{\gamma}, \hat{\eta}]$ is a vector of estimated parameters. The production possibility curve corresponds to $\ln D_0^{\,t}(x^{i,t}, y^{i,t}) = 0$ and the interior points to $-\infty < \ln D_0^{\,t}(x^{i,t}, y^{i,t}) \leq 0$. The time trend variables appear in two different forms (in a second order polynomial in t and associated with inputs) to allow the identification of non-neutral technical change over time which can vary from time to time and farmer to farmer. Imposing $\sum_{k=1}^{K} \eta_k = 0$ and $\sum_{k=1}^{K} \alpha_k = 1$, assumes neutral technical progress and constant returns to scale, respectively.

3.5.4 Empirical Estimation of the Stochastic Distance Function

To estimate the Cobb-Douglas (CD) distance function in equation (10), the function has to be transformed into a treatable form. One of the properties of output distance function is that homogeneity in outputs (Kumbhakar and Lovell, 2000). This implies that

$$D_0^t(x^{i,t}, \omega y^{i,t}) = \omega D_0^t(x^{i,t}, y^{i,t}), \text{ for any } \omega > 0 \tag{11}$$

Then it is possible to choose one of the outputs arbitrarily (say $y_m^{i,t}$) and set $\omega^{i,t} = 1/y_m^{i,t}$. Therefore,

$$D_0^t(x^{i,t}, y^{i,t}/y_m^{i,t}) = D_0^t(x^{i,t}, y^{i,t})/y_m^{i,t} \tag{12}$$

Transforming in logs and rearranging terms, the distance function in equation (12) can be rewritten as follows with the output selected for normalization as dependent variable.

$$-\ln y_m^{i,t} = CD(x^{i,t}, y^{i,t}/y_m^{i,t}, t; \theta) - \ln D_0^t(x^{i,t}, y^{i,t}), \tag{13}$$

Adding a stochastic error term, the familiar parametric stochastic frontier can be obtained as follows.

$$-\ln y_m^{i,t} = CD(x^{i,t}, y^{i,t}/y_m^{i,t}, t; \theta) - \ln D_0^t(x^{i,t}, y^{i,t}) + v^{i,t}, \tag{14}$$

$$-\ln y_m^{i,t} = CD(x^{i,t}, y^{i,t}/y_m^{i,t}, t; \theta) + \varepsilon^{i,t}, \tag{15}$$

Where $\varepsilon^{i,t} = u^{i,t} + v^{i,t}$ and $u^{i,t} = -\ln D_0^t(x^{i,t}, y^{i,t})$

$\varepsilon^{i,t}$ is the composed error term allowing inefficiency in production($u^{i,t}$) and statistical noise ($v^{i,t}$). The inefficiency term ($u^{i,t}$) is assumed to be a negative random term independently distributed as truncations zero of the $N(\mu, \sigma_u^2)$ distribution. In the literature several time-varying specifications for the technical inefficiency error components is available. This study follows the non-linear specification to separate the time effects following Battese and Coelli (1992).

$$u_{it} = \eta u_i = \{\exp[-\eta(t-T)]\} u_{it}, \tag{16}$$

η is unknown scalar parameter and T is the last period for which observations for the i-th firm are obtained. This model assumes that u_{it} decrease, remain constant or increases, as $\eta > 0$, $\eta = 0$ or $\eta < 0$, respectively. Setting $\eta = 0$ provides the time invariant model set in Battese, Coelli and Colby (1989). On the other hand, $\eta > 0$ implies firms tend to improve their level of efficiency over time and vice versa. $v^{i,t}$ is assumed to be independently and identically distributed $N(0,\sigma_v^2)$ random errors. Moreover, $v^{i,t}$ and $u^{i,t}$ are assumed to be independently distributed.

Based on these assumptions, the probability density function of the composite error term ($\varepsilon^{i,t}$) and its log likelihood function can be derived for the model in equation (16). The maximum likelihood (ML) estimates of the parameters are obtained from the derivatives of the likelihood function. The predicted value of the output distance function (technical efficiency) for producer i in period t can be estimated as the conditional expectation of the inefficiency component in the error term.

$$D_0^t(x^{i,t}, y^{i,t}) = E[\exp(-u^{i,t} / \varepsilon^{i,t})]$$

$$= \left\{ \frac{1-\Phi[\eta\sigma_i^* - (\mu_i^* / \sigma_i^*)]}{1-\Phi(-\mu_i^* / \sigma_i^*)} \right\} \exp[-\eta\mu_i^* + \frac{1}{2}\eta^2\sigma_i^{*2}] \qquad (17)$$

Where

$$\mu_i^* = \frac{\mu\sigma_v^2 - \eta'\sigma^2}{\sigma_v^2 + \eta'\eta\sigma^2},$$

$$\sigma_i^{*2} = \frac{\sigma_v^2\sigma^2}{\sigma_v^2 + \eta'\eta\sigma^2}$$

and $\Phi(.)$ is the distribution function of a standard normal random variable.[13]

[13] Its detailed derivation found in many texts including Coelli *et al.* (2005) and Kumbhakar and Lovell (2000). See also Battese and Coelli (1992).

A semi-logarithmic Cobb-Douglas specification is used to empirically estimate a single output multi-input case of the multi-output/multi-input distance function stared in equation (10) (Coelli *et al.*, 2005; Kumbhakar and Lovell, 2000).

$$\ln y_{it} = \alpha_0 + \alpha_1 \ln rain_{it} + \alpha_2 \ln area_{it} + \alpha_3 \ln lquality_{it} + \alpha_4 labor_{it} + \alpha_5 oxen_{it} + \alpha_6 fert_{it} + \alpha_7 edu_{it} + \alpha_8 farmcapital_{it} + \alpha_9 ext_{it} + \alpha_{10} irr_{it} + \gamma_1 t + \frac{1}{2}\gamma_2 t^2 + \varepsilon_{it},\ i = 1,...,I; t = 1,...,T \quad (18)$$

The dependent variable in equation (18) is the real value of production for all crops produced (y_{it}) by farmers for a given period. Several independent variables are identified as input in the production process. Variables that are supposed to be directly used in the production of crops (conventional inputs) are chosen. These variables have to be also under the control of the farmers decision (Lovell, 1993). t indicates the survey year which is a proxy for Hicks-neutral technical progress. The descriptions of independent variables used in equation (18) are shown in Table 3.1 below.

The amount of seed and other costs of productions (such as hired labor, payment for improved seed, land rental cost and rental of costs among others) are also integral to the production process. Unfortunately, the cost of the later two input variables is not included in the estimation of the model, for data were not collected for some survey years and its definition also varies across surveys. It is admissible that the exclusion of such costs may underestimate the costs of production.

Table 3.1: Description of variables used for the estimation of the stochastic frontier model

Variables	Descriptions
$\ln y_{it}$	the natural logarithm of real value of production for farmer *i* at time *t*
$\ln rain_{it}$	the natural logarithm of the amount of rainfall 12 months before the survey
$\ln area_{it}$	the natural logarithm of area cultivated
$\ln lquality_{it}$	the natural logarithm of land quality index for farmer i in period *t*
$labor_{it}$	the number of family members between the age of 10 and 65 as proxy for family labor
$oxen_{it}$	number of ploughing oxen owned
$fert_{it}$	amount of fertilizer consumption in kg
edu_{it}	years of schooling for the head of the household
$farmcapital_{it}$	the amount of real farm capital owned by the household in Birr
ext_{it}	whether the farmer participated in the government extension program
irr_{it}	Whether the farmers uses irrigation or not
t	the survey year which is a proxy for Hicks-neutral technical progress
α	Parameters to be estimated
γ	Parameters to be estimated
ε_{it}	The composed error term as defined in equation (18)

After estimation of the SFA in equation (18), the Malmquist productivity index in equation (6) should be estimated. The technical efficiency change index (ΔTE) between period *t* and *t+1* is the ratio of the *t+1* distance function to the distance function for period *t*. The technical change index (ΔTC) between period *t* and *t+1* for the *i*th farmer can be calculated directly from the estimated parameters. First evaluate the partial derivatives of the production function with respect to time using the data for the ith firm in period *t* and *t+1*. Then the technical change index between the adjacent periods *t* and *t+1* is calculated as the geometric mean of these two partial derivatives. Finally, the TFP change index is the product of the technical efficiency change index and technical change index (Coelli *et al.*, 2005).

economies in the process of consuming goods and services (Bigsten *et al.*, 2004). The use of per capita consumption, without converting into adult equivalents, as the welfare measure carries the assumption of no economies of household size. This might be a very strong assumption. In this study, unfortunately, adjustment is made only to household size.

There are two commonly used approaches in modeling poverty. The first most widely used method is the direct approach which can be written as follows:

$$P_{\theta,it} = \beta X_{it} + \varepsilon_{it}$$

Where $P_{\theta,it}$ is the Foster, Greer and Thorbecke (FGT) measure of poverty of household *i*, X_{it} represents vector of regressors, the β's are parameters to be estimated and ε_{it} is the error term assumed to be normally, identically and independently distributed with mean 0 and variance σ^2.

The second is termed as indirect approach which is a two-step procedure. First determinants of consumption at household level are modeled as in equation (19) below. At the second stage, poverty predictions are made using the Foster *et al.* (1984) class of poverty measures which can be defined as follows.

$$P_{\theta,it} = [\max(1 - c_{it} / z), 0]^{\theta}, \ \theta \geq 0$$

z represents the poverty line and θ is a nonnegative parameter indicating poverty aversion. When θ takes a value of 0 the poverty measure corresponds to the incidence of poverty or head-count index. Similarly, when θ assumes values of 1 and 2, the poverty measure corresponds to the poverty gap and the squared poverty gap indices, respectively. The aggregate poverty for a given population or subpopulation, with n households can be obtained by the mean of the poverty measure across all households weighted by its household size.

In this study, the indirect approach is preferred for the following three reasons as discussed in the relevant literatures (Mulat *et al.*, 2003, Simler *et al.*, 2004, Datt and Jolliffe, 2005). First, unlike the direct approach, the indirect approach has more informational content for estimation because it does not suppress information on household living standards above the poverty line. In other words, this approach does not treat all non-poor households as homogenous while it is the case in the direct approach. Second, the indirect approach estimates the consumption model independent of the poverty line. As a result, the approach avoids the change in poverty due to the problem of arbitrariness in the choice of the poverty line. Third, the method avoids strong distributional assumptions for the estimation of probit or logit model in the direct approach.

It is worth noting that the view of estimating consumption functions is preferable to directly modeling poverty is not unanimously accepted. There might be occasions to estimate poverty directly (Simler *et al.*, 2004).

In panel data settings, the basic framework for analysis is the unobserved effects model adapted from Wooldridge (2009) and Greene (2003) as follows:

$$\ln(C_{it}) = \alpha_i + \gamma prod_{it} + \beta X_{it} + \varepsilon_{it} \tag{19}$$

where $\ln(C_{it})$ is the natural logarithm of real household consumption per capita of household i, α_i is random individual-specific (unobserved) effects, β are vector of parameters to be estimated, X_{it} represent exogenous regressors listed in Table 3.2. $prod_{it}$ is indicator of productivity of farmers at time *t*. The idiosyncratic error terms (ε_{it}) are assumed to be uncorrelated with the exogenous variables (X_{it}).

Equation (19) can be estimated in three alternative ways based on the assumption made on α_i, the explanatory variables and the error terms. If all the regressors are assumed to be exogenous and the intercept ($\alpha_i = \alpha$) is constant across time and cross-sectional units, the standard ordinary least squares (OLS) procedure gives consistent and efficient estimates for the coefficients. This is often called pooled OLS or pooled regression. On the other hand, if the unobserved effects (α_i) are correlated with the regressors, estimation using pooled OLS is inconsistent and inefficient due to a consequence of omitted variable bias. Thus, the fixed effects model which allows for arbitrary correlation between α_i and the regressors in any time period can be used for unbiased and consistent estimation.

Finally, if the α_i is assumed to be purely a random variable implying that α_i is uncorrelated with the regressors estimation can be made using the random effects estimator. The choice between fixed effects and random effects models depends on whether there is a correlation between the observed explanatory variables and unobserved household specific effects. It is highly unlikely that the unobserved effects are not correlated with the regressors. Unobserved household characteristics such as preference and taste, the attitude of the household members on poverty and working habit, attitude towards food aid and other transfers and consumption habit, which affect consumption but uncounted in the model makes the random effects model less practical. The right model in this regard is, therefore, the fixed effects model. The Hausman test for random effects can also help in choosing which model to use.

The other very useful consideration in the estimation of equation (19) is that ε_{it} is highly likely to be correlated with $prod_{it}$ since $prod_{it}$ is endogenous which is to be determined by many factors. Therefore, the crucial assumption of exogeneity of the regressors is violated. In such cases, unbiased and consistent estimation is made using instrumental variables (IVs) or two stage least squares (2SLS).

The basic identification condition for the IVs to serve as good instruments to consistently estimate equation (19) is that one the one hand, the variables that are to be used as instrumental variables should be correlated with $prod_{it}$ ($\text{cov}(Z_{it}, prod_{it}) \neq 0$) and on the other hand, it should be uncorrelated with ε_{it} ($\text{cov}(Z_{it}, \varepsilon_{it}) = 0$). Since the assumption $\text{cov}(Z_{it}, \varepsilon_{it}) = 0$ cannot be tested, this assumption is maintained through economic reasoning. But $\text{cov}(Z_{it}, prod_{it}) \neq 0$ can be tested (Wooldridge (2009)). To show the test, let's write the $prod_{it}$ variable as a function of a vector of exogenous variables (Z_{it}) to be used as instruments and the other vector of exogenous variables (X_{it}) used in equation (19).

$$prod_{it} = \pi_1 Z_{it} + \pi_2 X_{it} + v_{it} \tag{20}$$

As usual, υ_{it} is assumed to be uncorrelated with Z_{it} and X_{it}. The main identification criteria for Z_{it} to serve as good instruments is that at least one of the coefficients of the variables in Z_{it} must not have $\pi_i = 0$. Thus a test $H_o : \pi_i = 0$ can be made against the two-sided alternative hypothesis: $H_1 : \pi_i \neq 0$.

The independent variables that are hypothesized to determine household consumption and hence poverty are listed in Table 3.2 below. The direction of their impact on consumption per capita per household is also indicated in the third column. Since the main interest of this study is to see the impact of growth in productivity on household consumption, productivity is represented by the growth in TFP, technical efficiency growth and technical change of farmers at time *t*. It is also hypothesized to have a positive impact as stated in the conceptual framework and hypothesis.

Table 3.2: Independent variables used for the estimation of the consumption model

Variables	Descriptions	Impact
sex	sex of the head of the household(1=Male-headed, 0 otherwise)	positive
age	age of the head of the household	negative
edu_h	Years of schooling for the head of the household	positive
h_size	Household size	negative
dep_ratio	dependency ratio	negative
creditc	access to credit for consumption purposes	positive
tlu	livestock ownership in tropical livestock units (TLUs)	positive
fpi	village level price index	negative
off_farm	participation in off-farm activities (1=Yes, 0 otherwise)	positive
$prod_{it}$	Technical efficiency growth , TFP growth and technical change	positive
dis_mkt	distance to nearest markets	negative

A set of household demographic variables including age, sex, education of the head of the household, household size and dependency ratio is also included in the regression. Dependency ratio and household size are expected to have a negative effect on household consumption. On the other hand, households with higher age of the head, being male-headed and with more years of schooling affect consumption positively.

High inflationary pressures imply low purchasing power of the birr and this might led households to end up in low consumption level. Village level price index (*fpi*) is used to control for inflationary pressures that might affect real per capita consumption.

Households might also smooth out their consumption through participation in off-farm activities and or borrowing. These two variables are controlled by dummy variables if members of households participate in off-farm activities (*off_farm*) and if the households have access to credit for the purpose of household consumption (*creditc*). Besides, wealth of households represented by household livestock ownership (*tlu*) in tropical livestock units (TLUs) is used as determinants of household consumption. The higher the wealth of the household, the higher will be its per capita consumption.

Finally, markets play a valuable role in promoting and facilitating exchange of goods and services. Therefore, proximity to urban areas measured by distance to towns (dis_mkt) is hypothesized to negatively and significantly affect per capita consumption.

When θ takes a value of 0, the poverty measure boils down to the head-count index ($P_{0,it}$):

$$P_{0,it} = \int_0^z \frac{1}{C_{it}\sigma\sqrt{2\pi}} \exp\left\{-\frac{1}{2\sigma^2}(\ln(C_{it}) - \beta X_{it})^2\right\} dC_{it} = \Phi\left(\frac{\ln(z) - \beta X_{it}}{\sigma}\right) \qquad (24)$$

$P_{0,it}$ measures the proportion of the population below the poverty line.

When θ takes a value of 1, the poverty measure boils down to the poverty gap index ($P_{1,it}$) or depth of poverty:

$$P_{1,it} = \int_0^z \left(\frac{z_t - C_{it}}{z_t}\right) \frac{1}{C_{it}\sigma\sqrt{2\pi}} \exp\left\{-\frac{1}{2\sigma^2}(\ln(C_{it}) - \beta X_{it})^2\right\} dC_{it} \qquad (25)$$

$$= \Phi\left(\frac{\ln(z_t) - \beta X_{it}}{\sigma}\right) - \frac{1}{z_t}\exp\left(\beta X_{it} + \frac{1}{2}\sigma^2)\right)\Phi\left(\frac{\ln(z_t) - \beta X_{it}}{\sigma} - \sigma\right) \qquad (26)$$

$P_{1,it}$ measures the extent to which individuals on average fall below the poverty line indicating the poverty gap. It can also be considered as a measure of the minimum cost of eliminating poverty relative to the poverty line.

Similarly, when θ takes a value of 2, the poverty measure boils down to the squared poverty gap index ($P_{2,it}$) or severity of poverty:

$$\begin{aligned} P_{2,it} &= \int_0^z \left(\frac{z_t - C_{it}}{z_t}\right)^2 \frac{1}{C_{it}\sigma\sqrt{2\pi}} \exp\left\{-\frac{1}{2\sigma^2}(\ln(C_{it}) - \beta X_{it})^2\right\} dC_{it} \\ &= \Phi\left(\frac{\ln(z_t) - \beta X_{it}}{\sigma}\right) - \frac{2}{z}\exp\left(\beta X_{it} + \frac{1}{2}\sigma^2)\right)\Phi\left(\frac{\ln(z_t) - \beta X_{it}}{\sigma} - \sigma\right) \qquad (27) \\ &+ \frac{1}{z_t^2}\exp(2\beta X_{it} + 2\sigma^2)\Phi\left(\frac{\ln(z_t) - \beta X_{it}}{\sigma} - 2\sigma\right) \end{aligned}$$

The squared poverty gap index implicitly puts more weight on observations that fall far below the poverty line. The measure is not easy to interpret and lacks intuitive appeal. Φ represents the standard normal distribution function. Predicted measures of poverty are obtained as the weighted averages of the estimated household probabilities of being poor corresponding to every predicted level of real per capita consumption.

CHAPTER IV

FINDINGS OF THE STUDY

In this chapter, the results and interpretation of the study are discussed. The first section attempts to present the descriptive statistics for the models developed in chapter III. The second section discusses the econometric results of the SFA model. In the third section, the sources of agricultural total factor productivity growth are presented. The last two sections are devoted to present the impact of growth in productivity, technical efficiency, on household welfare and the impact of alternative scenarios of government interventions for poverty reductions, respectively.

4.1 Descriptive Statistics

On average, as table 4.1 below shows, the age of the head of households were nearly 45 years in 1994. Male headship declined over the survey years. 86 per cent of the households were headed by male in 1994. However, the percentage of households headed by male dropped to 68 per cent in 2009. The data also showed that dependency ratio declined from nearly 1.5 in 1994 to less than 0.6 for other survey years. This implies that many members of households joined the working age population which helps in reducing the negative effect of higher dependency ratio on household welfare. However, the total household size did not change very much as compared to the change in household composition. It remained more than 5.95 in 2009 as compared to the 6.57 before fifteen years, 1994.

In 1994, 35 per cent of the households participated in different kinds of off-farm activities. The participation rate dropped to 22 per cent in 1999 and consistently rose to 36 per cent in 2004 and 41 per cent in 2009. The ERHS questionnaire asks if a member in the household have taken out a loan of at least 20 Birr. The percentage of people who obtained access to credit increased from 13 per cent in 1994 to 54, 56, and 64 per cent in 1999, 2004 and 2009 respectively. In this regard, access to credit is expected to help subsistence households to smooth out their consumption. Distance to the nearest towns in kilometers does not change over time indicating that there is no significant change in their proximity to markets and towns. On average, wealth of households measured by livestock ownership in tropical livestock units (TLUs) consistently rose from 2.9 in 1994 to 5.49 in 2009.

Table 4.1: Mean value of the variables used for the estimation of the household consumption model 1994-2009

Variables	1994	1999	2004	2009
Real consumption per capita	71.7	86.1	91	61.5
Sex of the head of the household	0.86	0.83	0.85	0.68
Age of the head of the household	45	49	51	53
Head's years of schooling	1.76	1.81	1.91	2.44
Household size	6.57	6.32	6.02	5.95
Dependency ratio	1.49	0.47	0.55	0.50
Percentage of households who have access to credit (1=Yes,0 otherwise)	0.13	0.54	0.56	0.64
Oxen ownership in tropical livestock units (TLUs)	2.90	3.16	3.29	5.49
Village food price index	100	114	115	352
Participation in off-farm activities (1=Yes,0 otherwise)	0.35	0.22	0.36	0.41
Technical efficiency	0.53	0.59	0.64	0.69
Distance to the nearest towns in kilometers	11.3	10.2	9.6	12.0

Source: calculated from the ERHS data

As Table 4.1 shows, real consumption per capita rose from nearly 78 birr to 86 birr in 1999 and 92 Birr in 2004. However, it sharply dropped to 62 Birr in 2009. It is surprising that mean real consumption per capita declined in 2009 in the middle of higher real value of output (see Table 4.2). Dercon *et al.* (2011) attributed the decline in real consumption per capita between 2004 and 2009 to severe localized droughts that caused considerable income loss in several villages in Tigray and Southern Nations, Nationalities and People Region (SNNPR). There was also unprecedented rise in the village level food price index. The index more than doubled, between 2004 and 2009 more than the rate of average growth in real value of production, not more than 7 per cent (from 2,475.42 birr to 2,618.61 birr). Dercon *et al.* (2011) also stated that many households in the ERHS data are net food buyers, the 2008 and 2009 price hike might reduce quantities consumed.

An indicator of productivity, technical efficiency of farmers, grew from 53 per cent to 69 per cent between 1994 and 2009. Figure 4.1 shows that the technical efficiency of many farmers scattered below 0.5 for the three consecutive survey years. However, as the bottom right panel of Figure 4.1 depicts the scatters are concentrated above 0.5 showing improvements in technical efficiency in 2009. A closer look at on the link between real consumption per capita and technical efficiency from the graph reveals that technical efficiency and real consumption per capita are positively correlated. This suggests that improving technical efficiency of farmers is important to increase production and hence real consumption per capita.

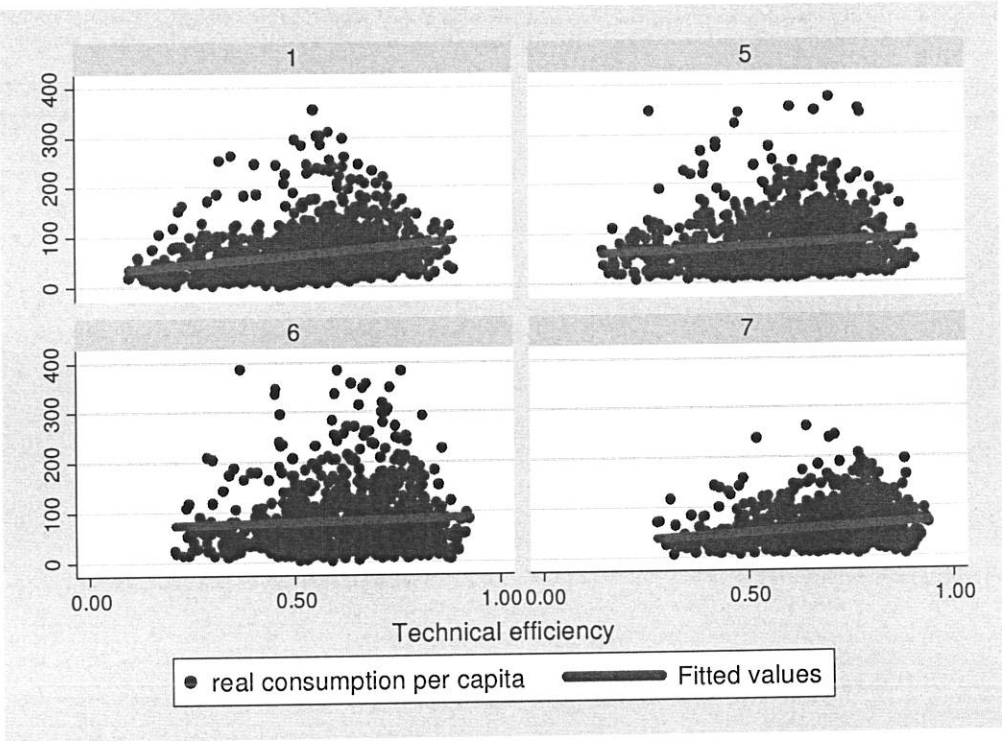


Figure 4.1: Scatter plot for real consumption per capita and technical efficiency by survey years 1994- 2009

A summary of the data on the different variables used in the stochastic frontier is given in Table 4.2. Farmers' real value of output was used as a dependent variable in the stochastic frontier model. It consistently rose across all survey years from nearly 1918 birr in 1994 to nearly 2619 birr in 2009.

As Table 4.2 also shows ownership of farm capital in real terms, years of schooling and participation in the extension program sharply rose over time. Use of irrigation reported by farmers' also increased from 3 per cent to 23 per cent in 2004 and declined to 9 per cent in 2009. The lower percentage of irrigation use in 2009 may be due to problems in the proxy used where water harvesting is used to represent it. Similarly, extension participation was also represented by extension visit which might exaggerate the percentage of households who participated in the extension program (49 per cent).

Except a slight decline in 2004 survey year as compared to 1999, fertilizer consumption grew. On the other hand, family labor in adult equivalent steadily dropped from 3.51 in 1994 to 2.78 in 2009. Perhaps some members left their households for various reasons including migration and marriage.

Area cultivated increased from 1.52 hectare in 1994 to 1.69 in 2009. The area expansion was also accompanied by an increase in average land quality index from 2.38 in 1994 to 1.95 in 2009.[14] Results of the descriptive analysis show that the amount of rainfall 12 months before the survey showed a decline in 2009. One fact which emerges out from the descriptive statistics above is that the growth in real value of output is partly due to increasing use of the factors of production.

Table 4.2: Mean values of households input-output data used in stochastic production frontier 1994-2009

Variables	1994	1999	2004	2009
Real value of output(in Birr)	1,917.70	2,218.11	2,475.42	2,618.61
Area Cultivated (in hectare)	1.52	1.29	1.70	1.69
Amount of rainfall 12 months before the survey	1,059.11	1,114.01	1,037.19	989.01
Average land quality Index	2.38	2.03	2.05	1.95
Family labor in male adult equivalent	3.51	3.24	2.82	2.78
Number of ploughing oxen	0.98	1.07	0.90	1.00
Amount of Fertilizer used (kg)	41.84	64.48	62.44	68.50
Years of Schooling of the head	1.76	1.81	1.91	2.44
Real value of farm capital(in Birr)	33.21	43.80	48.99	62.09
Participation in the extension program(Yes=1)	0.13	0.14	0.17	0.49
Farmers' Irrigation use(Yes=1)	0.03	0.11	0.23	0.09

Source: Calculated from the ERHS data

[14] As discussed in chapter III section 3.2, the closer the index to one, the higher the quality of land while it closer the index to nine, the lower is the quality of the index.

Moreover, on average, not only farmers overall resource utilization efficiency (technical efficiency) increased but labor productivity which is the ratio of real value of production in birr to the number of family labor in adult equivalents also increased significantly. Similarly, labor productivity for the median farmers also showed a significant rise in the survey years as shown in Table 4.3.

On the other hand, average land productivity (real value of production in birr per hectare) deteriorated from 5790 birr in 1994 to 1748 birr in 2004 and 3064 birr in 2009. This happens mainly because of extreme observations in the data. The median land productivity has improved over time as the third column of Table 4.3 shows.

The last column of Table 4.3 also shows land-labor ratio which might serve as an indicator of relative scarcity of land. The median land-labor ratio declined from 0.38 in 1994 to 0.36 in 1999 and rose up to nearly 0.5 in 2004 and 2009. For a given amount of area cultivated, land-labor ratio rose mainly due to the decline in the number of family labor from time to time as shown in Table 4.1. But it is clear that land is very scarce for these households. On average, an adult can only have less than half a hectare of land. This might be also an indication of the constraint in expanding area under cultivation underscoring the importance of increasing the productivity of factors of productions.

Table 4.3: Land and labor productivity for the ERHS households 1994 -2009 (in Birr)

Year		Land productivity	Labor productivity	Land-labor ratio*
	Average	5,790.35	562.96	0.52
1994	**Median**	**970**	**362.17**	**0.38**
	Average	5,072.81	779.13	0.5
1999	**Median**	**1,516.59**	**536.2**	**0.36**
	Average	1,747.90	1,004.36	0.79
2004	**Median**	**1,294.43**	**634.5**	**0.5**
	Average	3,064.84	1,007.62	0.75
2009	**Median**	**1,294.46**	**692.99**	**0.504**

Source: calculated from the ERHS data

* The number of household members between the age of 10 and 65 years are used to proxy labor use for the households.

The above analysis made it clear that for the median farmers' technical efficiency, labor productivity and land productivity showed improvement over the last 16 years. The results are also consistent with the growth in yield for crops as documented in Alemayehu *et al.* (2011) using the CSA nationally representative data. The improvement in these productivity indicators is expected to improve household welfare.

4.2 Econometric Results of the Stochastic Frontier Model

In this section attempt is made to directly present the results of the stochastic frontier since the way the data is built up is explained in chapter III at length. The Malmquist Productivity Index was estimated through the estimation of a parametric distance function. Its specification corresponds to a semi-logarithmic Cobb-Douglas specification production technology as defined in equation (18) in chapter III.

The findings are presented in Table 4.4. The Wald test shows the explanatory variables are jointly significant enough in explaining the dependent variable. This suggests that the estimated model is a good fit of the observed data. Heteroskedasicity might be inherent in the data. But the maximum likelihood estimator of the stochastic frontier model uses the observed information matrix (OIM) method of handling heteroskedasicity problems during the estimation of the variance–covariance matrix.

Besides, all the explanatory variables have the expected sign. The value of eta $(\hat{\eta})$ is highly significant indicating technical efficiency improves over time by the rate of 0.0143. In other words, the degree of inefficiency decreases over time by a factor of 0.0143. The variation in the inefficiency term $(\hat{\gamma})$ also explains 24 per cent of the total variance in the composed error term.

Real value of output is highly elastic to the amount of cultivated land. It is statistically significant at 1 per cent. Increasing the amount of area cultivated by 10 per cent, increases output by more than 2.3 per cent. Besides, real value of output is also elastic to the quality of the cultivated land. In this regard, the government's effort in improving the quality of land through improved land management practices is very commendable.

The elasticity of rainfall to real value of output is also high. It is not a surprising result since the Ethiopian agriculture is highly dependent on rainfall. The recurrence of drought and erratic rainfall significantly affects agricultural output and productivity of farmers. There were more than 37 per cent households who reported that their crop production was affected due to the occurrence of drought in

2009. The implication is that development policy should promote the use of alternative water sources in terms of water harvesting and or irrigation. The elasticity of the dummy for irrigation use by farmers is very high. The result suggests that investment on irrigation and or improved water management technologies tends to increase income of farmers consistent with Fistum *et al.* (2010).

Participating in government extension program is also highly elastic with real value of output. The sum of the elasticity of education and participation in the extension program with respect to real value of output is 0.236. This suggests that expansion of primary education and agricultural extension services are very important to raise real value of output.

As expected, the proxy for labor (family labor of age above 10 years and below 65 years of age) is highly elastic to output. It is statistically significant at 1 per cent. The estimated elasticity indicated that, a 10 per cent increase in labor, increases output by nearly 2 per cent. The implication is that in peak seasons, shortage of labor may reduces output significantly.

As discussed in the descriptive statistics, average real value of farm capital rose significantly over the surveyed years but its impact on output is very low as compared to other inputs. The elasticity of real farm capital to real value of output is 0.065.

Although the sign of the coefficient is positive as expected, the elasticity of oxen ownership is less responsive to output as compared to other inputs. It is also statistically significant at 1 per cent. In oxen dependent economy, this result seems strange. For a small plot of land, owning more ploughing ox may not be a cost-effective way which may lead farmers to switch to traditional ox-sharing arrangements.

The use of fertilizer consumption is highly elastic to real value of output at a high level of significance for the surveyed farmers. It shows that doubling the amount of fertilizer consumed will lead to a rise in real value of output by nearly 16 per cent. Hence, using fertilizer together with other complementary inputs such as irrigation increases output.

The last independent variable is the non-monotonous Hicks-neutral technical progress indicated by the time trend. The coefficient of time is 0.032, which indicates mean technical progress of 3.2 per cent per year. The negative coefficient of time squared indicates that the rate of technical progress decreases over time.

The findings are consistent with results of recent studies made by Fantu *et al.* (2011) and Fantu (2009) using the same data. However, the elasticity of output with respect to fertilizer consumption in this study is high in contrary to the results of these studies. The number of oxen ownership is also less responsive to output contrary to their results. These might be due to various reasons. First, the sample is smaller than these studies and additional variable, the dummy for use of irrigation, was also included while they did not. Moreover, the way farm capital is defined is different from them. The value of self-reported ownership of plough, hoe and sickle is aggregated to create one explanatory variable (farm capital). But they estimated it as count on the number of plough and hoe ownership excluding the number of sickle ownership. Using only the variables used by Fantu *et al.* (2011) and Fantu (2009), the results of the stochastic frontier are almost identical with the initial estimates. Perhaps fertilizer consumption and its application rate may significantly and systematically differ from those of the excluded households (for oxen ownership too).

Table 4.4: Results of the stochastic frontier model

Explanatory variables	Coefficient	Calculated Elasticity	Std. Err.	z	P>z
Constant	6.497		0.36	18.08	0.000
Family labor in male adult equivalent	0.068	0.210	0.01	6.87	0.000
Number of ploughing oxen	0.092	0.091	0.02	6.1	0.000
Amount of fertilizer used	0.003	0.163	0.00	14.44	0.000
Logarithm of area cultivated (hectare)	0.231	0.231	0.02	13.21	0.000
Logarithm of average land quality	-0.111	-0.111	0.03	-3.19	0.001
Years of schooling of the head	0.037	0.073	0.01	6.25	0.000
Logarithm of amount of rainfall 12 months before the survey	0.102	0.102	0.05	1.86	0.063
Real value of farm capital(in Birr)	0.001	0.065	0.00	5.49	0.000
Participated in New extension program	0.151	0.163	0.04	4.2	0.000
Farmers' Irrigation use	0.118	0.125	0.05	2.54	0.011
time	0.032		0.02	1.76	0.079
time squared	-0.002		0.00	-3.74	0.000
$\hat{\mu}$	0.12		0.42	0.27	0.784
$\hat{\eta}$	0.014		0.01	3.8	0.000
$\hat{\sigma}^2$	0.88		0.16		
$\hat{\gamma}$	0.24		0.13		
$\hat{\sigma}_u^2$	0.21		0.15		
$\hat{\sigma}_v^2$	0.67		0.02		

Log likelihood = -5272.8586; Wald chi2 (12) = 1327.86; Prob > chi2 = 0.0000
Source: estimated from the SFA model

As discussed in chapter III, the price for 1999 is calculated by scaling up the 1997 crop price data using the inflation rates for each village calculated by the IFPRI. Value of production was also aggregated using the zone level CSA producer price data for each village as an alternative. The coefficients and elasticity of the independent variables are similar to the initial estimates discussed above except the time indicator and oxen ownership. Oxen ownership is found to be more elastic to output than the initial estimates pronouncing the marked contribution of ploughing oxen for subsistence agricultural production. The time trend and its squared become negative and positive, respectively, as opposed to the initial estimates (see Appendix A for the results).

4.3 Sources of Agricultural Total Factor Productivity (TFP)

Having obtained the maximum likelihood estimates of the production technology, it is easy to calculate the Malmquist Productivity Index which shows the change in the total factor productivity and its sources (decompositions) across survey years. Since the index is based on discrete time, each household will have an index for every pair of years. Instead of presenting the detailed results for each household in each year, the average of the index for each agro-ecology is presented.

The results in Table 4.5 show that agricultural TFP grew by 16 per cent, 11 per cent and 4 per cent in 1999, 2004 and 2009, respectively. At the same time, the efficiency change index also went up by 15 per cent, 12 per cent and 10 per cent in the same period. On the other hand, the Hicks-neutral technical change index declined for all other years except for the period between 1994 and 1999 in all villages.

The growth of TFP and technical efficiency indices is higher for 1999 while it increased at a decreasing rate between 2004 and 2009. The technical change index also grew between 1994 and 1999 by nearly 1 per cent but declined in other years. The rise in the technical change index may be attributed to problems in the price data used for aggregation of the quantity of production rather than real technical progress. In section 4.2, it is noted that when the CSA price data are used to aggregate the dependent variable (real value of production) the coefficients of time has a negative sign and a positive sign for its quadratic term showing technological regress. The result of the technical change index using the scaled up ERHS 1997 price to aggregate production shows technical regress after 1999. On the other hand, when the zone level CSA producer price data are used, results indicate that the technical change index is below one showing a regress in technology all the time. But it showed little improvement from time to time (see Appendix B).

The clear picture from both ways of aggregating production is that growth in agricultural TFP is due to improvements in technical efficiency. The main source for TFP growth over these periods was, therefore, the improvements in technical efficiency of farmers. The results showed that remarkable and consistent growth in technical efficiency of farmers of all households throughout the survey years. On average, the technical efficiency of farmers rose from nearly 53 per cent in 1994 to nearly 59 per cent; nearly 64 per cent and 69 per cent in 1999, 2004 and 2009, respectively (see Table 4.1). This implies that, on average, there was at least a 30 per cent shortfall in technical efficiency deviated from the frontier in 2009. Thus, under the current state of technology, farmers can still increase their productivity through more efficient use of the available factors of production.[15]

When the CSA price data are used, most farmers become more efficient. On average, there is only nearly 9 per cent shortfall in technical efficiency deviated from the frontier in 2009 (see appendix C).

Moreover, variations in growth of TFP scores emerge out across villages. Households in the Northern Highlands have the highest TFP change indices for all periods while the households in the Arsi-Bale Highlands turned out to be the second highest in the TFP change index. The least is for the *Enset* growing households. The same thing happens for the technical efficiency Index. The Northern Highlands has also the highest TFP and efficiency change index. Although the Northern Highlands are resource-poor, the findings showed that farmers are more efficient and more productive than other areas (detailed village level indices are found in Appendix D). The production frontier of the Northern Highlands is superior to other regions consistent with Fantu (2009).

[15] The determinants of the growth in technical efficiency are extensively analyzed by Fantu *et al.* (2011) and Fantu (2009).

Table 4.5: Decomposition of the Malmquist Productivity Index from 1994-2009 by agro ecology.

	TFP Change Index			TE Change Index			Technical Change Index*		
Agro-ecology	1999	2004	2009	1999	2004	2009	1999	2004	2009
Northern highlands	1.30	1.21	1.14	1.28	1.23	1.18	1.01	0.99	0.97
Central highlands	1.13	1.08	1.04	1.12	1.10	1.08	1.01	0.99	0.97
Arsi/Bale highlands	1.16	1.11	1.06	1.14	1.12	1.10	1.01	0.99	0.97
Harerge highlands	1.09	1.05	1.02	1.07	1.06	1.05	1.01	0.99	0.97
Enset based	1.15	1.10	1.06	1.14	1.11	1.09	1.01	0.99	0.97
Overall mean	**1.17**	**1.11**	**1.06**	**1.15**	**1.12**	**1.10**	**1.01**	**0.99**	**0.97**

Source: authors' computation from the SFA model; * the technical change index is constant because of the Hicks-neutrality assumption.

A qualitative study made by Bevan *et al.* (2011), for the six of the 15 ERHS villages[16], indicated accelerating modernization in terms of economic improvements, lifestyle changes, improved service provision, increased access to justice, and declining gender inequalities between 1995 and 2010. Government and some aid-supported interventions were the key drivers of accelerating modernization process. But "the contribution of direct economic interventions involving extension services, improved seeds and fertilizer, and in some places small scale irrigation, varied significantly among the communities".[17] They stated that many destitute people and the youth are less benefited from the government services. One may claim, however, that efforts of the government for local development in the study villages might help to improve the efficiency of farmers over time supporting the evidence of increasing technical efficiency change index as discussed before.

[16] The six ERHS villages for the qualitative studies were Imdibir, Trirufe Ketchema, Korodegaga, Geblen, Dinki and Yetmen.

[17] Bevan *et al.* (2011) page 1.

It seems, however, that the impact of these developments on the state of knowledge of farmers is limited, as witnessed by the decline in technical change index. The marginal returns from the current farming techniques are on the decline. Farmers' techniques of production are traditional ploughs and hoe-based rudimentary technology. Thus, it is fair to claim that there is no growth in the state of knowledge of the farmers that significantly shifts the production frontier upward. This may indicate obsolesce and un-sustainability of the farming technology given the current conditions in the countryside. This finding is relevant for policy making showing the importance of developing new context-relevant farming techniques for each farming communities. However, it is not the objective of this study to claim any kind of technology and how it could be developed. A good introduction for the *pros* and *cons* of technology transfer from advanced and developing new ones domestically can be found in Fassil (2005). A more general treatment of technological change and development can also be found in Szirmai (2005).

To sum up, as the elasticity of many of the inputs showed in the second section, it is possible to increase production in the short-run by increasing use of inputs. Increasing the amount of fertilizer together with other complementary inputs such as water harvesting and increasing use of irrigation helps to increase output. It is also possible to increase the quality of cultivated land through improved farm management techniques. However, farmers do not always have the room of increasing the inputs indefinitely. Diminishing marginal returns sets in at some point.

The longer-term solution to boost production is through increasing productivity. That is, through increasing efficiency for the use of available inputs and introducing new techniques of production. Although the data shows decline in the technical change index, agricultural TFP and technical efficiency increased over the survey years. However, interpretation of the results should be made with care since the results are sensitive to changes in the price data used for the aggregation of quantity of production into value of production which served as a dependent variable.

To what extent the growth in technical efficiency and technical change affects household poverty is relevant for public policy making. An attempt is made to investigate this question in section 4.5. Before that it is important to look at the poverty profile and persistence of rural households.

4.4 Poverty Profile and Poverty Persistence of Rural Households

The cost-of-basic-needs approach was used to estimate the poverty line. Based on the 1994 data, a food poverty line was constructed by valuing a bundle of food items providing 2300 kilo calorie (Kcal). A specific value for this basket was obtained per survey site. Then an estimated non-food share was added to obtain the total consumption poverty line per day per adult. The poverty line is 50 Birr per capita per month (Dercon *et al.*, 2011; see Dercon and Krishnan, 1998 for detailed method).

The percentage of households who are below the poverty line (the head count index) declined from nearly 46 per cent in 1994 to 38 per cent in 1999 and 36 per cent in 2004. In line with the sharp drop in real consumption per capita in 2009 as stated in Section 4.1, the percentage of households who live below the poverty line jumped up to 50 per cent. Besides, Table 4.6 shows that the poverty gap index which indicates the minimum required amount of resources needed to bring all the poor to the level of the poverty line declined from nearly 24 per cent in 1994 to nearly 16 per cent in 1999 and 15 per cent of the poverty line in 2004. However, the minimum required to fill the poverty gap increased to nearly 21 per cent of the poverty line in 2009. Similarly, the squared poverty gap index declined between 1994 and 2004 as shown in the last column of Table 4.6. The squared poverty gap index also increased in 2009.

Table 4.6: Evolution of rural poverty for the sample households (in per cent) 1994–2009

Year	Head count poverty	Poverty gap	Squared poverty gap
1994	46.18	23.858	13.919
1999	37.84	16.308	8.149
2004	35.85	15.012	7.87
2009	49.45	21.069	11.013

Source: calculated from the ERHS data

In this study, poverty persistence is defined according to the proportion of households that are always, sometimes, or never poor across survey rounds. Consequently, those households who faced poverty transiently are called transiently poor. Households who live in poverty throughout the survey years are regarded as chronically poor. The non-poor households are those who did not fall into poverty throughout the survey years. Household poverty persistence is depicted in Figure 4.2 below. Out of 1007 households, only 209 (21 per cent) households remained non-poor. 95 households (9 per cent) were chronically poor (always poor). The remaining 703 (nearly 70 per cent of the sample households) households are transiently poor across survey years. For example, 45 households who were non-poor in 1994 fell into poverty between 1999 and 2009. Moreover, 90 households moved out of poverty between 1999 and 2009 after falling into poverty in 1994.

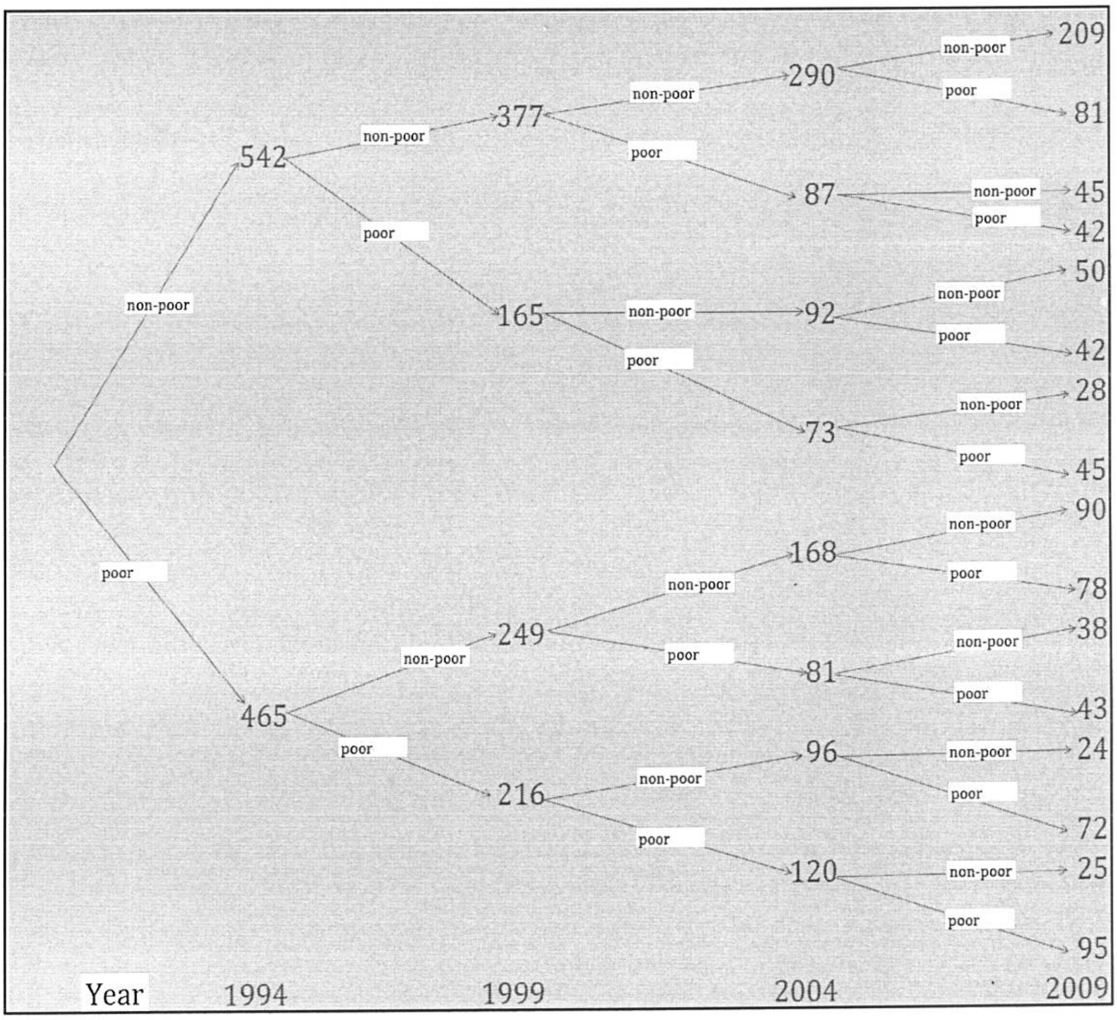


Figure 4.2: Poverty persistence for rural households 1994 - 2009

Table 4.7 provides the factors that are closely correlated with the persistence of poverty. Relative to the non-poor, the chronically poor and the transiently poor households have higher household size, higher dependency ratio, low livestock ownership and low productivity as indicated by their technical efficiency scores. Education of the non-poor is higher than the chronic poor and the transiently poor. Chronically poor households also have low credit access as compared to the non-poor households which limits their ability to smooth out their consumption and also constrained their ability to purchase agricultural inputs. Beside, in rural Ethiopia, off-farm activities serve as a coping mechanism for poorer households since chronically poor households have higher percentage of participation in off-farm activities.

Table 4.7: Household characteristics and persistent poverty 1994–2009

	Poverty Persistence		
Household Characteristics	**Non-poor**	**Always poor**	**Transiently poor**
Household size (numbers)	5.68	7.34	6.22
Dependency Ratio	0.74	0.82	0.75
education of the head	2.21	1.88	1.93
Participation in off-farm activities (1=Yes)	0.33	0.36	0.33
livestock ownership in TLUs	5.50	2.22	3.38
Access to credit (1=Yes)	0.60	0.51	0.56
Technical efficiency	0.65	0.56	0.60

Source: Calculated from the ERHS data

In sum, persistence of poverty is negatively correlated with productivity, education, livestock ownership and participation in off-farm activities while it is positively correlated with household size and dependency ratio.

4.5 The Impact of Agricultural Productivity on Household Poverty

Before presenting results of the model, it is important to mention three important points during the estimation of equation (19). First, the intention of this study was to use the agricultural TFP change index and its decompositions (the technical efficiency change index and technical change index) as regressors to $prod_{it}$ in equation (19). However, finding appropriate instruments for the TFP change index and the technical change index is the challenge. Results of the sources of total factor productivity growth also revealed that agricultural TFP growth were mainly due to growth in the technical efficiency component. As a result, it seems reasonable to represent $prod_{it}$ by the technical efficiency (TE_{it}) of farmers at time t.

Second, as noted in chapter III, ε_{it} is highly likely to be correlated with TE_{it} since TE_{it} is endogenous which is to be determined by many factors. As outlined in Wooldridge (2009), attempt was made to find exogenous variables which are correlated with TE_{it} but uncorrelated with the error terms (ε_{it}) in equation (19). Variables believed to serve as instruments to consistently estimate parameters of the regression are: number of plots farmers cultivated, a dummy variable if crops were affected by drought, a dummy variable if crops were affected because a farmer or someone in the family was too ill, a dummy variable if farmers participate in the extension program, whether farmers use irrigation and a dummy variable if the farmers owns more than one ploughing oxen.

Using these variables as instruments for TE_{it}, equation (19) is estimated. Results show that access to credit was insignificant with unexpected negative sign. This implies that having more access to credit reduces household consumption per capita which is counter-intuitive. Credit may also be endogenous. The poor may not have access to credit because they are poor. Conversely, the poor may be poor because they may not have access to credit (Alemayehu *et al.,* 2006). To achieve unbiasedness and consistency of estimates, similar steps to the endogenous TE_{it} were followed.

Access to credit depends on the repayment capacity of rural households. Variables that indicate the wealth of households are good indicators of access to credit which can serve as instruments. Livestock ownership, number of ploughing oxen, area cultivated by the household and value of farm assets might be good instruments. Livestock ownership cannot be used as instrument because it is correlated with poverty. Besides, a dummy variable if households have more than one ploughing oxen is used as instrument for technical efficiency. Since credit is binary, the logit fixed effects estimator was used to predict the probability of obtaining credit using area cultivated and farm asset ownership as instruments. The predicted probability of obtaining credit is used in the second-stage regression of equation (19).

The instrumental variables for technical efficiency: drought, illness, plot and irrigation are statistically different from zero at 1 per cent level of significance. On the other hand, participation in extension and the dummy variable for owning more than one ploughing oxen are not significant. The instruments cultivated land and farm asset ownership for credit is statistically different from zero at 10 per cent and 5 per cent, respectively. This suggests that the identification criteria mentioned in equation (20) for the instruments in both endogenous variables (credit and technical efficiency) are fulfilled (see Appendix F and G for the detailed estimates).

After controlling for the above-mentioned endogeneity problems, the findings are presented in Table 4.8 below. Estimation was made using fixed effects estimator. As argued in chapter III, unobserved household characteristics such as preference and taste may be correlated with the regressors. The choice of fixed effects over random effects was also supported by Hausman test for random effects (see the last raw of Table 4.8).[18]

The Wald test indicates that the coefficients are jointly statistically significantly different from zero. Besides, all coefficients have the expected sign and individually significant at 10 per cent for years of schooling, dependency ratio and the probability of obtaining credit. The remaining variables are highly statistically significant at 5 per cent and less level of significance. However, the coefficient of age is not statistically significantly different from zero. The model was also specified including a quadratic term for age to see any non-linearity in age. It is found that the result is similar to the model without the quadratic term in age.

The findings show that growth in productivity, as indicated by growth in technical efficiency (TE_{it}), has a positive and significant impact on real household consumption per capita. On average, a 10 per cent increase in technical efficiency increases household consumption per capita by nearly 15 per cent (see model 1 in Table 4.8). This finding confirms the hypothesis of this study and findings of

[18] The Hausman test tests whether the fixed effects and random effects estimator are significantly different. Under the null hypothesis, we assume that the $p\lim(\beta_{FE} - \beta_{RE}) = 0$. β_{FE} is the fixed effects estimator and β_{RE} is the random effects estimator Verbeek (2004).

previous studies made by Dorosh and Thurlow (2009) and Dio and Pratt (2005) in Ethiopia. It also confirms the findings of the cross-country study made by Thirtle *et al.* (2001).

However, when the technical efficiency estimates using the CSA price data is used as regressor, the impact of growth in technical efficiency on real consumption per capita is very small as compared to initial estimates. A 10 per cent increase in technical efficiency only increased real consumption per capita by nearly 5.3 per cent (Appendix E). As explained before, when the CSA price data are used most farmers become more efficient. Consequently, once famers become more efficient, that is, used their resources more efficiently, the impact of technical efficiency on real consumption per capita is negligible.

Fixed effects regression using real value of output in birr per land area cultivated in hectare and land area cultivated per family labor in adult equivalents was also made to see the impact of different productivity indicators on real per capita household consumption. Model two indicates that, on average, increasing land productivity by 10 per cent increases real consumption per capita by nearly 0.74 per cent. As model 3 made it clear, increasing labor productivity also increases real consumption per capita by almost the same rate as land productivity.

Irz *et al.* (2001) decomposed value-added per unit of labor into value-added per land cultivated and land cultivated per unit labor. Land cultivated per unit of labor indicates the relative shortage of land. The lower this ratio, the higher is shortage of land for a unit of labor. Following this logic, attempt was made to decompose real value of output per unit of labor into real value of output per area cultivated and land area cultivated in hectare per unit of labor. Model 4 shows the impact of land scarcity and land productivity on real consumption per capita. The coefficient of land productivity shows similar impact though it slightly increased by 0.003 as compared to model 2. The land scarcity coefficient is positive indicating that mitigating the problem of land shortage helps to enhance household welfare. Even though these coefficients are quite small, the findings are in line with many studies including Godoy and Dewbre (2010), Christiaensen *et al.* (2010), Christiaensen and Demery (2007), Majid (2004), Ravallion and Datt (2002), Sarris *et al.* (2006), Minten and Barrett (2005) and Getahun (2003).

From the results, convincing reasons are found that increasing the productivity of farmers is very useful for poverty reduction for the sample households. However, other variables included in the regression as control also affected real consumption per capita concomitantly.

Inflationary pressures measured by village level price index significantly and negatively affect welfare of rural households. The findings show that a 10 per cent increase in the aggregate price index reduces real consumption per capita by nearly 4.8 per cent. Reductions in consumption of households have serious implications on nutritional status which in turn affect productivity of rural households calling for government actions to reduce the adverse consequences of inflation. It may be due to this adverse consequence of inflation that rural households are found to be risk averse to price change. Barrett and David (2010) estimated that, on average, rural households would be willing to pay 6-32 per cent of their income to eliminate fluctuations in commodity prices using the first four rounds of the ERHS data.

The higher the household size and the dependency ratio, it is found that the higher is its impact on consumption per capita per household. The elasticity of these two variables to real consumption per capita is close 0.74, indicating a unit increase in the size and dependency ratio of the household reduces real consumption per capita by 0.74 per cent. Findings also show that male-headed households have higher level of real consumption per capita than female-headed households. Moreover, one more years of schooling increases real consumption per capita by nearly 0.03 per cent.

Credit access helps in increasing real consumption per capita and hence reduces poverty. The elasticity of the probability of obtaining credit with real consumption per capita is nearly 0.212. The higher the probability of obtaining credit, the higher is its impact on poverty in line with Alemayehu *et al.* (2006). Besides, results show that households who participated in off-farm activities have higher level of real consumption per capita than those who did not participate.

Table 4.8: Fixed effects regression results on the impact of productivity on real household consumption per capita (in Birr).

	Coefficients				
Independent Variables	Model 1[a]	Elasticity model 1	Model 2	Model 3	Model 4
Technical Efficiency	**2.487****	**1.519**			
Sex of the head of the household	0.162*	0.176	0.105**	0.124*	0.108**
Head's years of schooling	0.013***	0.026	0.017**	0.016**	0.016**
Age of the head of the household	0.000	-0.005	0.002	0.001	0.002
Household size	-0.111*	-0.690	-0.115*	-0.107*	-0.113*
Dependency ratio	-0.066***	-0.049	-0.131*	-0.141*	-0.136*
Logarithm of Village food price index	-0.481*	-0.481	-0.290*	-0.298*	-0.292*
Probability of obtaining credit	0.377***	0.212	0.825*	0.367**	0.747*
Participation in off-farm activities (1=Yes,0 otherwise)	0.078*	0.081	0.079*	0.088*	0.080*
Livestock ownership in Tropical Livestock Units	0.017*	0.063	0.013*	0.015*	0.013*
Distance to the nearest towns in km	-0.014*	-0.149	-0.014*	-0.015*	-0.014*
Logarithm of land productivity (Birr/hectare)			**0.074***		**0.077***
Logarithm of labor productivity (Birr/number of persons)				**0.072***	
Land-labor ratio					**0.032*****
Constant	5.357*		5.188*	5.526*	5.195*
Overall Wald test (F test)	174361*		62.98*	62.15*	58.06*
R-squared	0.17		0.21	0.23	0.21
corr(α_i, Xb)	-0.3292		0.0245	0.0573	0.028
F test that all α_i=0:	1.84*		1.94*	1.84*	1.93*
Hausman test for random effects [a]	1556.14*		182.74*	160.26*	177.34*

Source: computed from the model

*significant at 1 per cent, ** significant at 5 per cent, *** significant at 10 per cent, **a** indicates tests are based on the Wald test. The dependent variable for all models is the logarithm of real consumption per capita.

Having one more livestock, which is a measure of household wealth, also raises household real consumption per capita. Moreover, households living in near urban centers, have higher level of consumption per capita as indicated by the distance to the nearest towns in kilometers. Model 1 shows a 10 kilometer reduction in distance to the nearest small towns increases consumption per capita by 1.5 per cent.

These results suggest a combined effort to design policy interventions not only increasing productivity but also protecting asset of rural households, reducing inflationary pressures and prudent population policy. Results are also consistent for all models in Table 4.8.

4.6 The Impact of Alternative Government Interventions for Poverty Reduction: Simulation Results

As discussed in chapter III, it is possible to make alternative simulations of poverty reduction interventions and estimating the associated change in poverty levels. To achieve this, four alternative scenarios are developed. First, attempt is made to see the impact of increasing 6 per cent technical efficiency growth (simulation 1) on FGT poverty measures. The second scenario tried to see the impact of a policy aimed at reducing price of commodities (simulation 2). This simulation is made assuming that the government aims to achieve a single digit inflation target (6 per cent).

The third scenario is aimed at to see what would have happened to poverty if government policies were able to increase livestock ownership (simulation 3) by 2 TLUs for those who owned less than 5 TLUs. The fourth simulation is to see what would happen on poverty if the government plans to achieve a 6 per cent growth in technical efficiency and a single digit inflation target of 6 per cent (simulation 4). The last scenario simulates a combination of 6 per cent technical efficiency growth, target during the PASDEP period, head count poverty would have declined from 49 per cent to 13 per cent in 2009. Reducing inflationary pressure benefits those who are net-food-buyers while it might negatively affect net-food-surplus households. Due to data limitation, this study could not see the impact of local terms of trade (TOT) on household poverty.

As compared to other scenarios, increasing livestock ownership by 2 TLUs for those who owned less than 5 TLUs has small contribution to reduction of head count poverty. Simulation 3 shows that increasing livestock ownership by 2 TLUs for those who owned less than 5 TLUs reduces head count poverty by 2 percentage points in 2009 and less than 2 percentage points to other survey years.

The combination of the previous two simulations (simulation 3) indicate that the rate of decline in head count poverty is high due to 6 per cent increase in technical efficiency and at the same time achieving a single digit inflation rate of 6 per cent. Results reveal that head count poverty could be reduced by 4, 7, 5 and 39 percentage points in 1994, 1999, 2004 and 2009, respectively. The last scenario also confirms this result indicating the relevance of a combination of policy interventions to reduce poverty. Government policies aimed at poverty reduction should focus on a combination of interventions that boost productivity of farmers, reduces inflationary pressures and protect as well as increase the assets of rural poor farmers. For example, if this scenario would be implemented, head count poverty would decline from 45 per cent to 18 per cent in 1994, 38 per cent to 8 per cent in 1999, 36 per cent to 4 per cent in 2004 and 49 per cent to 4 per cent in 2009.

Table 4.9 also reveals similar results for the poverty gap index ($P_{1,it}$) and squared poverty gap index ($P_{2,it}$). For all simulations, the depth and severity of poverty declined in all survey years. As indicated in for the head count poverty, simulation 5 reduces $P_{1,it}$ and $P_{2,it}$ very much as compared to the base simulation and the other simulations.

Table 4.9: Simulation results of FGT poverty indices for the ERHS households 1994 - 2009 (in per cent).

Simulation No.	Description	1994			1999			2004			2009		
		$P_{0,it}$	$P_{1,it}$	$P_{2,it}$	$P_{0,it}$	$P_{1,it}$	$P_{2,it}$	$P_{0,it}$	$P_{1,it}$	$P_{2,it}$	$P_{0,it}$	$P_{1,it}$	$P_{2,it}$
Actual	Actual data	46.00	23.86	13.92	38.00	16.31	8.15	36.00	15.01	7.87	49.00	21.07	11.01
base	Base simulation	45.00	20.84	10.71	31.00	11.17	4.78	19.00	6.09	2.48	49.00	17.04	7.23
Simulation 1	6 percent increase in technical efficiency (TE)	41.00	18.74	9.54	26.00	9.40	4.06	14.00	5.06	2.06	41.00	13.58	5.66
Simulation 2	Single digit inflation target (6 percent)	45.00	20.84	10.71	29.00	10.39	4.42	17.00	5.61	2.27	13.00	3.93	1.42
Simulation 3	Increase livestock ownership by 2 TLUs for those who owned <5 TLUs	44.00	19.94	10.13	30.00	10.47	4.44	16.00	5.61	2.27	47.00	16.24	6.83
Simulation 4	Simulation 1+ Simulation 2	41.00	18.74	9.54	24.00	8.76	3.75	14.00	4.70	1.89	1.00	3.09	1.11
Simulation 5	Simulation 1,2 & 3	18.00	9.60	5.01	8.00	3.35	1.53	4.00	1.56	0.62	4.00	1.45	0.58

Source: computed from the ERHS data

CHAPTER V

CONCLUSIONS AND IMPLICATIONS FOR POLICY

This study decomposed sources of agricultural productivity growth, measured by growth in agricultural total factor productivity (TFP), in subsistence agriculture in rural Ethiopia. Stochastic Frontier Analysis (SFA) was used to decompose the Malmquist Productivity Index; a method to decompose productivity growth in to changes in technical efficiency and changes in frontier (technology).

The results of the descriptive statistics revealed that real value of output of the median as well as the average farmers consistently increased throughout the survey years. Moreover, many of the inputs used for production increased. The coefficients of the stochastic frontier analysis indicated that most inputs used in agricultural production are highly elastic to real value of output. This suggests that output can be increased through increasing use of agricultural inputs. For example, increasing the use of fertilizer together with other complementary inputs including water harvesting and increasing use of irrigation is useful for increase the income of farmers. It is also possible to increase the quality of cultivated land through improved farm management techniques. However, farmers do not always have the room to increase the inputs indefinitely. Diminishing marginal returns sets in at some point.

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APPENDICES

APPENDIX A: Estimates of the stochastic frontier model using the CSA price data for rural households 1994-2009.

Explanatory variables	Coefficient	Calculated Elasticity	Std. Err.	z	P>z
Constant	7.056189		0.39184	18.01	0.000
Family labor in male adult equivalent	0.0881417	0.2719897	0.01094	8.06	0.000
Number of ploughing oxen	0.1215655	0.1199056	0.01706	7.13	0.000
Amount of fertilizer used	0.002859	0.1695753	0.0002	14.15	0.000
Logarithm of area cultivated (hectare)	0.2246644	0.2246644	0.01622	13.85	0.000
Logarithm of average land quality	-0.1598879	-0.1598879	0.03377	-4.73	0.000
Years of schooling of the head	0.0426855	0.084673	0.00622	6.87	0.000
Logarithm of amount of rainfall 12 months before the survey	0.0974599	0.0974599	0.05307	1.84	0.066
Real value of farm capital(in Birr)	0.0010172	0.047829	0.00028	3.57	0.000
Participated in New extension program	0.0832983	0.08686597	0.04052	2.06	0.040
Farmers' Irrigation use	0.1671405	0.18192031	0.05165	3.24	0.001
time	-0.1404155		0.01864	-7.53	0.000
time squared	0.002996		0.00089	3.36	0.001
$\hat{\mu}$	-0.410048		0.41951	-0.98	0.328
$\hat{\eta}$	0.1675009		0.01635	10.24	0.000
$\hat{\sigma}^2$	0.9298478		0.04474		
$\hat{\gamma}$	0.0506708		0.03733		
$\hat{\sigma}_u^2$	0.0471161		0.03666		
$\hat{\sigma}_v^2$	0.8827317		0.02253		

Source: estimates from the stochastic frontier model

APPENDIX B: Estimates of the Malmquist Productivity index using the CSA price data for rural households 1994-2009.

	TFP Change Index			TE Change Index			Technical Change Index		
Villages	**1999**	**2004**	**2009**	**1999**	**2004**	**2009**	**1999**	**2004**	**2009**
Haresaw	3.09	1.66	1.23	3.48	1.81	1.31	0.89	0.91	0.94
Geblen	2.86	1.60	1.21	3.22	1.75	1.29	0.89	0.91	0.94
Dinki	1.41	1.15	1.05	1.59	1.26	1.11	0.89	0.91	0.94
Yetmen	1.59	1.20	1.06	1.79	1.31	1.13	0.89	0.91	0.94
Shumsha	1.30	1.10	1.03	1.46	1.21	1.09	0.89	0.91	0.94
Sirbana Godeti	1.36	1.12	1.03	1.54	1.22	1.09	0.89	0.91	0.94
Adele Keke	1.59	1.15	1.04	1.80	1.26	1.10	0.89	0.91	0.94
Korodegaga	2.28	1.41	1.14	2.56	1.55	1.21	0.89	0.91	0.94
Trirufe Ketchema	1.28	1.09	1.02	1.45	1.19	1.08	0.89	0.91	0.94
Imdibir	1.20	1.06	1.01	1.35	1.15	1.07	0.89	0.91	0.94
Aze Deboa	1.58	1.13	1.03	1.78	1.24	1.10	0.89	0.91	0.94
Adado	1.25	1.07	1.01	1.41	1.17	1.07	0.89	0.91	0.94
Gara Godo	1.47	1.17	1.05	1.65	1.28	1.12	0.89	0.91	0.94
Doma	2.40	1.45	1.16	2.70	1.58	1.23	0.89	0.91	0.94
Milki	1.18	1.05	1.00	1.33	1.15	1.07	0.89	0.91	0.94
Kormargefia	1.12	1.02	0.99	1.26	1.12	1.05	0.89	0.91	0.94
Karafino	1.30	1.10	1.02	1.47	1.20	1.09	0.89	0.91	0.94
Bokafia	1.42	1.16	1.05	1.60	1.26	1.11	0.89	0.91	0.94

Source: authors' computation from the SFA model

APPENDIX C: Estimates of technical efficiency using the CSA price data and ERHS 1997 scaled up price for rural households 1994-2009.

	ERHS 1997 Scaled up Price				CSA Price Data			
Peasant Association	**1994**	**1999**	**2004**	**2009**	**1994**	**1999**	**2004**	**2009**
Haresaw	0.18	0.24	0.31	0.39	0.11	0.35	0.62	0.81
Geblen	0.19	0.25	0.32	0.39	0.13	0.37	0.64	0.82
Dinki	0.46	0.52	0.58	0.64	0.44	0.67	0.83	0.92
Yetmen	0.54	0.60	0.65	0.70	0.41	0.64	0.81	0.91
Shumsha	0.51	0.57	0.63	0.68	0.51	0.72	0.86	0.93
Sirbana Godeti	0.58	0.64	0.69	0.73	0.51	0.72	0.86	0.93
Adele Keke	0.67	0.71	0.75	0.79	0.52	0.71	0.85	0.93
Korodegaga	0.41	0.47	0.54	0.60	0.24	0.49	0.72	0.86
Trirufe Ketchema	0.56	0.61	0.67	0.71	0.55	0.74	0.87	0.94
Imdibir	0.57	0.62	0.67	0.71	0.63	0.79	0.90	0.95
Aze Deboa	0.51	0.57	0.63	0.68	0.54	0.73	0.86	0.94
Adado	0.64	0.69	0.73	0.77	0.59	0.77	0.88	0.95
Gara Godo	0.44	0.51	0.57	0.63	0.43	0.66	0.82	0.92
Doma	0.40	0.47	0.53	0.59	0.22	0.47	0.71	0.86
Milki	0.62	0.67	0.72	0.76	0.60	0.78	0.89	0.95
Kormargefia	0.64	0.69	0.74	0.78	0.65	0.82	0.91	0.96
Karafino	0.56	0.62	0.67	0.72	0.53	0.73	0.86	0.94
Bokafia	0.55	0.60	0.66	0.71	0.42	0.66	0.83	0.92

Source: authors' computation from the SFA model

APPENDIX F: First stage regression result of the 2SLS: Technical efficiency score is the dependent variable.

Instrumental variables (IVs)	Coefficients	Standard Errors	t-value	P-value
Sex of the head of the household	-0.015	0.002	-6.080	0.000
Head's years of schooling	0.002	0.000	4.120	0.000
Age of the head of the household	0.001	0.000	8.200	0.000
Household size	-0.001	0.000	-4.040	0.000
Dependency ratio (dep_ratio)	-0.026	0.001	-24.420	0.000
Logarithm of Village food price index (lnfpi)	0.077	0.001	53.850	0.000
probability of obtaining credit (prob)	0.060	0.010	5.810	0.000
Participation in off-farm activities (1=Yes,0 otherwise)	0.004	0.001	2.520	0.012
Livestock Ownership in tropical livestock units (tlu)	0.000	0.000	0.080	0.936
Distance to the nearest towns (dis_town)	-0.001	0.000	-7.020	0.000
Number of plots cultivated	0.001	0.000	4.620	0.000
Crop affected by drop (1=Yes, zero otherwise)	-0.012	0.001	-8.320	0.000
Crop affected by illness of a farmer or a member (1=Yes, zero otherwise)	-0.007	0.002	-4.540	0.000
Participated in New extension program (1=Yes, zero otherwise)	0.002	0.002	0.880	0.381
Farmers' Irrigation use (1=Yes, zero otherwise)	0.026	0.002	11.680	0.000
The Household has more than one ploughing oxen (1=Yes, zero otherwise)	0.001	0.002	0.660	0.511
Constant	0.207	0.009	22.780	0.000
Overall F test			575.640	0.000
Overall R-squared			0.120	
corr(α_i, Xb)			-0.003	0.000
F test that all α_i=0			60.860	0.000

Source: model result

APPENDIX G: logit fixed effects estimator result: access to credit is the dependent variable.

IVs	Coefficients	Standard Errors	t-value	P-value
Logarithm of area cultivated in hectare	0.1856185	0.047821	3.88	0.000
Real value of farm capital	0.0058105	0.0009333	6.23	0.000
LR chi2(2)	67.61			0.000
Log likelihood	-1224.15			0.000

Source: model result