Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Economics

The Role of Agricultural Commercialization for Smallholders Productivity and Food Security

- An Empirical Study in Rural Ethiopia

Wondmagegn Tafesse Tirkaso

Master's thesis · 30 hec · Advanced level
Agricultural Economics and Management – Master's Programme
Degree thesis No 827 · ISSN 1401-4084
Uppsala 2013

The Role of Agricultural Commercialization for Smallholders Productivity and Food Security: An Empirical Study in Rural Ethiopia

Wondmagegn Tafesse Tirkaso

Supervisor: Sebastian Hess, Swedish University of Agricultural Sciences, Department of Economics

Examiner: Ing-Marie Gren, Swedish University of Agricultural Sciences, Department of Economics

Credits: 30 hec
Level: A2E
Course title: Independent Degree Project in Economics
Course code: EX0537
Programme/Education: Agricultural Economics and Management, Master's Programme
Faculty: Faculty of Natural Resources and Agricultural Sciences

Place of publication: Uppsala
Year of publication: 2013
Cover picture: Edible East Bay magazine
Name of Series: Degree project/SLU, Department of Economics
No: 827
ISSN 1401-4084
Online publication: http://stud.epsilon.slu.se

Key words: productivity, commercialization, food security, stochastic frontier, efficiency, output, Ethiopia

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Economics

Abstract

For the past few decades, continuing economic and demographic change across the world has brought an excess demand for different types of agricultural products. As a result, policy makers and international institutions have been advocating several policy instruments aimed to boost agricultural production and food security. In most cases, however, the potential role of smallholder commercialization has not been given due attention despite its importance. Therefore, this research assesses the potential role of commercialization for smallholder agricultural productivity and food security in Ethiopian farm households. Econometric model based on stochastic frontier analysis is used as the main technique in addressing the predetermined research questions. As a data set, the 2009 Ethiopian rural household survey compiled by International Food Policy Research Institute is used. Findings show that farmers are only 40.2 percent efficient relative to the most efficient farmers in the sample using the current input level. The variables related to educational level, access for radio, access for cell phone and level of commercialization are positively linked with technical efficiency. Results imply that output can be increased up to 59.8 percent by improving the existing input mixes used in the production process. Furthermore, estimated results for the determinants of farmers' commercialization identified different types of market as the main statistically significant variables. Besides, the amount of households' budget share allocated for food consumption expenditure is indirectly associated with level of commercialization suggesting possibility of substantial influence on quality and quantity of households' food consumption. Finally, with respect to policy recommendations, the overall results suggested that policy makers and international donors should prioritize their effort on increasing smallholders' degree of market participation as one of the main instrument in improving agricultural productivity and food security.

Acknowledgements

Foremost, I would like to express my sincere gratitude to my supervisor Dr. Sebastian Hess for his guidance, comment, support and encouragement during the entire research process. The thesis would not been in this form without his critics, continued follow up and thoughtful discussion. My sincere thanks should also goes to Professor Ing-Marie Gren (PhD) for her continued assistance during the entire research process.

Further, my gratitude should also goes to International Food Policy Research Institute (IFPRI) for freely availing the data used by the research. In addition, I would like to express my deepest appreciation for Kiristina Jansson, Bisrat Haile, Federico Belotti (PhD), Abenezer Zeleke, Shyam Basnet, Moges Gobena, Tesfaye Berhanu, Tesfaye Sebeko and Elazar Tadesse for their comment, suggestion and general help during my study time and particularly in the research process.

Besides, I would like to thank Josefine Jerlström and Tsegaye Hailesilassie for sharing their substantial amount of time in editing parts of the thesis. My appreciation is also goes to Yewerkwoha Beyene, Tewodros Yohannes, Kaleb Kifleyesus, Eyasu Kifleyesus, Genet and other Salem Ethiopian church fellows in Uppsala for the love they shared to me during my stay in Uppsala. Finally, I would like to thank my father Tafe, mother Anna and all other families for their prayer, support and encouragement in all the days of my life.

May the Lord bless Sweden!

Wondmagegn Tafesse

Table of Contents

Acronyms

ACI	Average commercialization index
AFCE	Average food consumption expenditure
ATFCE	Average total food consumption expenditure
APP	Average physical product
AY	Average income level (in Birr)
CI	Commercialization index (base year 2010)
ERHS	Ethiopian rural household survey
ExA	Extension access
FDRECSA	Federal democratic republic of Ethiopia, Central Statistics Agency
GDP	Gross domestic product
HCI	Households commercialization index
ICT	Information communications technology
IFPRI	International food policy research institute
KG	Kilograms
KMS	Kilometers
MLE	Maximum likelihood estimate
MPP	Marginal physical product
OLS	Ordinary least square
PDF	Probability density function
SLU	Sveriges Lantbruksuniversitet/Swedish University of Agricultural Sciences
SNNPRS	Southern nation’s nationalities and peoples regional state
CSA	Central statistical agency
TE	Technical efficiency
TSLS	Two stage least square
TVQ	Total value of output
TVS	Total value of sale
WB	World Bank

Lists of tables

Lists of figures

1. Introduction

1.1. Background of the study

Ethiopia is one of the emerging economies in Sub-Saharan Africa with an average GDP growth rate of 8.3 percent per annum between 2002 and 2011 (WB, 2012). The agricultural sector has been a dominant contributor having an average of 45.4 percent to the total GDP during the same period of time. In addition to larger contribution, studies revealed that agriculture has a significant potential in achieving faster economic growth and poverty reduction in the country (Bigsten *et al.*, 2003; Block, 1999; Diao & Pratt, 2007). However, maximizing this potential necessarily requires increasing the level of smallholders' agricultural productivity which is existed at base level due to several socio economic bottlenecks. For instance, backward technological setups coupled with diminishing cultivated land size, low level of technological adoption and institutional failures are among the main factors (Croppenstedt & Muller, 2000). Besides, poor linkage between market and the farm sector is mentioned as one of the main contributing factors for lower level of agricultural productivity (Fafchamps *et al.*, 2005). Similarly, study made by Braun (1995) indicated that smallholder commercialization is supposed to be vital in improving smallholder's wellbeing in terms of income and food security.

Despite its importance, most of the previous empirical studies particular to Ethiopia fail to identify the connection between agricultural productivity and commercialization[1]. Consequently, focusing on crops, this research investigates the state of agricultural productivity, commercialization and food security in a separate and communal basis across farmers. Specifically, it identifies those factors influencing the level of agricultural productivity and commercialization for the main crops across the country. Similarly, various studies indicated that commercialization has a significant impact on improving farmers income which is supposed to increase food consumption budget share (Barrett, 2008; Braun, 1995; Jaleta *et al.*, 2009; Juma, 2010). Most of these works which are particular to sub Saharan Africa advocates market oriented smallholder commercialization as one of the engine in achieving sustainable poverty reduction and food security. Thus, the final part of the research deals with differentiating the prevailing connection between smallholder commercialization and food security; and discusses households' food consumption expenditure behavior in relation to the level of commercialization.

---

[1] See Braun (1994), p.11, for the detailed definitions of smallholder agricultural commercialization.

1.2. Objectives

The research generally aims to analyze the role of agricultural commercialization in improving productivity and food security in rural Ethiopia. Specifically, it identifies the sources of technical efficiency loss and lower level of commercialization across the farmers. Furthermore, it distinguishes how commercialization interacts with food security through influencing households' food consumption expenditure level.

1.3. Research Questions

Four different specific questions are addressed by the research. These are:

1. How much is the average percentage of technical efficiency score among crop producers in rural Ethiopia?
2. What is the effect of commercialization on the level of technical inefficiency across the main crop producers in rural Ethiopia?
3. What factors determine farm household's level of commercialization in rural Ethiopia?
4. What is the linkage between commercialization and food security in rural Ethiopia?

1.4. Significance of the study

The research is expected to deliver several important outcomes. These include:

1. Delivery of information on the linkage between farm household level of commercialization, productivity and food security in Ethiopia
2. Information for stakeholders involved in the agricultural productivity issues, such as development organizations, agricultural extensionists and policy planners in Ethiopia
3. Add insights to the existing literature on interrelation between productivity, commercialization and food security

1.5. Scope of the study

The research estimates levels of productivity based on main agricultural crop producers in Ethiopia. The livestock sector is not covered by the study due to lack of full information in the data set. Besides, it computes and identifies the determinants of household commercialization level based on output side. The net effect of commercialization on food security is not assessed rather the research identifies the prevailing linkage.

2. Review of literature

2.1. The performance and structure of Ethiopian economy

According to the official statistics by MoFED (2010), Ethiopian economy is dominated by agricultural sector accounting 39.7 percent of the national GDP. Similarly, service and industry sectors constitute 45.5 and 12.9 percent of the national GDP, respectively. Notably, agricultural sector is used as the main source of livelihood for 83 percent of the total population in the country (WB, 2012). The sector is key supplier of inputs for food processing, beverage and textile industries (Endale, 2010). One of the main characteristics of Ethiopian agricultural sub sector is dominated by cereal crop production constituting a significant proportion of the sub sector (Taffesse *et al.*, 2011). Furthermore, it accounts for about 45 percent of the average food expenditure (Diao, 2010). Figure (1) illustrates some of the main contributions agricultural sub sector in Ethiopian economy.

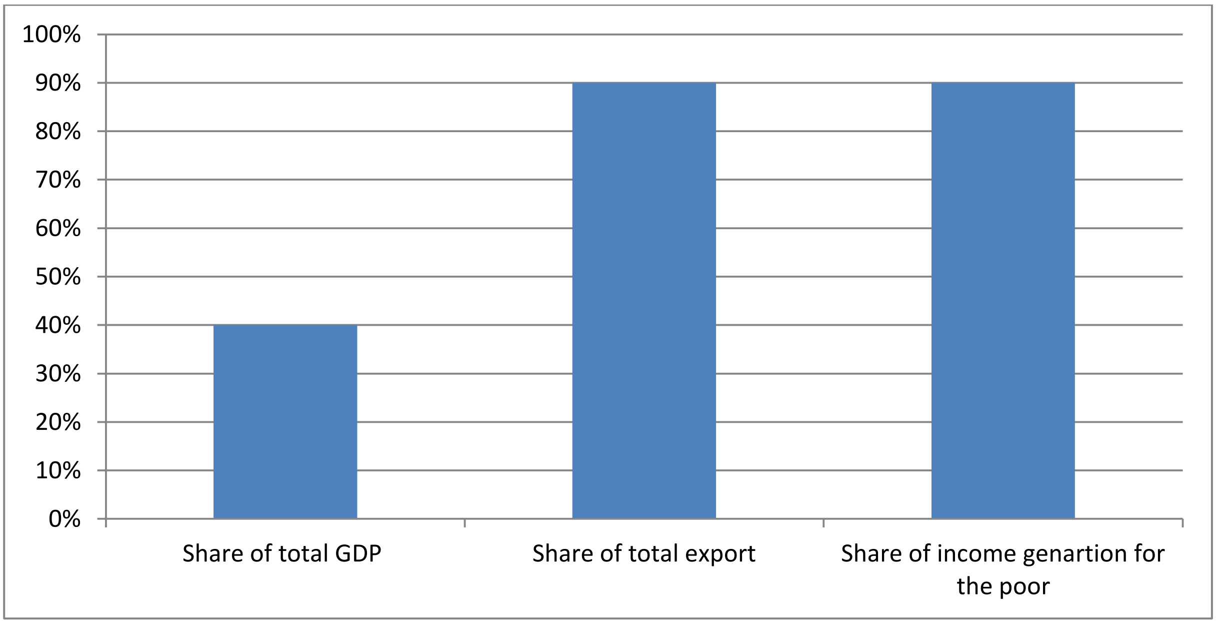

Figure (1): Contribution agricultural sector in Ethiopian economy.Source: Own illustrated based on Diao (2010)

Despite a substantial contribution of the sector, level of productivity is at lower stage due to several factors. For instance, studies indicated that average cereal producers have lower level of productivity with 46 percent technical efficiency[2] score (Nisrane *et al.*, 2011); suggesting considerable growth potential of the sector if substantial effort is made towards improving productivity. Accordingly, several socio economic factors are counted as the factor for lower

[2] The term technical efficiency refers to the most possibly achievable maximum output that can be produced using the same level of input. For detailed elaboration see Rao *et al.*, (2005), p. 241-242.

level of technical efficiency. These includes pattern of various input use such as size and quality of cultivated land, labor size, numbers of oxen and hoes, market failure and climates types are among the variables (Nisrane *et al*., 2011).

2.2. Commercialization and its determinants

Agricultural commercialization is a process involving transformation of agriculture to market oriented production which tend to impacts income, consumption and nutritional setup of the farm households (Braun, 1995). Importantly, it is more than producing surplus output to the market and thus includes household's decision behavior on product choice and input use based on the principle of profit maximization (Pingali & Rosegrant, 1995). However, there is also the prevalence of commercialization in subsistence agriculture where farm households supply certain proportion of their output to the market from their subsistence level (Gebre-ab, 2006). Generally, different approaches are used to measure household commercialization level (Braun. & Kennedy., 1994). Commonly, total sale to output ratio which is calculated by taking the value of sales as a proportion of total value of agricultural output is commonly used (Gebre-ab, 2006). Therefore, it is argued that the process of commercialization is determined by a number of factors linked with internal or external to farming activity (Jaleta *et al.*, 2009). Internally, households' resource endowments including land, labor and capital; and whereas, change in technology, infrastructure, demography and market institutions around the farm are among the external factors.

2.3. Commercialization and food security

Studies indicated that smallholder commercialization has a significant effect on the level of food security. For instance, Braun (1995) argued that commercialization has direct effect on household's income level which possibly leads to an increase in food and non-food expenditure. This postulation is directly associated with the famous Engel's law which shows the inverse relationship between the share of food consumption expenditure and total income (FAO, 2008). Based on this law, household are likely to spend more on food items as their income level grows up, but with a diminishing budget share allocated to food.

Similarly, it is argued that better access for food depends on income growth; in particular to most African smallholders where agriculture is the main source of income. This implies that improving degree of market participation can have a big impact on the status of farmers' food security (Strasberg *et al.*, 1999). The implication is that improving degree of market participation can have a potential effect on farmers' food security status. Notably, the process of agricultural growth involves unavoidable process interms of increased commercialization, integration of rural credit market (Mellor, 1990; Timmer, 1997).

Further, the net effects of commercialization on household's food consumption expenditure can be analyzed by considering the effect of price level as lower income households may not guarantee an improvement in welfare aspects if they face higher market price. Rather, those households with higher income may have better tendency to enjoy from commercialization mainly in those countries like Ethiopia where the share of food consumption expenditure accounts a significant part of income. However, evidences from Malawi suggested that food security status of small scale farmers are less likely to be affected than large scale farmers during price shock time as food is mainly supplied from home production (Wood *et al.*, 2012). Therefore, the overall implication behind promoting commercialization on household food security level comprises complex relationship that links income and price level.

3. Theoretical background

3.1. Theory of production and the concept of economic efficiency

The economic process of transforming various inputs in to final goods and service is known as production (Frisch, 1964). It involves choice of input and technology mixes that maximizes output with a least cost. Thus, the principal motive of rational producer is to maximize profit either by minimizing cost or maximizing output (Cobb & Douglas, 1928). Assuming the production of a single output with the use of two inputs which are labor and capital, the functional form of neoclassical Cobb-Douglas production function is given as:

$$Q = F(L, K) = AL^{\beta}K^{\alpha} \tag{1}$$

where L is amount of labor, K is capital, A is factor productivity, β and α are elasticity's. In equation (1), it is assumed that all units of labor and capital are homogenous function of degree k. Similarly, technology is assumed to be constant. Therefore, it is possible to drive concepts relying on both the short run production where all factors are fixed and long run where both factors are variable. In the short run, output can only be increased by changing the mixes of variable input, labor. However, producer can vary the output level by changing the mix of all inputs in the long run. Figure (2) provides the graphical illustration of neoclassical production function.

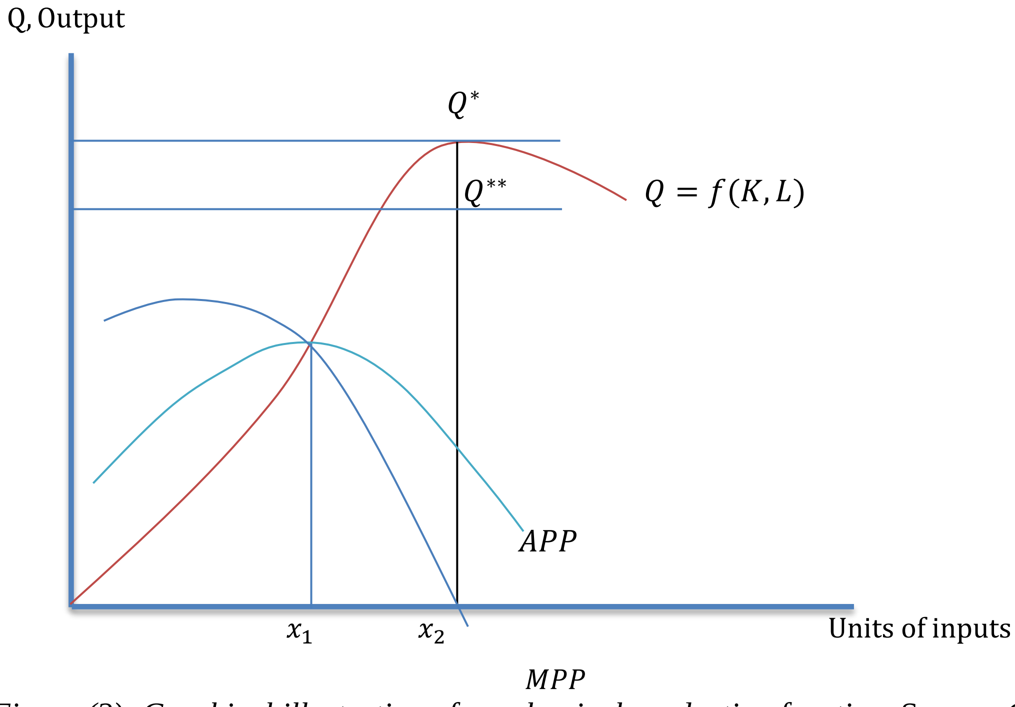

Figure (2): Graphical illustration of neoclassical production function. Source: *Own drawn*

According to the neoclassical economic theory, a rational producer always tries to reach the optimum level of output at a point where the marginal physical product of input (MPP) for labor and capital equals zero. Mathematically;

(2) $$MPP_L = \frac{\partial Q(K,L)}{\partial L} = 0$$

(3) $$MPP_K = \frac{\partial Q(K,L)}{\partial K} = 0$$

As indicated in the graph, a producer employs x_2 unit of inputs in order to produce maximum attainable output level. At this point, it is assumed that all the resources are utilized efficiently. However, in most cases rational producers fail to obtain Q^* units of output using x_2 units of input and rather laid down at much lower point, say at Q^{**} using the same unit of input level, x_2. This situation happens due to the presence of technical inefficacy that arises in the production process.

Explicitly, the neoclassical production function considers full technical efficiency during the production processes (Kalirajan & Shand, 1999). However, recent development in the area of production economics provides an alternative way of estimating production function from efficiency perspective using stochastic frontier model (Aigner *et al.*, 1977; Cornwell *et al.*, 1990; Schmidt & Lovell, 1979). Further concepts associated with stochastic frontier analysis are discussed in the next part.

3.2. Stochastic frontier analysis

Ordinary least square regression method has been used as the focal point of conventional economics in estimating production function despite its limitations. The approach considers the total error term as a random noise component which is the only source of output deviation from the maximum point. In fact there is a significant contribution of inefficiency part in deviating output from the possible maximum point. The first prominent concept on modeling and estimation of stochastic frontier analysis is forwarded by the empirical work of Aigner *et al.* (1977). Further, Battese and Coelli (1995);Greene (1990) and Wim and Broeck (1977) provides a significant contribution for the progress of stochastic frontier analysis considering different distributional assumption of the error term.

Basically, specification of production function under stochastic frontier distinguishes the error term associated with the production function in to statistical noise and inefficiency components. It is assumed that each component has their influence in deviating output from the most possible maximum level. Figure (3) previews the graphical illustration of stochastic frontier analysis.

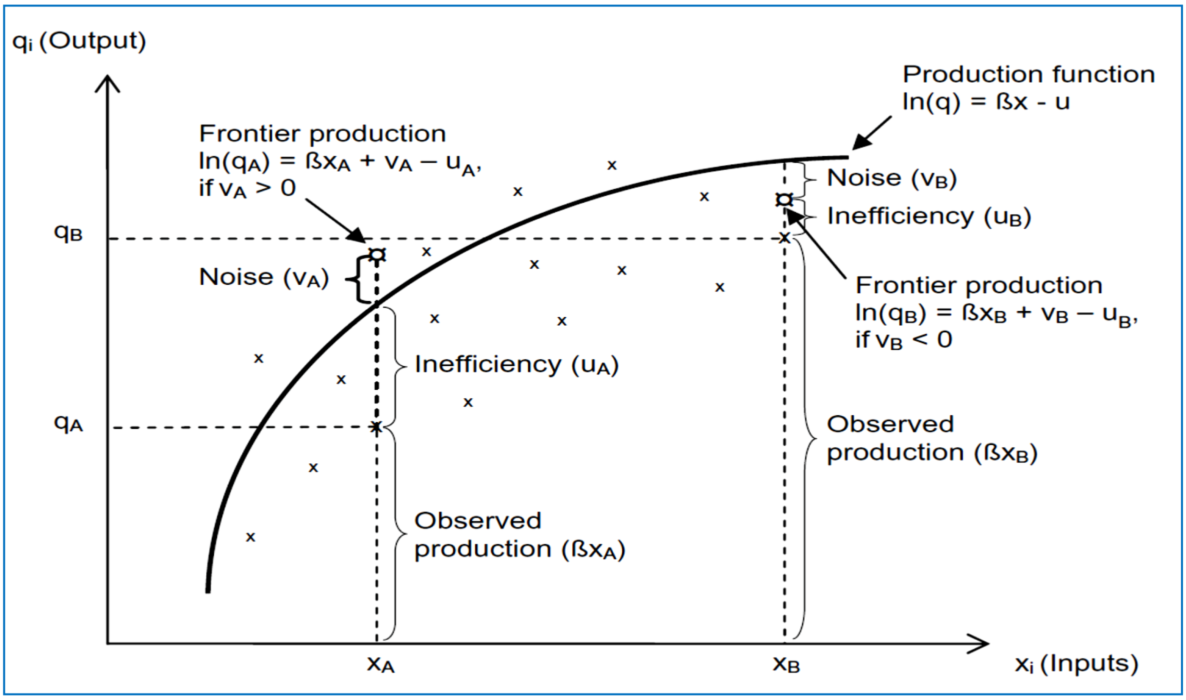

Figure (3): Graphical representation of stochastic frontier analysis. Source:*Neumann et al. (2010)*

The statistical noise or uncontrolled component (v_A) is represented by the distance between the most possible maximum point given by a production function ($\beta x - u$) and frontier production ($\beta_B + v_B - u_B$). Similarly, the inefficiency component (u_A) is represented by the distance between frontier production ($\beta_B + v_B - u_B$) and observed production (βx_A). This shows how estimating production function under stochastic frontier analysis considers the joint contribution of noise and inefficiency components. Therefore, achieving economic efficiency which is represented by production of maximum output ($\beta x - u$) from a given input level (x_B) is the principal goal of a rational producer.

Generally, economic efficiency is classified in to technical and allocative efficiencies (Sharma *et al.*, 1999). The concept of technical or productive efficiency is about combination of inputs in such a way that provides maximum output level and it is measured by the ratio of optimal and actual input use. On other hand, allocative efficiency deals with production of optimal output at the point where the market price equals the private marginal cost and calculated by taking the ratios of minimum and actual cost associated with a given production function.

3.3. Conceptualizing the linkage between commercialization, technical efficiency and food security

Smallholder commercialization as process of agricultural transformation is expected to have a significant impact on agricultural productivity and food security status of smallholder farmers. This in fact requires conceptualization of the expected causalities between each component which is vital in drawing appropriate strategies and policies supposed to improve the farmers' wellbeing. An illustrative diagram is given by figure (4).

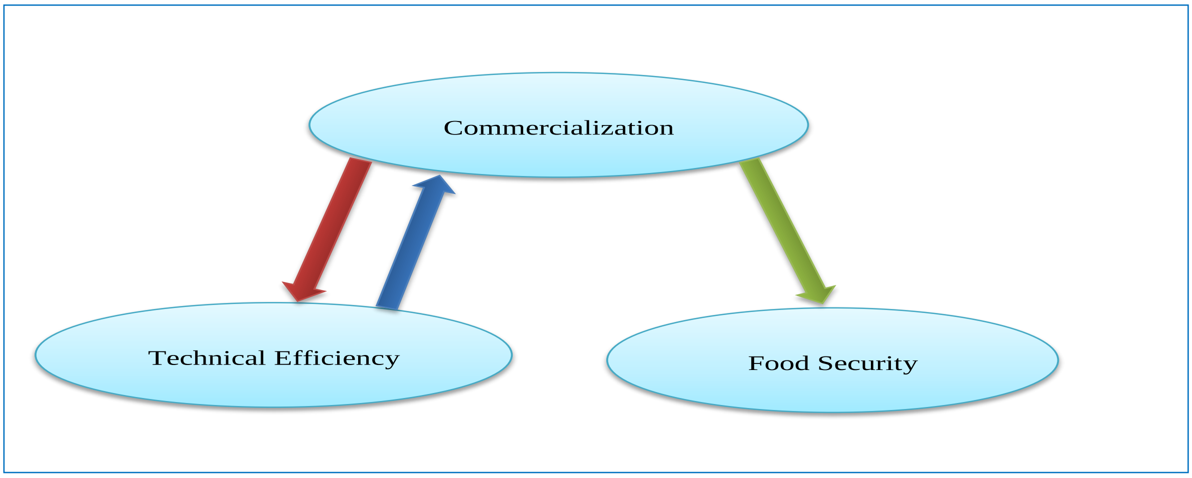

Figure (4): Conceptualizing commercialization, technical efficiency and food security.Source: Own illustration

Previous studies on households market participation behavior argued that a rational farmer tend to supply certain proportion of surplus output to the market after satisfying what his demand is satisfied (Braun, 1995; Govereh *et al.*, 1999; Jaleta *et al.*, 2009). This clearly suggested that being efficient and productive farmer has a positive influence on the level of commercialization and the possible effect is indicated by blue arrow in the above figure. However, recent findings suggested the requirement of categorizing farmers either in to subsistence or semi-subsistence and commercial farmer in examining the causality between commercialization and technical efficiency. For instance, farmers may supply their output to the market even they do not have surplus produce so as to meet their remaining demand (Gebre-ab, 2006). This supports the argument stating commercialization plays a key role for the improvement of technical efficiency in a situation where input market failures and credit constraints are dominant features of subsistence agriculture. The expected tradeoff is indicated by red arrow in figure (4). On other hand, commercialization is supposed to improve farmers' income where they can widen food consumption interms of quality and quantity (Braun, 1995), assuming the negative effects of price constant. This interaction is illustrated by green arrow of figure (4).

4. Methodological framework

4.1. Data

The 2009 Ethiopian household survey data which is compiled by international food policy research institute is used throughout the study (IFPRI, 2009). A total of 562 household heads from seven villages represented as a study population. Explicitly, three central criteria's are considered in selecting the villages. First, the survey sites are characterized by similar types of crop production mainly for subsistence purposes (IFPRI, 2009). Secondly, they have relatively similar agro ecological and demographic zone (IFPRI, 2009). Lastly, comparable distribution of poverty among the villages is taken in to account (Nisrane *et al.*, 2011). The criteria's are expected to increase the reliability of parameter estimates. Summary of descriptive statistics of variables that are used in the research is given on appendix (1).

4.2. Descriptive statistics of the study area

The villages are chosen from three main principal regions of Ethiopia comprising Amhara, Oromia and SNNPRS due to higher degree of representativeness. Accordingly, these regions represent 45 percent of the total population in the country comprising 82 million (CSA, 2012). Thus, village of Dinki, Yetmen, Adele Keke, Turfe Kechemane, Imdibir, Aze Deboa, and Addado are included. Figure (5) and (6) illustrates total population and area size of the study regions in relation to compare the country's total.

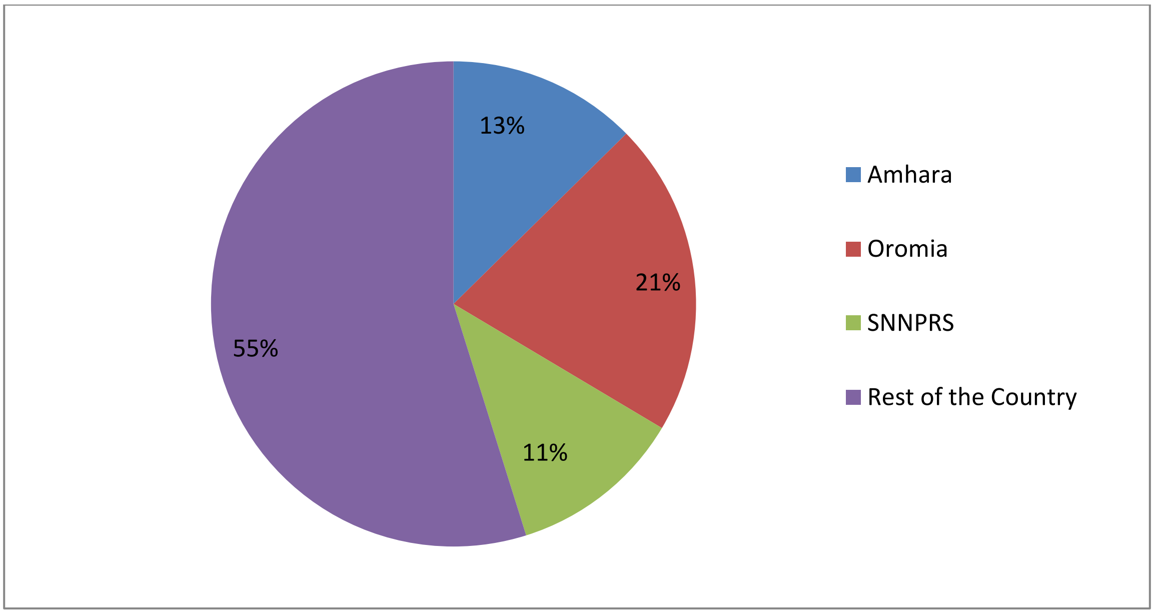

Figure (5): Population size of Ethiopia by main regions. Source: Own estimate based on CSA (2012)

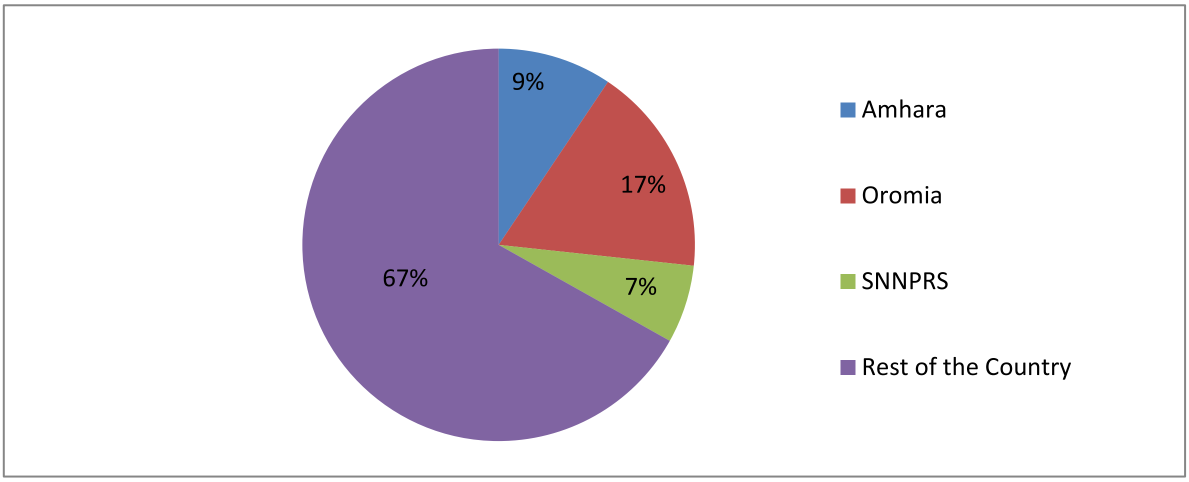

Figure (6): Area size of Ethiopia by main regions (in square kilometers). Source: Own estimate based on CSA (2012)

Importantly, these regions are known for their larger supply of agricultural output to the national economy. In this regard, survey study conducted by Central Statistics Agency of Ethiopia showed that both the largest grain cropped land area and highest volume of production is obtained from these regions (CSA, 2011). Table (2) summarizes the percentage and distribution of each survey sites along the corresponding region.

Table (1): Sample size distribution across the regions and villages

Region	Survey Site	Observations	Percent
SNNPRS	Adado	124	22.06
Oromia	Adele Keke	87	15.48
SNNPRS	Aze Deboa	73	12.99
Amhara	Dinki	74	13.17
SNNPRS	Imdibir	62	11.03
Oromia	Turfe Kechemane	92	16.37
Amhara	Yetmen	50	8.90
	Total	562	100.00

Based on the descriptive statistics given in appendix 1, the standard deviation of some variables indicates a substantial degree of variability between observations. For instance, relative farm size (12521.24), total output (5899.24), total sale (4119.13), off-farm income (4074.59) and food consumption expenditure (626.71) are widely distributed. Conversely, numbers of oxen (0.87), number of hoe (2.08), number of plough (4.31) and schooling year (3.30) have relatively lower standard deviation from the mean value, indicating lower variability among the framers.

4.3. Method of analysis

The first three research questions are directly linked with measuring the level of agricultural productivity and commercialization. As a result, three different estimates are obtained. Firstly, stochastic frontier production function is estimated in order to predict farmer's level of technical efficiency. This is followed by comparison of estimates following half normal, truncated normal, exponential and gamma distribution of the error term. This is supposed to provide an intuition on selecting the preeminent and representative model. Secondly, main factors influencing the level of technical inefficiency are identified from the estimation of frontier function. Thirdly, an econometric specification for the determinants commercialization is developed and estimated. The final part of the research deals with comparative analysis of the existing link between household's level of commercialization and food security.

4.4. Model specification

In the field of agricultural economics, stochastic frontier analysis is widely applied due to its effectiveness in measuring the level of productivity. Generally, it predicts the amount of individual technical efficiency score during the production process where agents are intended to obtain achievable maximum output from the employment of current input. Besides, it measures the allocative efficiency where production agents are able to use inputs in optimal proportions given their prices (Rao *et al.*, 2005). Four main distributional assumptions are linked with the error term (u_i) in equation (4) having different characteristics. Therefore, the research compares the parameter estimates from each assumption and chooses the one fitting various robustness criteria's.

4.4.1. The half normal model

This model is firstly forwarded by Aigner *et al.* (1977) assuming half normal distribution of inefficiency term. Based on this assumption, the Cobb-Douglas form of stochastic frontier model is defined as:

$$Q_i = f(X_{ij};\beta)\exp(v_i - u_i) \qquad i = 1,2,\dots,N;\ v_i - u_i = \varepsilon_i \tag{4}$$

where Q_i is total output level for i^{th} farm household, $f(X_{ij};\beta)$ is the deterministic part of the model, X_{ij} is i^{th} input use for j^{th} farm household, v_i is a statistical noise component with zero mean and captures the effects of uncontrolled random factors including weather, unexpected events and others. Whereas, u_i is a non-negative random variable associated with measurement of technical inefficiency by i^{th} farm household and finally, N represents the total number of observation.

In equation (4), it is assumed that both the random errors have their own statistical properties. The noise part; $v_i = 1,2,\ldots,N$ is normally, independently and identically distributed as $v_i \sim NIID(0, \sigma_v^2)$. Similarly, u_i is assumed to be non-negative truncations of half normal distribution as $u_i \sim NIID(0, \sigma^2)$ which is independent of v_i. Thus, the density for u_i and its two moments are given in equation (5) and (6), respectively.

$$(5) \qquad f(u) = \frac{2}{\sigma_u\sqrt{2\pi}} \exp\left(\frac{-u^2}{2\sigma_u^2}\right)$$

$$(6) \qquad E(u) = \frac{\sqrt{2}}{\sqrt{\pi}}\sigma_u \text{ and } V(u) = \left(\frac{\pi-2}{\pi}\right)\sigma_u^2$$

Since v_i and u_i are independently distributed, the joint density function can be derived by taking the product of each term as follows:

$$(7) \qquad f(u,v) = f(u) * f(v) = \frac{2}{\sigma_u\sigma_v 2\pi} \exp\left(-\frac{u^2}{2\sigma_u^2} - \frac{v^2}{2\sigma_v^2}\right)$$

Further, distribution for the sum of symmetric and truncated normal random variable is given by $\varepsilon = v_i - u_i$, and therefore the joint density is obtained by integrating $f(\varepsilon)$ over u. It is given in equation (8) as;

$$(8) \qquad f(u_i - v_i) = f(\varepsilon) = \int_0^\infty f(u,\varepsilon)du = f\left(\frac{\varepsilon}{\sigma}\right)[1 - F(\varepsilon\lambda\sigma^{-1})], \qquad -\infty \le \varepsilon \le +\infty$$

where $\sigma_v^2 + \sigma_u^2 = \sigma^2$, $\lambda = \frac{\sigma_u}{\sigma_v}$; where $f\left(\frac{\varepsilon}{\sigma}\right)$ a standard normal density is function, and $F(\varepsilon\lambda\sigma^{-1})$ is normally distributed function. From equation (8), it is necessary to interpret λ which is an indicator of relative variability among the two sources of random error. In this regard, two fundamental relationships are derived. First, as $\sigma_v^2 \to \infty$ or $\sigma_u^2 \to 0$, implying $\lambda^2 \to 0$, then the symmetric error which comes from the statistical noise part dominates determination of ε_i and it becomes the density of a normally distributed random variable with mean zero and variance σ^2. Secondly; if $\sigma_v^2 \to 0$, thus, the non-negative random variable side which is associated with measurement of technical inefficiency becomes the dominant source of variation in equation (4). Mathematical illustration is given in the appendix 2. Consequently, the density function which is asymmetric around zero with its mean and variance given by equation (9) and (10) as:

(9) $$E(\varepsilon) = E(v-u) = E(-u_i) = -\frac{\sqrt{2}}{\sqrt{\pi}}\sigma_u$$

(10) $$V(\varepsilon) = \sigma_\varepsilon^2 = V(u_i) + V(v_i) = (\frac{\pi-2}{\pi})\,\sigma_v^2 + \sigma_s^2$$

Finally, the log-likelihood functions by which estimation of parameters to be conducted is derived as follows:

(11) $$\ln(Q:\beta,\lambda,\sigma^2) \rightarrow L = n\ln\left(\frac{\sqrt{2}}{\sqrt{\pi}}\right) + n\ln\left(\frac{1}{\sigma}\right) + \sum_{i=1}^{n}\ln[1-F(\varepsilon\lambda\sigma^{-1})] - \frac{1}{2\sigma^2}\sum_{i=1}^{n}\varepsilon_i^2$$

where, $\varepsilon_i = \log Q_i - \beta\log X_i$

Consequently, maximizing equation (11) with respect to the unknown parameters and equating them to zero provides the parameter estimates[3]. Therefore, the technical efficiency level of each farm household is measured by computing the ratio of observed or actual output to the corresponding frontier or possible maximum output, depending on the level of input used by the respective farm households. On other side, it is expected that the actual production level is less than the frontier output (the deterministic part of the model). Mathematically, the technical efficiency for the i'^{th} farm household is given as:

(12) $$TE_i = \frac{Q_i}{Q_i^*} = \frac{f(x_i;\beta)\,exp(v_i-u_i)}{f(x_i;\beta)\,expe(v_i)} = exp(-u_i)$$

where Q_i corresponds to the observed agricultural output for the i'^{th} farmer and Q_i^* is related to the frontier output level (the deterministic part of the model). However, stata automatically predicts the individual efficiency scores by taking the natural logarithm of u_i. On the other hand, the potential output level of each household in the sample can be calculated by rewriting equation (12)[4].

4.4.2. The truncated normal model

According to Battese and Coelli (1995), the truncated normal stochastic frontier production model is given in equation (13) as;

---

[3] See Aigner *et al.* (1977), p. 19, for the second order derivation of equation (11).
[4] The mathematical derivation is given in appendix 4

(13) $$Y_i = \exp(x_i\beta + v_i - u_i)$$

where Y_i represent production function for the i^{th} household assuming Cobb-Douglas specification, x_i are inputs used in the production function, β is the parameter estimate, v_i and u_i represents random error associated with the noise and inefficiency component, respectively. Based on equation (13), the random error term, u_i in equation (4) can also follow a truncated normal distribution and thus the effect of inefficiency is calculated by truncation of the normal distribution, usually at zero. The functional form is illustrated as;

(14) $$U_i = z_i\delta_i + W_i$$

where the random variable, W_i is the truncation of normal distribution with a mean value of zero and variance, σ_u^2 such that the point of truncation is $-z_i\delta$. These assumptions are consistent with the nature of u_i which is a positive truncation of $N(z_i\delta, \sigma^2)$.

Similar to half normal assumption, maximum likelihood estimation[5] procedure is used in order to obtain the parameter estimates. According to Battese and Coelli (1993), the likelihood function is expressed as a function of a variance, σ_s^2 which is the sum of σ_v^2 and σ^2. Thus, gamma, γ which shows the sources of efficiency loss is calculated by taking the ratio of σ^2 and σ_s^2. Finally, the function representing technical efficiency of production for the i^{th} household is defined in equation (15) as;

(15) $$TE_i = \exp(-U_i) = \exp(-z_i\delta - W_i)$$

4.4.3. The exponential model

The stochastic frontier production function assuming exponential distributional assumption of the error term is elaborated by Wim and Broeck (1977). Accordingly, the Cobb-Douglas frontier production model is given in equation (16) as;

(16) $$Y_i = \phi(x_i)k_iu_i$$

where k_i and u_i measures an efficiency and noise components of the model, respectively. It is assumed that both of the error terms are mutually and independent distributed[6]. Generally, the random noise component is distributed with a mean value of zero and variance , σ^2 whereas, the inefficiency component distributed on the interval between zero and infinity, $(0, \infty)$.

[5] See Battese and Coelli (1993), p. 21 for detailed mathematical derivation of likelihood and other related functions.
[6] See Wim and Broeck (1977) for detailed derivation of estimates including the likelihood function

Therefore, stochastic frontier production function that follows the Cobb-Douglas model is given as;

(17) $$Y_i = A \prod_j x_i^{\beta_i^i} e^{-z_i} e^{-v_i}$$

where $k_i = -z_i$ and $u_i = -v_i$.

From equation (16), deriving the moments of $pdf's$ for efficiency and noise components k and u, respectively is vital step. In this regard, it is assumed that the efficiency component has a probability density function ranging between 0 and 1. Thus, the $pdf's$ for z and k are given as follows;

For the pdf of z,

(18) $$f_Z(z;\lambda) \begin{array}{ll} =\lambda e^{-\lambda z}, & z\geq 0 \\ =0, & Z<0 \end{array} \qquad (\lambda > 0)\,,$$

For the pdf of $K = e^{-z}$

(19) $$f_k(k;\lambda) = \lambda k^{\lambda-1}, \quad 0 < k \leq 1$$
$$= 0, \qquad elsewhere$$

The *pdf* for k is either monotonically decreasing or increasing for the value of λ on the interval of 0 and 1, 0< $\lambda < 1$. Hence, if $\lambda = 1$, k is uniformly distributed in the given interval. Finally, the average efficiency level is expressed as;

(20) $$\varepsilon_i = E(K) = \frac{\lambda}{\lambda+1}$$

4.4.4. The gamma model

The other distributional assumption is elaborated by Greene (1990) which assumes gamma distribution of the inefficiency component. This model is supposed to offer alternative frontier estimate as of half normal, truncated normal and exponential model. Particularly, the estimated inefficiencies under restricted model have much higher predicted values than the other models. Differently however, the gamma model considers the effects of restrictions that may have influence on pattern of estimated inefficiency level (Greene, 1990). The Cobb-Douglas form of stochastic frontier production model based on gamma distribution is given in equation (21) as follows;

(21) $$y_i = f(x_i, \beta_i) + v_i - u_i \qquad \text{where} \qquad u \sim G(\theta, P) \text{ and } v \sim N[0, \sigma^2]$$

Consequently, the density function for inefficiency term, u_i is given following equation (21), given as,

(22) $$f(u) = \frac{\theta^P}{\Gamma(P)} u^{P-1} e^{-\theta u}, \qquad u \geq 0,\ \theta, P > 0$$

The remaining derivation of parameter estimates can be referred at Aigner *et al.* (1977). Finally, one of the main features of u_i under gamma assumption is that it is truncated at zero having a truncated normal distribution with mean value of μ which is different from zero, and variance of σ_u^2. Similarly, the ratio of the two variance terms is given as;

(23) $$\frac{\alpha}{\sigma^*} = \frac{\sigma_v^2 \mu + \sigma_u^2 \varepsilon_i}{\sigma_v^2 + \sigma_u^2} \left[\frac{\sigma_v^2 \sigma_u^2}{\sigma_v^2 + \sigma_u^2}\right]^{\frac{-1}{2}} = \frac{\varepsilon_i \lambda}{\sigma} = \frac{\mu}{\sigma \lambda}$$

It is also highly recommended to refer Greene (1990) for further steps of mathematical derivation on mean, variance and inefficiency terms of the gamma model.

4.5. Estimation procedure

Maximum likelihood estimation procedure is used in estimating the stochastic production frontier relying on each of the four distributional assumptions. According to Schmidt and Lovell (1979), relying on MLE over OLS procedure provides three advantages. First, estimates are more efficient than ordinary least square as they have the lowest variance. Second, it guarantees the non-negativity conditions for the variances of error terms, σ_v^2 and σ_u^2. Finally, it prevents the possibility of finding the second and third moments, $\widehat{\mu_2}$ and $\widehat{\mu_3}$ such that $\widehat{\sigma_v^2} < 0$ which is against one of the main assumptions behind stochastic frontier estimation[7]. The other TSLS estimation is related to factors the influencing households' level of commercialization. Accordingly, technical inefficacy is with other proxy variables which are supposed to influence household commercialization level. Finally, the relationship between household food security and commercialization is comparatively discussed based on the nature of household food consumption expenditure.

4.6. Empirical models

The empirical analysis begins with specifying econometric model for stochastic frontier production function, assuming a log transformed Cobb-Douglas production function. The log of agricultural output is taken as a dependent variable on other explanatory variables which

[7] See Schmidt and Lovel (1979), p. 351 for detailed elaboration of the third assumption.

are supposed to determine output level. Generally, table 1 illustrates variables associated with stochastic frontier production function.

Table (2): Description of main variables related to stochastic frontier production function; the dependent variable is natural logarithm of total output

Variables	Description	Expected sign
Ln(ADUL)	Natural logarithm for number of adults in the household	+
Ln(FARM_SIZE)	Natural logarithm for total farm size in square kilometers	+
Ln(FERTIL)	Natural logarithm for total fertilizer use in kilogram	+
Ln(OXEN)	Natural logarithm for total number of ploughing oxen	+
Ln(HOE)	Natural logarithm for total number of hoes used in the farm	+
Ln(PLOUGH)	Natural logarithm for total number of plough used	+
Dummy_EXA	Dummy variable for extension access taking the value of ExA =1 if there is or 0 otherwise	+

Moreover, new specification for the determinants of technical inefficiency is developed by taking the predicted values of TE as a dependent variable. In this regard, studies revealed that sources of technical inefficiency are associated with farm and farmers characteristics, including age, gender, educational level, climate zone, types of crops produced by the household, farm distance from the market and credit access to the farmer (Aigner *et al.*, 1977; Alvarez & Crespi, 2003; Wadud & White, 2000).

The other emprial model is related to the determinats of comemrcialziation. Howevr, before specifiying model for the determinats of commercialziation, it is vital to differentiate various regioms of agriculture, particularly subsitence and semi-commercial or comemrrcial agriculure. In this regard, the distinction between subsistence and commercialized agriculture is explicitly elaborated by Pingali and Rosegrant (1995) as former is based on production feasibility and subsistence requirements, and selling only whatever surplus product is left after household consumption requirements are met. The later however involves production decisions based on market signals and comparative advantages.

In principle, it is argued that farm households always tend to supply certain level of their surplus produce to the market over what their consumption is satisfied (Gebre-ab, 2006). However, this rational behavior becomes distorted in the case of subsistence agriculture as the farm households tend to supply certain amount of product from subsistence level (Braun, 1995). Thus, scrutinizing commercialization in this context is crucial in order to come up with appropriate findings. In general, commercialization is an endogenous process influenced by various technical, economic and social factors. Therefore, an index for commercialization is calculated by taking the ratio of total value of agricultural sales in the market to total value of agricultural production, usually in percentage. Mathematically, it is given as:

$$HCL_i = \frac{TVS_i}{TVQ_i} \times 100 \tag{24}$$

where, HCL_i is level of commercialization by i^{th} household, TVS_i is total value of agricultural sale by i^{th} household and TVQ_i is total value agricultural product produced by $i'th$ household. In order to link an individual farm household's technical efficiency score with their respective commercialization level, $TSLS$ econometric specification is developed by taking it as a dependent variable. Under this specification, the exogenous factors are categorized as internal and external to farming activity. The external factors are associated with demographic, geographic, economic, technological and institutional factors existed outside the framing system (Pender & Alemu, 2007; Pingali & Rosegrant, 1995). On other hand, factors like smallholder resource endowments including land and other natural capital, labor, physical capital, human capital are among the internal factors influencing the level of commercialization. Mathematically, the empirical model is given as:

$$ln(HCL_i) = \beta_0 + \beta_1(MS) + \beta_2(Gen) + \beta_3 l\,n(Adul) + \beta_4 l\,n(Fs) + l\,n(MeAss) + \beta_6 ln(TE_i) + \varepsilon_i \tag{25}$$

where all $\beta's$ are unknown parameters to be estimated; MS is marital status; Gen is gender of the household head; $Adul$ is total number of adults in the household between age 16 and 60; Fs is size of the farm; $MeAss$ is membership of association and TE is the predicted technical efficiency score by the i^{th} household and ε_i is stochastic error term. However, it is supposed that technical efficiency is instrumented with other proxy variables which are indirectly influencing household's level of commercialization. Based on this thought, the empirical model is given as:

$$ln(TE_i) = \alpha_0 + \alpha_1 l\,n(Age) + \alpha_2\,ln(Educ) + \alpha_3(D_iRad) + \alpha_4(D_iCellPh) + \alpha_5 \ln(HCI) + \alpha_6(D_iMkt) + \alpha_7 ln(OFFinc) + \alpha_8(D_iExA) + \upsilon_i \tag{26}$$

where Age is age of the farmer; $Educ$ is farmers number of years in formal education; D_iRad is dummy for the use of radio, $D_iCellph$ is dummy representing cellphone use, HCL is farmer commercialization index, D_iMkt is dummy for i^{th} market; $OFFinc$ is the total value of off-farm income; D_iExA is dummy variable for extension access and $\upsilon_i$is the random error term.

4. Results and discussion

4.4. Frontier production estimate and comparison

An empirical work by Aigner *et al.* (1977) revolutionized the econometric modeling and estimation of neoclassical production function by adding a vital concept of technical efficiency on the previously used production function. In recent years however, alternative methods of estimation with various distributional assumption of the inefficiency component have emerged. Particularly, an empirical work by Schmidt and Lovell (1979) and Greene (1990) adds a significant impact on modeling and estimation of stochastic frontier production function. In most cases, there is minimal variation on parameter estimate under each assumptions and their directions are mostly to the same line (Liu & Myers, 2009). Thus, the main four different distributional assumptions of the inefficiency term, u_i under equation (4) include half normal, truncated normal, exponential and gamma distribution.

Although the half normal assumption has been dominantly used before, it is necessary to compare and select the robust estimate among each model as they have strong and weak side in fitting the collected data. For instance, some researchers avoid half normal and exponential distributions because they have a mode at zero (Coelli *et al.*, 2005). This implied that most inefficiency effects might be near to zero and the associated measure of technical efficiency would be near to one. On other side, the gamma model allows wider range of distributional shapes which can be seen to have non-zero modes and solves the problem associated with restriction in both half normal and exponential models (Greene, 1990). Besides, it may have larger influence on the form of estimated inefficiencies (Greene, 1990).

Moreover, differences in prediction of technical efficiency scores in each distributional assumptions are considered in selecting model (Coelli *et al.*, 2005). However, it can be possible to rank individual efficiency level on the basis of predicted technical efficiency scores as the ranks are often quite robust to distributional choice. In such cases, the principle of parsimony favors the simpler half normal and exponential models (Coelli *et al.*, 2005). Therefore, parameter estimates under each distributional assumption is conducted by thus research. Table (3) illustrates the parameter estimates for half-normal, truncated normal, exponential and gamma models

Table (3): MLE for the frontier production function under each distribution; the dependent variable is natural logarithm of total output

VARIABLES	Half-Normal	Truncated Normal	Exponential	Gamma
	Coef.	Coef.	Coef.	Coef.
Ln(ADUL) in number	0.360***	0.220*	0.220*	0.183*
	(0.137)	(0.116)	(0.116)	(0.108)
Ln(FARM_SIZE) in square kms	0.0646**	0.0551**	0.0551**	0.0504**
	(0.0266)	(0.0231)	(0.0231)	(0.0228)
Ln(FERTIL) in KG	0.0829**	0.0984***	0.0985***	0.110***
	(0.0344)	(0.0288)	(0.0288)	(0.0275)
Ln(OXEN) in number	0.549***	0.468***	0.468***	0.461***
	(0.170)	(0.136)	(0.136)	(0.127)
Ln(HOE) in number	0.184*	0.142*	0.142*	0.139*
	(0.0974)	(0.0776)	(0.0776)	(0.0726)
Ln(PLOUGH) in number	0.0391	0.00823	0.00822	0.00933
	(0.0777)	(0.0640)	(0.0640)	(0.0605)
Dummy_ExA	0.116	0.0896	0.0896	0.0671
	(0.116)	(0.0968)	(0.0968)	(0.0914)
Village_Dummy2	0.985***	0.714***	0.714***	0.633***
	(0.251)	(0.203)	(0.203)	(0.190)
Village_Dummy3	0.622**	0.440**	0.440**	0.418**
	(0.257)	(0.215)	(0.215)	(0.201)
Village_Dummy4	0.831***	0.558***	0.558***	0.477***
	(0.233)	(0.194)	(0.194)	(0.183)
Village_Dummy5	-0.0375	-0.227	-0.228	-0.301
	(0.254)	(0.224)	(0.224)	(0.216)
Village_Dummy6	0.00555	-0.194	-0.194	-0.267
	(0.249)	(0.208)	(0.208)	(0.195)
Village_Dummy7	1.205***	0.983***	0.983***	0.937***
	(0.281)	(0.241)	(0.241)	(0.230)
Usigma	1.790***	7.948***	0.696***	1.715***
	(0.074)	(1.720)	0.109	(0.187)
Vsigma	-1.400***	-1.220***	1.219***	-0.932***
	(0.192)	(0.143)	(0.143)	(0.112)
Sigma_u	2.447***	53.216	1.416***	2.357***
	(0.091)	(45.775)	(0.077)	(0.220)
Sigma_v	0.496***	0.543***	0.543***	0.627***
	(0.047)	(0.038)	(0.038)	(0.035)
Lambda	4.929	97.944	2.607***	3.758***
	(0.115)	(45.775)	(0.096)	(0.226)
Shape				0.430***
				(0.036)
Mu		-1994.370		
		(3435.89)		
Log Likelihood	-997.4869	-939.239	-939.151	-920.34
Mean Efficiency	29.3 %	40.2%	40.2%	57%
Observations	562	562	562	562

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

The result indicated that variance components of the two error terms in each model are significant at 99 percent confidence interval with the exception of σ_u under truncated normal model. Interestingly, the calculated lambda[8] (λ) value for exponential and gamma model becomes significant at 99 percent confidence interval confirming the existence of efficiency loss across the farmers. Conversely, in the case of half normal and truncated normal is not significant confirming the cause of deviation from the potential output is entirely a result of the noise or uncontrolled component. In practice however, there is always a contribution of inefficiency component in lowering output from the most possible maximum output level. Thus, the half normal and truncated normal models are rejected by this research since they could not satisfy one of the core assumptions in stochastic frontier analysis.

Similarly, it is vital to know what percentage of total variation in output is lost due to the existence of technical inefficiency or other uncontrolled factors. This involves calculating gamma[9] (γ) from the estimated standard errors of inefficiency and noise component. In half normal case, γ takes value of (0.961) confirming 96 percent of the total variation in the error term happened because of the farmer's technical inefficiency. Likewise, truncated normal, exponential and gamma distributions took (0.999), (0.872) and (0.934). This suggests, each model accounts for 99.9 percent, 87 percent and 93 percent of variation in the total error term happened due to farmer's technical inefficiency, respectively.

Consequently, the predicted mean efficiency score for half normal, truncated normal, exponential and gamma models showed a values of 29 percent, 40 percent, 40 percent and 57 percent, respectively. Interpretations of the scores are straight forward. For instance, assuming exponential distribution of the error term, farmers are 40 percent technically efficient given the same level of input used in their production function as compared to the most efficient farmers. Table (4) summarizes distribution of mean technical efficiency score in each model.

Table (4): Summary of technical efficiency distribution in each model

Models	**Observation**	**Mean TE[10]**	**Std. Dev.**
Half Normal	562	0.29	0.204
Truncated Normal	562	0.40	0.230
Exponential	562	0.40	0.230
Gamma	562	0.57	0.272

[8] For detailed elaboration see Aigner *et al*. (1976), p.8, and the mathematical derivation is given in appendix 3.
[9] See appendix 3 for mathematical derivation.
[10] This value is obtained by summing up all the individual farm households technical efficiency scores and dividing the sum to the total observations.

Since it is observed that the calculated lambda is not significant in half normal and truncated normal models, the research choses among the exponential and gamma models. Accordingly, the gamma model has the higher average efficiency score with 57 percent and exponential one with a mean efficiency score of 40 percent. Therefore, choosing consistent and unbiased model from these two models is a crucial step of the research. In this regard; as suggested by Coelli *et al.* (2005), comparison of variances and normality plot for the error terms and efficiency score is used as a criterion of selection.

4.5. Robustness of the econometric result

5.3.1. Skewedness test for OLS residuals

Checking the degree of skewedness for OLS residuals is one of the crucial steps in obtaining the most efficient maximum likelihood estimates in stochastic frontier model. According to Waldman (1982), whenever the third moment of the OLS residual is less than zero, a local maximum of the likelihood is found at a point other than the global maximum and whenever it becomes less than zero, no local maximum exists (Waldman, 1982). Therefore, if the third moment of a residual is positive, then it will always be the case that all the least square estimates represent a local maximum of the likelihood function. However, when it becomes negative, the likelihood has a greater value at some other point (Olson, 1980).In this regard, the Epanechnikov Kernel density[11] plot from the predicted OLS residual showed a positive skewedness of the OLS residuals. As a result, the maximum likelihood estimator becomes unique and consistent. Figure (7) shows estimated a positive sided Kernel density plot for OLS residuals.

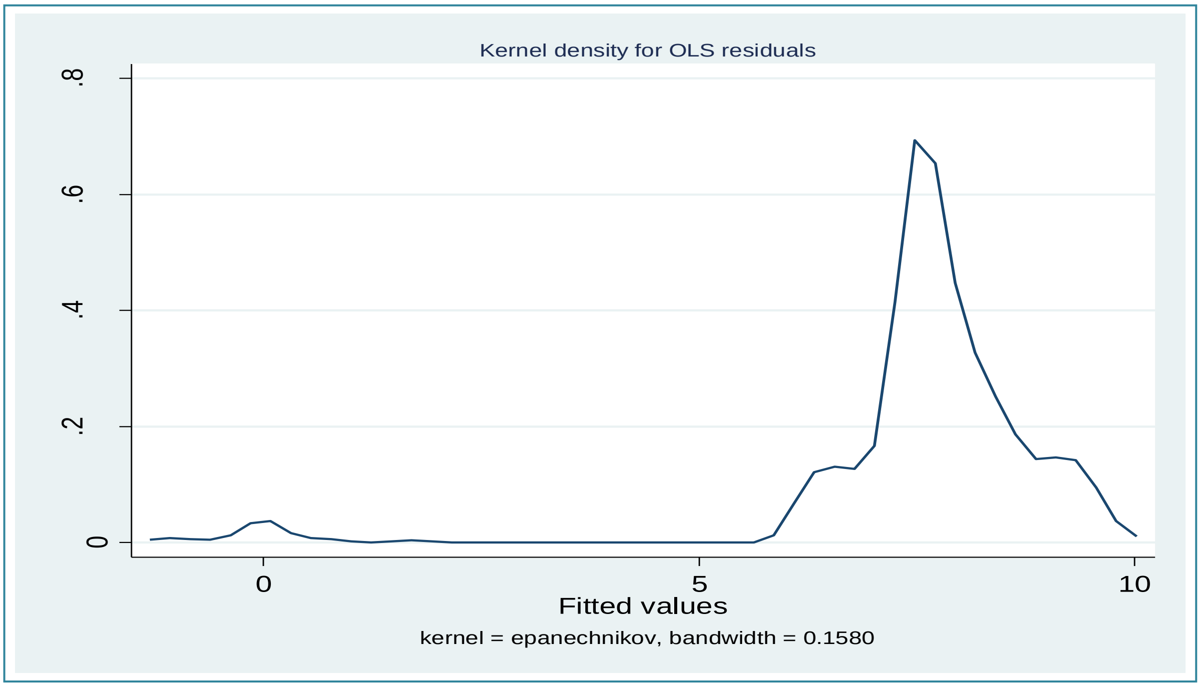

Figure (7): Epanechnikov Kernel density estimate plot for the OLS residuals

The OLS estimates for the log transformed Cob-Douglas production function is presented in table (5). Based on the result, R-square showed a value of 0.62 implying the exogenous

[11] Epanechnikov Kernel density estimate is preferred over other alternative density functions due to its better prediction efficiency. For detailed elaboration see Zucchini (2003), p.8.

variables in the model explains 62 percent of the total variation in the total output level with all variables having theoretically consistent coefficient sign. Besides, fertilizer use, oxen, hoe, extension access and being member of association in the community are statistically significant. Entire village dummies which are used to capture the regional variation and unseen effects become statistically significant with the exception of village 6 (Aze Deboa). It should be noted that the first village (Dinki) is omitted from the regression equation since it is used as a reference variable. However, the effect of village 2 (Yetmen) on total output is higher than 76 percent as compared to the village 1(Dinki).

Table (5): OLS estimates of log transformed Cob-Douglas production function; the dependent variable is natural logarithm of total output

VARIABLES	Coefficients	Std. Err.	P>t
Ln(ADUL) in number	0.195	0.154	0.207
Ln(FARM_SIZE) in square kms	0.026	0.032	0.418
Ln(FERTIL) in KG	0.132	0.035	0.000
Ln(OXEN) in number	0.492	0.148	0.001
Ln(HOE) in number	0.230	0.086	0.008
Ln(PLOUGH) in number	0.039	0.071	0.585
Dummy_EXA	0.201	0.114	0.080
Dummy_MCP	6.951	0.228	0.000
VILLAGE_ dummy 2	0.767	0.226	0.001
VILLAGE_ dummy 3	0.480	0.233	0.040
VILLAGE_ dummy 4	0.514	0.229	0.025
VILLAGE_ dummy 5	-0.655	0.278	0.019
VILLAGE_ dummy 6	-0.149	0.217	0.493
VILLAGE_ dummy 7	0.544	0.307	0.076
Constant	-0.642	0.253	0.012
Observations	562		
R-squared	0.62		

5.3.2. Normality test for the efficiency scores

The other central assumption associated with estimation of stochastic frontier model is related to the distribution of efficiency scores. In this regard, the inefficiency component is non-negatively truncated normal distribution with mean value of zero and variance, σ^2. Based on this postulation, Greene (2002) elaborated that the model with relatively normal and lower variance is representative. Thus, comparison of kernel density plot for efficiency scores in each model can affirm the most efficient model. Accordingly, the exponential and truncated normal models have similar kernel density plot in a relative term. However, it is observed that the value of lambda under truncated model is insignificant and contradicts the core theoretical justification on the prevalence of technical inefficiency (Aigner *et al.*, 1977; Coelli *et al.*, 2005; Greene, 1990). This leads to selection of exponential model as it fits the data in a better way than the other models. Besides, it is normally distributed on a positive range in relative term and has lower variance. However, the remaining models are not normally distributed in a relative term and characterized by larger variance. Figure (8) below shows the kernel density plot under each model.

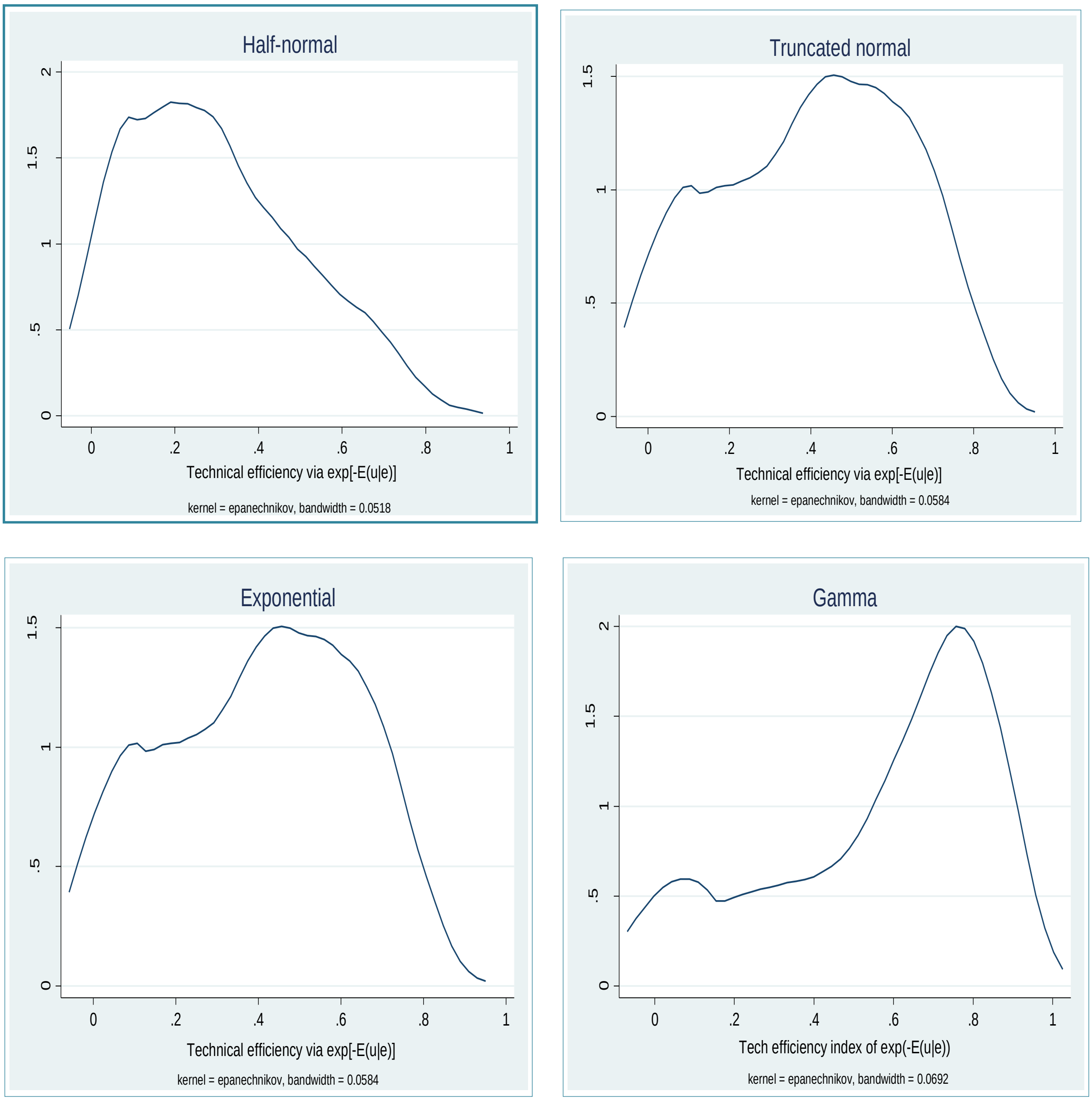

Figure (8): Comparison of Kernel density estimate for each distributional assumption

4.6. The potential output

According to Nishimizu and Page (1982), potential output or potential level of factor productivity is defined as the maximum factor of increase in actual output that can be produced with the observed mix of input employed at the actual productivity level. Based on this definition, figure (9) illustrates the gap between actual and most possible maximum output from tracing on the estimated result. The horizontal line represents ascendingly ordered farmers based on the actual output they produced and vertical line shows the total value of output in thousands of ETB. From the diagram, it is observed that farmers incur an efficiency loss of the area marked by red color. This region is in fact a loss where farmers can actually avoid without changing currently used level of input. On other hand, the bottom blue accent patterned area indicates the actual output where farmers are currently producing. It shows the actual output level which is produced below the potential level.

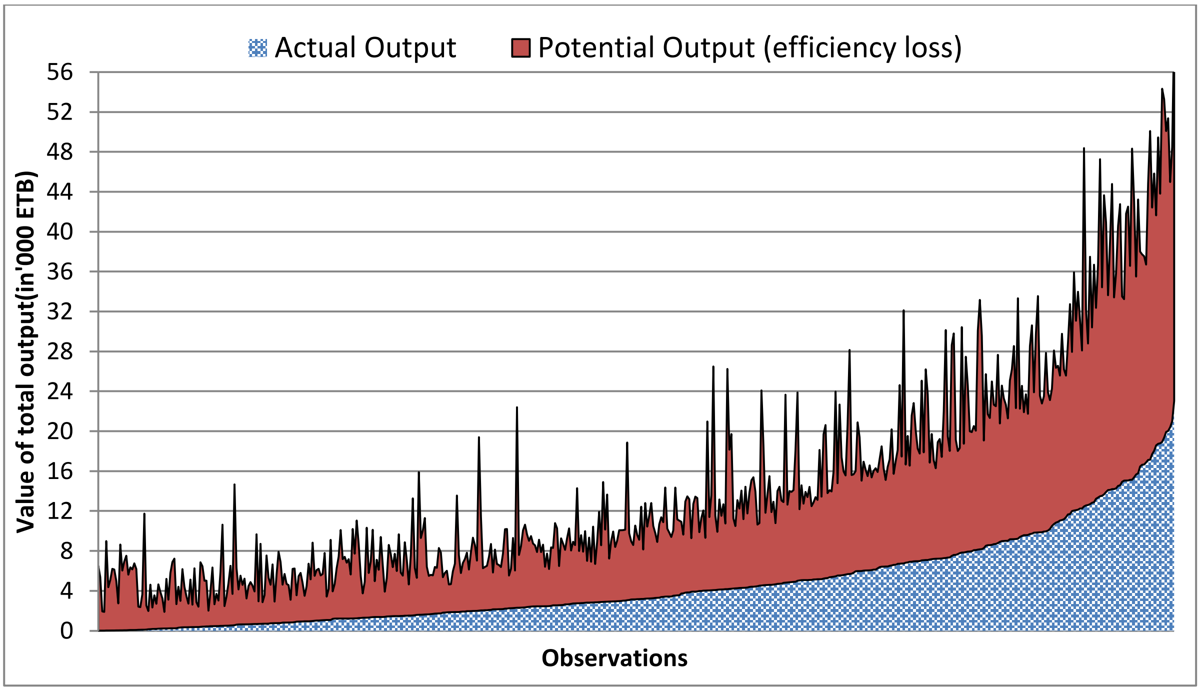

Figure (9): Comparison of actual and potential output. Source: Own illustrated based on the data and predicted efficiency score

Generally, farmers are at lower level of technical efficiency and they can still have to improve their level of productivity. Hence, it is important to identify those factors responsible for the prevalence of efficiency loss across the farmers. In particular, the expected role of commercialization in minimizing the red shaded area is the leading point of the research and will be presented in succeeding part.

5.4. Factor elasticity

Estimating factor elasticity is important in looking at the possible implications behind changing input mix used during production process. Literally, factor elasticity for the significant input variables shows a proportionate change in total output induced by a given proportionate change in the input level, assuming other factors held constant. The estimated elasticity value is generally important as it showed the effects of any policy intervention aimed on increasing agricultural production. For instance, certain public program with the objective of increasing agricultural production by allowing farmers to have more oxen by 1 percent results 0.46 percent increase in total output, assuming other factors constant. Table (6) summarizes the value of elasticity for significant inputs used in the frontier production function. Note that since the production function is a log transformed Cobb-Douglas form, coefficient values are directly taken as elasticity value.

Table (6): Estimates of factor elasticity for significant inputs

Inputs	Elasticity
Ln(ADUL) in number	0.220
Ln(FARM_SIZE) in square kms	0.055
Ln(FERTIL) in KG	0.098
Ln(OXEN) in number	0.468
Ln(HOE) in number	0.142

Similarly, with a one percent additional unit of labor in to the production mix leads to an increase of total output by 0.22 percent, holding other factors constant. On other hand, the effect of change in farm size in deviating total output is small in a relative term. For instance, an increase in in farm size by 1 percent results output to increase by 0.05 percent, assuming other factors constant. Further, an additional use of fertilizer by 1 percent can increases the total output by 0.09 percent, holding other factors constant.

There are certain general implications behind the estimated elasticity's. Firstly, total output is highly responsive to a small change in in the number of oxen used by the households which is also consistent with similar study made by Nisrane *et al.* (2011). Secondly, although the effect of increasing labor is relatively higher, it should be considered that output should only increased until the point where marginal physical product of labor equal to zero. Therefore, any policy aimed on using extensive labor in the agricultural production should take in to account each stages of production with respect to change in labor use. Thirdly, application of fertilizer by the average farm household is at minimal level which is 0.01kilogram/square kilometer[12]. However, it is observed that additional fertilizer use has statistically significant effect on the level of total output implying the requirement of substantial effort towards access for fertilizer to the farm households. Finally, increasing farm size may not be effective since the corresponding effect on output level is minimal in a relative term. Rather, it is vital to focus on other options that improve output per square kilometer.

5.5. Determinants of technical inefficiency

It is supposed that various socio economic factors around the farm are supposed to influence farmers' level of technical inefficiency. In this regard, the maximum likelihood estimate for the determinants of farmers' technical inefficiency level indicates four statistically significant variables. Firstly, farmer's educational level contributes for lower level of technical inefficiency. For instance, increase in the farmer formal schooling by one year leads to a reduction of inefficiency by 0.35 percent, holding other factors constant. Secondly, if the farmer has an access for radio, his/her level technical inefficiency is lower by 0.37 percent as compared to those farmers without access, holding other factors constant. Thirdly, cell phone application in the household plays a significant role in minimizing technical inefficiency. In this regard, those farmers using cellphone has lower level of technical inefficiency by 0.53 percent than those who do not have access, holding other factors constant.

Importantly, farmers' commercialization level is significant at 99 percent confidence interval showing negative effect on technical inefficiency level. Explicitly, one percentage increase in the household commercialization level leads to a reduction of technical inefficiency by 0.24 percent, holding other factors constant. The implication is that higher degree of market participation has a significant effect in reducing technical inefficiency across the farms. The other important variables related to availability of credit access and different markets are not statistically significant but showed theoretically consistent sign. Generally, table (7) illustrates the maximum likelihood estimates for the determinants of technical inefficiency.

[12] The figure is calculated by dividing the total use of fertilizer in all villages to total farm size in square kilometers.

Table (7): MLE for the determinants of inefficiency component; the dependent variable is technical inefficiency

Variables	**Coefficients**	**Std. Err.**	**P>|z|**
Ln(AGE)	-0.386	0.378	0.307
Ln(EDUC)	-0.352	0.145	0.015
SEX_ dummy	0.280	0.248	0.258
RADIO_ dummy	-0.375	0.231	0.105
CELL PHONE_ dummy	-0.533	0.300	0.076
Ln(HCI)	-0.243	0.072	0.001
MARKT_dummy2	-0.230	0.680	0.735
MARKT_dummy3	-0.391	0.297	0.189
MARKT_dummy4	-0.499	0.606	0.410
MARKT_dummy5	-2.928	1.867	0.117
CREDACC_ dummy	-0.196	0.223	0.381
Constant	2.433	1.542	0.115
Mean efficiency score	0.40		
Log likelihood	-769.513		
Observations	540		

In conclusion, the sign of coefficients for all variables become theoretically consistent having diverse implication. In particular, access for radio and cell phone which are associated with lower technical inefficiency score suggests the importance of improving ICT related infrastructure around the farm as it will increases agricultural productivity. This is perhaps linked with easy flow of information on input and output price, weather forecast and other related variables with the application of these technologies. Further, those framers with higher level of commercialization index are associated with better efficiency score. This finding supports the argument stating highly commercialized framers are more likely to become productive as farmers can overcome various constraints associated with factors of production (Govereh *et al.*, 1999; Strasberg *et al.*, 1999). Finally, although those variables representing different types of market around the farm are not statistically significant, they have theoretically consistent sign and particularly in line with the finding made by Nisrane *et al.* (2011).

5.6. Distribution of technical efficiency score across the farmers

The estimated technical efficiency score showed varied nature of distribution across the entire farmers. Accordingly, 23 percent of the farmers lied on a rage of between 20 percent and 40 percent. On other hand, 24 percent are less than 20 percent of the mean efficiency score indicating most farmers are relatively less efficient. Besides, 29 percent of the household found on the middle range of mean technical efficiency score which is between 40 percent and 60 percent. Similarly, only 29 percent of the farmers have the efficiency score more than 60 percent, indicating most farmers are still at lower efficiency level. Remarkably, one percent of the households have the technical efficiency score more than 80 percent, making them most efficient or outlier farmers in the sample. Figure (10) shows the distributions of technical efficiency score across farmers.

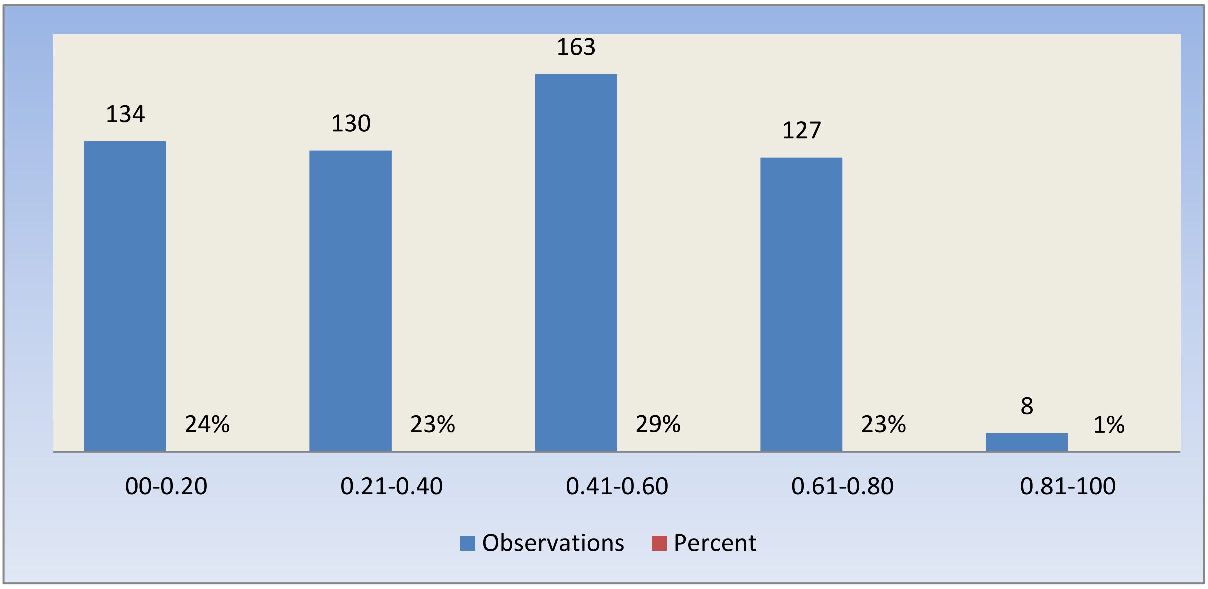

Figure (10): Range of technical efficiency distribution across the farmers

One of the main characteristics of most efficient farmers is that they are predominantly engaged in the production of coffee, wheat and maize which are cash crops in most areas. This suggests the occurrence of possible connection between market intensive crops and higher level of technical efficiency score. In general, the predicted efficiency score is evenly distributed across the farmers except those 1 percent outlier framers. In fact, those farmers with the higher efficiency score represents small proportion of the total sample in relative term and most of them are engaged in pure cash crop production. The detailed socio economic characteristic of efficiency score with respect to village's characteristics is presented in the subsequent part.

5.7. Regional pattern of technical efficiency distribution

Comparing the mean technical efficiency scores among village is important in assessing the sources of variation. Accordingly, Yetmen and Adele Keke which are characterized by densely populated, highland and largely commercials crops producing areas have higher mean efficiency score with a value of 45 and 44 percent, respectively. This showed that commercial oriented framer scores better efficiency level than the other farmers. Relatively, farmers in Imdibir area scored lower level of mean efficiency with a value of 33 percent. In fact, this village is characterized by dense population settlement and production of Enset which is home consumable drought resistant crop. Generally, farmers in those highland and mainly cereal producing villages such as Yetmen, Adele Keke and Turfe Kechemane are more efficient than the other villages. Particularly, these villages took higher volume of cereal production in Ethiopian domestic market (CSA, 2011). Table (8) summarizes efficiency score distribution and regional characteristics across the villages.

Table (8): Regional distribution of efficiency score

Region	Villages	Characteristics	Observation	Mean TE
Amhara	Dinki	Dry- millet and teff producer	74	37%
Amhara	Yetmen	Highland-teff, wheat and barley	50	45%
Oromia	Adele Keke	Highland- Millet, maize, coffee, chat	87	44%
Oromia	Turfe Kechemane	Highland-wheat, barley and teff	92	42%
SNNPRS	Imdibir	Densely populated- Enset, chat, coffee and maize	62	33%
SNNPRS	Aze Deboa	Densely populated-Enset, coffee, maize, teff, sorghum	73	41%
SNNPRS	Addado	Rich, densely populated-coffee and Enset	124	37%

Source: IFPRI (2009) and own estimate

5.8. Farmers level of commercialization and its determinants

Descriptive statistics on the distribution of mean commercialization index showed a substantial variation across the villages. For instance, farmers in Addado village sell 94 percent of their total produce to the market which make them the most commercialized village in the sample. In fact, this village is characterized by large settlement of rich farmers which are mainly relied on production of commercial oriented cash crop (coffee) (IFPRI, 2009).

Conversely, Adele Keke has the lowest mean commercialization index of which farmers supply only 9 percent of their average total produce to the market. This village is mainly characterized by production of home consumable millet and maize. Besides, the village is known for its lower mean annual rainfall distribution and frequent drought experience (IFPRI, 2009). On other hand, Turfe Kechemane and Aze Deboa scored an index of 24 percent. These villages are mainly characterized by teff production, densely settlement and better rainfall distribution throughout the year. Generally, the descriptive statistics indicated that average farmers are at lower level of commercialization with a mean index of 28 percent. This level is nearly consistent with the one cited by Gebre-ab (2006) where an average Ethiopian farmers supply 35 percent of their output to the market. Generally, the overall fining suggests the requirement of substantial effort towards improving farmers' market participation rate. Table (9) summarizes the distributions of commercialization index across the study villages.

Table (9): Distribution of mean commercialization index across the village

Study Village	Observation	Mean HCI
Dinki	74	14%
Yetmen	50	14%
Adele Keke	87	9%
Turfe Kechemane	92	24%
Imdibir	62	19%
Aze Deboa	73	24%
Addado	124	94%

Source: Own calculated based on ERHS/2009

Studies indicated that several socio economic factors influences smallholder's degree of market participation. Particularly, it is argued that relying on market oriented agriculture has an important role on farmers' level productivity and wellbeing in most developing countries where market failures and credit constraints are dominant (Braun, 1995; Govereh *et al.*, 1999; Jaleta *et al.*, 2009). This makes commercialization as an integrated process of agricultural transformation in these regions.

Generally, the peculiar nature of commercialization in substance agriculture is that smallholders still supply certain proportion of output to the market even if they are in shortage. For instance, the study made by Gebre-ab (2006) on Ethiopian smallholders indicated that average farmers supply output to the market even they do not have surplus produce in order to meet their remaining demand. Generally, as elaborated by Poulton and Leavy (2007), the main objectives of subsistence agriculture is achieving food selfsufficiency. However, this situation is different under large scale commercial oriented agriculture as farmers are mainly relied on profit maximization. As a result, analyzing the determinants of agricultural commercialization requires categorization of farmers either in to subsistence or commercial oriented farmer.

Based on this thought, it is vital to check the causality between level of smallholder commercialization and technical efficiency. This is analyzed by specifying appropriate TSLS regression model by instrumenting technical efficiency with other proxy variables which are supposed to determine commercialization. Broadly, variables related to demography, technology, institution, infrastructures are supposed to influence farmers level of commercialization (Braun, 1995; Moti *et al.*, 2009; Poulton & Leavy, 2007). TSLS estimates for the determinants of farmer's commercialization are provided under table (10).

Table (10): Log transformed TSLS estimate for the determinants of commercialization; the dependent variable is household commercialization level

Variables	**Coefficients**	**Standard Error**	**P>t**
Ln(TE)	-0.313	0.507	0.538
ASSOC_ dummy	-0.250	0.215	0.247
CREDACC_ dummy	0.254	0.186	0.172
VILLAGE_ dummy2	0.355	0.482	0.462
VILLAGE_ dummy3	-0.058	0.243	0.811
VILLAGE_ dummy4	0.156	0.375	0.677
VILLAGE_ dummy5	0.000	0.490	0.999
VILLAGE_ dummy6	0.223	0.331	0.501
VILLAGE_ dummy7	3.459	0.334	0.000
MARKT_dummy2	2.336	0.495	0.000
MARKT_dummy3	2.677	0.302	0.000
MARKT_dummy4	2.624	0.587	0.000
MARKT_dummy5	2.529	0.700	0.000
Ln(OFF_INCO)	0.030	0.031	0.339
F-statistics	27.59		0.000
Sargan test			0.3710
R-Squared	0.62		
Adj R-squared	0.59		
Observations	233		
Instrumented: ln(TE)			
Instruments: D_ASSOC, MARKT_dmmy2, MARKT_dmmy3, MARKT_dmmy4, MARKT_dmmy5, ln(OFF_INCO), D_CREDACC, VILLAGE_dummy2, VILLAGE_dummy3, VILLAGE_dummy4, VILLAGE_dummy5, VILLAGE_dummy6, VILLAGE_dummy7, ln(AGE), ln(EDUC), RADIO, CEL_PHONE, D_MCP, D_EXA			

Interestingly, the result indicated that instrumented farmers level of technical efficiency (TE) becomes statistically insignificant implying absence of influence on farmer's commercialization level. This is coincided with the argument made by Gebre-ab (2006) stating surplus or being productive is not the main drivers of market participation in subsistence agriculture as smallholders still supply certain proportion of their produce so as to cover other demand. However, it is found that all types of markets[13] are statistically significant with 99 percent confidence interval in determining commercialization level. For instance, if farm household is selling its output in market 4 (regional market), its expected level of commercialization is more by 2.6 percent than to those framers selling in market 1(local market), holding other factors constant. This suggests the vital importance of regional markets around the farm in order to improve smallholder's commercialization. Besides, dummy variable representing membership association *(maheber or ekub)* is become statistically insignificant although it has consistent expected coefficient sign. Note that the detailed elaborations for the term, *mahber* and *ekub* are given in appendix 5.

Checking relevance and exogenity of instruments is a key task in modeling and estimation of TSLS regression analysis as it guarantee the quality of parameter estimates. Primarily, instruments are supposed to be relevant if at least one of the coefficient value for the instruments is different from zero (Stock & Watson, 2003). Interestingly, the test for joint significance of instruments (F-statistics)[14] suggested rejection of the null hypothesis since instruments become jointly different from zero and statistically significant with 99 percent of confidence interval. Similarly, overidentification test which affirms whether instruments are exogenous or not indicates remarkable result. In this regard, the Sargan test[15] for overidentification confirmed that instruments are uncorrelated with the error term and thus we do not reject the overidentification restrictions.

[13] According to the data set provided by IFPRI (2009), available markets to the farmers are categorized under *local markets, village market, other village market, regional market* and *Addis Ababa*.

[14] The estimated F-statistics indicated the F value of $F(7, 553) = 99.85$ with $probability > F = 0.000$

[15] The test for over identifying restrictions or Sargan N*R-sq test indicated a value of 4.268 Chi-sq(4) with P-value = 0.3710. Similarly, the Basmann test shows a value of 3.993 $Chi - sq(4)$ with $P - value = 0.4070$

5.9. Commercialization and food security

It is believed that commercialization have a potential of improving farm households food security status through providing different types of resources in agricultural production; particularly, interms of investment in infrastructure and human capital (Govereh *et al.*, 1999). This argument indirectly suggests the expected role of commercialization for agricultural productivity in supplying different types of inputs. On other hand, Braun (1995) claimed that the process of smallholder commercialization has multiple effect on the overall welfare of farm households including on income and nutrition. The food security or nutrition effect of commercialization ultimately depends on the decision behavior of farm households in allocating resources including land, labor, time and capital. For instance, allocation of land for non-food cash crop may decrease household food supply unless the households should have other sources of off-farm income that could be used for food purchase. This suggests having better income through commercialization and off-farm income allowed households to widen their consumption pattern interms of quality and quantity. Explicitly, this research comparatively analyzes the relationship between commercialization and household income level allocated to food consumption. It should be noted that the effects of commercialization on households' calorie intake level is not considered due to lack of data on household's calorie intake level.

Consequently, plotted graph based on the collected data showed a positive connection between farmers' commercialization and agricultural income level. This indicated that those farmers with higher commercialization index are associated with higher agricultural income suggesting the possible positive effects of market participation on farmers' food purchasing power. Importantly, lower average commercialization index is associated with higher off-farm income which points the possible scenario that farmers can potentially widen their consumption pattern interms of quality and quantity with the income generated from off-farm sector. Figure (11) illustrates the linkage between household's agricultural income (with the blue line), off-farm income (with the red line) and commercialization index (the x-axis). It should be noticed that the illustration indicates only the sign of relationship between each of variables.

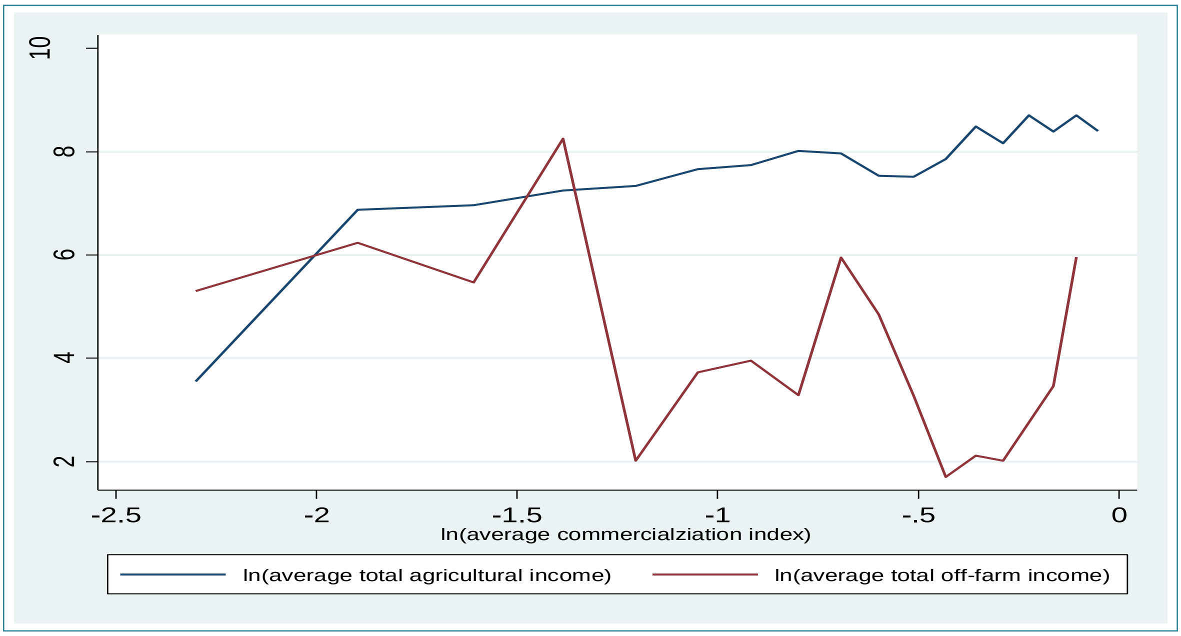

Figure (11): The relationship between log-transformed household's average agricultural income, off-farm income and commercialization level

Notably, the famous economic theory on household's food consumption expenditure stated that household's food consumption expenditure is a positive function of their income (Perthel, 1975) implying the dependence of expenditure on income. This provides an insight on how commercialization and food security across the farmers are interrelated. In this regard, figure (12) shows the relationship between households average commercialization index and average total food consumption expenditure.

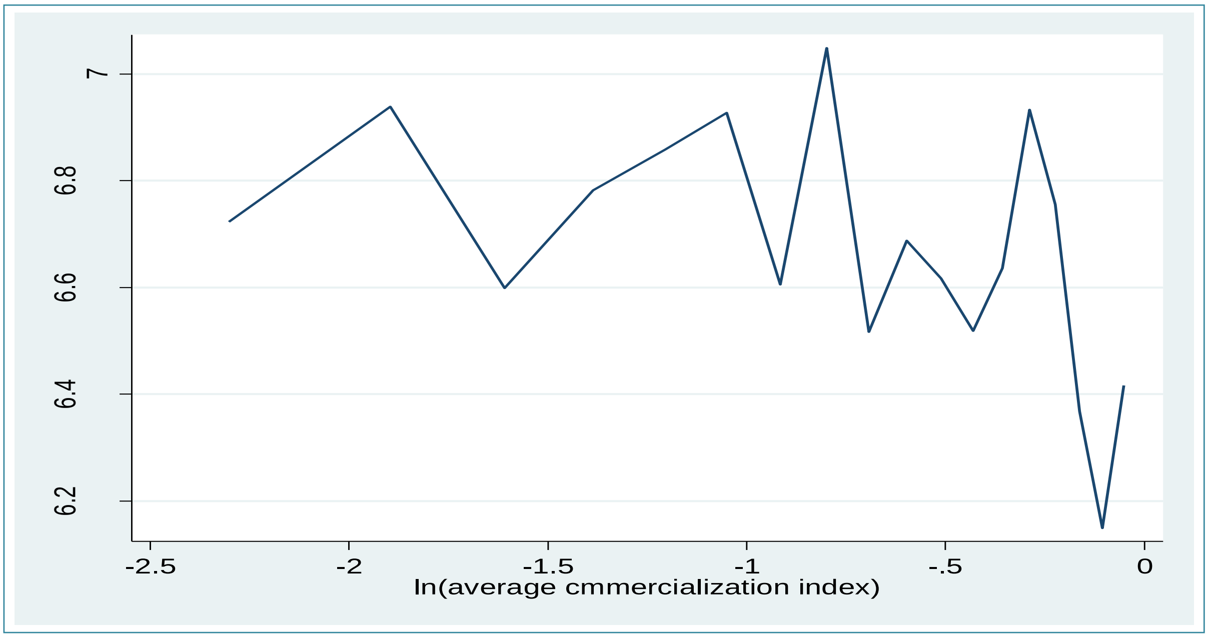

Figure (12): The relationship between log-transformed household average total food consumption expenditure and commercialization level

The above illustration is directly associated with a famous Engel's law dealing with the properties of households food consumption expenditure in relation to the total income. The law stated that change in the amount of budget allocated for food consumption expenditure is indirectly associated with the level of per capita income (Perthel, 1975). In this regard, the collected data on the percentage share of average total food consumption expenditure is consistent with the law having a negative relationship. As average total income of the household increases, the amount of average total food consumption expenditure diminished implying a declining pattern of budget share for food consumption. It should also be noticed that the decline is not associated with diminishing of food consumption interms of quantity and quality rather it is linked with effect of rising income level on food consumption expenditure budget.

In addition, it is vital to see the role of smallholder commercial agriculture from efficient market hypothesis perspective as it helps to minimize food insecurity arising from market failures (Barrett, 2008). In fact, this is conditional to different institutional arrangement around agriculture. For instance, availability of market information to the farmers at the right time has a significant impact on the degree of household market participation (Barrett, 2008). In conclusion, figure (13) shows the relationship between household income and budget share of budget allocated for food consumption. The figure revealed with a diminishing pattern with an indication of higher levels of market participation can possibly improves the quality and quantity of food consumption.

Figure (13): The relationship between log-transformed share of average total food consumption expenditure and commercialization level

Generally, a declining pattern suggests a possible improvement in the farmers' welfare level, assuming the adverse effects of market price level to be constant. Thus, it can be argued that the more farmers are well integrated to the market, their income level becomes increased and which finally leads farmers' capability of accessing different types of food.

6. Summary of findings

The estimated stochastic frontier production function indicated that average farmers are at lower level of technical efficiency in relation to the most efficient farmers in the sample. Accordingly, average farmers are only 40.2 percent technically efficient given the same level of input they are currently using as compared to the most efficient ones. The implication is that there is a potential gain of maximum 59.8 percent output that can be obtained using the current level of input mix. Furthermore, maximum likelihood estimate for the determinants of technical inefficiency revealed a number of socio economic factors. Farmer's educational level, degree of market participation interms of commercialization, access for radio and cellphone have statistically significant effect in minimizing technical inefficiency, with a coefficient values of 0.35, 0.24, 0.37 and 0.53, respectively. Similarly, the estimated factor elasticity for those significant variables showed that oxen is the most sensitive input variable in changing total output compared to other variables. Accordingly, a one more unit of oxen by the farmer will results 0.46 percent increase in total output, assuming other factors constant. Similarly, labor, farm size, and fertilizer use have elasticity values of 0.22, 0.05 and 0.09, respectively.

Finding on the prevailing causal relationship between commercialization and level of technical inefficiency confirmed that degree of market participation interms of commercialization significantly minimizes farmer's level of technical inefficiency. Particularly, the variable is significant at 99 percent confidence interval. On other hand, farmers' level of technical efficiency becomes statistically insignificant in affecting commercialization level. In addition, the log-transformed TSLS estimate for the determinants of household's level of commercialization found that all types of markets are statistically significant with 99 percent confidence interval. Besides, the research found a positive relationship between average framers commercialization level and food consumption expenditure in absolute term. Further, the result on the relationship between households budget share and food consumption expenditure coincided with the famous Engel's law with a decreasing pattern. Generally, the result implied that those households with higher level of commercialization showed an increasing pattern of food consumption expenditure in absolute term which is an indication of improving food purchasing capabilities, assuming other factors constant.

7. Conclusions

This research discovered the prevalence of direct link between smallholder commercialization and agricultural productivity as the former plays a significant role in improving the later one. This implies that any policy effort aimed on creating efficient tie between farmers and market will improve the performance of agricultural production particularly in a situation where financial and credit constraints widely prevail. Thus, increasing farmer's educational level, creating sufficient access of ICT tools including radio and cell phone significantly contributes for higher degree of market participation.

One of the key finding regarding causality between farmers level of productivity and commercialization is that productivity becomes a function of commercialization in a significant manner. In fact, this finding is coincided with the argument forward by Gebre-ab (2006) stating minimal influence of agricultural productivity on market participation in subsistence agriculture where farm households still supply certain proportion of output from their basic subsistence level. This is possibly associated with lack of diversified livelihood in rural Ethiopia where farmers are largely relied on subsistence agriculture.

Consequently, improved income has a potential of progressing the wellbeing of households in terms of food security, assuming other factors constant. Particularly, commercialization is supposed to bring a large impact on increasing farmer's income level which can be used as a source of fund for food purchase with better quality and quantity. However, other exogenous factors including price changes may reduce the consumption bundle of framers in a situation of price shock. This requires further econometric modeling that considers the net effect of commercialization on food consumption expenditure with respect to variation in market price and household income level. As a result, the study could not differentiate this interaction and rather put it as a future potential study area.

Appendices

Appendix 1

Summary of the descriptive statistics for the variables used in the research

Variable	Mean	Std. Dev.
Dummy for gender of the respondent taking 1 for male and 0 for women	0.674	0.469
Age of the respondent (in years)	52.206	15.076
Marital status of the respondent taking 1 if he/she is married and 0 otherwise	0.721	0.449
Households formal schooling (in years)	3.564	3.302
Total household size in number	6.059	2.758
Total number of adult person in the household (between the age 15 to 60)	5.696	2.518
Total farm size (in square kilometers)	3469.9	12521.24
Monetary value of total output (in birr)	4785.2	5899.236
Monetary value of total sale (in birr)	1654.6	4119.129
Household commercialization index	34.754	84.681
Total off-farm income (in birr)	885.75	4074.592
Mean annual rainfall in the village (in millimeter)	1330.1	449.901
Total fertilizer use (in kilogram)	46.394	83.064
Dummy for manure/compost use taking 1 if the household uses and 0 otherwise	0.733	0.443
Total number of oxen in the household	1.507	0.866
Total number of hoe used in the household	3.358	2.081
Total number of plough used in the household	4.132	4.312
Dummy for radio (1 if the household own and 0 otherwise)	0.545	0.498
Dummy for cell phone (1 if the household owns and 0 otherwise)	0.173	0.378
Locations of available markets to the farm	1.738	1.080
Dummy for extension access taking1 if the household has and 0 otherwise	0.324	0.468
Dummy for credit access taking 1 if the	0.598	0.491
Dummy for multi crop producer taking 1	0.966	0.181
Dummy for being membership association taking 1 if he/she is and 0 otherwise	0.204	0.403
Estimated total food consumption expenditure in (in birr)	819.915	626.705
Dummy representing unobserved variables at Dikni survey site	0.132	0.338
Dummy representing unobserved variables at Yetmen survey site	0.089	0.285
Dummy representing unobserved variables at Adele Keke survey site	0.155	0.362
Dummy representing unobserved variables at Turfe Kechemane survey site	0.164	0.370
Dummy representing unobserved variables at Imdibir survey site	0.110	0.314
Dummy representing unobserved variables at Aze Deboa survey site	0.130	0.336
Dummy representing unobserved variables at Addado survey site	0.221	0.415
Dummy representing selling of output at local market	0.655	0.476
Dummy representing selling of output at village market	0.027	0.161
Dummy representing selling of output at another village market	0.262	0.440
Dummy representing selling of output at regional market centers	0.039	0.194
Dummy representing selling of output at Addis Ababa	0.018	0.132

Appendix 2

This appendix shows one of the main statistical characteristics of the error term in stochastic frontier model with respect to its variance. For $\sigma_v^2 = 0$ and thus $\lambda = \infty$, the error term, $\varepsilon_i = v_i - u_i$ in equation (1) becomes half normal distribution as:

$$f(\varepsilon_i) = \begin{cases} \frac{\sqrt{2}}{\sqrt{\pi}\sigma_u} e^{\frac{1}{2\sigma_u^2}\varepsilon^2} & for\ \varepsilon \leq 0 \\ 0 & otherwise \end{cases}$$

Appendix 3

Lambda shows whether there is technical inefficiency or not by comparing the ratio of two sigma's. In other word lambda tells how much the total output varies due to noise part or inefficiency. Mathematically,

$$\lambda = \frac{\sigma_u}{\sigma_v}$$

Gamma is calculated by the ratio of standard error from the inefficiency component to the total variation in the error term. Mathematically, it is given by the formula:

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$$

Appendix 4

The potential maximum output can be derived from equation (12). Mathematically, calculated by taking the ratio of actual or observed output to the technical efficiency score as;

$$Potential\ output = \frac{Q_i}{TE}$$

Where, Q_i is actual output by the farm household and TE is technical efficiency level of the respective household.

Appendix 5

Maheber and *ekub* are well known local customary social institutions in Ethiopia where the former is mainly associated with communal resource mobilization including labor and related resources. Similarly, the latter is used as a rotating credit saving group in the community (Pratten, 1997).

References

Aigner, D., Lovell, C., & Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics, 6*(1), 21-37.

Alvarez, R., & Crespi, G. (2003). Determinants of Technical Efficiency in Small Firms. *Small Business Economics, 20*(3), 233-244.

Barrett, C. B. (2008). Smallholder Market Participation: Concepts and Evidence from Eastern and Southern Africa. *Food Policy, 33*(4), 299-317. DOI: Http://Dx.Doi.Org/10.1016/J.Foodpol.2007.10.005

Battese, G. E., & Coelli, T. J. (1993). *A Stochastic Frontier Production Function Incorporating A Model for Technical Inefficiency Effects* (Vol. 69): Department of Econometrics, University of New England Armidale.

Battese, G. E., & Coelli, T. J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics, 20*(2), 325-332. DOI: 10.1007/Bf01205442

Bigsten, A., Kebede, B., Shimeles, A., & Taddesse, M. (2003). Growth and Poverty Reduction in Ethiopia: Evidence from Household Panel Surveys. *World Development, 31*(1), 87-106.

Block, S. A. (1999). Agriculture and Economic Growth in Ethiopia: Growth Multipliers from a Four-Sector Simulation Model. *Agricultural Economics, 20*(3), 241-252.

Braun, J. (1995). Agricultural Commercialization: Impacts on Income and Nutrition and Implications For Policy. *Food Policy, 20*(3), 187-202. DOI: Http://Dx.Doi.Org/10.1016/0306-9192(95)00013-5

Braun., J., & Kennedy., E. T. (1994). *Agricultural Commercialization, Economic Development, and Nutrition* J. V. B. A. E. KENNEDY (Ed.)

Cobb, C. W., & Douglas, P. H. (1928). A Theory of Production. *The American Economic Review, 18*(1), 139-165.

Coelli, T. J., Rao, D. S. P., O'donnell, C. J., & Battese, G. E. (2005). *An Introduction to Efficiency and Productivity Analysis*: Springer.

Cornwell, C., Schmidt, P., & Sickles, R. C. (1990). Production Frontiers with Cross-Sectional and Time-Series Variation in Efficiency Levels. *Journal of Econometrics, 46*(1-2), 185-200. DOI: Doi 10.1016/0304-4076(90)90054-W

Croppenstedt, A., & Muller, C. (2000). The Impact of Farmers' Health and Nutritional Status on their Productivity and Efficiency: Evidence from Ethiopia. *Economic Development and Cultural Change, 48*(3), 475-502. DOI: Doi 10.1086/452607

CSA. (2011). The FDRECSA , Agricultural Sample Survey, Report on Area and Production of Major Crops: Federal Democratic Republic of Ethiopia, Centeral Statistical Agency.

CSA. (2012). Ethiopia Demographic and Health Survey, 2011. Addis Ababa Centeral Statistics Agency of Ethiopia.

Diao. (2010). Economic Importance of Agriculture for Sustainable Development and Poverty Reduction:The Case Study of Ethiopia: International Food Policy Research Institute(IFPRI).

Diao, & Pratt. (2007). Growth Options and Poverty Reduction in Ethiopia–An Economy-Wide Model Analysis. *Food Policy, 32*(2), 205-228.

Endale. (2010). Fertilizer Consumption and Agricultural Productivity in Ethiopia. Addis Ababa: Ethiopian Development Research Institute (EDRI).

Fafchamps, M., Gabre-Madhin, E., & Minten, B. (2005). Increasing Returns and Market Efficiency in Agricultural Trade. *Journal of Development Economics, 78*(2), 406-442. DOI: Doi 10.1016/J.Jdeveco.2004.10.001

FAO. (2008). OECD-FAO Agricultural Outlook 2008-2017: Food And Agricultural Organization(FAO).

Frisch, R. (1964). *Theory of Production*: Springer.

Gebre-Ab, N. (2006). Commercialization of Small Holder Agriculture in Ethiopia. *Note and Papers Series*(3).

Govereh, J., Jayne, T., & Nyoro, J. (1999). Smallholder Commercialization, Interlinked Markets and Food Crop Productivity: Cross-Country Evidence in Eastern and Southern Africa. *Michigan State University, Department of Agricultural Economics and Department of Economics, 39*.

Greene, W. H. (1990). A Gamma-Distributed Stochastic Frontier Model. *Journal of Econometrics, 46*(1–2), 141-163. DOI: Http://Dx.Doi.Org/10.1016/0304-4076(90)90052-U

Greene, W. H. (2002). Fixed and Random Effects In Stochastic Frontier Models. *Journl of Econometrics, 46(1–2), 141-163*. DOI: http://dx.doi.org/10.1016/0304-4076(90)90052-U

IFPRI. (2009). *Ethiopian Rural Household Surveys (ERHS), Addis Abab*

Jaleta, M., Gebremedhin, B., & Hoekstra, D. (2009). *Smallholder Commercialization: Processes, Determinants and Impact*: ILRI (AKA ILCA and ILRAD).

Juma, C. (2010). *The New Harvest: Agricultural Innovation in Africa*: Oxford University Press.

Kalirajan, K. P., & Shand, R. T. (1999). Frontier Production Functions and Technical Efficiency Measures. *Journal of Economic Surveys, 13*(2), 149-172.

Liu, Y., & Myers, R. (2009). Model Selection in Stochastic Frontier Analysis with an Application to Maize Production in Kenya. *Journal of Productivity Analysis, 31*(1), 33-46.

Mellor, J. (1990). Agriculture on The Road to Industrialization. *Agricultural Development in the Third World*, 70-88.

MOFED. (2010). *Growth And Transformation Plan*. Addis Ababa: MOFED.

Moti, J., Berhanu, G., & Dirk, H. (2009). *Smallholder Commercialization: Processes, Determinants and Impact*. Addis Ababa, Ethiopia.

Neumann, K., Verburg, P. H., Stehfest, E., & Muller, C. (2010). The Yield Gap of Global Grain Production: A Spatial Analysis. *Agricultural Systems, 103*(5), 316-326. DOI: Doi 10.1016/J.Agsy.2010.02.004

Nishimizu, M., & Page, J. M., Jr. (1982). Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change: Dimensions of Productivity Change in Yugoslavia, 1965-78. *The Economic Journal, 92*(368), 920-936. DOI: 10.2307/2232675

Nisrane, F., *Et Al.* (2011). Sources of Inefficiency and Growth in Agricultural Output in Subsistence Agriculture: A Stochastic Frontier Analysis: Citeseer.

Olson. (1980). A Monte Carlo Study of Estimators of Stochastic Frontier Production Function. *Journal Of Econemetrics, 13*, 67-82.

Pender, J., & Alemu, D. (2007). *Determinants Of Smallholder Commercialization Of Food Crops: Theory and Evidence From Ethiopia* (Vol. 745): IFPRI.

Perthel, D. (1975). Engel's Law Revisited. *International Statistical Review / Revue Internationale De Statistique, 43*(2), 211-218. Doi: 10.2307/1402900

Pingali, P. L., & Rosegrant, M. W. (1995). Agricultural Commercialization and Diversification: Processes and Policies. *Food Policy, 20*(3), 171-185.

Poulton, C., & Leavy, J. (2007). Commercialisations in Agriculture. London: Institute of Development Studies, Brighton; School of Oriental and African Studies (SOAS), University of London.

Rao, D. P., O'donnell, C. J., Battese, G. E., & Coelli, T. J. (2005). *An Introduction to Efficiency and Productivity Analysis*: Springer.

Schmidt, & Lovell, C. K. (1979). Estimating Technical and Allocative Inefficiency Relative to Stochastic Production and Cost Frontiers. *Journal of Econometrics, 9*, 343-366.

Sharma, K. R., Leung, P. S., & Zaleski, H. M. (1999). Technical, Allocative and Economic Efficiencies in Swine Production in Hawaii: A Comparison of Parametric and Nonparametric Approaches. *Agricultural Economics, 20*(1), 23-35.

Stock, J. H., & Watson, M. W. (2003). *Introduction to Econometrics* (Vol. 104): Addison Wesley Boston.

Strasberg, P. J., *Et Al.* (1999). Effects of Agricultural Commercialization on Food Crop Input use and Productivity in Kenya: Michigan State University, Department of Agricultural, Food, and Resource Economics.

Taffesse, A. S., Dorosh, P., & Asrat, S. (2011). Crop Production in Ethiopia: Regional Patterns and Trends. *Ethiopia Strategy Support Program II (Essp II) Working Paper*(0016).

Timmer, C. P. (1997). Farmers and Markets: The Political Economy of New Paradigms. *American Journal of Agricultural Economics, 79*(2), 621-627.

Wadud, A., & White, B. (2000). Farm Household Efficiency in Bangladesh: A Comparison of Stochastic Frontier and Dea Methods. *Applied Economics, 32*(13), 1665-1673.

Waldman. (1982). A Stattionery Point for the Stochastic Frontier Likelihood. *Journal of Econemetrics, 18*, 275-279.

WB. (2012). World Development Indicators. Retrieved 24-10-2012, From World Bank

Wim, M., & Broeck, J. V. D. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review, 18*(2), 435-444. DOI: 10.2307/2525757

Wood, B., Nelson, C. H., Kilic, T., & Murray, S. (2012). *Up in Smoke?: Agricultural Commercialization, Rising Food Prices and Stunting in Malawi.* Paper Presented at the 2012 Conference, August 18-24, 2012, Foz Do Iguacu, Brazil.