

FACULTY OF BIOENGINEERING

**ECONOMIC EFFICIENCY OF FABA BEAN PRODUCTION IN THE CASE OF
DEMBECHA AND DEBRE ELIAS DISTRICTS, AMHARA REGION, ETHIOPIA:**

A STOCHASTIC FRONTIER APPROACH

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“MSc” Degree in Agriculture, Food, and Environmental Policy Analysis
programme**

DECLARATION

This is to declare that this thesis entitled “**Economic Efficiency of Faba bean Production in the case of Demebecha and Debre Elias Districts, Amhara Region, Ethiopia. a Stochastic Frontier Approach**”, with a view to obtaining the award of master of science (MSc) degree from Catholic University of Louvain (UCLouvain) in Agriculture, Food, and Environmental Policy Analysis programme is an authentic work carried out by myself. The matter embodied in this thesis work has not been submitted earlier for the award of any degree or diploma.

Mehariw Worku Ayalew

Name of the Student



Signature

20/08/2023

Date

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ABBREVIATIONS AND ACRONYMS

ADLI	Agricultural Development-Lead to Industrialization
AE	Allocative efficiency
Chi2	Chi-square
CSA	Central statistical agency
EE	Economic efficiency
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GoE	Government of Ethiopia
Kg	Kilogram
LR	Likelihood ratio
MoA	Ministry of agriculture
NGOs	Non-governmental organisations
OLS	Ordinary least squares
SD	Standard deviation
TE	Technical efficiency
WFP	World food program

ABSTRACT

This study analysed the economic efficiency of Faba bean production in Dembecha and Debre Elias districts using 147 sample Faba bean producing households in 2021/22 production year with the aim of analysing the levels of technical, allocative and economic efficiency and to analyse the determinant factors affecting the production efficiency of Faba bean. According to the stochastic production and cost frontier model, the level of technical, allocative, and economic efficiency found to be 71.37%, 88.40%, and 63.21% respectively. This implies that there is still a room to improve the efficiency of Faba bean production in the study area. The Tobit model result indicated that household size, educational status, and frequency of extension visit had significant and positive effect on the level technical efficiency of Faba bean production. Age of the household head, distance to farmers' cooperative, and farm ownership found to have significant and negative effect on the allocative efficiency. Furthermore, household size, educational status, and frequency extension contact had a positive and significant effect on the economic efficiency. policy implications and strategies of the government and other concerned bodies should be geared towards those significant factors.

Keywords: Technical efficiency, Allocative efficiency, Tobit model

CHAPTER ONE. INTRODUCTION

1.1 Background

The agricultural sector plays a crucial role in the Ethiopian economy, serving as a backbone. It contributes 34.1% to the gross domestic product (GDP), 79% of employment, and 79% of foreign exchange earnings, and it is the major source of raw materials and capital for investment (Diriba, 2020). Despite its huge contribution to the economy, the sector is simply characterized by low productivity, smallholder subsistence farming, and rain-feed-dependent and traditional production systems (Kebede, 2020).

Enhancing agricultural productivity can be achieved through increased use of inputs, technological improvement, and improved efficiency among farmers (Ayele *et al.*, 2019). Factors like inefficiencies in input management, outdated farming techniques, limited access to modern agricultural technologies, inadequate extension, credit, marketing, and infrastructure services, as well as biased agricultural policies, result in differences in agricultural productivity among farmers even with the similar resources (FAO and WFP, 2012). The government of Ethiopia (GoE) has a strategy to improve agricultural productivity by adopting new technologies and the use of modern inputs (Asfaw and Bekele, 2010). The country is following a strategy called Agricultural Development-Lead to Industrialization (ADLI) with the government's overarching policy in response to Ethiopia's food security and agricultural productivity challenge. The strategy promotes the utilization of improved agricultural practices (Kebede, 2020).

In developing agricultural economies like Ethiopia where resources are meager and opportunities for development and opportunities for technological advancement are limited, efficiency is a very important factor in productivity growth. In such economies determining the possibility to increase productivity or increase efficiency, at the existing resource base or technology is crucial. Each type of inefficiency is costly to a firm or production unit, in the sense that, inefficiency causes a reduction in profit below the maximum value attainable (Kebede, 2020).

Policymakers in Ethiopia mainly focus on the adoption of modern agricultural technologies rather than improving production efficiency (Kifle *et al.*, 2017; Mustefa *et al.*, 2017; Tadie *et al.*, 2019). But given the same level of input and current technology, there is room to improve production and

productivity by improving the efficiency of production to the maximum possible output (Tadie *et al.*, 2019). Theoretically, introducing modern technologies can increase agricultural productivity and production. However, in areas where there is inefficient utilization of existing inputs and technologies, trying to introduce new technologies may not have the expected results and it is not cost-effective and it is time taking. Rather than solely relying on introducing new technologies, efficient utilization of the existing technology and resources proves to be more cost-effective (Assefa, 2012). The existence of inefficiency in agricultural production comes from the inefficient use of scarce resources (Lagiso and Geta, 2019).

Globally, Faba bean (*Vicia Faba L.*) production occupied nearly 2.1 million hectares of land (Ren *et al.*, 2019) with a total global production volume of 4.4 million tons (Semba *et al.*, 2021). China, Ethiopia, Australia, France, and Sudan are the primary global producers of Faba Bean, with China leading at 1.64 million tons, followed by Ethiopia at 0.92 million tons (Semba *et al.*, 2021). In addition to that, Ethiopia ranks as the fourth largest exporter of Faba Bean trailing France, Australia, and the United Kingdom (FAO, 2016). Faba bean takes the largest area share with 492,271.60 ha and a production amount of 1.04 million tons among the pulses grown in Ethiopia (CSA, 2021; Ojiewo *et al.*, 2020; Tamene, 2017). The average national yield of Faba bean is about 2.1 tons per ha (CSA, 2018; Ojiewo *et al.*, 2020) which is very low compared to the average yield of 3.7 tons per hectare in major producer countries (FAOSTAT, 2017).

Amhara region has the highest coverage of pulse crops, accounting for 43.7% of the total area and contributing 47.0% of national production followed by the Oromia region, with 38.0% of the area and contributing 39.0% of national production (Gebbru and Mesganaw, 2021). Despite the potential for Faba Bean production in the Dembecha and Debre Elias districts of the Amhara region there still exists a significant yield gap. Therefore, analysing the economic efficiency of Faba Bean becomes crucial to assess the level of production efficiency by farmers and factors deriving the inefficiency in production. Therefore, this study aims to analyse the economic efficiency of Faba bean production and identify factors influencing the production efficiency of Faba bean in the Dembecha and Debre Elias districts

1.2 Objectives of the study

1.2.1 General Objective

The general objective of this study is to analyse the economic efficiency of smallholder farmers' Faba bean production in the Dembecha and Debre Elias districts.

1.2.2 Specific Objectives

This study has the following specific objectives;

1. To assess the production level of Faba bean in the Dembecha and Debre Elias districts.
2. To analyse the level of technical, allocative, and economic efficiency of Faba bean production in the study area.
3. To analyse the determinants of technical, allocative, and economic efficiency of Faba bean production in the study area.

1.3 Statement of the problem

Crop productivity can be enhanced through either technological improvements or improvements in production efficiency. Technological improvements involve the advanced use of technology in the production process, while efficiency improvements focus on optimizing the utilization of existing inputs given a fixed level of inputs and technology. For smallholder farmers in developing countries, improving productivity through efficiency improvements is often a more viable option than adopting new technology, as the latter requires significant capital investment and may be costly (Mechri *et al.*, 2017).

In Ethiopia, most farmers lack knowledge about the exact quantities of inputs such as land, labor, oxen power, fertilizer, seed, and capital required for crop production. This highlights the importance of emphasizing efficiency improvements in resource utilization as a key strategy to enhance the productivity of smallholder farmers (Abro, 2019; Anbes, 2020). Therefore, conducting crop-specific efficiency analysis becomes relevant in generating empirical evidence that informs policy decisions.

In Ethiopia, most of the cereals and grain legumes production comes from smallholder farmers. However, the productivity of grain crops in the country is hindered by large yield gaps resulting from low input, labour-intensive farming, fragmented landholdings, and reliance on rainfed agriculture (KIT, 2019). In the country, about 40% of the increment in crop production was due

to an increase in farmland size (Ministry of agriculture (MoA, 2019)). But nowadays due to the increasing population size and urban expansion, there is only little suitable new land left for agricultural expansion, calling the necessity of increasing crop productivity per unit of available land through the best use of inputs such as improved farming technologies, fertilizers, pesticides, and agronomic practices.

Yield levels in grain crops Faba bean are still considerably low compared to the potential they exhibit in research improvements. While improving crop productivity and ensuring food self-sufficiency and food security are national priorities, the factors contributing to the yield gaps, the levels of technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE), and the factors influencing farmers' production efficiency are not well understood. To explain the existing yield gaps and to identify areas of improvement, a detailed understanding of the yield-defining factors, mainly crop management practices, the functioning seed system, input usage, and their application, are important (Belachew, 2022).

Although Faba Bean is an important pulse crop for achieving food security and generating income for farmers, the attention given by the government is low compared to cereal crops, resulting in lower productivity levels.

TE studies conducted in the Oromia region by Wubie (2019), and Kebede (2020) have reported that there is a potential to increase Faba bean yield by up to 31% through better utilization of existing resources and technology. Despite being the leading producer of Faba Bean, there is a lack of sufficient studies on the production efficiency of Faba Bean in the region and there is no studies have been conducted on the EE of smallholder Faba bean producers in the study area.

One major challenge in production function analysis is the endogeneity problem associated with inputs of production. Unfortunately, most crop-specific efficiency studies ignored the problem and failed to address the issue. However, in this study, the researcher employs an exogenous instrumental variable technique to minimize the impact of the endogeneity problem.

Dembecha and Debre Elias districts are among the potential Faba bean producer districts in the Amhara region. Despite the districts' potential, there still exists a significant yield gap in Faba Bean production. In particular, the productivity of legume crops such as Faba Bean is declining

not only in those two districts but also in most areas of the region. The sources and level of yield inefficiencies are not yet well understood. Additionally, it is important to identify the constraints that affect Faba bean crop production in these districts. Therefore, this study aims to assess the technical, allocative, and economic efficiencies of Faba bean-producing smallholder farmers in the Dembecha and Debre Elias Districts to fill the existing information gap regarding efficiency levels and contextual factors that contribute to efficiency differentials between Faba bean producing farmers.

1.4 Significance of the Study

The efficiency measurement plays a crucial role in all areas of production as it contributes to productivity growth. It provides insights into the potential for increasing production costs without increasing inputs, thus reducing total production costs without compromising output levels. Efficiency studies are valuable in determining the extent to which it is possible to raise productivity by improving the efficient use of available scarce resources and technology. A study on the EE of Faba bean is very important for obtaining useful information about technical, allocative, and EE and identifying factors that determine efficiency differences among producing farmers. Crop-specific efficiency studies in Ethiopia can serve as an entry point for policy interventions aimed at improving the resource utilization efficiency of smallholder farmers. Moreover, the study of EE can be used by different stockholders like extension workers, different government offices, NGOs, and others in the provision of knowledge-based support to farmers to improve their livelihood. It can also help the concerned bodies in supporting farmers to come up with some important ideas for efficient utilization of available production input for those who are inefficient farmers and not utilizing their scarce resources efficiently in the study area. They can also play an important role in informing inefficient farmers to derive lessons about better production practices from more efficient farmers operating in the same environment and level of technology. Considering Faba Bean's production potential of the country and the study area, this study can provide useful insights into productivity gaps and the drivers of the production inefficiency of Faba bean. In addition, the result of the identification of determinants of technical, allocative, and EE of Faba bean production in Dembecha and Debre Elias districts is important for various planning and policy purposes as a country and are also useful for other crops that usually have similar production processes. Therefore, this study was undertaken to measure the production efficiency level of Faba Bean

production and identifies basic factors that determine the technical, allocative, and EE differences among farmers in the study area.

1.5 Scope and Limitations of the Study

This study focuses on Dembecha and Debere Elias districts which are major Faba Bean-producing districts from West and East Gojjam zone districts respectively. Only two sample *kebeles* from each district are included in this study. Farmers in the districts are mainly producing Maize and Wheat among cereals, and Faba Bean from pulses, and those crops are the major crops in terms of area coverage as well as in quantity of production by smallholder farmers. This study focused on measuring TE, AE, and EE of Faba Bean production during the *meher* production season (main rain production season) of the 2021/2022 production year in the study area. This study employs cross-sectional data to analyse the TE, AE, and EE levels and to identify the sources of production inefficiency differences among farmers in the study area. In addition, only two districts and 147 Faba Bean-producing households were considered in this study.

CHAPTER TWO. LITERATURE REVIEW

This chapter presents theoretical reviews on the production and productivity of Faba bean, the definition of basic concepts, approaches, and models of efficiency measurement, reviews of empirical studies on cereal and pulses production efficiency and a conceptual framework of the study.

2.1 Production system of Pulses in Ethiopia

In Ethiopia, there are 12 different species of pulses grown. These include Faba bean, Field pea, Chickpea, Lentil, Grass pea, Fenu Greek, Lupine, haricot bean, soya bean, cowpea, pigeon pea, and mung beans. The highland pulses, which thrive in cooler highland regions, consist of Faba bean, field pea, Chickpea, Lentil, Grass pea, Fenu Greek, and Lupine. On the other hand, haricot bean, soya bean, cowpea, pigeon pea, and mung beans are predominantly grown in the warmer lowland areas of the country. Faba beans contribute the largest share of production accounting for 36%, followed by haricot beans (17%) and chickpeas (16%), and other pulses (e.g., lentils, peas, lupines, and mung beans) account for the remaining 32% (Yirga *et al.*, 2019). This indicates the diversity of pulse cultivation in Ethiopia, with various species being cultivated in different regions based on their adaptability to the local climatic conditions and ecological zones.

Pulse crops are cultivated throughout Ethiopia, covering around 13% of the total cropped land area. However, Amhara and Oromia regions are the primary producers of pulses. These two regions contribute significantly to pulse cultivation, with a dominant share in various pulse crops. Specifically, they account for 92% of chickpea production, 85% of Faba bean production, 79% of haricot bean production, and 79% of field pea production. The concentrated production in these regions highlights their importance in the overall pulse sector of Ethiopia. Among the major pulse varieties, the Amhara region stands out as the largest producer of Faba bean, chickpea, and haricot bean, while Oromia leads production in the other major varieties like field pea (Yirga *et al.*, 2019).

Faba beans and field peas are typically cultivated during the main growing season on both red and black soils primarily in Amhara, Tigray, Oromia, and SNNP regional states. In contrast, the cultivation of Haricot beans is primarily concentrated in the drier and warmer regions of the country, particularly along the Rift Valley, as highlighted by Yirga *et al.* (2019). These areas provide favorable conditions for the growth and production of Haricot beans, which explains the concentration of cultivation in these specific regions. This distribution of pulse production

highlights the regional variations in climatic conditions, soil types, and ecological factors that influence the suitability and preference for different pulse varieties in Ethiopia.

Table 1. Faba bean production in Ethiopia (2015-2021)

Year	Area harvested (ha)	Total production (tons)	Yield (tons/ha)
2015	448293	853576.62	1.9041
2016	427697	878010.00	2.0529
2017	437106	921761.54	2.1088
2018	492272	1041953.51	2.1166
2019	466698	1006751.83	2.1572
2020	504570	1070636.54	2.1219
2021	498802	1089489.25	2.1842

Source: FAOSTAT (2022)

2.2 Concepts and Definitions of Efficiency

The concept of efficiency is inherently related to production economics and it is impossible to accurately define efficiency measures without referring to production economic theory (Coelli *et al.*, 2005). This is because efficiency measurements can only be derived with respect to benchmark, that is, an ideal level of performance or best practice frontier. Production economics provides the theoretical foundation for understanding and calculating the bench performance or best practice.

Efficiency may be described as the relationship between ends and the means and has an application in production analysis as well as in consumption theory and demand analysis (Afriat, 1972). Efficiency compares the observed output and input of a producer to their optimal values. It can involve comparing observed output to the maximum potential output achievable from the input, comparing observed input to the minimum input required to produce the output, or a combination of both approaches (Farell, 1957). Efficiency and productivity are interrelated concepts, but

efficiency measures provide more accurate comparisons by assessing actual output against the most efficient frontier output, rather than simply taking the ratio of outputs to inputs as done in productivity measures.

2.2.1 Technical efficiency

TE can be defined as the ability of a firm to produce as much output as possible with a specified level of inputs, given the existing technology. It is an engineering concept and refers to the physical input-output relationship. A firm is said to be efficient if it is operating on the production frontier (Ali and Byerlee, 1991). On the other, Xu and Jeffrey (1998) described TE as the ability to produce a given level of output with a minimum quantity of inputs under certain technology. Yilma (1996), while studying efficiency among the smallholder coffee producers in Uganda, defines an efficient farm as that which produces more output from the same measurable input than that one which produces less.

TE concerns the way in which physical quantities of inputs are converted into physical quantities of output. Farmers are said to be technically efficient if they achieve the maximum feasible output from input. In other words, TE can be described as a situation where it is impossible with current technical knowledge, to rise output from given inputs or alternatively, to produce a given output using less of one input without using more of other inputs. According to Forsund *et al.* (1980), inefficiency can be regarded as the amount by which a firm lies below its production or profit frontier, and the amount by which it lies above its cost frontier. Once the frontier is known, simply comparing the position of the firm relative to the frontier can help to assess the inefficiency of any particular firm. Therefore, the frontier must be constructed first from the available observation to determine the efficiency level of the firm. In economic terms, TE refers to failure to operate on the production frontier and generally is assumed to reflect inefficiencies caused by the timing and method of application of production input (Byerlee, 1987).

Potential causes of technical inefficiency are inadequate information or insufficient technical skills. technically efficient producer could produce the same output with less of at least one input or could use the same inputs to produce more of at least one output. Technical inefficiency arises when actual or observed output from a given input mix is less than the maximum possible and it can stem from a variety of sources including a lack of knowledge of available techniques or

inadequate management due to a lack of motivation, skill, and/or personnel (Scarborough and Kydd, 1999).

2.2.2 Price or allocative efficiency

AE, as described by Inoni (2007), refers to the extent to which an enterprise effectively allocates its production inputs in the optimal combination to maximize profits. It is a measure of how efficiently resources are allocated to different factors of production in order to achieve the best possible outcome in terms of profitability. Thus, the allocative efficient level of production is where the farm operates at the least-cost combination of inputs. Most studies have been using gains obtained by varying the input ratios based on assumptions about the future price structure of products say sesame output and factor markets.

Indeed, an alternative definition of AE, as mentioned by Inoni (2007), relates to the comparison between the total costs incurred in producing a unit of output using the actual factor proportions in a technically efficient manner and the total costs of producing the same unit of output using the optimal factor proportions in a technically efficient manner. This definition emphasizes the aspect of achieving efficiency in input allocation.

It is worth noting that estimating AE has traditionally been challenging without the availability of input and output prices. However, modern methods have been developed to overcome this limitation. Additionally, some scholars, including Farrell, have referred to AE as "price efficiency," highlighting the firm's ability to select the optimal combination of inputs based on the prevailing input prices.

2.2.3 Economic efficiency

According to Farrell (1957), EE is a separate concept from technical and AE, although it is influenced by both. EE represents the overall efficiency of a production process, taking into account both TE (the ability to produce output using the least quantity of inputs) and AE (the optimal allocation of inputs to maximize profits). In other words, EE is the result of achieving both technical and AE simultaneously. It indicates the ability of a firm or production system to generate the maximum possible output given the available resources and the current input-output relationship. By considering technical and AE together, EE provides a broader perspective on the effectiveness of resource utilization and output generation.

That means, EE is achieved when the producer combines resources in the least combination to generate maximum output (technical) as well as ensuring the least cost to obtain maximum revenue (allocative) (Chukwuji *et al.*, 2006).

2.3 Approaches to Measure Efficiency

Productivity levels can vary due to variations in production technology, production processes, and environmental factors that influence production. In order to determine efficiency, producers are considered efficient if they have maximized their output using the inputs they have utilized and have done so at the lowest possible cost, as stated by Greene (1997). This definition emphasizes the achievement of both output maximization and cost minimization as indicators of efficiency. In other words, efficient producers are those who have effectively utilized their available resources to produce the highest output possible while keeping costs at a minimum. Both technical and AE can be measured by two main approaches: that are input approach and the output approach (Debreu, 1951; Farell, 1957).

2.3.1 Output-oriented measurement

The output approach is considering the ability to avoid waste by using as little input as output production allows, i.e. it is used to evaluate the ability to maximize outputs while keeping inputs fixed (Porcelli, 2009). The output-oriented measure of efficiency can be answering the question “By how much can output be increased without increasing the amount of input used?” (Coelli *et al.*, 1998).

Output-oriented measures can be illustrated by considering the case where a production involves two outputs (q_1 and q_2) and a single input (x). If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve in two dimensions.

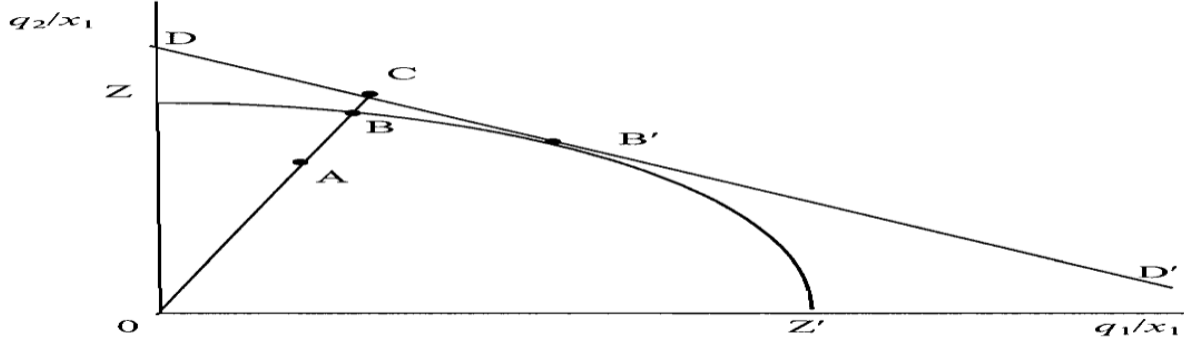


Figure 1. Output-oriented measures of TE and AE

Source: Coelli *et al.* (1998).

In the Figure above, the distance AB represents technical inefficiency. That is the amount by which outputs could be increased without requiring extra input. Hence, a measure of output-oriented TE is the ratio:

$$TE = \frac{OA}{OB} \quad (2.1)$$

The two outputs q_1 and q_2 are produced using single input (x_1). The curve ZZ^* shows the production possibility frontier at which the maximum possible combination of output q_1 and q_2 are produced using single input x_1 . The point B which is on the production frontier curve shows a technically efficient point, whereas the distance CB represents the level of technical inefficiency, and it represents the amount by which outputs could be increased without utilizing extra inputs.

The line DD^* shows the slope of the iso-revenue line. Using the iso-revenue line, we can express AE as the ratio;

$$AE = \frac{OB}{OC} \quad (2.2)$$

The economically efficient method of production, can be represented by the point of tangency between the iso-revenue line (DD^*) and the production possibility curve (ZZ^*) at point B^* . This point signifies the optimal combination of inputs and outputs that maximizes revenue while utilizing resources efficiently. We can express EE as:

$$EE = TE \times AE = \frac{OA}{OB} \times \frac{OB}{OC} = \frac{OA}{OC} \quad (2.3)$$

2.3.2 Input-oriented measurement

The input approach is considering the ability to avoid waste by producing as much output as input usage allows, i.e. it is used to evaluate the ability to minimize inputs used for production keeping outputs fixed (Porcelli, 2009). The input-oriented measure of efficiency addresses the question of how much input quantities can be proportionally reduced without affecting the output quantities produced, as stated by Coelli *et al.* (1998). This measure focuses on identifying the extent to which inputs can be reduced while maintaining the same level of output. In other words, it evaluates the potential for input reduction while keeping the production process and output constant. This measure provides insights into the efficiency gains that can be achieved by optimizing input utilization and reducing input waste. A farm can be on or above the unit isoquant on the input per unit of output space and cannot be below or to the left of it. A deviation from the unit iso-quant, which represents a constant level of output, indicates technical inefficiency. The further farms are from the unit iso-quant, the greater the degree of inefficiency. In other words, the distance between a farm's actual production point and the unit iso-quant serves as a measure of its technical inefficiency. The larger the distance, the more inefficient the farm is considered to be in terms of utilizing inputs to produce a given level of output. This concept highlights the importance of striving to operate closer to the unit iso-quant to improve TE and optimize input-output relationships.

Farrell illustrated three measures of efficiency using a simple example involving firms that use two inputs (X_1 and X_2) to produce a single output (q), under the assumption of CRS.

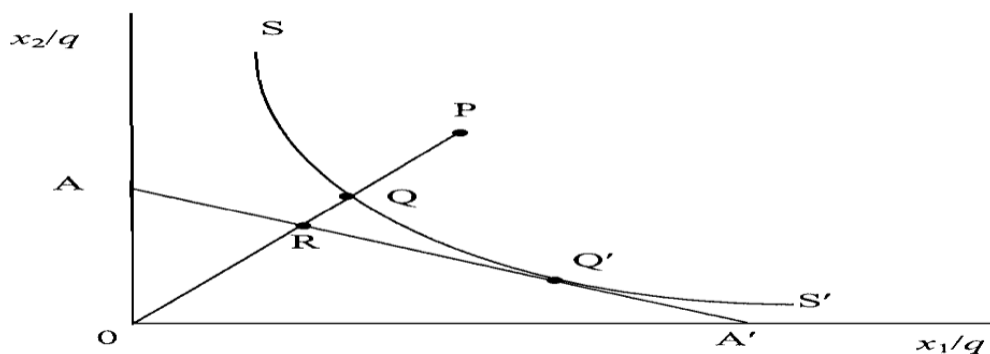


Figure 2. Input-oriented measures for TE and AE

Source: Coelli *et al.*, (2005), and Farrell (1957)

The line SS' represent the iso-quant at which the producer or the farm is producing efficiently. In another way, the line drawn from the origin to point P which crosses the iso-quant at point Q, shows efficient if the farmer produces at point Q, and if an increase in the use of any unit of input above Q to P leads to inefficient use of input. The TE of the observed firm can be defined as the ratio of the distance from point Q to the origin over the distance of point P from the origin:

$$TE = \frac{OQ}{OP} = 1 - \frac{QP}{OP} \quad (2.4)$$

The distance QP represents the technical inefficiency of the observed firm, indicating the extent by which all inputs could be proportionally reduced without a decrease in output. This measure quantifies the potential for input reduction while maintaining the same level of output.

The value of TE ranges between 0 and 1. A firm is considered technically efficient when TE is equal to 1, meaning it is operating at the maximum level of TE, utilizing inputs optimally to produce the given output. If the value of TE is less than 1, it indicates technical inefficiency. In other words, the firm is not achieving the maximum potential output given the input resources. The smaller the value of TE, the greater the degree of technical inefficiency in the firm's production process.

Whereas line AA' represent the input price ratio or isocost line which gives the minimum amount of expenditure a firm intended to maximize profit. The firm using the input combination at point P is inefficient as compared to the firm producing at point R. So the level of AE is represented by:

$$AE = \frac{OR}{OQ} \quad (2.5)$$

The farmer is allocatively efficient if it produces on the line AA', particularly at point R instead of producing at point P.

EE can be represented by;

$$EE = TE \times AE = \frac{OQ}{OP} \times \frac{OR}{OQ} = \frac{OR}{OP} \quad (2.6)$$

The three measures of efficiency are bounded between zero and one. The most efficient farmer which is efficient in all economic, allocative, and technically efficient produces at point Q' which shows a 100% efficient farmer.

2.4 Models for Measuring Efficiency

Efficiency measurements are usually done using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. These methodologies are broadly categorized under two frontier models; namely parametric and nonparametric. Parametric models are typically estimated using econometric methods, where specific functional forms are assumed for the relationship between inputs and outputs. These models require specific assumptions and estimation techniques based on statistical and economic theory. On the other hand, non-parametric models, such as Data Envelopment Analysis (DEA), take a different approach. DEA involves the use of linear programming methods to construct a non-parametric piece-wise surface, often referred to as a frontier, over the available data. This frontier represents the maximum feasible output that can be achieved for a given set of inputs, without making any specific functional form assumptions. DEA allows for a flexible assessment of efficiency and enables comparisons among multiple units (e.g., firms, organizations) based on their relative efficiency scores. The non-parametric nature of DEA makes it a versatile tool for efficiency analysis, as it does not rely on specific functional form assumptions and can handle various types of data (Coelli *et al.*, 1998).

The selection of a specific frontier model depends upon many considerations such as the type of data, cross-sectional or panel data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data, and the objective of the study.

2.4.1 Non-parametric Model

The non-parametric method is a commonly used approach for measuring efficiency. In this method, the DEA frontier is considered both non-parametric and non-stochastic because it does not enforce any pre-defined parametric constraints on the underlying technology of the frontier. This means that it doesn't require specifying a particular functional form and doesn't make any assumptions about the distribution of inefficiency. Unlike parametric methods, the non-parametric DEA approach provides flexibility by not imposing any specific restrictions on the technology and inefficiency term, allowing for a more versatile and adaptable analysis of efficiency. Therefore, the model avoids the imposition of unwarranted structures on both the frontier technology and the inefficiency component that might create distortion in the measurement of efficiency (Fare *and*

Grosskopf., 1985). The non-parametric deterministic frontier is based upon Farrell's original approach of piecewise linear convex isoquant such that no observed points lie to the left or below it (Farrell, 1957). This work has been extended by Charnes *et al.* (1978) and was called Data Envelopment Analysis (DEA). Charnes *et al.* (1978) proposed a model which had an input-oriented constant return to scale model of DEA. CRS assumption is only appropriate when all firms are operating at an optimal scale. In case of different constraints, may cause a firm to be not operating at optimal scale. When the constant return to scale (CRS) assumption is applied in efficiency analysis, it assumes that all firms are operating at their optimal scale. However, in reality, not all firms operate at this optimal scale. This can lead to a conflation of measures of TE with scale efficiency. The shortcoming of scale efficiency is that the value does not indicate whether the firm is operating in an area of increasing or decreasing returns to scale (Coelli *et al.*, 1998). These methods can also accommodate multiple-output farms and can also be applied to almost any industry (Coelli *et al.*, 2002).

The advantage of the non-parametric approach is that no functional form is imposed on the data (Forsund *et al.*, 1980). The main criticism of DEA is that it assumes all deviations from the frontier are due to inefficiency, and because of this, non-parametric frontier methodology may overstate inefficiencies, and hence outliers may have a profound effect on the magnitude of inefficiency (Llewelyn and Williams, 1996). The conventional formulation of Data Envelopment Analysis (DEA) involves creating a distinct linear program for each decision-making unit, which can lead to computational challenges, particularly with large-scale problems. The computational intensity arises from the need to solve multiple linear programs simultaneously. In the context of efficiency measurement for smallholder farmers, Mengistu (2017) employed the DEA approach to assess their efficiency levels. However, due to the computational demands of the standard DEA formulation, alternative methods have been widely adopted to address the issue of noise in the data.

2.4.2 Parametric model

Early works on the efficiency of Ethiopian agriculture ranged from those that applied partial measures such as yield per hectare and output per unit of labor to those that apply traditional response functions and programming methods (Alene & Hassen, 2003). The parametric frontier model is classified into deterministic and stochastic frontier methods. Typically, both models use

econometric techniques to estimate the parameters of pre-specified functional forms. The deterministic model, in the context of efficiency measurement, assumes that any deviation observed from the frontier is solely attributed to inefficiency. It does not account for other factors that may contribute to the deviation, such as measurement errors or external disturbances. In contrast, stochastic approaches allow for a more nuanced analysis by distinguishing between TE and statistical noise. These approaches consider the presence of random variation and aim to separate the inherent inefficiency from other sources of variation. Parametric models, on the other hand, are estimated using econometric methods. They involve specifying a functional form for the production function or frontier and estimating the model parameters based on the data. These models provide a more structured framework for efficiency analysis, as they require assumptions about the functional relationship between inputs and outputs. Coelli and Battese (2006) have contributed to the development and application of parametric models in efficiency measurement. By employing econometric techniques, these models enable researchers to estimate the parameters of the specified functional forms and gain insights into the underlying efficiency levels of the analyzed entities.

In summary, while the deterministic model assumes all deviations from the frontier are due to inefficiency, stochastic approaches provide a more nuanced understanding by separating TE from statistical noise. Parametric models, estimated using econometric methods, offer a structured framework for efficiency analysis, allowing for the estimation of model parameters based on specified functional forms.

2.4.2.1 Deterministic frontier model

Deterministic models in efficiency analysis encompass all the observed data points and aim to quantify the gap or distance between the actual production levels and the maximum achievable production levels determined by the frontier and available technology. This difference is interpreted as technical inefficiency. In these models, the observed data points are compared to the frontier, which represents the best possible production levels given the available technology and inputs. The frontier is constructed based on the data points that lie on or near the production possibilities boundary, indicating the most efficient use of resources. Any deviations from this frontier are considered as indications of technical inefficiency. The deterministic model uses an

econometric technique to estimate the parameters of specified functional forms. The deterministic parametric frontier production functions of n sample firms are specified as (Aigner and Chu, 1968).

$$Y_i = F(X_i, \beta) - u_i \quad (2.7)$$

Where: i - shows the number of farms in the study and Y_i -the actual output of i^{th} firm. X_i is a $(k \times 1)$ row vector of inputs, β is a column vector of the unknown parameters to be estimated, and u_i is a non-negative random variable associated with technical inefficiency, representing the shortfall of actual output from its maximum possible value. The production function can be expressed either in Cobb-Douglass, trans log form, or quadratic.

The main criticism of the deterministic frontier model is that it does not account for the possible influence of measurement error and other noises (such as bad weather) upon the shape and positioning of the estimated frontier (Coelli *et al.*, 1998) and therefore, it attributes any deviation from the estimated frontier are the result of technical inefficiency. Timmer (1971) developed the probabilistic frontier as a solution for the problem (associated to outline the above deterministic estimation approaches). He imposed the Cobb-Douglas type of production function and estimates the parameters using linear programming by discarding outliers until the parameter values stabilize. Therefore, the presence of high random error in data to exaggeration of inefficiency estimates in the deterministic model as compared to other models, which take random error into account. Even though, the empirical findings publicized that the smaller the random noises present on the data in question, the closer will be inefficiency estimate between deterministic and stochastic frontier models; most empirical production efficiency studies in agriculture are treated by the stochastic frontier model. This is because agricultural outputs are easily vulnerable to natural hazards climatic conditions and measurement errors that could contribute to the existence of noises in the data (Coelli *et al.*, 1998).

2.4.2.2 Stochastic frontier production model

A method of measuring the productive efficiency of a farm relative to other farms was first suggested by Farrell (1957) using a production frontier. A production frontier is specified to represent the maximum output for a given set of inputs and existing production technology. Failure to attain the frontier output implies the existence of technical inefficiency. Farrell's proposed methodology in efficiency analysis, known as the Farrell's deterministic frontier model, attributed all deviations from the "best practice" level of production to inefficiency. In this deterministic

approach, any deviation from the estimated frontier was considered as an indication of inefficiency. The stochastic frontier production model was independently proposed by Aigner *et al.* (1977) and Meeuse and Broeck (1977). Stochastic approaches in efficiency analysis provide a framework that allows for the differentiation between TE and statistical noise. Unlike deterministic models, which attribute all deviations from the production frontier to inefficiency, stochastic approaches acknowledge that there may be factors beyond inefficiency that contribute to variations in production levels. The merits of this approach over DEA is that it accounts for a composite error term for both statistical noise and technical inefficiency effects in the specification and estimation of the frontier production function.

For a number of reasons, the stochastic frontier analysis approach has generally been preferred in the empirical application of the stochastic production function model in developing countries' agriculture like Ethiopia. This is due to the assumption that all deviations from the frontier arise from inefficiency by DEA is hard to accept, given the inherent variability of smallholder agricultural production due to external factors like pests, drought, and other weather conditions. Second, most farms are very small and operated by family labor, and hence farm records are kept rarely (Wudineh & Endrias, 2016). The original specification of the production function for cross-sectional data incorporated an error term consisting of two components. One component accounted for random effects, which captured the unobserved heterogeneity among different units or firms in the dataset. The other component accounted for technical inefficiency, representing the deviation from the maximum attainable production level given the available inputs.

The original specification involved a production function specified for cross-sectional data which had an error term with two components, one for random effects and another for technical inefficiency. The stochastic frontier model can be expressed in the following form:

$$Y_i = F(X_i; \beta) + \varepsilon_i \quad i=1,2,3,\dots,N \quad (2.8)$$

Where i is the number of firms in the study; Where Y_i is the output of the i^{th} firm, X_i is the vector of input variables for the i^{th} firm, $F()$ is the appropriate functional form, β is the vector of unknown parameters to be estimated, and ε_i is the composed error term, which equals $V_i - U_i$. The random factor (V) is a symmetric error, which accounts for random variations in output due to external factors beyond the control of the farmer, e.g., weather and disease outbreaks, and it is assumed to be independently and identically distributed with $N(0, \sigma_v^2)$ while the technical inefficiency

effects, (U), is often assumed to have a half normal distribution $N(0, \sigma_u^2)$. U_i reflects the fact that each firm's output must lie on or below its frontier $f(X_i; \beta) + V_i$. Any such deviation is the result of factors under the firm's control, such as technical inefficiency. But the frontier itself can vary randomly across firms and on this interpretation the frontier is stochastic, with random disturbance $V_i \leq$ or ≥ 0 being the result of favorable as well as unfavorable external events.

Stochastic production function can be estimated using a maximum-likelihood method, which is consistent and asymptotic efficient. Cobb-Douglas, translog, and quadratic production functions are the three commonly used functional forms to represent the production function (Coelli *et al.*, 1998). Each of the three functional forms has its own strength and shortcoming. The Cobb-Douglas functional form has been commonly used in the empirical estimation of the frontier model. The attractive feature of the Cobb-Douglas function is its simplicity but this simplicity is associated with different restrictive features like constant elasticity, constant returns to scale for all firms, and elasticity of substitution are equal to one. The Translog functional form put no restriction upon return to scale or substitution possibility whereas the quadratic form has the return to scale restriction. However, the translog and quadratic functional forms are susceptible to multicollinearity and degree of freedom problem (Kopp and Smith, 1980). Besides, the stochastic frontier approach is consistent with most of the agricultural production efficiency studies (Jema, 2008; Kehinde and Awoyemi, 2009).

2.5 Empirical Studies on production Efficiency of Crops

Under this section, different studies related to the production efficiency cereal and pulse crops are reviewed. The first part of this section focuses on review of studies related to the production efficiency of Cereal crops in Ethiopia, while the last section focuses on the review of studies on pulse production efficiency.

Wollie *et al.* (2018) analyzed the EE of smallholder barley producer farmers in the Meket district of the Amhara national regional state in Ethiopia. The researchers employed the stochastic production frontier model to estimate the technical, allocative, and economic efficiencies of the sampled farmers. The results showed that the estimated efficiencies were approximately 70.9% for TE, 68.6% for AE, and 48.8% for EE. Among the hypothesized variables to influence EE, the study found that extension contact and the number of barley plots had significant and positive

effects on all efficiency levels. This suggests that increased interaction with extension services and having a greater number of barley plots positively impacted the efficiencies of the sampled farm households. Furthermore, distance from the nearest main market was identified as a significant factor with a negative effect on all efficiency levels. This implies that greater distances from the main market had a detrimental impact on the efficiencies of the sampled farm households. Overall, the findings of the study highlight the importance of extension contact, the number of barley plots, and proximity to main markets in enhancing the EE of smallholder farmers engaged in barley production in the Meket district of Ethiopia.

Tesema *et al.* (2019) employed a parametric approach to examine the EE of smallholder farmers in Maize production in Gudeya Bila District, Oromia National Regional State, Ethiopia. The parametric approach result found that the technical, allocative, and EE levels were 71.65%, 70.06%, and 49.89%, respectively. The findings from the Tobit model analysis revealed that education levels, family size, farm size, frequency of extension contact, use of credit, and participation in off/non-farm activities had a positive significant effect on the TE. Moreover, livestock holding and engagement in off/non-farm activities had a positive impact, whereas the distance between the maize plot and the household had a negative significant influence on AE. Additionally, education levels, family size, use of credit, extension contact, and participation in off/non-farm activities were found to positively affect EE, while the distance between the maize plot and the household had a negative significant effect on EE.

The study by Asfaw *et al.* (2019) conducted a study on the EE of smallholder farmers involved in wheat production in the Abuna Gindeberet district of the Oromia National Regional State in Ethiopia. The study aimed to estimate the mean values of technical, allocative, and economic efficiencies. The results showed that the estimated mean values were 78% for TE, 80% for AE, and 63% for EE. Using the two-limit Tobit model, the researchers identified several factors that significantly affected efficiency levels. For TE, the sex of the household head, education level, extension contact, engagement in off/non-farm activities, and soil fertility had a positive and significant impact. However, land fragmentation had a negative effect on TE. Regarding AE, age, education level, extension contacts, and engagement in off/non-farm activities were found to have a positive and significant influence. Furthermore, for EE, the sex of the household head, age, education level, extension contact, engagement in off/non-farm activities, and soil fertility were

identified as factors that positively and significantly affected efficiency levels. Overall, the study highlighted the importance of various factors such as education, extension contact, off/non-farm activities, and soil fertility in enhancing the EE of smallholder farmers involved in wheat production, while also noting the negative impact of land fragmentation on TE.

According to the study conducted by Melese *et al.* (2019) in Guraferda Woreda, Southern Nations Nationalities People's Region, Ethiopia, the EE of smallholder farmers engaged in rice production was analyzed. The study reported mean values for technical, allocative, and economic efficiencies as 78.5%, 80.56%, and 63.18% respectively. Through the implementation of the two-limit Tobit model, the researchers identified several significant factors that influenced EE. Specifically, education level, frequency of extension contact, and membership in cooperatives were found to positively and significantly impact EE. On the other hand, proximity to the market and non-farm income were identified as factors that negatively and significantly affected EE.

Hailu (2020) analyzed the determinants of TE in Wheat production in Ethiopia using cross-sectional data from 1611 sample farm households selected using a multi-stage random sampling technique. This study used a stochastic production frontier and two-limit Tobit regression models to estimate the level of TE and identify factors affecting TE respectively. The model result showed that the average TE level of wheat-producing farmers was 62% implying that there was TE variation among smallholder farmers in the study area. According to the two-limit Tobit regression model result, the experience of growing wheat, family size, own farm labor, livestock size, extension contact, and training had a positive and significant effect on TE. However, the distance of wheat plots had a negative and significant effect on the TE level of the farmers.

Naramo and Tafesse (2022) studied the production efficiency of maize in Damot Woyede District, Southern Ethiopia using the stochastic frontier analysis. The study was conducted using 384 sample farming households selected using a multi-stage sampling technique. The mean TE, AE, and EE were 82, 75, and 62%, respectively. Factors like land size, the quantity of fertilizer, family labor, oxen power, seed, and pesticides determined the output of Maize. According to the study, gender of the household head, landholding, training, education, farm experience, membership in cooperatives, age, distance from the plot of land, off-farm activities, livestock holding, and distance from the credit institution are factors affecting TE, AE, and EE of Maize production.

A study by Birhanu *et al.* (2022) on the TE farming households in major “Teff” growing mixed farming areas of Ethiopia employed a stochastic meta-frontier approach and Tobit regression framework was applied to analyze the TE and to identify factors related to farm inefficiency respectively. The result of the study revealed a mean TE of 58%, implying that the farm households can improve cereal output by about 36% with the current level of input mix and technologies. According to the Tobit model result, the use of high-yielding varieties and research-based recommended seed rate affects the TE of farm households positively and significantly. The study also reported that gender, age, mobile telephone ownership, cooperative membership, access to input market, and crop damage as significant factors affecting the efficiency of farm households.

Muleta and Getahun (2022) analyzed the Technical, Allocative, and Economic Efficiencies of Teff Producers in Ejersa Lafo District, Central Oromia, Ethiopia using 472 teff producers. The stochastic frontier model and Cobb-Douglas production function used in this study revealed that the mean technical, allocative, and EE scores were 80.85%, 88.91%, and 71.89% respectively. According to the Cobb-Douglas production function land, labor, fertilizer, chemicals, seed, and size of the plot allotted for teff significantly affected yield per hectare. Moreover, the study also found that sex, education, experience in teff production, age of the head, distance from farmers’ training center, and dependence ratio significantly affected the technical inefficiency of teff producers.

The next section of the literature review includes a review of studies on the production efficiency of pulse crops in Ethiopia and some other African countries.

A study by Sibiko *et al.*, (2013) on the analysis of economic efficiency in Bean production in Eastern Uganda employed a stochastic frontier cost function and a two-limit Tobit regression model to analyze the level of economic efficiency and to analyze the determinants of economic efficiency of Bean using a randomly selected 580 sample households. The study reported that the mean economic efficiency level was 59.94% and it was positively influenced by value of assets, off-farm income, credit and farmers’ primary occupation.

A study on the analysis of technical efficiency of lentil production in the case of Moretha Jiru district in North Shewa Zone of Amhara national regional state, Ethiopia was conducted by Gudeta, (2018). This study aimed to estimate the level of technical efficiency of lentil production

and its determinants in Moretha Jiru district North Showa Zone Amhara region of Ethiopia. This study used a cross sectional data collected from 126 randomly selected households. By using a stochastic frontier model, the study found that mean efficiency level of lentil farmers was 62.6%, with the minimum and maximum efficiency level of about 12.9 and 98%, respectively. In addition to that, plot fertility, age of the farmer, lentil farming experience, extension service, access to credit, off/non-farm activity, cooperative membership, and household size are significant determinants of inefficiency of lentil production.

A study conducted by Wubie (2019) Assessed the TE of smallholder faba bean farmers in Kersa Malim District, South West Shewa Zone of Oromia, Ethiopia. The data was collected from 181 respondents selected using a multi-stage sampling technique. Stochastic frontier and translog functional form with a one-step approach were used to assess the TE and factors affecting the TE of farmers respectively. The result showed that the mean TE of Faba bean was found to be 69%. The TE analysis also showed that about 60% of the farmers were above the average and 38% were below the average of mean TE. According to the study result, the production efficiency of faba bean farming was determined by education, livestock holding, distance to all-weather roads, distance to Faba bean plot, and slop negatively, whereas Age, extension contact, and family size positively affected the inefficiency of Faba bean farmers.

Mekonnen *et al.* (2015) studied the EE of sesame production in the Selamago district of the South Omo zone in southern Ethiopia. This study was conducted using cross-sectional data from 120 randomly selected farm households during the 2010/11 production season in the Selamago District of the South Omo zone, SNNPR. The study employed the stochastic production frontier model to estimate the levels of technical, allocative, and economic efficiencies. The Tobit model was also employed to identify factors that impacted the efficiency levels. The findings revealed significant inefficiencies in sesame production within the study area. The mean technical, allocative, and economic efficiencies of the sampled households were determined to be 67.1%, 67.25%, and 45.14%, respectively. Labor and seed variables were found to positively affect sesame production. The results from the Tobit model indicated that soil fertility, non-farm income, and access to credit had positive and significant effects on TE. Soil fertility also had a positive and significant impact on AE. On the other hand, experience in sesame production, the distance between the sesame farm and residence, non-farm income, and extension contact were found to have negative and significant

effects on AE. Regarding EE, soil fertility, non-farm income, and credit access were identified as factors with a positive and significant influence. However, extension contact had a negative and significant effect on EE.

Fufa and Haji (2016) conducted a study on the EE of sesame production in the Babogambel District of West Wollega Zone, Oromia Region, Ethiopia with the aim of measuring the levels of technical, allocative, and economic efficiencies of sesame producers and identify factors affecting them in the district using 124 randomly selected farm households. The study employed the Stochastic production frontier model and Tobit to estimate technical, allocative, and EE levels, and to identify factors affecting efficiency levels respectively. According to the study, the mean technical, allocative, and economic efficiencies of sample households were 75.16%, 72.95%, and 53.95%, respectively. According to this study, the positive factors that influenced the production efficiency of sesame were land, labor, and oxen. The Tobit model findings indicated that family size, experience in sesame production, and non-farm income had a positive and significant impact on TE. However, having a larger total cultivated land had a significant negative effect on TE. Regarding AE, experience in sesame production, family size, and extension contact had a negative and significant impact. On the other hand, soil fertility and education level had a positive and significant effect on AE. When it comes to EE, education level, experience in sesame production, and soil fertility positively and significantly affected it. However, extension contact had a negative and significant impact on EE.

Argaw *et al.* (2021) analyzed the technical, allocative, and EE of Soya bean Production in Pawe District, Ethiopia using 203 randomly sampled households. The study employed a stochastic frontier approach and Tobit model to measure the technical, allocative, and EE of soya bean production and to analyze the factors affecting the efficiency of soya bean production in the district respectively. The Stochastic frontier model analysis revealed that the variables of land, labor, and fertilizer were identified as factors influencing the frontier function. The findings indicated that the average levels of technical, allocative, and EE were 72.72%, 35.378%, and 25.05%, respectively. Furthermore, the estimated value of gamma, which was found to be 0.7384, suggests that approximately 73.84% of the variation in soya bean output can be attributed to technical inefficiency. In addition, the Tobit model result showed that age, level of education, extension

service, access to credit, farming experience, off/nonfarm income participation, and training affected the technical, allocative, and EE of soya bean producer farmers in the study area.

From the above literature reviews, we can draw the following conclusions and insights;

- There are only a few studies on the production efficiency of pulses in the country and especially only a few studies are available related to the production efficiency of Faba bean.
- The reviewed studies clearly showed that there is a huge efficiency gap in pulse crop production in different parts of Ethiopia.
- Socio-economic, demographic, institutional, and farm/plot characteristics can affect the TE, AE, and EE of cereal producers.
- However, less emphasis is given to plot/farm characteristics in analysing the factors affecting the level of both cereal and pulse crops production efficiency.
- In addition to that, the reviewed literature ignores the effect of the endogeneity of input factors and the error term in the production function.
- As far as the researcher's review is concerned, there is no study on the production efficiency of Faba bean in the Amhara region and in the study area. But it is known that the region is the leading pulse producer in Ethiopia.

2.6 Conceptual Framework

The EE of smallholder farmers' Faba bean production is assumed to be affected by a wide range of factors. From the extensive reviews, the various factors can be grouped as institutional factors, socio-economic factors, demographic characters, farm-level factors, and cost factors. Factors related to the institutional factors include the use of credit, extension service, agricultural training, plot distance, distance from the nearest market, and cooperative membership. These factors can have an impact on the farmers' knowledge, access to resources, and market opportunities, which in turn can affect their EE. Socioeconomic characteristics include the educational level of the household head, livestock holding, off/non-farm activity, and number of oxen. These factors reflect the human and capital resources available to the farmers, which can influence their production decisions and overall efficiency. The factors related to land/farm characteristics include land size, soil fertility, land fragmentation, slope, and land ownership. These factors are directly linked to the physical characteristics of the farming environment and can affect the productivity

and profitability of Faba bean production. The factors related to demographic characteristics include age, sex, and family size. These factors may influence the labor supply, decision-making, and resource allocation within the household, thereby impacting the farmers' efficiency levels. Other factors related to cost which can affect influence EE are related input costs as well as the price of Faba bean output. Input costs include the cost of herbicide, cost of labor, cost of land, cost of oxen, cost of fertilizer, and cost of seed. Households are the decision-making units where all decisions on types and amounts of inputs to be used in the production process and managerial practices to be done are made. The managerial practices the household made are affected by institutional factors, socio-economic factors, demographic characters, land/ farm factors, and cost factors, which together with the inputs determine the quality and quantity of outputs produced and overall farm gain of the household. Depending on this the conceptual framework of the EE of Faba bean production can be drawn as follow:

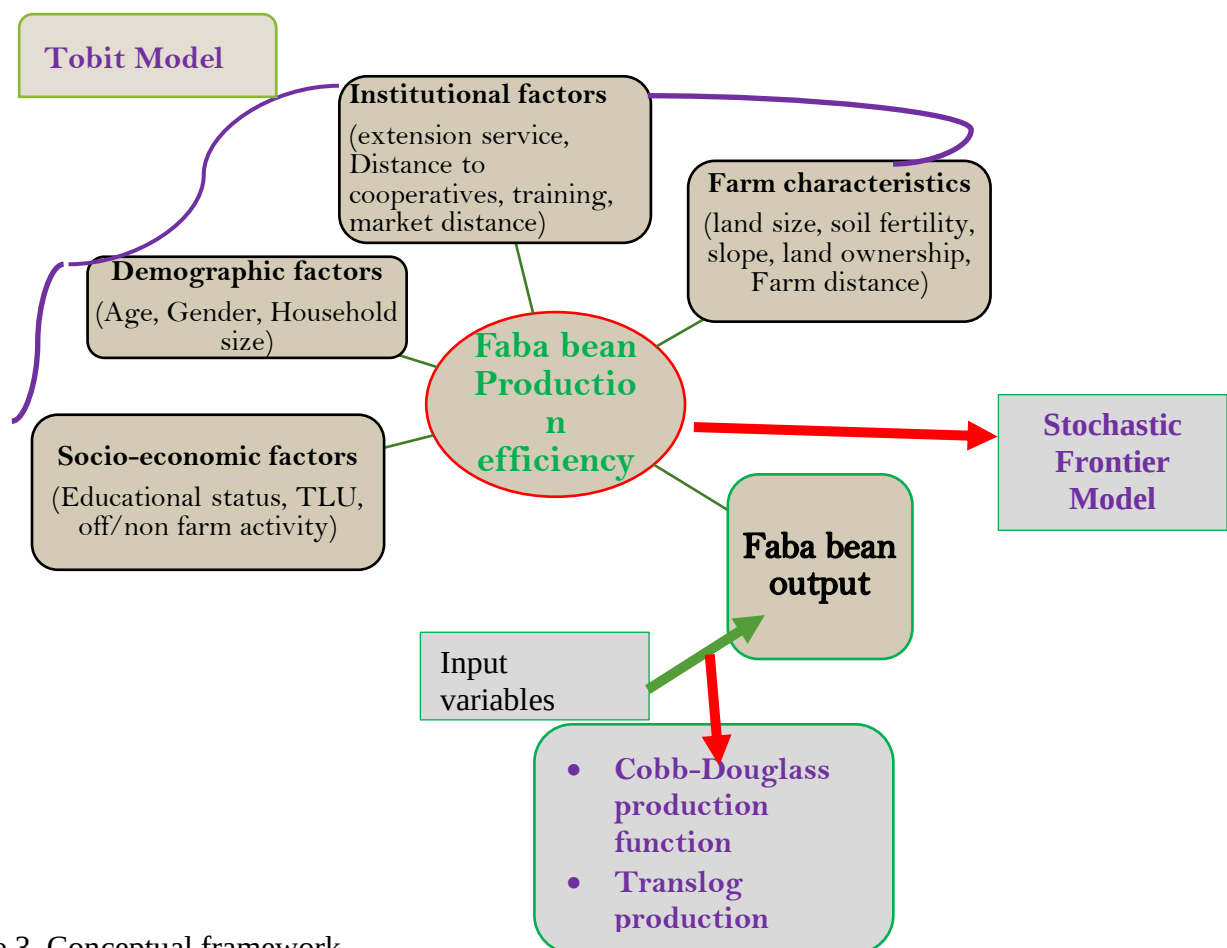


Figure 3. Conceptual framework

Source: Own sketch from the reviewed literature

CHAPTER THREE. RESEARCH METHODOLOGY

3.1 Research area description

The study was conducted in Dembecha and Debre Elias districts. The description of the study areas is presented in this section.

Dembecha district: it is one of the districts in the Amhara Region of Ethiopia, part of the West Gojjam Zone. The district is bordered on the west by Bure, on the northwest by Jabi Tehnan, on the north by Dega Damot, and on the east and south by the East Gojjam Zone. Based on the 2022 population projection conducted by the Central Statistical Agency of Ethiopia (CSA), this district has a total population of 173,905, of whom 87,196 are men and 86,709 women. A total of 30,731 households were counted in this district. The majority of the inhabitants practiced Ethiopian Orthodox Christianity, with 99.13% (CSA, 2021).

In the district, agricultural output is the primary source of income. Maize, wheat, sorghum, teff, and pepper are the principal crops grown in the area. Cattle, sheep, goats, horses, and donkeys are the most common livestock. The district extends in altitude from 1500 to 2999 meters above sea level. Dembecha district's agroecological conditions are ideal for growing grains and grain legumes. Approximately 87% of the district's land area is mid-highland (*Woinadega*), with the remaining 12% being highland (*Dega*) and less than 1% being lowland (*Kolla*). With an average annual rainfall of 1006mm, the district has a monomodal rainfall distribution (Dembecha district office of agriculture, 2022).

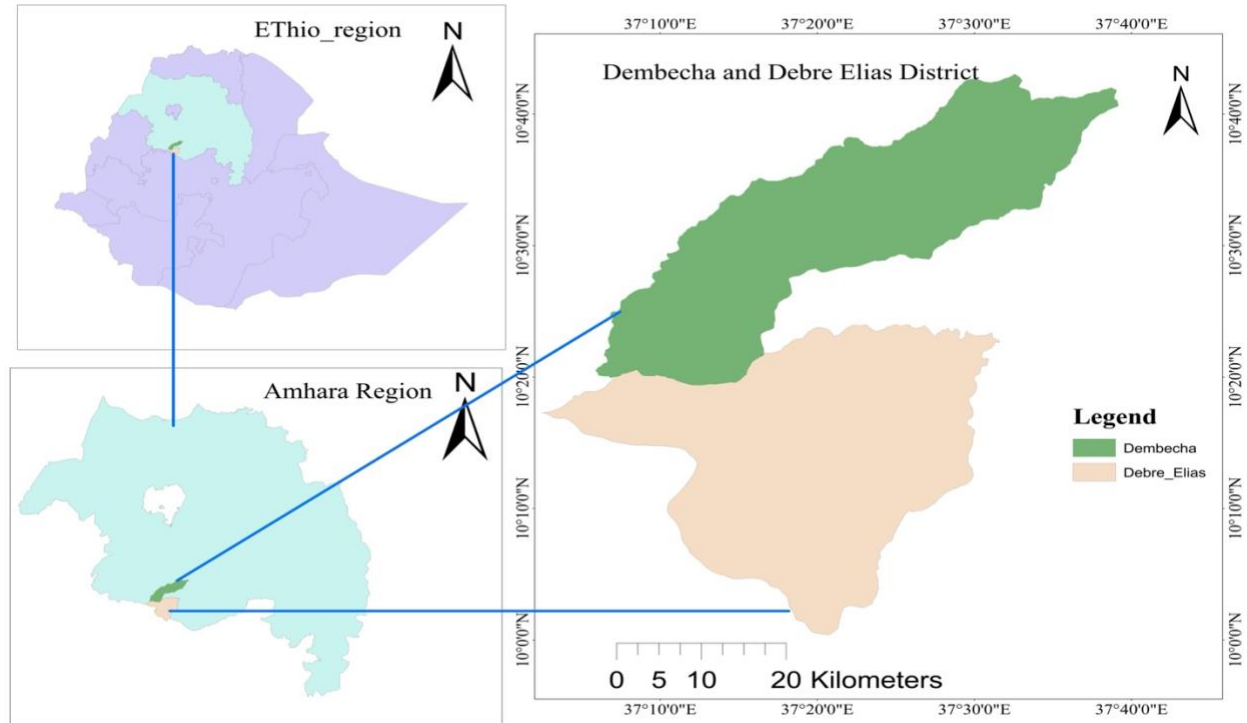


Figure 4. Study area map

Debre Elias District: It is one of the eighteen districts', found in East Gojjam Zone, Amhara regional state of Ethiopia, which is located around 340 km Northwest of Addis Ababa and about 41 km Northwest of Debre Markos town. It is bounded by the Abay River at the south and west, West Gojjam Zone at the northwest, Machakele district at the north, and Gozamen district at the east. The altitude of the district ranges from 800-2200 meter above sea level and receives mean annual rainfall of 1150 mm, which occurs mainly in the June, July, August and September. Other months of the year are almost dry with erratic rainfall. The average daily temperature ranges from 18- 27 C⁰ (Melaku and Abebe, 2012) . Moreover, the red soils are the dominant soil type and it is moderately fertile. The Woinadega (mid highlands) agro ecological condition of the study area accounts for 98 %and the rest 2% accounts Kolla ((Debre Elias district office of agriculture, 2022).

In the district there are sixteen *Kebele* administrations with one urban *kebele* and fifteen rural *kebeles*. Wheat, Teff, and Maize are the dominant and most important crops, serving as both the main food and cash crops. Other crops grown in the study area includes Barley, Nougé, and Beans. Crop sales make the largest contribution to the household income together with sheep and goats

for their cash earnings. Cattle, sheep, goats, donkeys, horses, honeybee production, and chickens are the most reared livestock (Debre Elias district bureau of agriculture, 2022).

Based on the 2022 population projection conducted by CSA, this District has a total population of 106,864 , of whom 53,364 are men and 53,500 women. A total of 12033 male headed and 1084 female headed households are living in the district. The majority of the inhabitants practiced Ethiopian Orthodox Christianity, with 98.94% reporting that as their religion, while 1.01% of the population said they were Muslim (CSA, 2021).

3.2 Type and Sources of data

This study used both primary and secondary sources of data. The primary sources of data include data obtained directly from interviewing sample households and personal observations. The primary data include detailed information regarding demographic and socioeconomic characteristics of sample households, resource endowments, agricultural production, access to extension, and farm characteristics. Secondary sources of data for this study were reports of Bureaus of agriculture, district, and *kebele*¹ level reports in addition to different published journals and articles related to the research title.

3.3 Methods of data collection

Focus group discussions (FGDs) and key informant interviews from elders, Women, selected farmers, and key informants who have adequate knowledge and information about the study area were held before the main survey. One focus group discussion per *kebele* with a member of 10 individuals was conducted. General information about agricultural production, land use, land management practices, livelihood activities, crop production pattern, and other background information about the study area was obtained.

The data was collected by five trained enumerators through face-to-face interviews using a structured questionnaire from April 17, 2021, till May 12, 2021. The questionnaire was pretested before the actual survey. The data collection method was tablet-assisted using the CSPro 7.3 application.

¹ *The smallest administration level in Ethiopia*

3.4 Sampling and sample size

A multi-stage purposive sampling technique was used to select sample *kebeles* and households. Dembecha and Debre Elias districts are selected for the study considering their potential in legume and cereal production, especially Faba bean production. Two sample *kebeles* were selected randomly from each district. Angot and Asteboji *kebeles* from the Dembecha district and Jabigenet and Yeguarat *kebeles* from the Debre Elias district were the sample *kebeles*. After selecting the sample *kebeles*, 75 sample households from each *kebeles* were selected randomly. A list of household heads was taken from the District Office of Agriculture and the records of kebele development agents to randomly select households using the lottery method.

A total of 300 sample households were included in the survey from both districts. Among those households, 147 households were Faba bean producers in the 2021/2022 production year.

Table 2. Sample selection and sample size

District	Sample Kebeles	Number of households			Samples households
		Male headed	Female Headed	Total	
Dembecha	Angot	912	82	994	75
	Asteboji	881	74	955	75
Debre Elias	Jabigenet	857	60	917	75
	Yeguarat	1022	79	1101	75
Total sample					300
Faba Bean Producers:					147

3.5 Methods of data analysis

The collected data was imported into STATA software and all the data management and data analysis was executed using this software. To address the objectives of the study, descriptive statistics, inferential statistics, and econometric models were used. Mean, standard deviation, percentage, and frequencies were used to describe the household, institutional, and farm characteristics. Inferential statistics (t-test and chi-square test) is also employed to check the mean difference in terms of continuous variables between sample households from the two sample districts and to check the association between categorical variables respectively.

Regarding the econometric model analysis, the stochastic frontier model was employed to analyze the production efficiency of Fababean producers in the Dembecha and Debre Elias districts. In addition to the stochastic frontier model, the Tobit model was also used to analyze the factors affecting the technical, allocative, and EE of sample households.

3.5.1 Specification of econometric models

3.5.1.1 Analysis of the level of TE, AE, and EE

In this study, the stochastic frontiers model was used to analyse the level of TE, AE, and EE of Faba bean production in this study. Originally this model was proposed by Aigner, Lovell (1977), and Meeuse and Van den Broeck (1977). The general functional form of this model was specified as follows.

$$Y_i = f(X_i, \beta) + \varepsilon_i \dots \dots \dots (3.1)$$

Where: Y_i is Fababean yield per hectare of the i th sample household ($i= 1, 2, 3 \dots 238$), X_i represents vectors whose values are functions of input variables (land size allocated for Fababean in hectare, the quantity of seed used in kilograms per hectare, human labor used in man-days per hectare, oxen days per hectare, and quantity of fertilizer used in kilograms per hectare) for the i th farmer, $f()$ is the appropriate functional form and β vector of unknown production parameters to be estimated, and ε_i is the composed error term (V_i and U_i).

To represent the production function, cobb-Douglas, and the transcendental logarithmic (Translog) functions have been the most widely used functional forms in most empirical production analysis studies. Each functional form has its own advantage and limitations. The Cobb-Douglas functional form has advantage of simplicity and convenient in interpreting the elasticity of production but it is less flexible as it imposes severe priori restriction on the farm's technology by restricting the elasticity of production to be constant and very parsimonious with respect to degrees of freedom. Although, the trans log production function is susceptible to multicollinearity problems when we have more interaction variables, it has the advantage of showing the effects of the interaction among input variables on the output and it is more flexible functional form (Leavy *et al.*, 1999; Wilson and Hadley, 1998). For this study, the researcher employed a constrained translog production function.

Aigner *et al.* (1977) proposed the log likelihood function for the stochastic frontier model above assuming half normal distribution for the technical inefficiency effects (u_i). They expressed the likelihood function using lambda (λ) parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. $\lambda = \sigma_u / \sigma_v$). However, Battese and Corra (1977) proposed that the gamma (γ) parameterization, where ($\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$), to be used instead of λ . It is because λ could be any non-negative value while γ ranges from zero to one and better measures the distance between the frontier output and the observed level of output resulting from technical inefficiency. Both parameters γ and λ can be associated using the following formula proposed by Bravo and Pinheiro (1997).

$$\gamma = \lambda^2 / (1 + \lambda^2) \dots \dots \dots (3.2)$$

The significance of γ and σ^2 parameters is used to test whether the technical inefficiency affects output or not, and to test whether the conventional average production function can represent the data or not respectively.

3.5.1.2 Analysis of the determinants of TE, AE, and EE

To analyse the factors affecting the level of TE, AE, and EE of Faba bean production, there are two approaches; one-stage and two-stage estimation approach.

A one stage simultaneous estimation approach in which the inefficiency levels are expressed as a function of a vector of demographic, socio-economic, institutional and farm-specific variables together with the production function. In this approach parameters of the frontier production function are simultaneously estimated with those of an inefficiency model, in which the inefficiency levels are specified as a function of other variables. The one stage simultaneous approach is also implemented in frontier and in addition to the basic parameters the program also provides coefficients for the inefficiency model (Battese and Coelli, 1995).

On the other hand, the two-stage estimation procedure is an approach in which the stochastic production function is estimated first, and from which efficiency scores are derived, then in the second stage the derived efficiency scores are regressed on socio-economic, demographic, institutional, and farm level variables using ordinary least square method or Tobit regression. This approach assumes that the factors influencing efficiency are distinct from the production-related variables, specifically

those connected to farmers' attributes. This approach is presented to counteract the potential bias in the first stage, where efficiency level is presumed independent of these variables, whereas in the second stage, they are treated as dependent factors. The merit of this approach lies in its ability to isolate the impact of specification errors in the second phase, affecting only the coefficients of the estimated determinants, not the frontier coefficients (Murillo-Zamorano, 2004). As emphasized by Lovell (2000), this technique is applicable to both non-parametric and parametric methodologies. The second-stage regression can be executed employing the OLS method or a Tobit model, which considers the truncated nature (ranging between 0 and 1) of the dependent variable (efficiency). Therefore, this study employed the two stage estimation approach due to the measurement procedure of the overall economic efficiency.

3.6 Definition of Variables and Hypotheses

3.6.1 Production function variables

Yield: This is the dependent variable of the production function. It is the physical quantity of Faba bean produced in quintals by the sample household.

Land: Represents the physical unit of the cultivated area under Faba bean in hectare operated by the farmer, including that owned, rented in, contracted in, and obtained through gift in 2021/2022 production year.

Labor: This represents the aggregate labor used for Faba bean production in the production season. It was measured in man-days (eight hours are equivalent to one man-day) and converted to a homogenous variable using the standard conversion set by Storeck *et al.* (1991).

Seed: This refers to the quantity of Faba bean seed used in kg for Faba bean production by each household in the production season.

Fertiliser: This refers to the amount of fertiliser in kg used by the sample household for Faba bean production during the 2021/22 production season.

Oxen: It represents the amount of oxen power utilized for Faba bean production by a household. It was measured in oxen-days (one oxen-day is equivalent to eight working hours).

Soil fertility status: It was treated as a categorical variable that takes the value of 1 if a household head perceives his land for Faba bean as fertile, 2 for medium, and 3 for infertile. The researcher considered this variable as an input in the production function since the level of farm fertility is more linked to the yield.

3.6.2 Cost Function Variables

Cost: it represents the total cost of Faba bean production in the 2021/22 production year in *Birr*².

Land cost: This variable represents the rental cost of land (*Birr*) for Faba bean production in the 2021/22 production year. In countries where purchasing agricultural land is hardly exists but has considerable tenancy, the rental value of land provides a fairly good indication of the net value of production.

Fertilizer cost: This represents the cost of fertilizer used in *Birr* for Faba bean production in the 2021/22 production year. The market price of fertilizer during the production year was used to measure the cost.

Seed cost: This variable represents the cost of Faba bean seed used in *Birr* during the 2021/22 production year. The market price of seed during the production year was used to measure this cost.

Labor cost: This variable represents the wage for hired labor and the opportunity cost of family labor if the family has other nonfarm alternatives. In addition to the wage of the hired labor, the opportunity cost of rural labor measured in market wage paid of peak seasons can be accepted as the economic value of the rural labor (Gittinger, 1982). Since the wage of labour is different during peak and normal season, the researcher used an average wage of a labour in the study area per day as 150 *Birr*/day.

Oxen cost: It represents the cost of renting oxen in *Birr* for ploughing Faba bean plots and thrashing during the 2021/22 production year. The average rental price for a pair of oxen was used to calculate the oxen cost. In the study area, the average rental price of a pair of oxen was 100 *Birr*/day.

3.6.2 Factors affecting efficiency

The level of TE, AE, and EE can be affected by socio-economic, demographic, institutional, and farm-level characteristics. The variables and their hypothesized effect on the level of TE, AE, and EE are explained in detail here below.

² Local currency of Ethiopia. 1 *Birr*=0.02 USD

Age of a household head (AGEHH): This refers to the age of the household head measured in years. It is believed that age can serve as a proxy for experience. In this case, farmers with more years of experience are expected to be more efficient than their counterfactuals. On the other hand, older farmers are relatively unlikely to change their long-life farming exercise, which is usually traditional and less efficient. Moreover, labour productivity decreases with age indicating that younger farmers tend to be relatively more productive, because of the tough nature of farm operations (Ike and Inoni, 2006). Therefore, in this study, it is hypothesized that this variable can have an indeterminate relationship between age and efficiency.

Educational status of the household head (EDUCHH): This variable refers the number of years that the household head spends in formal education. This variable is used as a proxy variable for the managerial ability of the decision-making unit (household head). It is assumed that through education the quality of labor can be improved and the farmer can become active in using the available resources efficiently (Kebede, 2001). Therefore, this variable is hypothesized to have a positive effect on the efficiency level of Faba bean production.

Household size (HSIZE): This is a continuous variable representing the total number of people in the household measured in man equivalents. Family labor is an important source of labor supply for agriculture in developing countries like Ethiopia where the access to modern farm machineries is very limited. A household with large household size, it will be easy to manage crops on time and may be able to use appropriate input combinations (Essa, 2011). Thus, household size is expected to have a positive influence the on efficiency of Faba bean production.

Extension contact (EXTN): This variable measures the frequency that the household head contacted the extension agents during the 2021/22 production year. It is expected that farmers that have frequent contact with extension workers could have better access to agricultural information like input utilization and land management and new technologies that can enhance the productivity of their farm (Fekadu and Bezabih, 2008). Therefore, this variable is hypothesized to affect the efficiency level of Faba bean production positively.

Non-farm/off-farm participation (NONFARM): This variable represents the participation of the household head in different non-farm/off-farm activities during the 2021/2022 production year. It is a dummy variable with a value of 1 if the household head participated in non/off-farm activities or 0 otherwise. Non-farm/off-farm activities can supplement agricultural activities in terms of

providing cash income to purchase necessary farm inputs timely. On the other hand, farmers engagement in non-farm/off farm activities can take the time and labor that should be invested in agriculture (Hyuha, 2006). Therefore, this variable is hypothesized to have an indeterminate effect on the efficiency of Faba bean production.

Farm ownership (FARMOWN): This variable represents the ownership status of Faba bean farms. It is a categorical variable taking 1, and 2 for owned or gifted plots, and rented in/shared in plots respectively. Farmers may give more attention to the owned farms due to the tenure security than the counterfactual farms. On the other hand, marketable farms may have better qualities than owned plots. This can make rented/shared in plots to be better off in terms of production efficiency. Hence, farm ownership is hypothesized to have an indeterminate effect on the efficiency of Faba bean production.

Farm distance (FARMDIS): This is the distance of the Faba bean farm from the homestead measured in walking minutes. It is hypothesized that the distance of Faba bean farms could be negatively related to efficiency. This is because those farms far away from home could receive less management attention from the farmer than other nearer farms (Kinde, 2005).

Distance to farmers' cooperative (DISCOOP): This variable represents the distance between farmers homestead and farmers' cooperative in walking minutes. In the study area, farmers cooperatives are the sources of farm inputs like fertilizer and seed. Farmers living close to farmers' cooperative can access farm inputs easily and on time than those farmers living far. Long distance between farmers' homestead and cooperatives can lead to a waste of time to travel and to get inputs and may also lead farmers to more cost. Farmers' who cannot travel long distance to get inputs may choose to buy inputs from informal traders living closer to them; which is more costly.

CHAPTER FOUR: RESULT AND DISCUSSION

In this chapter, the results of descriptive, and econometric analysis results are presented and discussed.

4.1 Descriptive statistics results

4.1.1 Faba Bean Production

Among the total 147 sample households, 84 (57.14%) were from Debre Elias district, while the rest of the sample households were from Dembecha district.

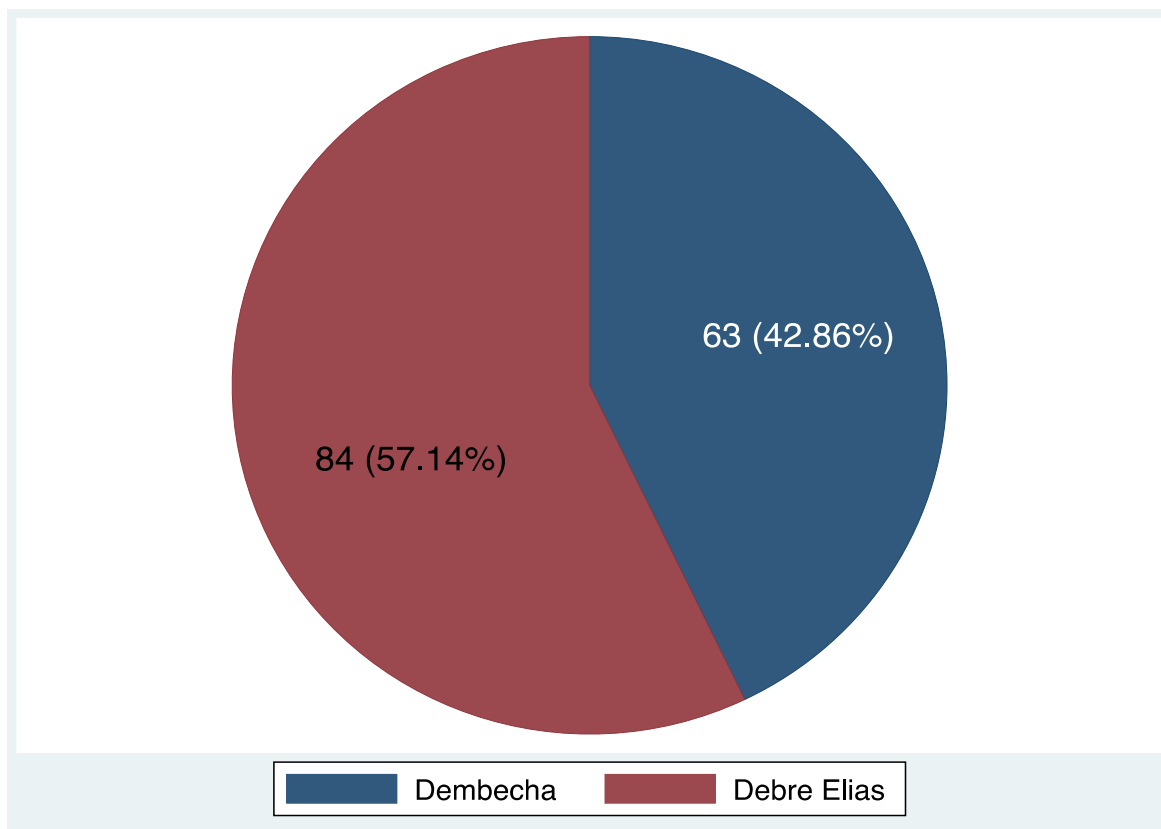


Figure 5. Sample households from the two districts

Regarding the level of Faba bean production, the average yield was found to be 15.52 quintals per hectare with a standard deviation of 17.15 quintals. The yield is below the average national production level, which is 21 quintals. The average Faba bean in Dembecha and Debre Elias districts was found to be 12.39, and 17.90 quintals. According to the t test result, there was a significant mean difference in terms of faba bean yield among the two districts at a 10% significance level.

4.1.2 Production function variables

Faba bean farm size, the quantity of seed, the quantity of fertiliser, amount of labour used for faba bean production, oxen days, and plot fertility were the variables in the stochastic production function.

Farm size: The average size of Faba bean farm was 0.138 hectare with a standard deviation of 0.121 hectare. Farmers in Dembecha have a higher average Faba bean land size (0.153 hectare) than the farmers from Debre Elias (0.127 hectare). However, the mean land size difference was not statistically significant according to the t test result.

Seed quantity: It is known that seed is the most important input and without it we cannot even imagine any production. Out of the total sample households, 107(72.79%) households used local seed, while the rest used an improved seed of Faba bean. The quantity of Faba bean seed used by the sample households ranges from 1 to 100 kg. The average quantity of Faba bean seed was found to be 13.64 kg with a standard deviation of 14.28 kg. The average seed quantity used by farmers from Dembecha and Debre Elias was found to be 11.96 kg and 14.90 kg respectively. According to the t test result, the mean difference in the seed quantity among farmers from the two districts was not significant.

Fertiliser: It is one of the key inputs in Faba bean production. The most common fertiliser that the farmers used is NPS fertiliser. Almost all the sample households (146) used NPS fertiliser. However, there was only 4 farmers applied UREA fertiliser for Faba bean production during the 2021/2022 production year. On average, sample households applied 24.64 kg of fertiliser for Faba bean production with a standard deviation of 20.35 kg. According to the t test result, the mean difference between Dembecha and Debre Elias districts in terms of fertiliser applied was not statistically significant.

Labour: The main source of labour for Faba bean production comes from family labour. During peak season and when households do not have enough labour, they hire additional labour. On average, 22.34 man-days were needed to produce Faba bean with a standard deviation of 14.44 man-days. The average labour required for Faba bean production in Dembecha and Debre Elias districts was found to be 24.06 and 21.05 man-days respectively. According to the t test result, the mean difference in labour for Faba bean production between Dembecha and Debre Elias districts was not statistically significant.

Oxen days: In developing countries like Ethiopia, where access to farm machineries is low, oxen are mainly used for ploughing and thrashing crops. According to this study, sample households used 7.11 oxen days on average. Dembecha district used more oxen power (7.24 oxen days) on average than Debre Elias District (5.02 oxen days). The mean difference between the two districts in terms of oxen days was found to be statistically significant at 5%.

Farm fertility: One of the key factors that can determine the yield level of a crop is the quality of land. according to this study, 80 households reported that the farm used for Faba bean production was fertile plot. The remaining 44, and 23 households reported that the fertility status of the Faba bean farm was medium, and infertile respectively. Debre Elias district had more fertile Faba bean farm responses (48) than Dembecha district (32). The chi square test was employed to see the association between district and farm fertility. It is found that the association was not statistically significant.

Table 3. Descriptive statistics for variables in the production function

			Dembecha district		Debre Elias district		T test
Variables	Mean	SD	Mean	SD	Mean	SD	
Yield	15.517	17.152	12.389	10.365	17.900	20.5876	-1.964*
Land size	0.138	0.121	0.153	0.132	0.127	0.111	1.327
Seed	13.641	14.275	11.964	11.496	14.899	16.000	-1.236
Fertiliser	24.636	20.346	23.762	15.538	25.292	23.384	-0.450
Labour	22.338	14.443	24.057	18.290	21.050	14.893	1.247
(man day)							
Oxen day	7.109	3.894	7.235	5.338	5.023	5.514	2.440**

		Dembecha District		Debre Elias District		
	Categories	Freq. (SD)	Freq. (SD)	Freq. (SD)		Chi-Square
Plot fertility	Fertile	80(54.42%)	32(50.79%)	48(57.14%)		0.6964
	Medium	44(29.93%)	21(33.33%)	23(27.38%)		
	Infertile	23(15.65%)	10(15.87%)	13(15.48%)		

Note: **, and * refers to 5%, and 10% significance level respectively.

4.1.3 Cost function variables

In Faba bean production, land cost, seed cost, labor cost, and oxen cost are the main input costs. The cost of land is related to the rental cost of the farm. The cost of labor includes both the cost of hired labour and the opportunity cost for family labour if the family member has another alternative to be hired during the time or to be engaged in either non-farm or off-farm activities. The average minimum cost of Faba bean production was found to be 4094.92 *Birr* with a standard deviation of 1647.84 *Birr*.

The average land cost, seed cost, and fertiliser cost was found to be 493.63, 530.62, and 468.09 *Birr* respectively. The mean cost for labour and oxen cost was found to be 1749.50, and 853.09 *Birr* respectively.

Table 4. Descriptive statistics for variables in the cost function

Variables	Dembecha		D/Elias				T-test
	Mean	SD	Mean	SD	Mean	SD	
Land cost	493.633	907.609	544.286	977.896	455.643	855.147	0.585
Seed cost	530.615	507.723	466.136	422.090	578.9735	561.1089	-1.337
Fertilizer cost	468.085	386.567	451.476	295.215	480.542	444.288	-0.450
Labour cost	1749.499	854.990	1834.624	959.108	1685.655	767.527	1.046
Oxen cost	853.087	467.279	946.381	499.215	783.117	431.698	2.121**

Note: ** represents a 5% significance level.

4.1.4 Demographic, socio-economic, institutional, and farm characteristics

Table 5. Descriptive statistics for demographic, socio-economic, institutional, and farm characteristics

Variables	Min.	Max.	Mean	SD.	T-value
AGEHH	22	78	46.2108	12.0996	1.3498

HSIZE	1.5	8.1	3.12244	1.178855	2.622***
EDUCHH	0	8	1.71428	2.064043	1.624
DISMKT	3	300	105.9864	64.1253	-0.355
DISCOOP	1	150	35.91156	28.71087	3.841***
EXTN	0	52	10.87075	13.00067	0.066
FARMDIS	0	120	13.56849	19.51406	1.620
Categories		Freq.	Chi2 value		
NONFARM	No	101	0.214		
	Yes	46			
FARMOWN	Owned	103	0.0027		
	Rented/shared in	44			

Note: *** refers a 1% significance level.

4.2 Econometric model analysis result and discussion

4.2.1 Stochastic frontier production function

The deviation from the frontier may not be only due to TE. Agriculture in developing countries is more vulnerable to measurement error and there are many factors which are out of the farmers control like climate change, and pest invasion. The stochastic frontier analysis model has the advantage of considering both the inefficiency and other statistical noises as a reason for the deviation from the frontier.

The endogeneity test was executed to check the existence of the problem of endogeneity of the input variables. Since households mainly rely on family labour for Faba bean production, we can consider labour as an exogeneous variable. Usually farm size is also exogeneous. The usual suspect to be endogenous is fertiliser. According to the test result, the Durbin chi-square, and Wu-Hausman-Hausman F (1, 139) value were found to be 12.43 and 12.84 respectively and significant at 1% level of significance.

Once we confirmed the presence of the endogeneity problem, we need to find the appropriate instruments for the endogenous variable (fertiliser). The age of the household head and educational level of the household head was found to be strong instruments for fertilizer. The two-stage least square (2sls) instrumental variable regression and the weak instrumental variable test result are presented in the Appendix section.

Table 6. Stochastic frontier analysis result

lnyield	Coef.	St.Err.	T-value
Lnseed	0.256	0.058	4.29***
Lnland_size	0.139	0.059	2.34**
lnlabour	-0.021	0.033	-0.64
lnoxen_day	0.012	0.043	0.29
Plot fertility			
Medium	-0.070	0.109	-0.64
Infertile	-0.214	0.139	-1.54
sqlnfertiliser	0.038	0.02	1.87*
lnfertiliser	0.272	0.116	2.35**
AGEHH	0.005	0.004	1.18
EDUCHH	0.07	0.023	3.04***
Constant	3.578	0.383	9.34***
/lnsig2v	-1.809	0.26	-6.97***
/lnsig2u	-0.846	0.322	-2.63***
sigma_v	0.404	0.053	
sigma_u	0.655	0.105	
sigma2	0.593	0.115	
Lambda (λ)	1.690	0.146	

Gamma (γ)	0.741
LR test of sigma_u	Chibar2(01) = 7.02***

Note: *, ** and *** refers to 10%, 5% and 1% significance level, respectively.

The likelihood ratio test of sigma_u was found to be significant as reported from the stochastic frontier analysis result. The null hypothesis of this test (Ho: No inefficiency deviation) was tested against the presence of inefficiency in Faba bean production. The chi-square value of the test result was found to be 7.02 and it is statistically significant at 1%. This implies that there is inefficiency in the production of Faba bean and it is meaningful to use the stochastic frontier analysis to measure the level of efficiency (inefficiency), otherwise we could use the ordinary least square regression.

The parametrisations sigma-u and sigma-v was found to be 0.655 and 0.404 respectively. This implies that the standard deviation due to inefficiency is 65.5%, while the standard deviation due to statistical noise is 40.40%. The gamma (γ) estimate was found to be 0.741 indicating that 74.10% of the variation in the total Faba bean production was caused by technical inefficiency. The Coefficient of sigma square (δ^2) was significant at 1% level, and indicated the goodness of fit and correctness of the specified assumptions of the distribution of the compound error term.

According to the stochastic frontier analysis, seed quantity, farm size, fertiliser and the square of fertiliser was found to have a statistically significant effect on the yield of Faba bean. This indicates that the production of Faba bean was responsive for the quantity of seed, farm size, and fertiliser applied. The coefficients of the input variables are interpreted as elasticities. As the quantity of Faba bean increases by 1%, the yield of Faba bean increases by 0.26% keeping other variables constant (*ceteris paribus*). Regarding farm size, a 1% increase in the farm size can increase the Faba bean yield by 0.14% *ceteris paribus*. This result was in line with the findings of Kebede (2020). Fertiliser was found to be the main input affecting the yield of Faba bean. A 1% increase in the application of fertiliser can leads to a 0.27% rise in the yield of Faba bean *ceteris paribus*.

After the stochastic frontier production analysis, the level of TE was predicted. The value of the TE was found to be 71.37% with a standard deviation of 0.1608. The result implies that it is possible to increase Faba bean yield up to 28.63% through better use of existing resources and

technology. In other words, farmers on average could decrease the quantity of farm inputs by 28.63% to get the output they are currently getting, if they apply inputs efficiently. This result is almost the same to the findings of Kebede (2020), and Wubie (2019). The two studies reported that the TE of Faba bean was 69%. However, the mean technical efficiency value is higher than the level of technical efficiency reported by Gudeta (2018), which is 62.6%. According to the t test statistic, there is a statistically significant mean TE difference between Dembecha and Debre Elias districts at 5% level of significance. The average of the TE level for farmers from Dembecha district was found to be 73.81%, while the average TE level for Debre Elias households was 68.11%.

4.2.2 Stochastic frontier cost function

According to the stochastic frontier cost function, all the variables found to have a statistically significant effect on the cost of Faba bean production. The LR test of $\sigma_u=0$: $\chi^2(01)$ is found to be 20.46 and significant at a 1% level of significance. This implies the presence of technical inefficiency in Faba bean production by sample households.

Table 7. Stochastic frontier cost function

lncost	Coeff.	St.Err.	Z-value
lnland_cost	0.049	0.003	17.34***
lnferti_cost	0.062	0.017	3.67***
lnoxen_cost	0.239	0.018	13.44***
lnlabour_cost	0.469	0.021	22.55***
lnseed_cost	0.109	0.023	4.84***
Y*	0.095	0.040	2.40**
Constant	1.441	0.142	10.14***
/lnsig2v	-6.449	0.428	-15.07***
/lnsig2u	-3.621	0.173	-20.95***
sigma_v	0.040	0.009	
sigma_u	0.164	0.014	
sigma2	0.028	0.004	
lambda	4.113	0.020	

LR test of $\sigma_u=0$: $\chi^2(1) = 20.46^{***}$

Note: ** and *** refers to 5% and 1% significance level, respectively.

Labour cost was found to be the main determining factor for the cost of Faba bean production and is statistically significant at 1% level of significance. A 1% increase in labour man days results in an increase in the cost of Faba bean production by 0.469%. In addition to labour cost, land cost, fertiliser cost, oxen cost, and seed cost were found to have a statistically significant effect on the cost of Faba bean production at 1% level of significance. In addition, output adjusted for statistical noise was found to have a statistically significant effect on the cost of Faba bean production at 5% level of significance.

Using the stochastic cost function, the researcher predicted the AE level of Faba bean production. The AE level was found to be 88.40%. This implies that Faba bean producer households can save 11.6% of their current cost of inputs if they use the right mix of inputs given their prices. The AE of households in Dembecha and Debre Elias district was 88.50%, and 88.35% respectively. The two districts do not have a statistically significant mean difference in terms of AE as confirmed by t test.

The EE was calculated as a product of technical and AE. Conversely, the level of EE was found to be 63.20%, implying that that an economically efficient household can reduce the cost of Faba bean production by 36.8%. The EE of households in Dembecha and Debre Elias district was 60.45% and 65.18% respectively. The two districts have a statistically significant mean difference in terms of AE at 10% level of significance as confirmed by t test.

4.2.3 Tobit model regression result

To analyse the factors affecting technical, allocative and EE, the estimates derived from the stochastic frontier analysis model were regressed on demographic, socio-economic, institutional and farm variables that explain the variations in efficiency across farm households using Tobit regression model.

The likelihood ratio (LR $\chi^2(9)$) for the determinants of TE, AE, and EE found to be 79.569, 174.589, and 84.589 respectively and statistically significant at 1%. This implies that among the 9

variables in the Tobit model, at least one variable found to affect TE, AE, and EE of Faba bean production.

The estimates of the Tobit regression model showed that among the 9 variables used in the analysis, household size, educational status, frequency of extension visit, and plot ownership were found to be statistically significant in affecting the level of TE of farmers.

The model also revealed that age of the household head, distance of farmers' cooperative, and plot ownership are found to have a statistically significant effect on the AE of Faba bean producers. Whereas, household size, education, and frequency of extension visit had a statistically significant effect on the EE of Faba bean producers.

Table 8. Tobit model result

	TE		AE		EE	
Variables	Coef. (St.Err.)	Marginal effect	Coef. (St.Err.)	Marginal effect	Coef. (st.Err.)	Marginal effect
HSIZE	0.025** (0.011)	0.024** (0.010)	-0.0004 (0.006)	-0.0004 (0.006)	0.020* (0.010)	0.020* (0.010)
EDUCHH	0.015** (0.007)	0.014** (0.006)	0.0035 (0.0035)	0.0035 (0.0035)	0.017*** (0.006)	0.017*** (0.006)
AGEHH	-0.0002 (0.001)	-0.0002 (0.001)	-0.0022*** (0.0005)	-0.0022*** (0.0005)	-0.0006 (0.001)	-0.0006 (0.001)
NONFARM (Yes)	-0.023 (0.028)	-0.022 (0.027)	-0.011 (0.014)	-0.011 (0.014)	-0.020 (0.027)	-0.020 (0.027)
DISMRKT	-0.0002 (0.0002)	-0.0002 (0.0002)	-0.00007 (0.0001)	-0.00007 (0.0001)	-0.0002 (0.0002)	-0.0002 (0.0002)
DISCOOP	-0.0002 (0.0004)	-0.0002 (0.0004)	-0.0005** (0.0002)	-0.0005** (0.0002)	-0.0003 (0.0004)	-0.0003 (0.0004)
EXTN	0.003** (0.001)	0.0028*** (0.001)	-0.0003 (0.0005)	-0.0003 (0.0005)	0.002** (0.001)	0.002** (0.001)

FARMOWN (Rented/shared in)	0.057** (0.028)	0.055** (0.026)	-0.036** (0.014)	-0.036** (0.014)	0.031 (0.027)	0.031 (0.027)
FARMDIS	0.0004 (0.0007)	-0.0004 (0.0006)	-0.0009 (0.0003)	-0.0009 (0.0003)	-0.0004 (0.0006)	-0.0004 (0.0006)
Constant	0.6082*** (0.0694)		1.025*** (0.034)		0.575*** (0.067)	
Sigma	0.1403 (0.0082)		0.073 (0.004)		0.0770 (0.0045)	
Log likelihood	79.569		174.589		84.790	
LR chi2(9)	39.55***		28.60***		33.18***	

Note: *, ** and *** refers to 10%, 5% and 1% significance level, respectively.

The coefficients in the above table represents the coefficients of the latent TE, AE, and EE. The coefficients can be interpreted as the usual OLS regression coefficients. The marginal effects indicate the effects of different variables on the actual or observed TE, AE, and EE levels.

AGEHH: According to the Tobit model result, the marginal effect of the age of the household head found to have a statistically significant and negative effect on the AE of Faba bean producers at 1% significance level. This implies that younger farmers were found to have higher levels of AE of Faba bean production. This is possibly due to the reason that younger farmers' better educational status which can help them to allocate inputs in an efficient way, while older farmers prefer to stick with the traditional production system. Another possible explanation is as the farmer gets older, his ability to manage farming activities becomes decreased. This finding is in line with the findings of Argaw *et al.* (2021), Kebede (2020), and Wubie (2019).

HSIZE: This variable was found to have a positive and statistically significant effect on the level of both TE and AE at 5% and 10% level of significance respectively. The result is similar to the hypothesis that farmers having large household size are more efficient than farmers having small household size. This is because family labor is the main input in crop production and for farmers having large household size it would be easy to manage crop plots on time effectively. In addition to that, having a large household size can help farmers reduce the costs of hired labor and can help them to be able to use appropriate input combinations. This finding is in line with the finding of

Fufa, & Haji (2016), and Gudeta (2018). They justified that having large household size can help farmers to manage crop plots on time and may be able to use appropriate input combinations. However, this finding is contradicting the findings of Wubie (2019).

EDUCHH: The educational status of the household head had a positive and significant relation with TE, and EE of Faba bean producers in the study area at a 5% and 1% significance level respectively. The possible explanation is that education increases the managerial ability of farmers and leads to good decisions in farming. Due to their better skills, access to information, and better farm planning ability; educated farmers are better to manage their farm resources and agricultural activities and minimize the cost of production than less educated ones. This finding is in line with the findings of Kebede (2020), Fufa, & Haji (2016), Naramo & Tafesse (2022), and Wubie (2019). In addition to those studies, this result is in line with the finding of Gudeta (2018), who found the positive and significant effect of education on the efficiency of lentil production.

DISCOOP: The main source of agricultural inputs in the study area is from farmers' cooperatives. This variable was found to affect the AE of Faba bean producers negatively at a 5% level of significance. This implies that farmers living far away from cooperatives have lower level of AE of Faba bean production than those farmers living closer to cooperatives. In addition to that, farmers living far from cooperatives cannot get the agricultural inputs on time and they may be forced to buy from other expensive sources like from traders due to the distance. Usually, those traders (either legal or illegal traders) of agricultural inputs charge farmers a higher price than agricultural cooperatives. Furthermore, those farmers may not be able to get enough inputs if they cannot be able to travel that long distance during the input supply time. This will affect the efficiency of input allocation. In another way, farmers closer to cooperatives could have economies of scale through collective purchasing of inputs and equipment, resulting in cost savings. Farmers situated nearby can take advantage of these cost-effective opportunities, leading to efficient resource utilization and reduced expenses. In line with this study finding, studies by (Birhanu *et al.* 2022; Kelemu, 2016; Lemessa *et al.*, 2017; Muleta and Getahun, 2022) also confirmed that proximity to the source of modern inputs is one of the determinants of crop output of farm households.

EXTN: According to the Tobit model output, this variable has a positive and statistically significant on the level of TE, and EE of Faba bean production at 1%, and 5% significance level.

This implies that those farmers who have more contact with extension agents are technically and economically more efficient than those who have less/no contact with extension agents. This is because farmers can get more knowledge and understanding of how to allocate farm inputs efficiently and how to minimize the cost of production from extension agents. Regular contact with extension agents can provide farmers with updated information, modern techniques, and best practices that can enhance their production efficiency. The positive effect of frequency of extension contact with TE, and EE is in line with the finding of Argaw *et al.* (2021), and Gudeta (2018). He reported that farmers who get adequate extension contacts are able to access modern agricultural technology for input mobilization, input use, and disease control, which enable them to reduce technical inefficiency and improve production efficiency. However, this finding is contradicting with the finding of the study by Fufa, & Haji (2016), and Mekonnen *et al.* (2015).

FARMOWN: Based on the Tobit model result, farm ownership has a statistically significant effect on the level of TE of Faba bean production at a 5% significance level. Farmers with rented /shared in Faba bean farms were found to have more TE than farmers with owned Faba bean farms. Usually, rented/shared farms have some qualities since they are marketable farms. To be marketable, farms should have at least some qualities than other farms. Due to this, farmers who produced Faba bean on rented /shared in farms have more level of TE. However, this variable was found to have a statistically significant negative effect on the level of AE of Faba bean production at a 5% significance level. This is possibly due to the high cost of rented/shared in farms. The negative effect of farm ownership is in line with the finding of Hailu (2020).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Agricultural productivity can be enhanced through either technological progress or efficiency improvement. Improving efficiency of the farmer plays a great role in increasing productivity, given the current state of technology. This study aimed to analyse the level of TE, AE, and EE and the factors influencing the production efficiency variation among Faba bean producing farmers in Dembecha, and Debre Elias districts, Amhara region, Ethiopia. Both primary and secondary data were utilised, with a face-to-face household survey from 147 sample Faba bean producing households.

Descriptive statistics like mean and standard deviation, and econometric techniques were employed for data analysis. The mean yield of Faba bean in the study area was 15.5 quintals. The stochastic frontier production with trans log production function and cost functions were estimated to derive the levels of TE, AE, and EE. According to the stochastic production, land size, seed, fertiliser found to have a statistically significant effect on the yield of Faba bean. This implies that better access and utilisation of these inputs would lead to higher Faba bean production in the study area. In addition to that, the stochastic cost function result indicated that the costs of all the inputs of the production function and the Faba bean output level adjusted to statistical noise (Y^*) found to affect the cost of Faba bean significantly.

On average, the level of TE, AE, and EE of Faba bean production by the sample households were found to be 71.37%, 88.40%, and 63.205 respectively. This suggests that farmers in the study area could potentially increase Faba bean production by 28.3% through technical efficiency improvements, and reduce input costs by 11.6% through allocative efficiency improvements. Similarly, operating at full efficiency levels could lead to 36.8% reduction in production costs while maintaining the same output.

The study also analysed the relation between TE, AE, and EE, and various factors affecting farm efficiency using the Tobit regression with 9 explanatory variables. The study identified that age of the household head influenced the allocative efficiency of Faba bean production Negatively, possibly due to older farmers' challenges in adopting new technologies. Educational status of a household head is also found to have a positive and significant role in improving households' TE

and EE. In addition to these variables, household size, frequency of extension visit, and plot ownership affected TE of Faba bean production positively and significantly. While the AE of Faba bean production was affected significantly by age of the household head, distance to farmers' cooperative, and plot ownership. The EE of Faba bean production was significantly affected by household size, education, and frequency of extension visit. In conclusion, the size of the household head, the age of the household head, education, extension contact, farm ownership, and distance to farmers' cooperative are significant determining factors affecting TE, AE, and EE of Faba bean production.

This study can lead to a significant conclusion of the existence of substantial potential to improve the TE, AE, and EE of Faba bean producing farmers. This implies that introducing and disseminating agricultural technologies alongside efforts to enhance existing efficiency levels can lead to considerable gains in production or reduction in production costs. By focusing on efficiency improvements, farmers can optimise their resources, increase output, and achieve greater economic prosperity, positively impacting the agricultural sector and the broader economy.

5.2 Recommendations

The results of this study can give information to policy makers and concerned bodies on how to improve farm level efficiency of Faba bean production and identify the determinants for specific efficiency types. Based on the findings and conclusions of this study, we can draw the following recommendations and policy implications.

- The findings of this study revealed the presence of substantial variability in all aspects of efficiency and efficiency scores among the sample households. This can suggest that focusing only on enhancing the present level of TE, AE, and EE of Faba bean production may not result in a significant improvement in Faba bean production in the long run. Therefore, it becomes essential to pay attention to the introduction of alternative farming practices and improved technologies in order to get transformative changes in the lives of farmers. But for short run, policymakers should prioritise the augmentation of efficiency levels, considering the substantial cost associated with adopting improved technologies.

- In this study, educational status of the household head was a significant factor that contributed positively to the improvement of TE and EE of Faba bean production. So, the government and other concerned bodies should give more attention to provide educational service for farmers through both formal and informal farmer education programs, training canters, technical and vocational schools in order to increase efficiency and agricultural productivity of the country in the long run.
- The age of the household head was found to affect the AE of Faba bean production significantly and negatively. Considering this result, it is recommended to provide targeted training programs that focus on modern farming systems, efficient resource allocation, and innovative techniques for older farmers. In addition to that, knowledge transfer between older farmers and younger generations has to be facilitated.
- Distance of farmers' cooperative was one of the significant factors affecting the production efficiency of Faba bean. Cooperatives are the main sources of farm inputs in the country. Considering that, the formation of farmers' cooperatives closer farming households has to be encouraged. These cooperatives can provide essential resources, knowledge, and services, thus enhancing allocative efficiency. Improving access to infrastructures in general is recommended to improve the production efficiency of crops.
- Frequency of extension contact was one of the significant factors affecting the production efficiency of Faba bean. Therefore, increasing the frequency of extension services to faba bean farmers has to be prioritized. Regular and consistent contact with extension agents can help farmers adopt more economically efficient practices. To facilitate the contact with extension agents, we can recommend to develop mobile extension services that bring extension agents expertise and guidance directly to farmers, bridging the gap caused by distance. This can ensure that farmers receive support and information even if they are geographically distant from extension agents. Provision of training for farmers to improve their skills in use of improved seed, management post-harvest handling, and general farm management capabilities can improve farm productivity. These training programs should cover cost-effective practices, resource allocation, pricing strategies, and market access to maximize economic returns.

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