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Technical efficiency of farmers in Ethiopia: A stochastic production frontier approach

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Technical Efficiency of Farmers in Ethiopia:

A Stochastic Production Frontier Approach

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BY

Askal Ayalew Ali

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Abstract

This study is to investigate the farmer's efficiency in Ethiopia. The stochastic production function is applied to estimate the technical efficiency of farmers. Using 2006 survey data conducted by the World Bank in collaboration with Ethiopian Economic Policy Research Institute, shows that farmers produce under the production frontier, and the average technical efficiency of the farmers is 62.4 percent.

Variation in efficiency comes from many factors, however, this study focuses on extension program participation, education, and land ownership. Lack of extension program and education cause inefficiencies of 59.8 percent and 60.21 percent respectively. Land ownership is found to have mixed results. Also, the analysis supports applying modern inputs to increase the productivity of farmers.

Acknowledgement

This paper is based on data collected by the World Bank in collaboration with the Ethiopian Economic Policy Research Institute (2006). I would like to thank the World Bank researchers for their aid in providing survey data to complete this paper. Also, I am grateful to Millie Parikh for her editing skills. At last, I like to thank my thesis advisor, Dr. Hui Li as well as Dr. Mukti Upadhyay and Dr. Linda Ghent for their valuable input.

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1. Introduction

Poverty and low level of economic growth are the major problems in developing countries. As the significant majority of the population particularly in sub-Sahara Africa heavily relies on smallholder, subsistence agriculture, the performance of this sector is indispensable for poverty alleviation as well as economic development. Traditionally, this sector is expected to generate employment, to serve as major source industrial inputs and to feed a rapidly growing population both in urban and rural areas. However, this sector has so far failed to fulfill its role in most of the sub-Saharan African countries. As a result, low level of productivity in this sector has been pointed out as one of the main reasons for the growing gap between the supply of and demand for food. Poor infrastructure and low level of education, lack of key technologies and modern inputs, and limited access to markets are some of the main factors that are responsible for low level of productivity in this sector. Given the available production technology, inefficient use of resources also partly contributes to the poor performance of this sector.

The study of efficiency of farmers has received growing attention as it helps policy makers to choose the right development strategy in order to achieve sustainable growth in the agricultural sector. To this effect, a number of empirical works have shown the variation in the technological efficiency of farming depends on knowledge, information, experience and education of the operating farmers (Bravo-Ureta, Solis, Lopez, Maripani, Thiam and Rivas, 2006). Provision of extension packages to smallholder farmers is found to have positive effects on technological efficiency (Alene and Hassan, 2003).

In the African context, a number of studies have examined the (in)efficiency of farmers using stochastic production frontier. It has been shown that technical inefficiency plays a major role for the variability of agricultural production (e.g., Belloumi and Matoussi (2006) in Tunisia date production; Binam, Tonye and Wandji (2008) in Cameroon peasant farming; and Msuya, Hisano and Nariu (2008) in Tanznia maize farmers). The results from these studies suggest that the chance to increase agricultural production, given the existing technology, is in the range of 33% to 40%. While education, farm experience, availability of credit, distance from home to the farm, contact with extension agent and other farm household characteristics are found to be the main factors that affect technical efficiency in Tanzania and Cameroon, environmental factors beyond the control of farmers are the ones that cause inefficiency in the case of Tunisia.

Ethiopia is a good country to explore the inefficiency of smallholder farmers, and the findings will have important policy implications. The livelihood of more than 85% of the population depends on small scale, rainfed agriculture. To increase the productivity and efficiency of this sector, the Ethiopian government has been implementing an extension package program focusing on the provision new agricultural technologies to participating farmers. Although considerable amount of resources have been spent to implement the program, the performance of the agricultural sector is not yet sufficient enough to boost the overall Ethiopian economy. The productivity of this sector is still hovering at a low level due to limited use of modern inputs, traditional practices and decline of soil fertility (CSA, 2001). Inefficiency of farmers also contribute to the low level of productivity of smallholder farming in Ethiopia (Alene and Hassan, 2003; Gebereegziabher, Oskam and Woldehanna, 2004). However, the results of these studies are based on data from specific regions of the country with small sample size.

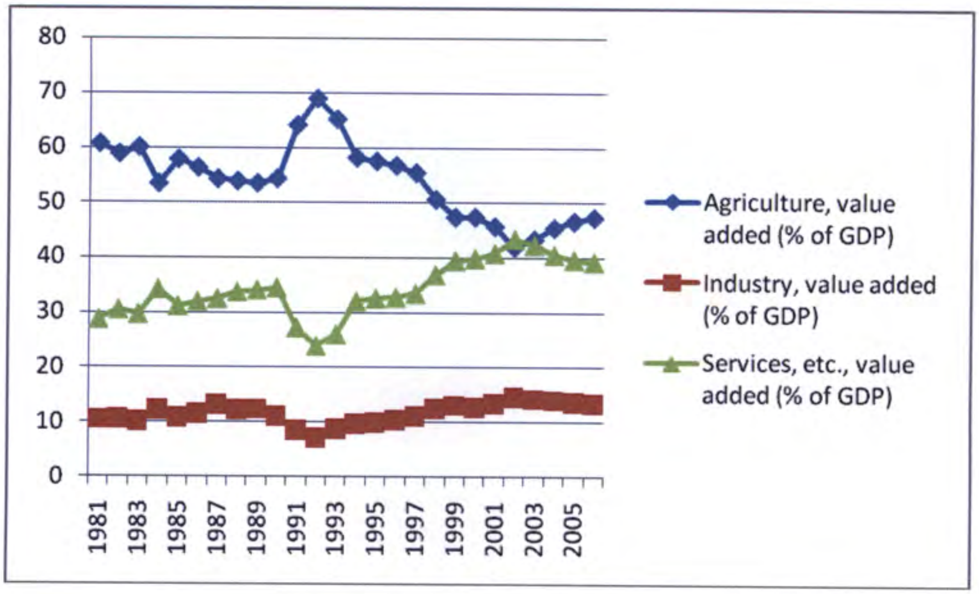
On the other hand, this study has the advantage of using a nationally representative rural household survey data conducted by the World Bank in collaboration with the Ethiopian Economic Policy Research Institute (2006). This survey covers the four major regions of the country (Amhara, Oromia, SNNPR and Tigray) with diverse agro-ecological zones. I therefore use this rich dataset to measure the technical (in)efficiency of small farmers and then attempt to disentangle the factors that makes them inefficient. Tighten, lending only to individuals whom they know well. The study is split into six sections; section two entails the background of the country, section three is literature review; section four describes the data, the study area, and the model; section five describes efficiency results in Ethiopian farmers based on my model, and finally, section six presents the conclusion and policy recommendations.

2. Background

2.1 The Role of Agriculture

Agriculture plays an important role in the economy of Ethiopia. The agricultural sector in Ethiopia has dual characteristics, composed of farming practices that produce for local markets and those for export crops like coffee, oil seed, hide and skins, chat and others. Accounting for 80% of the labor force, more than 40% of the GDP and 80% of exports of Ethiopia depend on the agricultural sector. Furthermore, agricultural products are a major source of industry inputs, and feed a rapidly growing population.

Figure 1: Sectors value added annual growth percentage of GDP



Source: WDI

Figure 1 shows the comparison between the three major sectors (Agriculture, service, and Industry) share of GDP for the years 1981 to 2006. The figure shows that while agricultue is falling it is still the dominant sector.

Agriculture is a source of income for most of the rural poor society, thus agricultural production is important for food security (World Development report, 2008). According to this report about 200 million people who live in Sub-Saharan Africa suffer from recurrent food emergencies. There is an uncertainty of food aid in the region. Unfortunately, the performance of agriculture has failed to fulfill its major role in boosting Ethiopia's economy. Ethiopian subsistence agricultural has huge implications on the environment. The low productivity means increased exploitation of the environment. Due to the low yields, more land has to be cleared to produce more crops to feed the people. This leads to deforestation issues as well as soil erosion. Better access to markets as well as credit and technical assistance programs can help improve this problem (Gebre-Selassie 2004).

Numerous researchers point out that the reason for the growing gap between food supply and demand is the low productivity of this sector. Gebere-Selassie (2004) points out more than 5 million people suffer from chronic food insecurity as most of these people live in rural areas where small holder agriculture could not provide employment and livelihood for the growing population. Ethiopia is a food deficit economy with 8.5% of the population facing chronic food shortages (Gebre-Selassie 2004). Gebere-Selassie says this could be from the inclusion of degraded lands into cultivation which lowers crop yields and contributes to erosion. The inclusion of degraded land could be a reason for the low return from the inclusion of fertilizers. Further, Gebere-Selassie (2004) says that this causes low farmer income which stagnates the growth of other sectors. The low productivity of the agricultural sector is attributed to unconstructive agricultural policy and a lack of focus on agricultural development (Alene and Rashid M. Hassan, 2003). Gebreeziabhare, Oskam, and Woldhanna (2004) add that scarcity of capital, problems of draft power, and also small and fragmented land holdings are the main constraints of low productivity of Ethiopian farmers. According to a report by the Central Statistic Agency of Ethiopia (CSA), the low productivity of the agricultural sector can be attributed to the limited use of modern inputs, traditional practices and decline of soil fertility.

In many other studies, low productivity is the result of an insufficient rainfall, since the country possesses a predominantly dry and inhospitable climate. Poor infrastructure limits farmer ties with other sectors through imperfect dissemination of information such as prices, output, and market situations (Alemu, Oosthuizen and

Schalwyk 2003). Alemu, Oosthuizen and Schalwyk (2003) blame the subsistence farming situation on a plethora of structural problems, mainly the technological constraints, credit constraints, land tenure, and infrastructure. The availability of chemical fertilizers, improved seeds, and pesticides is limited to only a few farmers. Alemu, Oosthuizen and Schalwyk (2003) attribute this to financial as well as credit constraints. Moreover, they added that civil war had also been a major deterrent in the agricultural sector. The agricultural community was a major supply of volunteer and compulsory military labor (Alemu, Oosthuizen and Schalwyk 2003).

Marian, Coffin and Eisemon (2007) suggest that increasing the area of cultivation, improving productivity of the land, or both, are the best methods to increase food supply in Ethiopia. However, they add, it is impossible to achieve the goal of food self-sufficiency by increasing the area of cultivation because of the landscape of the country, growing demand caused by an increasing population, and finally, the nature of the highlands of Ethiopia where there is a high density of livestock.

It is also important to understand the characteristics of farmers in Ethiopia. Ethiopia is a country that operates with smallholder farming. In 2000, roughly 87.4% cultivated less than 2 hectares and about 67% cultivated less than one hectare. The small farms, on average, have around 2-3 plots (Gebreselassi, Future Agriculture). Zerfu and Larson (2010) say there is not much difference in the level of agricultural output per capita between the years 2003 and 1961. Cereals (teff, wheat, sorghum, barley, etc) are the major food staple for Ethiopia. Despite time changes and policy changes, marginal cereal production has remained unchanged throughout time in Ethiopia, averaging around 11 to 14 quintals per hectare (Gebre-Selassi 2004).

In a country that has unfertile and dry land the use of modern input is emphasized in a country like Ethiopia to the productivity of land. The major reasons that the country land fertility goes down is that the farmers do not use the animal manure for fertilizer instead they use it for fuel and also the crop residues are used for animal feed (africa.upenn.edu). Thus, Zerfu and Larson (2010) conclude the rise in the use of fertilizers are indispensable to increase production. The main fertilizers used by the farmers as pointed out in different researches are DAP, Urea, and a mix of the two. In addition to fertilizers the farmers use high variety seeds, pesticides, irrigation methods, and apply soil conservation methods. Around 45% of the total land is treated with chemical fertilizer with an average application of 81kg per hectare. Only 15% is treated with pesticides. Improved seed is used on 3.5% of land and extension agents only reach 11% of the total crop land (Zerfu and Larson 2010)[1]. Meanwhile only 1 percent of the total arable and permanent crop land is irrigated (africa.upenn.edu).

The low use of these modern inputs is attributed to lack of capital, unconstructed credit market, undeveloped infrastructure, health, education, and accessible markets. Low modern input usage is also due to the lack of insurance. The price of modern inputs is often high. Therefore a farmer needs to make a high down-payment to secure the inputs. The high cost of modern inputs, despite the higher output they can bring, means the risk of default for the farmer is very high. A crop failure, such as a drought, means the farmer will lose more money than a non-crop farmer and for farmers currently at subsistence levels this is a deterrent. The lack of adequate credit markets means the insurance option will not function as desired as farmers will not be able to secure access to credit and insurance for many reasons such as lack of collateral (Zerfu and Larson

[1]: Zerfu and Larson are taking the fertilizer and pesticide area data from the Central Statistics Agency of Ethiopia report of 2007/2008, however, this paper was not available for my review.

2010). Another discouraging factor is the distance of farmers to fertilizer vendors which often requires a farmer to travel 20-30km. With such a great distance required for sub-saharan farmers to travel to obtain fertilizer, one cannot expect them to use fertilizer (Gregory and Bumb 2006).

2.2 Government Intervention

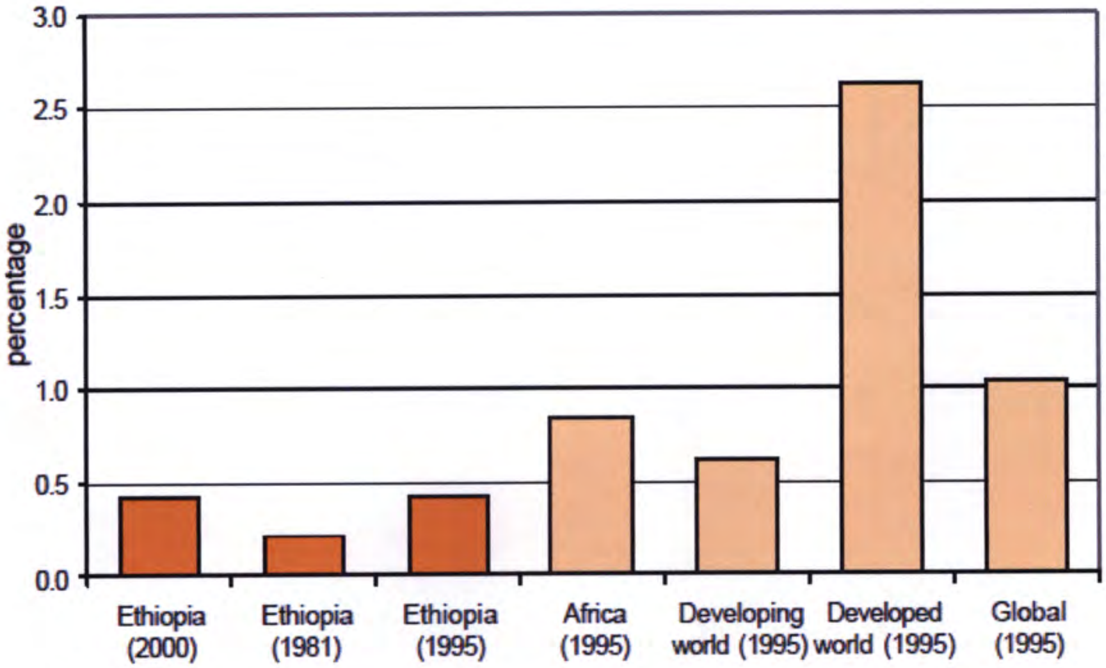
For a country with the hope of poverty reduction and elimination of chronic food insecurity, improvement of agriculture productivity is indispensable. Hence, the government of Ethiopia intervenes in the agricultural sector by focusing on increasing the productivity of land through conducting scientific research (agricultural extension). To increase the productivity of the agricultural sector, the government attempts to increase the productivity of the farmers by implementing an extension package program or using new agricultural technologies. The extension program, which is the application of scientific research and new knowledge to agricultural practices, was initiated in 1952 (Kassa and Degenet, 2004). The agricultural extension system has been reorganized three times since 1970 (Alemu, Oosthuizen and Schalwyk 2003).

One of the major reforms associated with the extension program was the introduction of public agricultural research, which is traced by the initiation and establishment of agricultural service institutions. However, the programs were not as effective as expected: "One of the policy shifts since the change of government in 1992 has been the substantial emphasis placed on improving the productivity of peasant agriculture through increased use of a package of improved agricultural technologies" (Alene and Rashid M. Hassan, 2003).

After critical evaluation of past extension programs, the new government design to eradicate barriers to agricultural advancement and increase yields, is to enhance the productivity of small farmers and to improve food security in rural and urban areas. The new plan set forth by the government is called Agricultural Development-Led Industrialization (ADLI). ADLI created a new extension program, launched in 1995, which is known as the Participatory Demonstration and Training Extension System (PADETES). The aim of this extension system is to provide demonstrative and participatory training to farmers in using improved technologies; "initially, PADETES concentrated on promoting the use of input packages (usually fertilizers and improved seeds) in high rainfall areas. A national agricultural extension program was created to promote new technology and high-yield seeds. The program led to a 4 million metric ton increase in production (from 6 million to 10 million) in the 1990's as compared to the 1980's. Despite this gain, the policy was not enough to stabilize the food economy or reduce food aid (Gebre-Selassie 2004). However, very recently technology packages were developed for the arid and semi-arid areas of the country" (Belay and Abebaw, 2004). Currently, PADETES encourages farmers to produce market oriented outputs, attempts to increase the participation of rural women and youths, and conserve vital aspects of agriculture such as soil and water.

PADETES considers three basic elements of an extension system, including a package of technology, credit, and communication. To implement these elements, many actors are involved, such as input suppliers that work on behalf of credit institutions, extension agents, state council officers and others. For instance, to distribute fertilizer there is a chain of actors involved: input importers, input suppliers, banks to provide foreign currency, extension agents, regional government and local administrative officers. Individuals as well as corporations/businesses are necessary for the extension system to run smoothly. However, Gebre-Selassie points out that this program was not adequately backed by private and public investment and that the program overlooked wealth creation and capital accumulation in rural areas and did not facilitate capital mobility to rural areas. The ADLI program failed to adequately address the problems of low productivity and low incomes that have plagued the subsistence agriculture sector (Gebre-Selassie 2004). In addition Gebre-Selassie (2004) noted that issues like high population pressure, erratic weather conditions, and low, declining labor productivity are not address by this policy reform. Moreover, the ADLI strategy emphasizes the relationship between the dependency of industrialization on agricultural improvements. It also stresses the effect that industrialization has on the development on the agricultural sector. However, Gebre-Selassie points out that the ALDI fails to document sufficiently how they would be able to realize the objectives from these linkages (Gebre-Selassie 2004).

Figure 2 —Ethiopia's public agricultural research intensity compared regionally and globally



Source: Beintema and Solomon 2003

Figure 2 shows the research expenditure for every $100 of agricultural output. In 2000, Ethiopia has $0.43 of research for every $100 of output. This is compared to nearly $2.50 for developed countries. Ethiopia had nearly doubled its research expenditure from 1981 to 1995, however, from 1995 to 2000 the research expenditure has stayed the same.

In addition to introducing new agricultural research and developments, the government intervenes through policy reforms. There have been different land reforms in Ethiopia at different times. The period 1957 to 1973 resource allocations had been made by the market, however, in 1974 the market allocation was taking over by the command-driven economic system (Alemu, Oosthuizen and Schalwyk, 2003). "In 1975 land was nationalized and was distributed among the tillers on an egalitarian basis" Alemu, Oosthuizen and Schalwyk (2003). The 1975 land reform aims to distribute land from landlords to individual households plus nationalize the land right based on family size.

This land reform has its own advantages and disadvantages, Ali, Dercon, and Gautam (2007) describe how this law restricts transfer of land by sales, lease or mortgage, and private use of land and increases the land tenure insecurity in the rural areas. From 1975-1990 the amount of credit available to famers was limited by the credit policies of the socialist government. The high cost of credit shut out small farmers. This is attributed to the focus of the socialist government being on the creation of state farms and producer cooperatives (Alemu, Oosthuizen and Schalwyk 2003). This put a restraint on farmers own production decisions and the free operation of input and output markets (Alemu, Oosthuizen and Schalwyk 2003). On the contrary, this law accommodates the need of new entrants. The government also gained more control over farmer marketing decisions through different regulations. These regulations made it more difficult for farmers who want to sell their products on the open market. This was done by changing fixed price systems to free quota systems and free quota systems to fixed quota systems. Many famers changed their production mix in an attempt to evade the quota systems causing the government to introduce more stringent measures (Alemu, Oosthuizen and Schalwyk 2003).

Since 1992 macro policy changes have been enacted to correct policies made in the command-driven era (Alemu, Oosthuizen and Schalwyk 2003). This law was amended in 1995 after the fall of the Derg regime with no basic difference except giving the mandate to regional governments for its administration, however, the new policy allows leasing to the third party (Ali, Dercon, and Gautam, 2007). Changes in the farming structure were done without changing the land holding system, which was done in previous former socialist countries. The existing land policy is blamed for causing land fragmentation, deforestation, low productivity, and reduction of holding size (Alemu, Oosthuizen and Schalwyk 2003). The existing land policy (state owned land) has been partly responsible for the unresponsiveness of agricultural GDP to policy changes. Fragmented plots are believe to limit the potential increase in output through limiting application of modern inputs. The low land productivity is believed to be caused by the tenure insecurity (Alemu, Oosthuizen and Schalwyk 2003). There is constant debate in politics over the road to take for land ownership. The government idea is that if there is not state owned land, a farmer will sell his/her land and move to an urban area. However if the farmer is unable to find a job in the urban sector he/she will be unable to move back to the rural sector as he/she has no land. This will cause individuals to be unemployed.

A secured property right is an incentive to farmers to increase investment on land. According to Ali, Dercon, and Gautam (2007), the property right makes it easier to use land as collateral, facilitate the development of an efficient land market, minimize factors that hinder the factor mobility, and hence enable the allocation of land from the less to the most productive farmers through the lease market. According to them this law has created fear of losing land without compensation due to land redistribution at any time in the near future, especially those who has a large plot size. The other argument by Holden and Yohannes (2002) was property ownership increases the use of purchased inputs. However, they find out the impact of land insecurity has a little impact on use of purchased farm inputs. Ali, Dercon, and Gautam (2007) in conclude there is a strong positive relationship between the share of land allocated for coffee production and land transfer right; meanwhile, expectation of losing land in the next five years due to land reform reduces coffee planting. Further, they conclude transfer right insecurity and tenure insecurity decreases the efficiency of farm activity and growth. Ali, Dercon, and Gautam (2007) conclude that the effort of government to improve the livelihood of the farmers by commercializing agriculture does not have the expected result since the current policy shortens the time horizon and pushes the farmers to focus on single period crops. As a result, the policy makes there return low and leaves them at subsistence production levels.

The government has started to issue certificates for land in hopes of improving tenure security. However, these certificates do not guarantee the right of the owner to sell the land or use it as collateral (Gebre-Selassie 2004).

3. **Literature review**

3.1 **Adoption and constraint of new agricultural technology**

The new technology or extension package is designed to ensure that farmers adopt improved technologies to increase production. Since the agricultural sector of most developing countries is the key source of income and economic growth, employment and foreign exchange applying or implementing the extension package is very important. Dean, *et.al* (1991) state: "without an efficient agricultural sector, a country is severely constrained in its ability to feed itself or import foreign products for domestic consumption and development."

To improve the production of the agricultural sector, a large amount of financial and material resources must be invested to undertake extension in both developed and developing countries. With the expectation that new technologies will offer an opportunity to improve production and income sustainability, the adoption of new technology also attracts considerable attention to less developed countries (Feder, Just and David Zilberman, 1985). However, the introduction of new technology is only partially successful because of the following hurdles: lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absences of equipment to relieve labor shortages, and inappropriate transportation infrastructure. According to Anderson and Feder (2003), since extension research and development requires huge investments, the public sector, various NGOs and the private sector invested more than six billion US dollars worldwide in 1988. Dean, *et.al* (1991) add that in 1980 most developing countries were spending as much on extension as on research.

According to Dean *et.al* (1991), agricultural technology advancement has been in place since World War II. The authors add advancements that have brought a great deal of change to agricultural production and have also highlighted the importance of rapid and efficient transfer of knowledge to the farmer. Feder (1980), states that the socioeconomic impact of agricultural technology innovations on the agricultural sector of developing countries has been a subject of considerable interest to economists.

The productivity of technology changes drastically from country to country. The adoption of new technologies is determined by the availability of modern inputs, infrastructure, credit service, information, profitability and knowledge. With the expectation of increased agricultural productivity due to improved technology, and the impatience associated with speeding up economic growth, many developing country governments introduce new production systems. However, since these countries lag behind developed countries in infrastructure and access to information, people are not able to utilize their full potential to improve their economic, social and environmental condition (Anderson and Feder, 2003).

Many countries attempt to remove some of the constraints faced by farmers in improving agricultural productivity by providing credit in monetary terms or giving in-kind credit; Feder, Just, and Zilberman (1985) state that the removal of these constraints is expected to increase not only the adoption of new technologies but also the change in crop composition, which tends to increase average farm incomes.

Since agriculture is the backbone of the economy of almost all developing countries, many studies focus on the role of agriculture in a country's development. Kassa and Degent (2004) explain that in the 1980s and 1990s, with the expectation of enhancing economic performance and eradicating the obstacles of free market operations, many sub-Saharan African countries took on novel economic reform programs. Farm improvement involves a process of social, technological, economic, educational and administrative changes. Development of the agricultural sector has critical importance for the development of a country's economy. Most developing countries need to make the necessary changes prescribed by agricultural economists and scientists to improve the sector, including the creation of colleges that train agricultural development agents and work to discover new agricultural policies to fit current needs.

3.2 Determinants of production efficiency

Studies on technical efficiency are important as they allow the government to see where improvement in output can be made without increasing the resources used or developing new technology (Rezitis, Tsiboukas, and Tsoukalas 2002). Efficiency occurs when the economy operates on the production possibility frontier, which implies producing at the maximum output level with given inputs, and also producing at the lowest possible cost. Efficiency includes technical, allocation, and overall efficiency. Technical efficiency (TE) is the ability to produce the maximum output given a set of inputs. According to Bravo-Ureta and Pinheiro (1993) Technical inefficiency reflects the failure to obtain the highest level of output given a certain level of inputs and technology. Allocative efficiency deals with using the optimal proportion of inputs at a given input price. Finally, the overall efficiency, or economic efficiency, is a combination of technical and allocative efficiency and is equal to technical efficiency times allocative efficiency.

Many reasons account for the varying nature of productivity amongst producers, such as the adoption of new technology, environment, and location for markets (input and output). Bravo-Ureta, *et.al* (2006), in their study on technical efficiency in farming, explain that improvements in decision-making is dependent on many variables, including knowledge, information, experience, and education. Alene and Hassan (2003) find that extension packages have a positive impact for technological efficiency for wet highland zones. However, new extension packages have no positive impact on the productivity efficiency of farmers; according to their study, it has a negative impact on allocation efficiency. Additionally, the positive impact is attributed to education, credit and experience. Kalirajan and Shand (1989) and Gonzalez (2009) say the wide variation of technical efficiency of farmers is determined by socioeconomic environment like access to credit, climate conditions, extension services, farming experience, and farmers' education.

Through experience producers are better able to allocate their resources leading to more efficient production. However, Coelli *et al* (2002), find that with experience comes age. An increase in age is found to have a negative effect on efficiency as older producers are less open to adopting modern inputs. Thus, an experienced older producer is found to be less technical and cost efficient. Coelli and Battese (1996) say that older farmers may have more experience in farming and less inefficiency but they are also more likely to be conservative and less willing to adopt new practices causing greater inefficiencies.

The amount of land a farmer has is expected to have a negative relationship with inefficiency. The negative relationship is because farmers with smaller landholdings are more likely to have alternative sources of income. These alternative sources of income may be more important than the farming income and hence the farmers put less effort into the farming of their land (Coelli and Battese 1996). Coelli and Battese (1996) find that land has a negative relationship with inefficiency in India. Coelli and Battese point out that this finding contradicts popular belief that small land holding are more efficient than large holdings. In Bangladesh the dry season farmers who have a larger farm size are allocatively inefficient although, they are cost efficient. This implies that in the dry season farmers experience a decreasing return to scale whereas they experience increasing returns to scale in the monsoon time (Coelli, Rahman, and Thirtle 2002).

Furthermore, other factors related to land have influence. One of the factors that cause variation of output between farmers is the quality of the soil. However, Coelli *et al* (2002) say that soil fertility does not have a significant influence on the efficiency of rice farmers. Education, age, experience, extension, and training also do not have a large influence on efficiency level.

The efficiency of a farm is determined not only by farm size, but also the organization and governance of a farm. Labor productivity on a small farm is higher compared to large farms because the average productivity of labor per land is higher for small farms than large farms (Sawers, 1999). Kurkalova and Jensen (1998), in their study of Ukraine grain production, find economic reforms are costly in terms of technical efficiency. The reason given by the researchers is that the old production ties deteriorated and the new production intermediaries have not yet emerged.

Using modern technologies, or adopting the extension program efficiency itself, depends on the availability of professional extension workers that are qualified, motivated, committed, responsible and experienced, since the agricultural extension work is a process of learning by doing (Belay and Abebaw, 2004). Further, the increase in input prices, shortage and late delivery of inputs, lack of extension agents and shortage of working capital, are other constraints on farmers. However, Belbase and Grabowski (1985) find that farming experience has no relationship with technical efficiency in the case of Nepalese farming.

Moreover, Fan (1991) argues that taking technological change as the sole factor to productivity growth without institutional change overestimates the impact of technology. The author adds that institutional change shifts labor from agriculture to industry, which tends to increase the land-labor ratio beyond the increase in income. Also, institutional change helps farmers to allocate their resources in a way they maximizes profits. Mathis and Swinnen (2001) state that the organization and governance of the farm affects its technical and scale efficiency." They go on to explain that the inefficiency gap between collective farming and individual farming will fade due to specialization with institutional reform, organizational restructuring, and liberalization.

Labor is the main resource in agricultural activities. However, Coelli, Rahman, and Thirtle (2002) find out in their study of the rice production in Bangladesh that those who have large families are less efficient compared to those who have a small family size. In their conclusion, most of the allocative inefficiencies are caused by overuse of labor and fertilizers. However, a better access to input markets and devoting more time for agriculture activities increases the efficiency level of farmers in Bangladesh. Unlike the study of Coelli, Rahman, and Thirtle (2002),Kurkalova and Jensen (1998) find labor abundance is an important factor in achieving effective utilization of inputs.

In addition, human capital plays a significant role in productivity and public investment designed to boost human capital can expect to generate additional output in the absence of new technologies (Bravo-Ureta and Pinheiro 1993). Bravo-Ureta and Pinheiro (1993) note that some researchers find the level of schooling was not statistically significant in explaining variations between maximum and actual yields. The farmer's non-formal education did have a significant impact. The non-formal education is defined as their current understanding of current technology.

In addition, the factors mentioned above will affect the efficiency of developing country agricultural practices. Belbase and Grabowski (1985), find that technical efficiency in Nepalese agriculture is directly related to nutritional levels, family income and education, but education is not the strongest factor. However, other researchers state otherwise. For instance, according to Naik and Dwarakinath (1968), education is a debatable determinant of efficiency since farmers are independent of each other, and the extension education will determine the efficiency of his or her own agricultural production. This implies that the acquired capabilities of each farmer are important and may be a primary determinant of agricultural production efficiency.

Better health and nutrition can increase household income and poor health can decrease household income through loss of days worked and lower productivity. Large elasticities of labor productivity with respect to health and nutrition would benefit from the implementation of policies related to the wage efficiency framework such as food aid and land redistribution (Croppenstedt and Muller 2000). Croppenstedt and Muller (2000) note that the return to one extra year of education for the head of the household is a 4% increase in output for Ethiopian farmers. A change of one standard deviation in the weight-for-height index (a proxy for nutrition) of the head of household leads to a 27% increase in output. Croppenstedt and Muller (2000) find a male wage elasticity with respect to Body Mass Index (BMI) of 3.04 in Ethiopia. This indicates that the returns from improved nutrition are quite high.

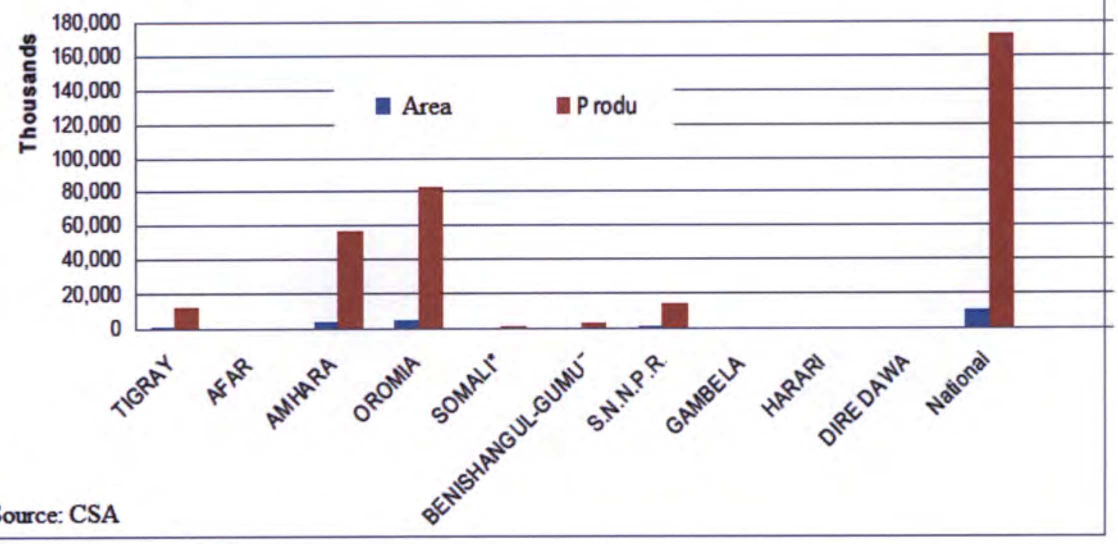
In efficiency is not only a problem of developing countries but also developed countries. Rezitis and Tsiboukas (2002) present a paper to estimate the technical efficiency of Greek farmers from 1992-1995 using a stochastic production function. They concluded that on average, output falls short by 34.6 percent meaning there is a potential to increase average farm output. The authors do note that the efficiency on farms varies widely meaning the potential to increase individual farm output varies greatly. In their study of New England dairy farms, Bravo-Ureta *et a*l (1991) find the average technical efficiency is 83 percent, average economic efficiency is 70.2 percent, and average allocative efficiency is 84.6 percent. Policy implications which Rezitis, Tsiboukas, and Tsoukalas 2002 suggest are easier access to education, extension services for expansion and propagation of modern techniques, and better farm credit. Rezitis, Tsiboukas, and Tsoukalas 2002 note that the estimates provided in their study can be used to identify the least efficient farms which are subject to bankruptcy and liquidation.

4. **Data and methodology**

4.1 Data

This paper explores a household survey data in rural Ethiopia. The completed survey was carried by the World Bank in collaboration with Ethiopian Economic Policy Research Institute in 2006. The survey covers four regions including Tigray, Amhara, Oromia and SNNPR. These regions have diverse demographic, geologic conditions, and the weather pattern. For example Amhara and Tigray have similar weather conditions, and these regions are dryer than to Oromia and SNNPR. The land in Amharra and Tigray is infertile, while Orimia and SNNPR have fertile land, and abundant rainfall which is suitable for agricultural activities. Therefore, heterogeneity exists among the regions. For example figure 3 shows the grain production by region, measured in hectors, and production, measured in quintals. The most productive regions are the Amhara and Oromia which also have the largest land area. Tigray and SNNPR follow Amhara and Oromia in grain production.

Fig. 3. Area and Production of Grain crops by Region; 2008/09 (2001 E.C.), Meher Season



Source: CSA

The main crops in Ethiopia are cereals, pulses, oilseeds, coffee, chat, tobacco, cotton, sugarcane, fruits, and vegetables. These crops are widely used for food, clothing, and as stimulus (chat and coffee). There are two agricultural seasons. The Belge season, starts March and end in August, production during this season covers only around 10 percent of the grain production. The season, Meher, begins around September and end in February, which is considered as the primary crop production season. The average total crope production of Meher season is approximately 90 to 95% (UNDP-EUE, 1998).

The household survey was done at plot level for randomly selected 2315 farmers, and their covering 887, 3323, 4682, 1423 hectares of land area in Tigray, Amhara, Oromia and SNNP respectively. There were 242, 558, 1036 and 479 households are interviewed in Tigray, Amhara, Oromia, and SNNP respectively. Currently, only 7827 hectares is used for crop production in the four regions. The data is collected across the two production seasons and it is conducted through face to face interviewing farmers and by taking physical measurement the plot. The data includes demographic and social information by gender, age, employment, and exchange labor in crop production. The information on crop output includes harvest data measured in terms of value calculated at the market price in 2006. As well as the number of oxen days that farmers used oxen to prepare their land, usage of fertilizer, pesticides, and manure inputs is the quantity used in the crop production. The summary statistics are provided in Table 1 and Table 2.

The total usable observations in the analysis is 2232, this drop is due to the elimination of zero crop area. The dummy variables are also constructed to complete the characteristic of high variety seeds, soil quality, irrigation, and slope of the land.

Table 1.

Summary statistics for the variables in the production frontier

Variables	Definition	Mean	Standard deviation
vcrpm	Value of crop production in Ethiopian currency	5317.752	14333.03
Crparea	The crop area, in hectares	1.939427	8.18373
Famlab	Number of labor used in production; includes male and female adult and child labor during the production season	181.9889	272.0859
halab	Number of hired adult (male and female) labor	15.88239	43.13379
exlab	Number of exchange adult(male and female) labors	18.63822	43.59325

Qfert	Quantity of fertilizer used; in kilograms	95.66235	145.9414
qpest	Quantity of pesticides used; in kilograms	39.58351	1176.185
Qmanu	Quantity of manure used; in kilograms	791.0136	5483.474
Oxdays	Number of days oxen used	7.39716	31.07115
Dhyv	Dummy variable having a value 1 if the farmer used high variety seeds on more than 25% of land[1], 0 otherwise	.2199821	.414327
Dpltirr	Dummy variable having a value 1 if the farmer applied irrigation on more than 25% of land, 0 otherwise	.0434588	.2039332
$lnqfetirr_i$	Interaction between quantity of fertilizer and dummy variable for irrigation method	.0971828	.6932841
Lnqpestirr	Interaction between quantity of pesticides and dummy variable for irrigation method	.025124	.3235656
Dhyvirr	Interaction between for high variety seeds and dummy variable for irrigation method	.0094086	.0965622

[1]. Twenty five percent was chosen as the cutoff due to the poor land quality and low usage of modern inputs. This allows for a sufficient number of observations for each dummy variable.

Table 2

Summary statistics for exogenous variables in the inefficiency model:

Variable	Definition	Mean	Standard deviation
hage	Age of the head of the household	47.54391	13.4156
dlit1	Dummy having a value 1 if the farmer is illiterate,0 otherwise	.4807348	.4997407
Dprim	Dummy having a value 1 if the farmer finished the primary school	.2258065	.418206
Dextn	Dummy variable having a value 1 if the farmer participated in an extension program, 0 otherwise	.2665771	.8585235
dpltslop1	Dummy variable having a value 1 if the topography of the plot is meda (flat) on more than 25% of the land, 0 otherwise	.4882233	.3697905
dsoilqlt1	Dummy variable having a value 1 if the soil quality is good on more than 25% of the land, 0 otherwise	.3637353	.3388137
Hfem	Dummy viable having a value 1 if the head of the household is female, 0 otherwise	.4386201	1.440527
Distime	Average distance from homestead to the plot in	10.84351	13.07231

	walking minutes		
Hhsize	Household size	6.741487	2.418352
Numplot	Number of plot	4.513223	.3230112
Daylst	Total number of work days lost for over the last 12 months. If 2 people are sick on the same day, it counts as 2 days lost.	28.36111	71.44865
Dhvecrt	Dummy variable, equals 1 if the farmer has a certificate of ownership to the land, otherwise 0	.5443548	.4981404
Dhredu	Dummy having a value of 1 if the farmer has had religious education	.0259857	.1591281

4.2 **Model**

An economic model helps to simplify the complex process of the real world and helps to explain and organize the thought of the analyst. In general, economists use models to identify and sort the complicated chains of cause and effect that influence a number of variables in the economy. The ideal frontier function measures the maximum output i.e efficient output for a firm, however it is never realized in the real world. The frontier function overcomes problems related to deterministic production frontier with a measure of efficiency. Bravo-Ureta, et al (2006) and Coelli and Battese (1996) explain that the frontier function can be examined using both measures. The data envelopment analysis model is categorized under the non-parametric approach of the frontier model. The advantage of applying non-parametric method is that it doesn't require a specification for technology. However, the non-parametric models are deterministic and are affected by extreme observations.

In this study cross-sectional data is for one production year. The primary concern with using this type of data is the validity of the efficiency results. Efficiencies may be distorted by period specific abnormalities and if these distortions are significant, the efficiency estimations may not be reliable. This is why stochastic production frontiers have been highly praised (Bravo-Ureta and Pinheiro 1993). Stochastic are superior to deterministic models because the stochastic models account for both the measurement error and random noise. In real world, the production process is not completely deterministic. Externalities always exist, for example, extreme weather. The models using the parametric method can be divided into two approaches. One is the deterministic model which assumes any deviation from the frontier is due to inefficiency. The other is the stochastic model which estimates the function with white noise. Another feature of the SFPF is that it allows the data to predict the curvature of the function rather than imposing a prior assumption (fao.org).

The main difference between these two approaches is the deterministic approach assumes the deviation of the actual output and the maximum output is due to the inefficiency whereas the stochastic frontier model assumes the deviation of the production arises from the stochastic noise in addition to the inefficiency problem (Bravo-Ureta *et al* 2006).

The stochastic frontier production function incorporates both the errors of the statistical noise (v_i) and inefficiency (u_i). The inefficiency error term reflects that each firm's output lies below the frontier curve.

To measure the production efficiency, there are two ways. As in this study, the primal approach is output oriented and explains how much output can be produced. The second approach, called the dual approach, is input oriented and emphasizes the minimization of production costs to produce a given level of output.

The stochastic frontier production function (SFPF) is:

$$Y_i = f(X_i;\beta)^* \, TE_i \qquad (1)$$

Where Y denotes the observed scalar output of farmer i, i=1,.........n, quantity of output; X_i is a vector of inputs used by farmers i; β is a vector of parameters to be estimated, $f(X;\beta)$ production function, TE_i is technical efficiency defined as the ratio of observed output to maximum feasible output. $TE_i = 1$ implies the ith farmer obtains the maximum feasible output while $TE_i < 1$ provides a measure of the shortfall of the observed output from a maximum feasible output, meaning the farmer produces below the production frontier. The technical efficiency of a farmer at any given time is the ratio of observed output to the frontier output of a fully-efficient firm. Thus the efficiency of a farmer is between 0 and 1 (Coelli and Battese 1996).

The stochastic frontier production function acknowledges random shocks affecting the process outside the control of the farmer; for instance, a shock may include, but is not limited to, a change in the weather. Due to the possibility of random shocks, the production function can be further illustrated as:

$$Y_i = f(X_i;\beta)^* \, TE_i * \exp\{ v_i\} \qquad (2)$$

$$\text{Ln } Y_i = f(X_i;\beta)^* \, TE_i + v_i - u_i \qquad (3)$$

Where v_i denotes the stochastic noise which is normally distributed with a mean zero and variance σ^2_v. The TE_i can be written as $\exp\{-u_i\}$, where u_i is a non-negative random variable that captures the inefficiency of the producer and is assumed to be independently and identically distributed as half-normal, $u_i \sim |N(0, \sigma^2_u|$.

Therefore we can separate the efficiency from the random influence (Badunenho, Fritsch and Stephan, 2008). To recap, after studying the technical efficiency, the results from (3) are used to estimate the effects of various factors on inefficiency. A two-stage procedure is applied. The frontier is first estimated and the technical efficiency of each farmer derived. In the second stage(equation 4), the predicted inefficiencies subsequently regressed against a set of variables (Z_i) which are expected to influence inefficiency using an ordinary least squares regression (Coelli and Battese 1996).

The mean technical inefficiency is defined as:

$$u_i = Z_i\delta \qquad (4)$$

Where Z is a vector of farm specific variables assumed to be associated with technical efficiency. δ denotes a vector of unknown parameters.

The ratio of the two error terms indicates the relative variability of the two sources of variation. $\sigma^2_u / \sigma^2_v = \lambda$. According to Gebreeziabhare, Oskam and Woldhanna (2004), "If the value of the λ is close to zero implies that the discrepancy between the observed and the maximum attainable levels of output is dominated by random factors outside the control of the producer." Thus, u_i is significantly larger than zero when inefficiency exists. To examine $\sigma^2_u / \sigma^2 = \alpha$ where $\sigma^2 = \sigma^2_u + \sigma^2_v$, if α is equal to zero then inefficiency does not exist.

While the parametric stochastic function provides low estimates of technical efficiency, the model exhibits convenience to estimate the effects of various factors. Bravo-Ureta and Pinheiro (1993) argues this model works best to estimate technical efficiency.

In order to investigate technical efficiency the Cobb-Douglas production function is applied in this study. The Cobb-Douglas function is defined as follows:

$$lnVCRPM_i=\beta_0 + \gamma_1 dpltirrr+ \beta_1 lncrparea_i+ \beta_2 lnfalab_i+\beta_3 lnhalab_i +\beta_4 lnexlab_i$$
$$\beta_5 lnqfet_i+\gamma_2 lnqfetirr_i+\beta_6 lnqpest_i+\gamma_3 lnqpestirr_{ii}+ +\beta_7 lnoxday_i + \beta_8 dhyv1_i + \beta_9 lnqmanu_i$$
$$+\gamma_4 dhyvirr_i + v_i - u_i \qquad (5)$$

Where prefix "ln" at the start of the variable name denotes the variable is in its natural logarithmic form.

Since the main focus of this study is to provide an empirical analysis of the determinants of technical efficiency of farmers in Ethiopia, the second step will be to identify determinants of technical efficiency and analyze the relative impacts of these factors on efficiency. The mean technical inefficiency is defined as:

$$u_i = \delta_0+ \delta_1 hage_i+ \delta_2 dprim_i+ \delta_3 dextn_i + \delta_4 dpltslop1_i+ \delta_5 distime_i + \delta_6 hfem_i + \delta_7 dlit1_i +$$
$$\delta_8 dsoilqlt1_i + \delta_9 hhsize_i + \delta_9 nuplot_i + \delta_{10} daylst_i + \delta_{11} hvecrt_i \qquad (6)$$

δ s, γs and βs are the unknown parameters to be estimated in the efficiency model and Cobb-Douglas production function respectively

4.3 **Predictions**

The major factors of production in this model include labor, land, and the number of oxen. These variables are expected to have a positive effect on production. However, the sign of exchange labor is unclear depending on the ability and performance of labor. The number of oxen days is expected to have a positive expected relationship with output due to the fact that oxen help farmers to prepare plots of land in a more timely fashion.

Considerable amounts of modern inputs have been used by Ethiopian farmers, such as fertilizer, pesticides, and hybrid seed varieties. The evidence about how much modern input have increased productivity in agriculture remains mixed in the literature. However, the use of these inputs is expected to have a positive effect on crop production.

Expanding the scale of production may cause an increase or decrease in output depending on the marginal productivity of inputs. To capture this scale effect, the number of plots that the farmer has is used as a proxy. The result is expected to be negative given the limitation of capital. Having fragmented land with small plot size will increase travel time by requiring the famer to travel from one plot to another since they do not spend the whole day working on one plot. Thus, fragmented land will decrease production.

The other exogenous variables that affect the efficiency of a farmer is whether or not the farmer has participated in the government extension programs where they obtain training on how to use modern inputs, what type of modern inputs are available to use, and how to improve productivity through the visitation of extension agents. Participation in extension programs (hvecrt) is expected to have a positive effect on crop production. Another exogenous variable is the age of the head of the household (hage), which also has an unclear effect due to the age and performance of the farmer varying. Usually when farmers are older, the accumulation of experience over the years is expected to increase efficiency. However, age has its own negative impact; old people are tend to stick to the traditional farming methods, and are reluctant to adopt new farming practices, including agricultural technology.

Education is another factor that affects efficiency. Reading and writing helps farmers to understand the use of new technologies. Thus, education is expected to have a positive effect. In this study, three dummy variables are constructed to indicate the level of education. The first dummy variable is if the head of the household is illiterate (dlit1). Second, a dummy variable is for if the head of the household finished primary education (dprim). The third dummy variable is if the head of the household has religious education (dhredu) .

4.4 Hypotheses

Based on the modeling strategy and available data, I propose the following hypotheses. First I would like to examine whether the implementation of modern inputs improves productivity. Thus, I will test the hypothesis that the effects of three modern inputs: fertilizer, pesticides, and high variety seeds increases output (H_1: $\beta_5 = \beta_6 = \beta_9 > 0$) against the null hypothesis of no effect on crop production. I expect to reject the null hypotheses.

The primary interest of this study is to examine the technical efficiency. Against the null hypothesis of no effect, technical efficiency exists when H_1: $\alpha > 1$. I expect to reject H_0 therefore showing inefficiency exists.

Another test is to see whether the OLS function or the frontier function is appropriate, which is the null hypothesis. Testing the null hypothesis, H_0: $\alpha = 0$, ($\sigma^2_u / \sigma^2 = \alpha$), implies that there is no technical inefficiency in the model. The rejection of the null hypothesis shows that there is inefficiency. I expect H_0 to be rejected showing there is inefficiency.

This study attempts to address the focal question of whether the implementation of modern inputs improves productivity or not. Thus, I will test the use of three modern inputs (fertilizers, pesticides and of high variety seeds).

Finally, I am interested in testing the effect of government supplemental programs. Against the null hypothesis of no effect, I will test H_2: $\delta_6 > 0$. I expect to reject H_0.

5. Empirical results and Discussion

5.1 Technical efficiency estimation using frontier production function

Table 3 provides the maximum-likelihood estimation results of the stochastic frontier production function. An SFPF was to examine the technical (in)efficiency of the farmer by controlling for three different factors separately: education, not owning land, not participating in the extension program. As expected, the variables of crop area (Lcrparea), family labor (lnfamlab), hired labor (lnhlab), and quantity of fertilizers (lqfert) have a statistically significant effect on crop production, while use of pesticides (lqpest), manure (lqmanu), number of days oxen are used (loxdays), and the dummy for high variety seeds (dhivar1) are insignificant. That is, larger crop area, more family and hired labor, and the use of fertilizers contribute to higher output.

The number of days oxen are used in the crop production is expected to have a positive relationship with output, but it turned out insignificant in all models except when controlled for land ownership. The dummy variable for the use of high variety seeds has the expected sign, but turned out insignificant except when controlled for land ownership.

Another interesting result is the quantity of pesticides and high variety seeds, which are expected to have a positive relation and high significance, but the regression results are inconsistent. The use of high variety seed has a significant effect on output in model 4 but it is insignificant in other models.

Further, to see how the modern inputs (fertilizer, pesticides and high variety seeds) are significant in affecting crop production in Ethiopia jointly is hypothesized with a null that these inputs do not affect crop production. The regression result rejects the null hypothesis with a χ^2statistic of 30.28, implying that these factors significantly affect crop production.

The other inconsistent results in the models are the use of irrigation (dirr) and exchange labor (lnexlab). Access to irrigation is significant in three models but turns out insignificant in one of the models where we control the land ownership. However, the level of significance is different in model 1. Exchange labor has the expected result in model 1 and model 4, however, it shows a negative relationship with output in model 2 and it is statistically insignificant.

The interaction variable for when farmers use high variety seeds with irrigation is insignificant and quantity of fertilizer interaction between irrigation is significant at 5 percent significant in model 1 and 10 percent in models 2 and 4. However, when fertilizer interacts with irrigation, the sign turns negative. The interaction between pesticides and irrigation methods turns out insignificant.

In general, when controlling for education (for farmers with no primary education), land ownership (for those with no ownership certificate), and those not participating in the extension program, the overall performance of the models is very consistent with a slight variation across the model.

Table 3: parameter estimation of the frontier production function

Independent/dependant variables	No education (1)	No land owner (2)	No extension program participation (3)	General (4)
	lvcrpm	lvcrpm	lvcrpm	Lvcrpm
Lqfert	0.042*** (0.012)	0.068*** (0.016)	0.045*** (0.011)	0.046*** (0.010)
Lqpest	0.031 (0.030)	-0.022 (0.033)	0.017 (0.028)	0.013 (0.025)
Lqmanu	0.001 (0.007)	0.015 (0.010)	-0.002 (0.007)	-0.001 (0.007)
Loxdays	0.028 (0.024)	-0.049* (0.029)	0.018 (0.023)	0.029 (0.021)
Lcrparea	0.622*** (0.060)	0.812*** (0.087)	0.681*** (0.059)	0.664*** (0.053)
Lnfamlab	0.090*** (0.008)	0.082*** (0.012)	0.092*** (0.008)	0.083*** (0.007)
Lnhlab	0.098*** (0.012)	0.135*** (0.017)	0.096*** (0.011)	0.095*** (0.010)
Lnexlab	0.017* (0.010)	-0.001 (0.015)	0.013 (0.009)	0.015* (0.009)
Dirr	0.373** (0.149)	0.086 (0.226)	0.262* (0.145)	0.258* (0.137)
Fertirr	-0.112** (0.051)	-0.026 (0.075)	-0.085* (0.046)	-0.076* (0.042)
Pestirr	0.090 (0.148)	0.060 (0.088)	0.045 (0.080)	0.056 (0.074)
dhivar1	0.026 (0.059)	-0.019 (0.083)	0.051 (0.061)	0.097* (0.051)
Hivarirr	-0.062 (0.313)	-0.064 (0.421)	0.105 (0.260)	0.080 (0.239)
Observations	1,728	1,017	1,928	2,232

Absolute value of z statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Another null hypothesis in the model is that α is equal to zero, which explains there is no technical inefficiency in the model. The likelihood ratio test rejects the null at the 1% significant level. Also, the value of λ is equal to .82, which explains that the variation of the actual output and the maximum attainable output is due to the technical inefficiency of farmers. This result confirms that the frontier model is preferable to the OLS model.

Table 4: Summary statistics of technical efficiency estimates

Variable	No education (1)	No land ownership (2)	No extension program participation (3)	General (4)
Mean	60.21%	60.71%	59.80%	62.4%
Minimum	5.51%	9.75%	6.33%	8.92%
Maximum	90.19%	88.28%	89.51%	89.6%

Table 4 presents the predicted efficiency of production across three controlled models. Efficiency levels of the farmers vary across those who are lacking education, land ownership, and participation in the extension program. The estimation results suggest that there is potential to increase productivity without any additional inputs. For example, average efficiency of the farmer is only 62.4% according to model 4 indicating that there is a 37.6% shortfall in output in which the farmers can increase output by using the existing resources. Joining agricultural extension will help the farmers use modern inputs better. Improving education will also leads in a gain to efficiency as compared to the general model. The results suggest that extension participation, further education, and greater land ownership would increase efficiency.

5.2. Determinants of inefficiency using OLS

As noted previously, identifying factors affecting the efficiency of the farmer will help to increase efficiency. We already explored how controlling for education, land ownership, and extension program participation can explain variations in technical efficiency. Thus, a follow up analysis to estimate factors that influence technical efficiency is necessary. A set of farmer specific variables are included to explain technical inefficiency derived from model (4). The estimation results are presented in Table 5.

Table 5: Estimated parameters of the inefficiency model

VARIABLES	(5)	(6)	(7)
age1			0.014 (0.026)
age2			0.021 (0.028)
age3			0.013 (0.026)
age4			0.026 (0.029)
dlit1	0.025** (0.010)	0.023** (0.011)	0.024** (0.010)
Hfem		0.002 (0.002)	0.002 (0.002)
Distime		-0.001*** (0.000)	-0.001*** (0.000)
Dprim	-0.005 (0.011)	-0.007 (0.011)	-0.008 (0.011)
hhsize1	-0.004* (0.002)	-0.004* (0.002)	-0.003 (0.002)
dpltslop1	-0.047*** (0.017)	-0.046*** (0.017)	-0.046*** (0.017)

Dextn	-0.006* (0.003)	-0.006* (0.003)	-0.006* (0.003)
Numplot	0.004 (0.003)	0.006** (0.003)	0.006** (0.003)
dsoilqlt1	-0.024 (0.015)	-0.046*** (0.018)	-0.045** (0.018)
Dhvecrt	0.042*** (0.008)	0.042*** (0.008)	0.042*** (0.008)
Dhredu	-0.016 (0.019)	-0.015 (0.019)	-0.016 (0.020)
Distsoil	-0.001*** (0.000)	0.000 (0.001)	0.000 (0.001)
Daylst	0.000** (0.000)	0.000** (0.000)	0.000** (0.000)
Lhage	0.018 (0.017)	0.016 (0.017)	
Observations	2,232	2,232	2,232
R-squared	0.042	0.044	0.044
RMSE	0.196	0.196	0.196
R^2	0.042	0.044	0.044

Robust t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Three models are implemented to control for different variables. Not surprisingly age (hage) is not significant in terms of affecting the technical efficiency of farmers. While the variable has the expected sign, it is not significant. A possible explanation may be that the farmers are too conservative to adopt new technologies, or are to constrained by lack of capacity.

The education variables included in the models above are if a head of the household finished primary education (dprim), if the head of the household is illiterate (dlit1) and if the head of the household has religious education (dhredu). Finishing primary education and attending religious education have the expected sign but they are insignificant. The illiterate dummy (dlit1) is positively significant, suggesting that a farmer who is illiterate is less efficient in farming than a farmer who is literate.

Household size (hhsize1) possesses a negative relationship with technical inefficiency and is significant at the 10% level in model 5 and 6 but it turns out insignificant in model 7. This implies that the larger the size of the household, the more efficient the farming.

Having good quality of soil (dsoilqlt1) and good topography (dpltslop1), characterized by flatness, increases the technical efficiency level of farmers. Topography (dpltslop1) increases technical efficiency at 1 percent significant level in the three models, while soil quality (dsoilqlt1) is significant at the 1percent and 5 percent in models 6 and 7 respectively. Owning several plots has a positive relationship with the technical inefficiency of farmers. This goes along with the literature that having fragmented land holdings increases farmer inefficiency.

The last hypothesis is that that individuals participating in the extension program display greater efficiency than others. The efficiency of the farmer is, however, not explained by participating in the extension program. The rejection of this hypothesis means that participating in the extension program does explain the technical inefficiency of farmers. Participation in the extension program (dextn) has the expected negative sign and is significant at 10 percent. An interesting result is that a shorter distance from a farmer's home to his/her farm enhances efficient in farming.

Another interesting finding is about land ownership. In the above section, we saw how those farmers who have a certificate of ownership to their land had higher efficiency levels. However, in this section we find the opposite. At the 1% level land ownership is found to have a positive relation with inefficiency. This means that land ownership, in this model, reduces efficiency. Because of the mixed results between the two models in this paper, a straightforward conclusion cannot be drawn on the effect of land ownership.

However, land ownership should generally lead to more efficient farming as it is the only logical expectation.

The proxy included for health of the farmer and his/her family is the total days of work lost due to illness (daylst). This variable exhibits the expected sign of a positive relation with inefficiency. Illness is significant but there is a very small effect on the efficiency of farmers for a single day lost.

In general, the goodness of fit of the model is 4%. This indicates that there are other factors that determine the technical efficiency of farmers in Ethiopia. Data on access to credit was not available. We note, however, that in other studies this is shown to be one of the key factors contributing to the variation of efficiency among farmers.

6. Conclusion and policy implications

Ethiopia is one of the poorest countries in the world and the economy of the country heavily relies on the productivity of agriculture. Thus, achieving higher efficiency is essential to feed its increasing population and to meet the input demands of small scale industries. In addition, the agricultural sector is a primary means of accumulating foreign currency through exports of agricultural output, such as coffee. Considering all of these factors, government's support to the farmers will be crucial to accelerate farm productivity.

This paper used stochastic frontier production function to measure the impact of new agricultural inputs and to determine whether the farmers are producing below the production function and what factors affect the efficiency of farmers in Ethiopia. The estimated mean technical efficiency is 62%. It indicates that there is room to increase the crop production by increasing the technical efficiency of farmers. The result suggests that participation in the extension program has a positive impact on technical efficiency. Encouraging non-participant farmers to participate in the extension program and increasing the size of the program will increase technical efficiency.

Another factor that increases the efficiency of farmers is the level of education. The government focus on policies and programs that increase the primary and secondary education rates will help to further increase the productivity of farmers. Furthermore, the use of fertilizers to increase crop production has a significant effect. Thus, encouraging farmers to use modern inputs, especially fertilizer, will increase food supply.

However, property rights exhibit a mixed result. Perhaps controlling for both farmers and plots might lead to clearer results on property rights. Therefore, a further research on the impact of property rights on technical efficiency of farmers in Ethiopia is needed.

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