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Analysis of Technical Efficiencies of Small Scale Irrigation Technologies

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Analysis of Technical Efficiencies of Small Scale Irrigation Technologies

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by

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The thesis entitled "Analysis of Technical Efficiencies of Small Scale Irrigation Technologies" by Mr. ______________________________ is approved for the degree of Master of Science in Economics.

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Acronyms

MoWR Ministry of Water Resources

IMF International Monetary Fund

GDP Gorss Domestic Product

ILSSI Innovative lab for small scale irrigation

ILRI International Livestock Research Institute

IWMI International Water Management Institute

USAID United States Aid for International Development

FtF Feed the Future

SFA Stochastic Frontier Analysis

DEA Data Envelopment Analysis

NCAT North Carolina A&T State University

IFPRI International Food Policy Research Institute

MOA Minstry of Agriculture

REDS Rural Economic Development Survey

NCAER National Center for Agricultural Economics and Policy Research

AGP Agricultural Growth Program

CSA Central Statistics Agency

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Abstract

This research work made a comparative analysis of Technical efficiencies of two small scale irrigation technologies; rope and washer and pulley practiced by farmers in two places. It also attempted to identify factors that contribute to the inefficiencies in using these technologies for the production of crops. Stochastic Frontier Analysis (SFA) is the model used for estimating the efficiency levels and the ordinal regression analysis has been employed to factor out determinants of inefficiency. Experimental population data has been used from two selected kebles in two different woredas of the Amhara region. The results obtained from the stochastic frontier analysis indicates that farmers are operating at a significantly lower efficiency level indicating the existence of a room for increased production level. A number of socio-economic, demographic and farm characteristics were identified as factors for the inefficiencies which can be used as a policy tool too boost production to the best possible.

Key words: Stochastic frontier analysis, Small scale irrigation, Technical efficiency

1 Introduction

1.1 Background

Ethiopia is the second-most populous country in Sub-Saharan Africa with a population of 96.5 million, and population growth rate of 2.5% in 2014. One of the world's oldest civilizations, Ethiopia is also one of the world's poorest countries. The country's per capita income of $550 is substantially lower than the regional average. The government aspires to reach middle income status over the next decade WorldBank (2015).

44.2 % are age 14 and under, the productive age 15-64 accounts 52.9 % and those who are greater than or equal to 65 constitute 2.9 % of the population. Hence, the young age dependency ratio is 77.2 % and that of the old age is 6.3 % this makes the societal dependency ratio as 83.5 % CSA (2014)

Ethiopia's economy is heavily dependent on the agricultural sector, which contributes more than 45% of the GDP, providing livelihood for 85% of the population and accounting for 60% of the foreign exchange earning. This sector, mainly dependent on rain fed and very traditional farming practices, accounts for 96% of the food produced in the country Kelemework (2008).

The fact that the sector is heavily dependent on rain and make very limited use of improved farming technologies makes the country to stay under developed and puts the nations food security in danger. At times when the country is hit by drought it has a devastating consequence resulting in famine and the loss of life of thousands of its rural citizens.

The country covers a land area of 1.13 million sq.km of which 99.3 percent is a land area and the remaining 0.7 percent is covered with water bodies of lakes (MOWR 2002). It has an arable land area of 10.01 percent and permanent crops covered 0.65 percent while others covered 89.34 percent.

The mean annual rainfall is 812.4 mm, with a minimum of 91 mm and a maximum of 2,122 mm; with a highest rainfall ranging from 1,600–2,122 in the highlands of the western part of the country, and a lowest rainfall from 91-600 mm in the eastern lowlands of the country. The mean annual temperature is 22.2 degrees Celsius. The lowest temperature ranges from 4-15 degrees Celsius in the highlands, and the highest mean temperature is 31 degree Celsius in the lowlands at the Denakil Depression. On the other hand, it is estimated that the major river basins of the country can irrigate about 3.5 million-hectare of land and at present only about 161,010 ha or 4.6% is irrigated around the major river basins.

At current per capita fresh water resource of 1924 cubic meters, Ethiopia is one of the countries endowed with the largest fresh surface water resources in Sub-Saharan Africa. Moreover, Ethiopia's land resource potential for irrigation development, disregarding available water is very large. Despite this potential, Food and Agricultural Organization estimates showed that 49 percent of Ethiopia's population is undernourished Bogale and Bogale (2005).

Since the mid-1980s, the Ethiopian government has responded to drought and famine through promoting and construction of irrigation infrastructure aimed at increasing agriculture production. These are traditional, small, medium and large-scale irrigation schemes performing at different levels. Irrigation development has positive socio-economic and some negative environmental impacts. Formally accounted overall irrigation development is estimated at some 5 – 6 percent of the developable potential of 3.7 million ha MoWR (2004).

Three major types of irrigation schemes are practiced in Ethiopia: *traditional schemes*, *modern community schemes* and *large-scale schemes*. Large-scale irrigation is mainly concentrated in Awash Valley and operated by state farms. Traditional irrigation schemes are small-scale irrigation schemes built under the self-help program of peasant farmers on their own initiative. The schemes are operated and maintained by farmers themselves Bogale and Bogale (2005).

Because of the ambitious government plans to expand small scale irrigation in Ethiopia, it is important to study, among other performance parameters, the production efficiency of small scale irrigation schemes. Many believe that the existing irrigation schemes are not operating efficiently, and that much has to be done to improve their efficiency.

In countries like Ethiopia, where food deficit is prevalent due to recurrent droughts, the challenges of moisture stress could be met with irrigation schemes that make the best use of the available irrigation technology. One of the necessary agenda in this context would be a study on resource use efficiency and the factors that contribute to resource use inefficiency in the production of irrigated crops. Therefore, this study investigates the level of technical efficiency of irrigated vegetable and irrigated fodder farms and identifies the factors that limit the level of efficiency for the schemes under consideration.

1.2 Statement of the Problem

For a poor country like Ethiopia resources are not only scarce but also unavailable in many instances. Such countries need to use these resources in a way that can give the maximum production possible. The best combination of input resources that are technically possible to achieve a desirable production level is determined by a number of socioeconomic, demographic and agronomic characteristics. Gebregziabher et al. (2012) recommended that water control must precede or implemented in tandem with improved seeds and fertilizer technologies.

Theoretically it is believed that farmers are never (or very rarely) 100% efficient. Though there is no a specific threshold level of efficiency above which we are tolerable, we allow for some degree of inefficiency as it is less likely to remove it all completely. So the level of inefficiency is what matters for possible policy actions. A farmer who is producing in a very inefficient manner needs to see his/her input/output schedule so as to increase the efficiency level.

Therefore a critical investigation of the level of efficiency and the factors that affect is a very important step to start with in an effort to increase the level of production given the available scarce resource, and hence to alleviate poverty.

This issue is not well addressed scientifically in Ethiopian farmers. In so far as the researcher knows only very few papers are made in assessing efficiency in irrigated farms; (Gebregziabher et al. (2012), Kelemework (2008), Bogale and Bogale (2005), Kitila and Alemu (2014), Yami et al. (2013), Geta et al. (2013) and Asayehegn et al. (2011))

This paper, in an effort to fill this gap, tries to contribute to this issue only by taking those farmers who are using and implementing the selected technologies. It is also an attempt to help the ILSSI project achieve its objectives.

1.3 Objectives of the Study

In general, the objective of this study is to examine as to how to use resources efficiently in order to increase the level of output obtained from irrigated farms in the selected intervention areas, given the available resources and practices. It focuses on the assessment of resource use efficiency in the production of irrigated onion, tomato and fodder using the two technologies, Rope-and-Washer and Pulley.

The specific objectives of the study are:

- To evaluate and make a comparative analysis of technical efficiency of irrigated farms using the Rope-and-Washer and Pulley water lifting technologies

- To identify the determinants of technical efficiency in irrigated farm, so as to assist in finding ways and means by which the level of technical efficiency could be increased.

1.4 Significance of the Study

The central element of this study is technical efficiency of house hold level small scale irrigation technologies. Its results are expected to have a significant contribution in improving the productivity and efficiency of farmers through identifying the existence of inefficiency in their farming practice and factors responsible for it. It will also help policy makers to make informed decisions to improve farmers' production efficiency and productivity. Gender mainstreaming programs can benefit much from activities that It can also used as a basis for further studies.

2 Literature Review

2.1 Theoretical review

2.1.1 Efficiency

In economics two distinct concepts of technical efficiency have emerged. The first concept, associated with Debreu (1951) and especially Farrell (1957), is related to the traditional radial efficiency measure. Focusing on input efficiency, it is defined as the minimal equi-proportionate reduction in all inputs which still allows production of given outputs. This radial measure implicitly defines technical efficiency relative to the iso-quant of technology. The second concept stems from the work of Koopmans (1951) who provided a definition of technical efficiency that focuses on the efficient subset of technology, but who refrained from defining a related efficiency measure. In his view a producer is technically efficient if an increase in any output or a decrease in any input requires a decrease in at least one other output, or an increase in at least one input. Thus, for each technology for which isoquant and efficient subset diverge, there is a potential conflict between both technical efficiency concepts.

To evaluate observations relative to this efficient subset, the theoretical literature has suggested a variety of non-radial efficiency indices as alternatives to the standard radial index which can conflict with Koopmans' definition of technical efficiency. A first article proposing an axiomatic approach to the problem is Färe and Lovell (1978) who suggested four properties that a measure of input efficiency should satisfy and proposed an alternative non-radial efficiency measure satisfying these axioms.

To put it in short According to Koopmans (1951) *"a producer is technically efficient if an increase in an output requires a reduction in at least one other output or an increase in at least one input,* *and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output*". And Differently, Debreu (1951) and Farrell (1957) defined the following measure of technical efficiency known as the **Debreu-Farrell** measure: *"one minus the maximum equiproportionate reduction in all inputs that still allows the production of given outputs, a value of one indicates technical efficiency and a score less than unity indicates the severity of technical inefficiency*".

2.1.2 Socio-economic and Demographic Characteristics

The importance of education in labor market success of individuals and governments all around the world is apparent, and routinely advocates further investment in education. As the majority of the population in developing countries depends on agriculture for their livelihoods, knowledge of market returns to education is less useful as a guide to increase educational investment in such agrarian societies. In theory, education is expected to improve productivity in all spheres of activities including agriculture. A positive return to education arises, for example, because educated farmers are better managers, adopt more modern farm inputs and prefer risky (high-return) production technologies.

Household size is a useful unit of analysis given the assumptions that within the household resources are pooled, income is shared, and decisions are made jointly by responsible household members. Household requirements are many and one person in most cases cannot handle them alone and small-holder farmers depend on family labour for most of the agricultural activities. Large families are suppose to be more economically efficient than smaller ones who depended on hired labour. This is because family labour is more efficient than hired labour as family labour is more motivated than hired labor. moreover as the family size gets smaller, the larger proportion of farm labor is compensated by hired labor making family labor more engaged in coordination tasks only.

Older people gain lots of lessons from the mistakes done in the past. As a result it is expected that their informed decision and best farm management practice help them to gain efficiency advantages. On the other hand, youngsters are naturally endowed with a number of characteristics that are in favor of better efficiency. They are energetic, have positive future anticipation, highly motivated and so on. It is theoretically believed that better efficiency can be achieved using this naturally gifted characteristics. It seems that having a closer look at to the labour force might bring some positive and positive implications for efficiency

Women constitute half of the rural farming community in Ethiopia, contributing 48% of labor over all agriculture, and 70% of household food production (MOA, EPDR report 1992). A number of studies indicate that investments in women's access to agricultural inputs and agronomic practices can bring up to a 30% increase in production. Similarly, addressing gender inequality at the national level can contribute up to a 1.9% increase in GDP. Further, investments in women farmers' productivity and income has a ripple effect on improving household nutrition, children's schooling, and the ability of the household to make further investments through nest egg savings.

Household irrigation has many important implications for gender mainstreaming and gender relations. It is usually undertaken on a small plot of land with intensive care and vegetable farming is traditionally placed in women's sphere. Thus, because irrigation introduces cash potential into a traditionally female domain, it can be a powerful tool to increase women's empowerment both through greater access and control over income, and through overall improvements in quality of life. In addition, women tend to be responsible for guaranteeing a steady supply of water, and many spending up to two hours a day walking to retrieve water. When irrigation agriculture makes a water pump affordable and justifiable for farm households, it can help reduce some of women's labor needs.

On the other hand, female farmers' productivity and their engagement is lower than that of their male counterparts. Woman-headed households have significantly lower take-up rates of irrigation as compared to men: only 2.9% of female headed house holds, but 4.8% of male headed households, currently use irrigation. Though this can be partly explained by the fact that woman-headed households tend to have lower incomes, that does not seem to be the only explanation. Women are also less likely to know about supply channels or have access to credit. Thus, the gender implications of household irrigation are twofold: while irrigation can do a great deal to improve women farmers' quality of life, it must also be implemented with women's particular needs in mind.

Some household irrigation technologies are more gender-sensitive than others. With treadle pumps, operators are elevated above the ground in exhausting physical activity that communities sometimes consider undignified and inappropriate for women. Other styles of manual pumps such as rope-and-washer pumps and hip-height pumps are comparably affordable and effective and have been more easily adopted by women.

All the above theoretical developmets stresses that the issue of gender is an important variable to deal with to explain the inefficiency of farm activities especially in the developing countries like Ethiopia. Females are highly intertwined with many cultural and religious beliefs making them unable to fully utilized their physical and mental resources in their entire life.

2.1.3 Farm Characteristics

Plot size

The discussion on the inverse relationship between land size and productivity in agriculture could be traced back to the work of Chaynov (1966) who examined data of Russian agriculture for the 1920s and 1930s. It was observed that small farms on average employed more input (per unit area) and as a result had a higher output. The debate was initiated by Sen (1966) who argued that if the market wage rate is imputed to family labor, many of the farms would show losses and profitability increases with the size of the holdings. Sen, 1966 provides an explanation in his theory of 'agricultural dualism' where the traditional small peasant is assumed to be well endowed with plentiful labor with low or zero opportunity cost while facing a severe constraint on credit. It was argued that these farms would employ labor up to the point of zero marginal productivity. Large farms, however, would employ labor up to the point where the wage rate equalled the marginal product. This could explain declining productivity in terms of output (per unit area) but increasing profitability. This is so because large farms cannot be considered as linear replicas of small ones. Incentives to use inputs vary with production scale; that is, larger farms use different technologies than small farms. But soon after then it was subsequently argued that the higher productivity of smallholdings would disappear with the adoption of superior technology, modernization and growth in general. Recently, farm size begins to become an issue determining agricultural productivity negatively.

2.2 Empirical Review

2.2.1 Efficiency

Several studies made it clear that inefficiency is an inherent problem in almost all activities that human undertakes. A number of studies are made on different farm activities such as diary farms, crop production, in the livestock farm and so on each of which have reported the existence of inefficiency. From the list of studies done on farm related efficiency the most recent ones which are done in the last 15 years are presented in table 1 and table 2. The mean technical efficiency in these studies ranges from 40.3 to 98.4. All the studies are made on diary farms and as can be seen none of them are in the developing African countries, indicating the need to do one.

The literature on productive or technical efficiency in African agriculture is emerging. Globally, there is a wide body of empirical research on the economic efficiency of farmers both in the developed and developing countries (for reviews see Battese and Coelli (1992) and Coelli (1995)). While the empirical literature on the efficiency of farmers is vast in developed countries and Asian economies, few studies focus on African agriculture. Heshmati and Mulugeta (1996) estimates the technical efficiency of Ugandan matoke-producing farms and find that the matoke-producing farms face technologies with decreasing returns to scale with mean technical efficiency of 65%, but find no significant variation in technical efficiency with respect to farm sizes. This study, however, does not identify the various sources of technical efficiency among matoke-producing farmers.

Seyoum et al. (1998) investigate the technical efficiency and productivity of maize producers in Ethiopia and compare the performance of farmers within and outside the program of technology demonstration. Using Cobb-Douglas stochastic production functions, their empirical results show that farmers that participate in the program are more technically efficient with mean technical efficiency equal to 94% compared with those outside the project with mean efficiency equal to 79%. Gebregziabher et al. (2012) made a comparative efficiency analysis, using the data from small holder farmers in the tigray region of Ethiopia, between irrigated and rain fed agriculture and showed that irrigated agriculture suffers from sevier inefficiency problem as low as 45% though it provides better revenue as compared to the rain fed agriculture.

Given the current state of technology Yami et al. (2013) argued that it is possible to increase wheat production by 45% for some selected water logged areas of Ethiopian farmers. In a study made to asses productivity of maize production in southern Ethiopia Geta et al. (2013) observed the level of efficiency to be as low as 40%.

Kitila and Alemu (2014) analyzed the data from small holder maize producing farmers of the

Oromia region of Ethiopia and estimated technical efficiency that ranges from 0.06 to 0.92 with a mean technical efficiency of 0.66 (66%).

Using the stochastic production frontier approach, Kelemework (2008) analyzed the awash river basin farmers data and conclude that the existing irrigation systems are not that efficient and there is a need to make them operate near their production frontier. On the other hand for potato producing farmers of Awi zone-Ethiopia Bogale and Bogale (2005) found that the efficiency levels are fairly better 77% and 97% for modern and traditional irrigation schemes, respectively.

Table 1: Efficiency estimates for deterministic models

Author(s)(Year) Journal, Country	**Sample size**	**MTE**
Arzubi and Berbel (2001), Rev. Esp. Estud. Agrosoc. Pesq., Argentina	35	77.8
Arzubi and Berbel (2002), Invest. Agrar. Prod. Sanid. Anim., Argentina	42	87.5
Arzubi et al. (2004), Rev. Argent. Econ. Agrar., Argentina	45	90.5
Asmild et al. (2003), J. Prod. Anal., Netherlands	1808	80.5
Kaliba (2004), Q. J. Int. Agric., Tanzania	240	75.9
Lachaal et al. (2002), Mediterr. J. Econ. Agric. Environ., Tunisia	17	68.0
Mathijs and Vranken (2001), Post Communist Econ., Hungary	26	42.3
Pardo et al. (2002), Empir. Econ. Lett., Spain	68	65.2
Reinhard et al. (2000), Eur. J. Oper. Res., Netherlands	1535	79.7
Silva et al. (2004), New Medit, Portugal	122	66.6
Álvarez and Arias (2004), Agric. Econ., España	1176	70.0
Haghiri and Simchi (2003), Empir. Econ. Lett., USA.	210	67.4
Karagiannis et al. (2002), J. Prod. Anal., U.K.	2147	70.4

Continued on next page

Table 1 – *Continued from previous page*

Author(s)(Year) Journal, Country	**Sample size**	**MTE**
Lachaal et al. (2003), Eur. Assoc. Anim. Prod., Tunisia	61	75.0
Maietta and Sena (2000), Eur. Rev. Agric. Econ., Italy	533	55.0
Orea et al. (2004), J. Prod. Anal., Spain	445	65.6

Table 2: Efficiency estimates for Stochastic models

Author(s)(Year) Journal, Country	**Sample size**	**MTE**
Haghiri et al. (2004), Appl. Econ., Canada	1021	58.2
Brümmer and Loy (2000), J. Agric. Econ., Germany	5093	96
Brümmer (2002), Am. J. Agric. Econ., Germany, Netherlands and Poland	300	86.9
Cuesta (2000), J. Prod. Anal., Spain	410	82.7
Haghiri and Simchi (2003), Empir. Econ. Lett., USA	210	83.1
Lawson et al. (2004), Livest. Prod. Sci., Denmark	574	94.5
Lawson et al. (2004), J. Dairy. Sci., Denmark	514	92.8
Mbaga et al. (2003), Can. J. Agric. Econ., Canada	1143	94.8
Moreira López et al. (2006), Arch. Med. Vet., Chile	92	72.2
Pierani and Rizzi (2003), Agric. Econ., Italy	533	65.9
Reinhard et al. (2000), Eur. J. Oper. Res., Netherlands	1535	89.4
Reinhard and Thijssen (2000), Eur. Rev. Agric. Econ., Netherlands	2589	83.8

Continued on next page

Table 2 – *Continued from previous page*

Author(s)(Year) Journal, Country	Sample size	MTE
Saha and Jain (2004), Indian J. Agric. Econ., India	23	90.2

2.2.2 Socio-economic and Demographic Characteristics

Despite such common beliefs regarding the benefits of schooling in farm activities, there is weak empirical evidence to advocate educational investment in agrarian societies.

The existing studies on the determinants of farm productivity and efficiency are largely inconclusive on the question of a positive return to education. For instance, Ali and Flinn (1989), Wang et al. (1996), and Seyoum et al. (1998) demonstrate significant role of farmers' education in raising farming efficiency in Pakistan Punjab, India, China, and Ethiopia, respectively. On the other hand, Battese and Coelli (1995) and Llewelyn and Williams (1996) fail to identify any significant impact of farmers' education on farming efficiency in India, and Java-Indonesia, respectively. Hasnah et al. (2004) rather report a significantly negative impact of education on technical efficiency in West Sumatra-Indonesia. Also Yami et al. (2013) and Kitila and Alemu (2014) found a negative and statistically significant coefficient for education in the efficiency model using data in the Oromia region of Ethiopia. Nevertheless, there is some agreement in the literature that education significantly influences adoption of technological innovations in agriculture (for example, Hossain et al. 1990, Weir and Knight, 2004, Asfaw and Admassie (2004).

Hussain (1999), Battese et al. (1996) and Hassan (2004) showed that secondary level of education dummy variable carry a statistically significant positive coefficients. it is believed that secondary education is an important factor in enhancing agricultural productivity. Azhar (1991) also found that the effect of higher education on efficiency was higher compared to that of primary education during the Green Revolution in the entire irrigated areas of Pakistan. Using data in maize producing farmers of eastern Ethiopia Seyoum et al. (1998) also confirmed the positive relationship between efficiency and years of schooling. Educated farmers usually have better access to information about prices, and the state of technology and its use. Better-educated people also have a higher tendency to adopt and use modern inputs more optimally and efficiently (Ghura et al. (1992)). According to Nkhori (2004), education increases the ability of farmers to use their resources efficiently and the locative effect of education enhances farmers‘ ability to obtain, analyze and interpret information. It is more likely that the farmers with higher educational status are more perceptive to agriculture expert advice as noted by Mushunje et al. (2003). In addition, education enhances the acquisition and utilization of information on improved technology by the farmers as well as their innovativeness (Dey et al., 2000; Effiong, 2005; Idiong, 2006).

The results from this study suggest that primary education had a negative but insignificant effect on efficiency for the sampled households. On the other hand, Hussain(1989) argue that there is no association between education and agricultural efficiency. For the Indian village of Kanzara, Coelli and Battese (1996) found that the farmers with more years of schooling were more technically inefficient.

Weir (1999) investigates the effects of education on farmer productivity of cereal crops in rural Ethiopia using average and stochastic production functions. This study finds substantial internal benefits of schooling for farmer productivity in terms of efficiency gains but finds a threshold effect that implies that at least four years of schooling are required to lead to significant effects on farm level technical efficiency. Using different specifications, average technical efficiencies range between 0.44 and 0.56, and raising education from zero to four years in the household leads to a 15% increase in technical efficiency. Moreover, the study finds evidence that average schooling in the villages (external benefits of schooling) improves technical efficiency.

Weir and Knight (2004) analyse the impact of education externalities on production and technical efficiency of farmers in rural Ethiopia, and find evidence that the source of externalities to schooling is in the adoption and spread of innovations which shift out the production frontier. Mean technical efficiencies of cereal crop farmers are 0.55 and a unit increase in years of schooling increases technical efficiency by 2.1 percentage points. Nonetheless, one limitation of the Wier (1999) and Weir et al. (2000) is that they only investigate the levels of schooling as the only source of technical efficiency.

Access to and control over household income. Studies on the gender implications of irrigation in Ghana and Zambia found that, in male-headed households, the wife's decisions about the use of produce from her own plot and the husband's plot appears to be stronger when irrigation is used, versus in households reliant on rain-fed agriculture. In Nepal, 92% of women in the study area of a drip irrigation pilot did not have any income source under their own control at the start of the study, but by the project's conclusion, women custodians of the irrigation income were able to exert more influence in their community and even benefited from a more equitable distribution of household labor.

There is evidence that flexible financing options dramatically increases women' adoption rate. In Kenya, women were only 11% of the purchasers of pumps under straightforward purchase, but comprised 33% who purchased under a layaway scheme for KickStart's hand-powered pumps. Finally, working through women's groups as collective purchasers is an effective means to increase adoption of motor pumps among female-headed households

2.2.3 Farm characteristics

Townsend et al. (1998) using data envelopment analysis investigate the relationship between farm size, returns to scale and productivity among wine producers in South Africa and find that most farmers operate under constant returns to scale, but the inverse relationship between farm size and productivity is weak.

The relationship between farm size and productivity has been intensely debated. A large number of studies during the 1960s and 1970s provided convincing evidence that crop productivity per unit of land declined with an increase in farm size (Sen 1962, 1964; Mazumdar 1965; Khusro 1968; Hanumantha Rao 1966; Saini 1971; Bardhan 1973; Berry 1972) which provided strong support for land reforms, land ceiling and various other policies to support smallholders on ground of efficiency and growth. Subsequently, various analysts started exploring reasons or factors for higher productivity of smallholders (Berry and Cline 1979; Bhalla 1979; Binswanger and Rosenzweig 1986; Dong and Dow 1993; Frisvold 1994; Raghbendra et al 2000) and some of them even questioned the inverse relationship between farm size and productivity.

Foster and Rosenzweig (2010) using plot level panel data (over the span 1999-2008), of the Rural Economic Development Survey (REDS) data of the National Centre for Agricultural Economics and Policy Research (NCAER), and using a model incorporating supervision costs, risks, credit-market imperfections and scale economies associated with mechanisations, report that small-scale farming is inefficient in India. Thapa and Gaiha (2011) using all India survey, REDS, 2006 of NCAER data, analysed the farm size crop yields relationship, using the Kernel density function, and observed that the relation varies with food commodity group. They also report that "while much lower fractions of smallholders are concentrated in lower ranges of yields compared with medium- and large-landholders, segments of smallholders also obtain very low yields".

In a study for identifying factors affecting the efficiency of maize producing farmers in the southern Ethiopia found farm size and use of improved seed variety carrying a positive and significant coefficient Geta et al. (2013).

3 Methodology

This research is concerned with measuring the performance of irrigated farms, which convert inputs (labor, capital) into outputs (agricultural products). The performance of these farms can be defined in many ways. One natural measure of performance is a productivity ratio: the ratio of outputs to inputs, where larger values of this ratio are associated with better performance. Performance is a relative concept. For example, the performance of a farm in 2015 could be measured relative to its 2014 performance or it could be measured relative to the performance of another farm in 2015, etc.

The terms, **productivity** and **technical efficiency**, are often used interchangeably, but this is unfortunate because they are not precisely the same things.

If information on prices is included, and a behavioral assumption, such as profit maximization or cost minimization, is appropriate, then it is possible to consider **allocative efficiency**. Allocative efficiency in input selection involves selecting that mix of inputs (e.g. labour and capital) that produces a given quantity of output at minimum cost (given the input prices which prevail). Allocative and technical efficiency combine to provide an overall economic efficiency measure.

3.1 Study Area and data

3.1.1 Innovative laboratory for small scale irrigation technologies (ILSSI)

The Feed the Future Innovation Lab on Small-Scale Irrigation (FTF-ILSSI) is a cooperative agreement funded by USAID under the Feed the Future program to undertake research aimed to increase food production, improve nutrition, accelerate economic development and contribute to the protection of the environment. The project seeks these objectives through identifying, testing and demonstrating technological options in small-scale irrigation and irrigated fodder, supported by a continual dialogue approach with stakeholders and capacity development toward sustained use of research approaches and evidence.

As the lead institution, Borlaug Institute for International Agricultural/Texas A&M University System is responsible for leadership, management and administration of the overall cooperative agreement. Together under sub-agreement with BI/TAMUS, several partners will conduct research and carry out the goals and objectives set forth. Partners in the FTF-ILSSI cooperative agreement include the International Water Management Institute (IWMI), the International Food Policy Research Institute (IFPRI), the International Livestock Research Institute (ILRI), North Carolina A&T State University (NCAT) and Texas A&M AgriLife Research (TAMUS).

This paper attempts to contribute to achieve the objectives set by the project. ILSSI chooses 4 agricultural places from the Feed The Future Woredas to run the experiment, two of which are located in the Amhara region and are the areas where this research is about.

3.1.2 Area Description

Dangila is one of the *Agricultural Growth Program (AGP)* and *USAID Feed the Future* woredas in the Amhara regional state. It is located about 80 kilometers south west of Bahir Dar. In the woreda, there are 27 rural Kebeles among which 16 of them have access to perennial rivers. Average annual rainfall is about 1600 mm, but varies between 1180-2000 mm. The mean annual potential evapotranspiration (PET) is 1250 mm. Monthly PET during November to April exceeds monthly rainfall implying the importance of dry season irrigation. Current status of groundwater use for domestic and irrigation is presented below. Groundwater mapping by IDE also shows that Dangila woreda is one of the potential areas for manual well drilling and thus suitable for piloting and demonstration of smallholder irrigation technologies for sustainable intensification. In this

Table 3: Ground Water use in Dangila Woreda

Well Category	Depth below surface(m)	Current Use	No of wells
Hand dug wells	≤ 25	Irrigation and Domestic water supply	2281
Shallow wells	25-27	Domestic water supply	3
Deep wells	≥ 27	Domestic water supply	ll

woreda one kebleie (Dangishita) is selected for the ILSSI project implementation.

Robit-Bata is one of the rural kebeles in Bahir-Dar Zuria woreda of Amhara regional state. It is located 10 km north of Bahir Dar. Bahir Dar zuria woreda is one of AGP and Feed the Future woredas in the region. It has a sub-tropical ("Woina Dega") climate. The livelihood system is based on cereal and high value irrigated crop production. Groundwater potential and experience in smallholder irrigation is relatively high. Motor pumps together with manual water lifting devices are widely used in the kebele. Shallow groundwater, river diversion and lake pumping are the main source of irrigation water. In 2014, about 1820 ha of land was irrigated of which 85% using motor pumps. There are about 4000 individual wells in the kebele.

According to IDE, Bahir-Dar Zuria is one of the potential areas suitable for manual well drilling. Given its proximity to the regional capital, dairy is one of the emerging businesses implying that demand for improved livestock feed is high and growing. About 53 households are currently producing irrigated fodder which can be developed into business for market. Thus Robit-Bata kebele of Bahirdar-Zuria woreda is the other area where this study's target households located.

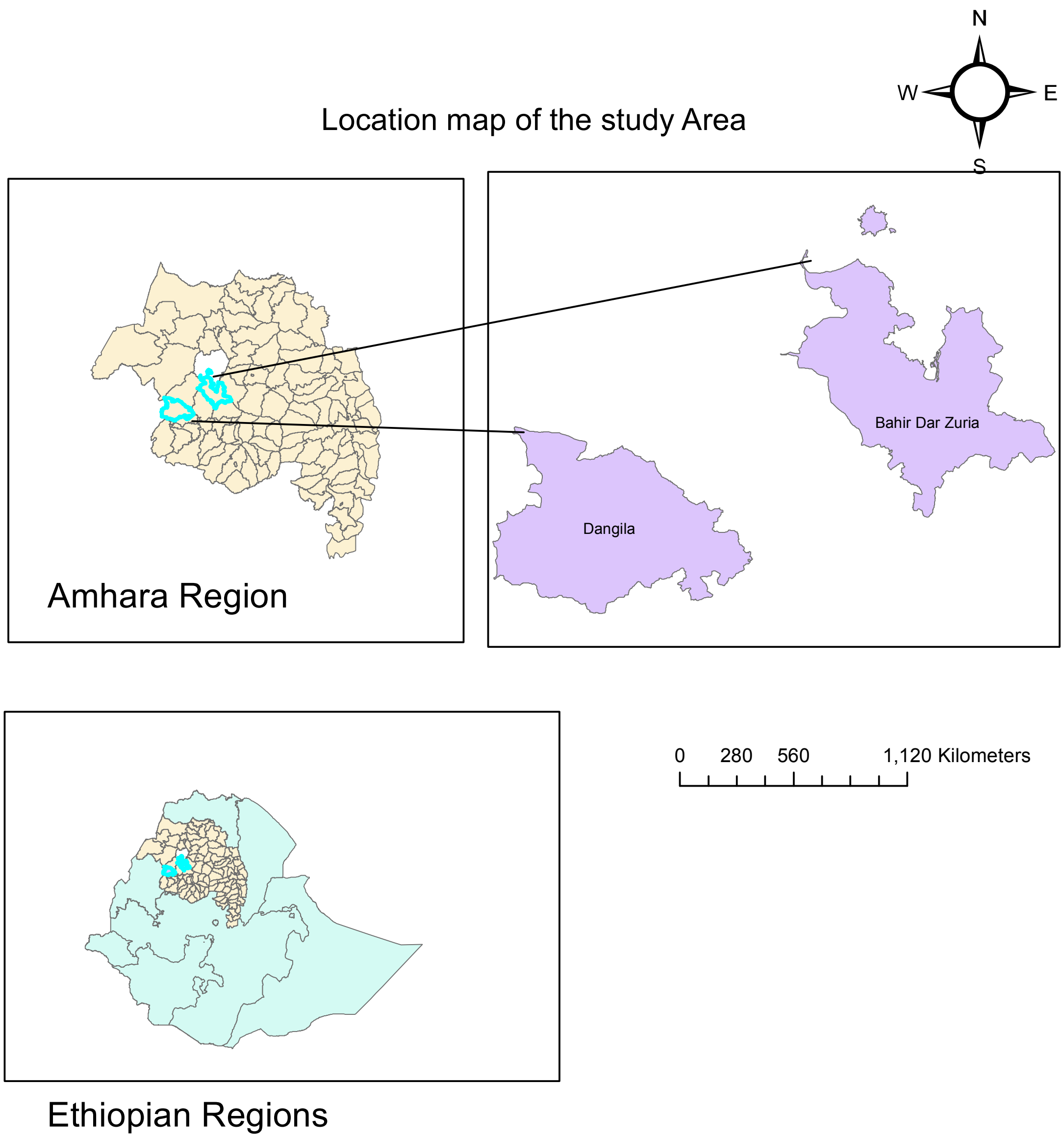

Figure 1: Areas where ILSSI is implementing its project

3.1.3 Sample and data nature

From the above two purposely selected areas, 54 target households were selected by the kebele administrators and community leaders of the respected areas within the areas whose farms reside on a specified water sheds. For this target households (22 from dangishita kebele and 32 from Robit-Bata keble) two irrigation technologies (Rope-and-Washer and Pulley) were made available on credit basis with which they cultivated a common crop (Tomato and elephant grass in Robit and onion in Dangishita) during the 2014/2015 dry season. 33 percent of the farms under the experiment are owned by female household heads.

The irrigated farms were allowed to run on different plot sizes ranging from 50 meter squares to 250 meter squares. These farms enjoyed a close follow up of different agricultural professionals. A number of training were also provided that includes land preparation, nursery preparation, plant spacing, fertilizer application, irrigation scheduling, financial literacy and so on.

A number of data collection instruments were employed. Before the intervention, a base line survey is made using a well structured and in depth questioner. It is used to capture information about the socioeconomic, demographic, agronomic practice etc of the household and family members. The field book which is used to collect every agronomic activity all through the land preparation to harvest time has helped us a lot in capturing a huge data. Focus group discussions and key informants interviews were also undertaken repeatedly to have complete picture of the phenomena. This paper takes all the households(considers the population) for its analysis.

3.2 Efficiency

Efficiency is one of the most important topics in economic theory. It is the relationship between what an organization produces and what it should feasibly produce, under the assumption of full utilization of the resources available. Efficiency represents the degree of success which producers achieve in allocating the available inputs and the outputs they produce, in order to achieve their goals, namely to attain a high degree of efficiency in cost, revenue, or profit.

As stated in Kumbhakar and Lovell (2000), efficiency is the ability of a decision making unit to obtain the maximum output from a set of inputs or to produce an output using the lowest possible amount of inputs. A production frontier refers to the maximum output attainable given sets of inputs and existing production technologies. The production frontier defines the technical efficiency in terms of a minimum set of inputs in order to produce a given output or a maximum output produced by a given set of inputs. This approach involves selecting the mix of inputs which produces a given quantity of output at a minimum cost, namely the production frontier.

3.3 The stochastic frontier model

The stochastic frontier production function models were first introduced by Aigner et al. (1977) and Meeusen and Van Den Broek(1977), which is more realistic and in line with the economic theory than the so called average production function. This model assumes that the disturbance term, in the general production function model given below, has two components. That is $\epsilon_i = v_i + u_i$.

$$y_i = f(x; \beta) + \epsilon_i \tag{1}$$

$$y_i = f(x; \beta) + v_i - u_i \tag{2}$$

where $v \sim N(0, \sigma_v^2)$ and $u \sim N_+(0, \sigma_u^2)$ (most common assumption, see below) and y is the amount of output units produced using x input units and β is the parameters to be estimated.

The error component v_i represents the symmetrical disturbance that captures random errors caused outside the firm's control such as measurement errors, random shock, and statistical noise. This component is assumed to be identically and independently distributed as $v_i \sim N(0, \sigma^2)$.
The u_i component of the error term is the asymmetrical term that captures the technical inefficiency of the observations and assumed to be independent of v_i, and also satisfy that $u_i \geq 0$. The non-negative component (u_i) reflects that the output of each firm must be located on or below its frontier (Battese and Broca,1997). If $u = 0$ the firm is 100% efficient, and, if $u > 0$, then there is some inefficiency.

Knowing the range of values that the inefficiency term takes on is not enough. (Battese and Broca,1997) stress the need to make some statistical assumptions on the pattern of the values of this term. The assumption of which distributions the u_i's are following is picked for a variety of reasons, such as ease of use, ease of estimation, level of skewness, number of parameters, etc. Most common distributions are the *Half-Normal* , *Truncated Normal*, *Exponential*, and *the Gamma*. Others have been used but these four dominate the empirical literature.

The central element of the Stochastic Frontier Analysis models rests on the degree of asymmetry of the error term, ϵ, which is the convolution of the two components, v and u in the model. And since we have already made a statistical assumption on the pattern of the normal term v, the observed pattern of ϵ, will tell us the pattern of u. The degree of asymmetry can be represented by the following parameter:

$$\lambda = \frac{\sigma_u}{\sigma_v} \tag{3}$$

The larger λ is, the more pronounced the asymmetry will be. On the other hand, if λ is close to zero, then the symmetric error component dominates the one-side error component in the determination of ϵ_i. Therefore, the complete error term is explained more by the random disturbance v_i than by u, which follows a normal distribution. ϵ_i therefore has a normal distribution.

To estimate the Stochastic frontier analysis models, that is, to determine the values of the unknown parameters β, σ_v^2 and σ_u^2 we will make use of the maximum likelihood principle. That is, we estimate the parameter values as the values that make the observations as likely as possible. To do so, however, we must know the density of the combined error term

$$\epsilon = v - u$$

When the model is estimated to find β, σ_v^2 and σ_u^2, the error term can easily be calculated as

$$\epsilon_i = v_i - u_i = y_i - f(x_i; \hat{\beta})$$

3.4 Normal and half normal distributions

The density function for a single observation of one error term, v, is the normal distribution give as:

$$f(v) = \frac{1}{\sqrt{2\pi\sigma_v^2}} e^{\frac{-1}{2}\frac{v^2}{\sigma_v^2}}$$

$$-\infty < v < \infty$$

and the density for the inefficiency term u is the half–normal distribution, which is the normal distribution truncated at 0.

$$f(u) = \frac{2}{\sqrt{2\pi\sigma_u^2}} e^{\frac{-1}{2}\frac{u^2}{\sigma_u^2}}$$

$$u \geq 0$$

When we look at a single observation $(X; y)$ we can not directly calculate the v and u terms. We can calculate the total error term $\epsilon = v - u$ as $\epsilon = y - f(x : \beta)$. We therefore need to find the distribution function or the density function of ϵ. The total error $\epsilon = v - u$ is the sum of v and $-u$ and therefore the distribution of ϵ is the convolution of the distribution of v and u, and this is given by

$$f(\epsilon) = \frac{\sqrt{2}}{\sqrt{\pi\sigma^2}} \Phi(-\frac{\lambda\epsilon}{\sqrt{\sigma}^2}) e^{\frac{-1}{2}\frac{\epsilon^2}{\sigma^2}}$$

$$-\infty < \epsilon < \infty$$

where as before

$$\sigma^2 = \sigma_v^2 + \sigma_u^2$$

$$\lambda = \sqrt{\frac{\sigma_u^2}{\sigma_v^2}}$$

and Φ is the distribution function of the standard normal distribution.

The two components of the error term are completely characterized by their respective (parameter) variances as their mean is set to zero by assumption. So we say one estimate dominates the other if its parameter is larger than the other. If v dominates u, that is, the variance of v, σ_v^2 , is much larger than the variance of u, σ_u^2 then the distribution of ϵ looks like the distribution of v which is an ordinary normal distribution; . If, on the other hand, u dominates v, then the distribution of ϵ looks like the distribution of u, that is, a truncated normal distribution. Of course, there are intermediate states.

This can be easily seen by the help of Figure 2 through 7 of the three errors' density functions. If the variance of the inefficiency term is very small, that is, λ is close to 0, the density of the inefficiency term u is very narrow as the dashed line in Figure 2. In such cases, it is hard to distinguish between the total error term ϵ and the normal error term v, the bold line and the

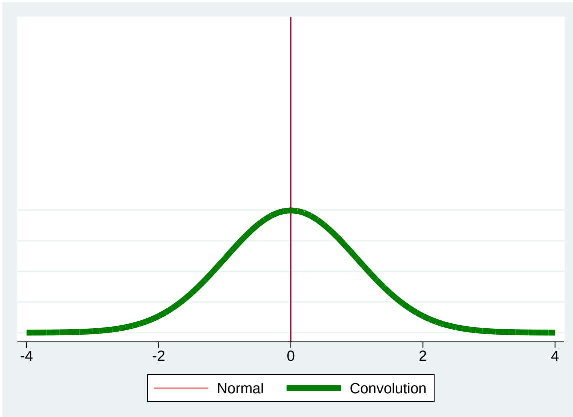

Figure 2: Normal distribution with no inefficiency ($\sigma_v^2 = 1, \sigma_u^2 = 0, \lambda = 0, \sigma^2 = 1$)

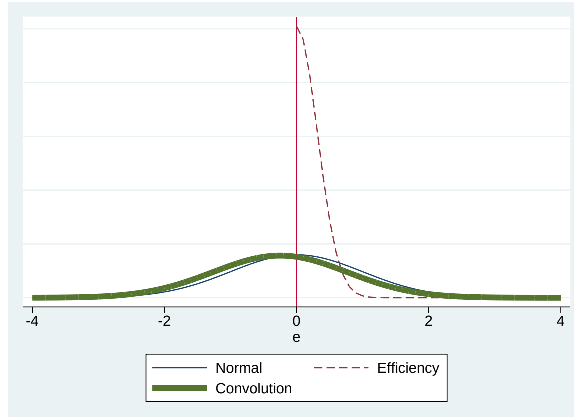

Figure 3: Normal distr with very little inefficiency ($\sigma_v^2 = 1, \sigma_u^2 = 0.1, \lambda = 0.3, \sigma^2 = 1.1$)

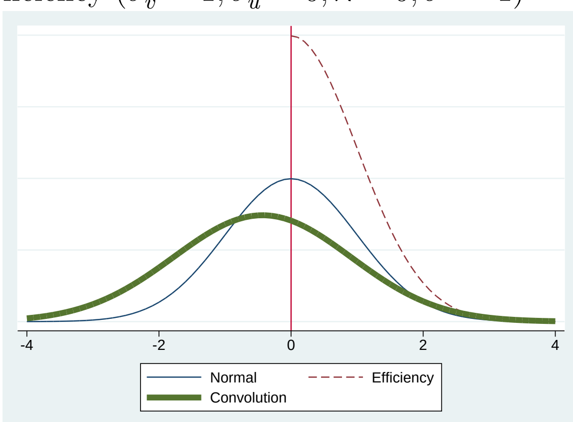

Figure 4: Normal distribution with little inefficiency ($\sigma_v^2 = 1, \sigma_u^2 = 1, \lambda = 1, \sigma^2 = 2$)

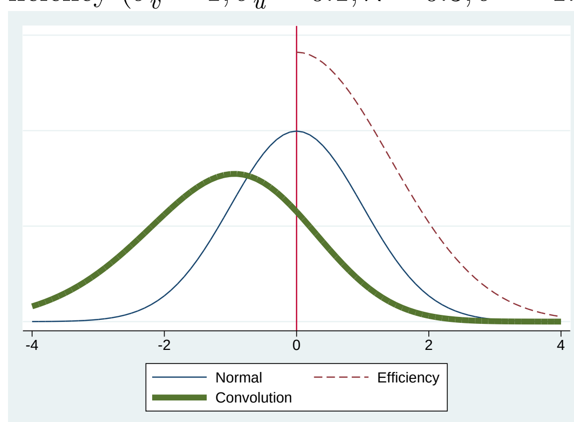

Figure 5: Normal distribution with some efficiency ($\sigma_v^2 = 1, \sigma_u^2 = 2, \lambda = 1.4, \sigma^2 = 3$)

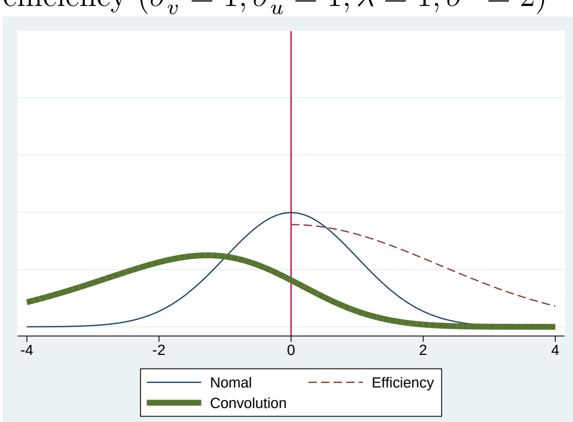

Figure 6: Normal distribution with high inefficiency ($\sigma_v^2 = 1, \sigma_u^2 = 5, \lambda = 2.2, \sigma^2 = 6$)

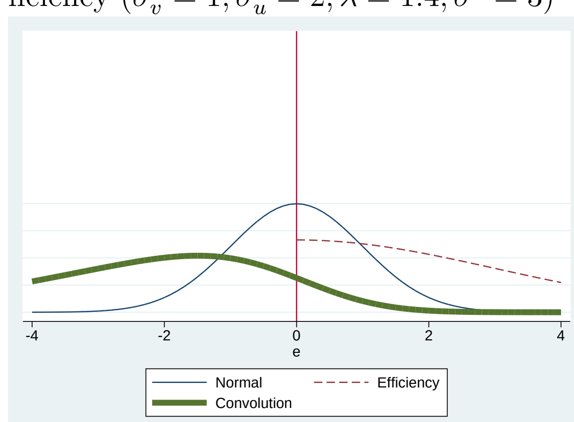

Figure 7: Normal distribution with very high inefficiecy ($\sigma_v^2 = 1, \sigma_u^2 = 9, \lambda = 3, \sigma^2 = 10$)

normal line are almost identical in this figure. When $\sigma_u^2 = 0$ and therefore $\lambda = 0$, we have the ordinary regression case with error terms like the plot in Figure 2.

When the variance for the inefficiency term u is positive, it follows a half-normal distribution on the positive part, which is shown as the dashed line in the plots in Figure 3 to Figure 7. The normal part is the full line, and the total error, that is, the normal error minus the efficiency term, is shown as the bold line. When the variance of the inefficiency term is getting larger relative to the variance of the normal error term, that is, λ gets bigger, the density of the total error term is broader and skewed to the negative part. This is shown in the plots in Figure 3 to Figure 7. λ is large implies that u is dominating, and it is becoming most of the error term is due to differences in efficiency.

When we look at the combined error terms, we can say that a more skewed distribution indicates a greater degree to which the efficiency term dominates the normal error term. This explains how we can actually estimate the two error terms, even though they do seem to be unidentified in Equation 1

3.5 Firm specific efficiency

So far, we have focused on the estimation of the functional form and whether the deviations from the production function can be decomposed into noise and inefficiency. We have not, however, analyzed the efficiency of individual firms, which,after all, is the major concern of this study. Let us now turn in to how firm specific efficiency can be estimated. Technical efficiency is measured as the ratio of actual production to potential production. Using the models in the stochastic frontier analysis it can be written as;

$$TE_i = \frac{ActualProduction}{PotentialProduction} = \frac{f(x_i;\beta) + v_i - u_i}{f(x_i;\beta) + v_i} \tag{4}$$

where all the variables are in logarithmic form. If it is raised to e and simplifying it we will get;

$$TE_i = \frac{e^{f(x_i;\beta)+v_i-u_i}}{e^{f(x_i;\beta)+v_i}} \tag{5}$$

$$TE_i = e^{-u_i} \tag{6}$$

The above equation requires us to get an estimate of u_i for each farm in the sample. And this needs a bit more mathematical manipulation as it is not directly observed from the model. Rather it is embedded in the combined error term ϵ.

The estimate of ϵ_i does carry some information about u_i. If $\epsilon_i > 0$, then chances are that u_i is not very large, as $E(v_i) = 0$, suggesting that technology i is relatively efficient. If, on the other hand, $\epsilon_i < 0$, then u_i will tend to be large, suggesting that technology i is relatively inefficient. This tells us that the estimate of the (unobserved) efficiency term, u_i depends of the the (observed) error term ϵ_i.

We will therefore look at the conditional distribution of u_i given ϵ_i and use the conditional expectation $E(u_i/\epsilon_i)$ as an estimator of u_i. The joint density of v_i and u_i is the product of the individual densities, as they are independent $f_{v,u}(v,u) = f_v(v)f_u(u)$ Substituting $\epsilon + u$ for v we get $f_{\epsilon,u}(\epsilon,u) = f_v(\epsilon + u)f_u(u)$.

Therefore, using Bayes' theorem, the conditional density of u given ϵ is;

$$f(u/\epsilon) = \frac{f_v(\epsilon + u)f_u(u)}{f_\epsilon(\epsilon)}$$

Here recall that the functional forms f_v, f_u and f_ϵ are as assumed at the beginning. That is they are, respectively distributed as Normal, Half Normal and the Convolution of the two. Using this assumption and after some algebraic manipulation one can arrive at

$$E(u/\epsilon) = \mu_* + \sigma_* \frac{\phi(\mu_*/\sigma_*)}{\Phi(\mu_*/\sigma_*)}, \tag{7}$$

where

$$\mu_* = -\epsilon \frac{\sigma_u^2}{\sigma^2} = -\epsilon \frac{\lambda^2}{1+\lambda^2} = -\epsilon\gamma$$

$$\sigma_* = \sqrt{\frac{\sigma_u^2 \sigma_v^2}{\sigma^2}} = \sigma \frac{\lambda}{1+\lambda^2} = \sqrt{\gamma(1-\gamma)\sigma^2}$$

and $\phi(.)$ is the density function, and $\Phi(.)$ the cumulative distribution function of a standard normal distribution. When we substitute the estimated values for ϵ, σ^2, and λ then we have an estimate of u conditioned on the estimate of ϵ. We, thus now get an estimate of TE.

3.6 The Logit Model

Once the existence of inefficiency is identified it gives sound to look for factors that are potential sources of it as these are the most important tools for policy makers to take relevant measures. To find out these factors the ordered logit model is an option to use.

Given a dependent variable, say y (where, in our case threshold levels), taking a state value of being in one the k possibilities where this possibilities are ordinal in nature, the basic ordered logit model will have the form:

$$logit(p_1) = log(\frac{p_1}{1-p_1}) = \beta X \tag{8}$$

$$logit(p_1+p_2) = log(\frac{p_1+p_2}{1-p_1-p_2}) = \beta X \tag{9}$$

$$logit(p_1+p_2+p_3) = log(\frac{p_1+p_2+p_3}{1-p_1-p_2-p_3}) = \beta X \tag{10}$$

and

$$p_1 + p_2 + p_3 = 1 \tag{11}$$

Here the p_i's are the probabilities of being in one of the ordered events of the dependent variable and the the β's are the vector parameters to be estimated (using the maximum likely hood method) and the X's are the vector of variables that are proposed to influence the probability of being in one of those ordered dependent variable.

This model is known as the proportional-odds model because the odds ratio of the event is independent of each category. The odds ratio is assumed to be constant for all categories.

This paper classifies the levels of inefficiency in to three groups as *efficient*, *average efficiency* and *inefficient* by splitting the different levels of inefficiencies obtained from the analysis at two cut off points . And this different levels of inefficiency are tested if it can be explained by a number of socio-economic, demographic and other farm characteristic variables included on the right side of the model.

4 Results and Discussion

Table 4: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Yield obtained (Kg/hectare)	10228.36	10613.07	549.45	46000	54
labor invested (in mandays)	1597.8	1042.52	309.07	6200	54
Plot size (in m^2)	135.88	45.07	50	272	54
Cost of seeds (Eth Birr)	74.78	50.1	20	250	54
Cost of fertilizer (Eth Birr)	0.32	0.23	0	0.9	54
Oxen cost (Eth Birr)	17.59	7.99	3.6	39.96	54
Highest education of the head	2.99	3.73	0	15	272
Age of the head	22.03	15.66	1	70	272
Land holding (hectares)	1.38	0.82	0.25	3.25	54
Livestock holding (TLU)	5.14	3.26	0.1	16.12	54
Irrigation experience (in years)	2.8	3.39	0	12	54
Distance to the nearest market (hours spent)	1.4	0.79	0.5	5	54
Income from non-farm activities (Eth Birr)	1455.08	8341.49	0	61000	54
Income from farm activities (Eth Birr)	29914.54	40017.23	100	278450	54
Family size	5.46	1.99	1	10	54

4.1 Data description and analysis result

The variables of interest are presented in the summary statistics table below. The experimental plots where the crop is cultivated is as small as 135 meter squares on average. As one of the objectives of the intervention was environmental concern ground and surface water monitoring is easy for small plots. It was also difficult to find farmers who have larger sized farms next to their water source to provide for the experiment.

Tomato, onion and elephant grass were the crops cultivated. The yield obtained varies between the different sites, gender, water lifting technology used and across the types of crop cultivated. Hybrid seed has been used for tomato cultivation and local seed for onion. Though the hybrid seed is expensive as it is brought abroad the total cost is observed to be higher for tomato producers (2077 birr/hectare) than onion producers(8505 birr/hectare)

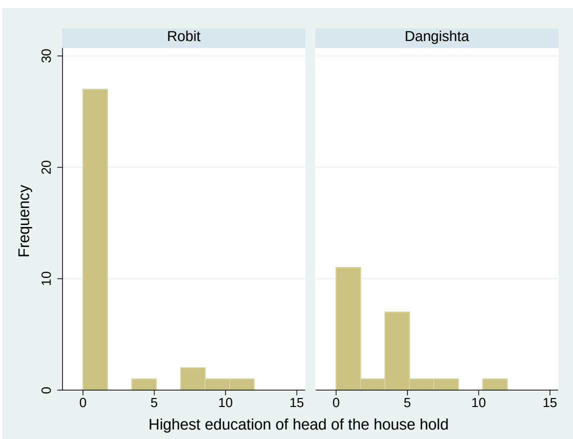

Figure 8: Schooling in years

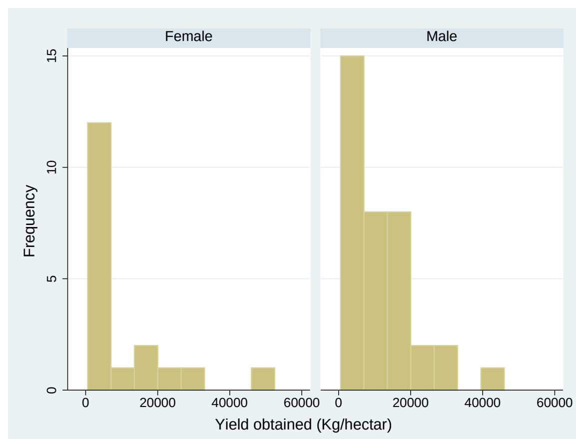

Figure 9: Yield in Kg/hectare

An important socio-economic variable which affects the lives of individuals and society's well being is education. As is the case in the rural areas of the country, the educational attainment level of the farmers under the experiment is as low as 2 years of schooling on average. About 84% of the Robit farmers and 50% of Dangishita farmers are totally illiterate. Dangishita beneficiaries are relatively better educated having an average of about 5 years of schooling.

Farmers who cultivated onion produced not only much below the standard yield (FAO 200 quintals/hectar) level but also less than those who chose to cultivate tomato. This is most likely attributed to the fact that onion producing farmers had no any irrigation experience before as compared to the other group who had been using irrigation for the last decade. The lower education level observed have also played its role in making them unable to invest their scarce resources in a way that they can achieve the maximum attainable production.

Onion producing farmers had used their technology and labor unwisely. The labor to yield ratio observed is much higher than was required in the standard agronomic requirement of the crop comparing it to the tomato crop.

One of the ways that the gender imbalance can be reflected is through education that a woman attains and the income she earns. As it is the case in most of the Ethiopian rural households, their schooling and income differentials is very significant (0.88 school years for females , 2.33 school years for males and 410 birr/year for females, 1978 birr/year for males respectively.)

The proximity to market access in fact has got a lot to do when it comes to non-farm income activities as it is explained by the farmers in the two sites 2455 birr/year for robit farmers and no at all for dangishita farmers. It also helped them a lot in making available alternative cropping options such as chat which generates more income, most demanded in the nearest urban areas and harvested repeatedly through out the year. As the result these farmers are richer than those who are a bit far from town.

The population data is used for anlysing the efficinency of the farms under the experiment. The SFA model assumes the Cob Douglas production function. And the result is presented below in table. The model fitted is

$$Yield = f(Labor, Capital)$$

where in its logarithm transformation and the substitution of all labor and capital components takes the form

$lnYield = \beta_0 + \beta_2 lnplotsize + \beta_1 lnlabour + \beta_4 lnferti + \beta_3 lnseedcost + \beta_5 lnoxco + \beta_6 Age + \beta_7 eduhh + \beta_8 Gender + \beta_9 croptype + \beta_{10} technontype + v - u$

where

Yield–the amount of yield obtained in Kg Labor – the amount of labor invested in mandays

landhlding – the amount of land holding of a farmer in hectares

plotsize – the size of the plot allotted to the experiment in hectares

seedcost – the cost of seeds used in Birr

ferti – ferilizer applied in Kg

oxco – Cost spent for ploughing using oxen in Birr

eduhh – schooling in years of head of the household

Croptype–type of crop cultivated

technotype–type of water lifting technology installed Age–age of the household

Gender–sex of head of the household

The main interest of fitting the above production function is to find an estimate for the parameter u which is σ_u^2. The variance of u is estimated from the above model using SFA to be 0.23. The Normal-Half normal model has been employed and tested for its adequacy using BIC. The estimates of the term u is then obtained using equation 7 for each and every farm. Finally the required estimates of the efficiency term is computed based on definition presented above in equations 4 through 6. The results from the SFA model indicates that there are farmers who are suffering form

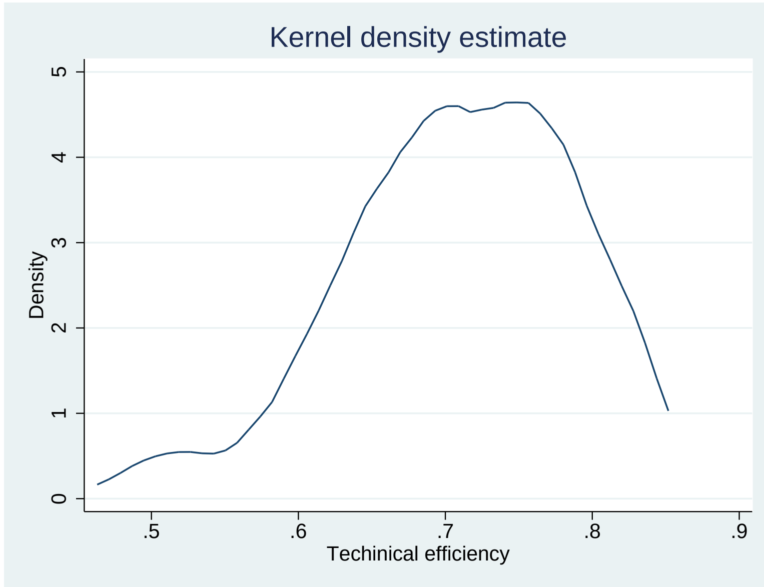

Figure 10: Kernel density estimates of TE

inefficiency levels as low as 51%. It is easily seen that production can be doubled for some farmers though the average technical efficiency level is about 70%. Figure 4.1 shows the distribution of the efficiency level.

It indicates the existence of a significant room for improvement of about 30%. Before looking in to advancements in technology it pays for us to manage resources in a way that can provide us a significant amount of production. From the literature reviewed in is not surprising to see farmers who are at a very lower efficiency level in the rural community. It has been argued by many researchers that it is an inherent problem and can not be removed at all.

For Rope-and- washer users the severity of inefficiency is higher than farmers who chose to use pulley. This is due to the intensive labor and technical skill requirement of the technology. This problem is even more sevier for robit farmers as the opportunity cost of labor is higher. Farmers in Dangishita apply their labor expecting the additional income from irrigation which the never of very rarely do it before.

Women headed households appear to have slightly lower efficiency level. The even performed better in the production of irrigated fodder. The fact that animal feeding is a difficult task for women and the used the opportunity of irrigated fodder as the option to use it at its best.

Table 5: Efficiency for vegatable farmers

Gender	mean	sd	min	max	N
Female	.68	.07	.53	.81	13
Male	.71	.08	.49	.82	26
Total	.70	.08	.49	.82	39

Table 6: Efficiency of robit farmers by gender

Gender	mean	sd	min	max	N
Female	.70	.08	.53	.80	10
Male	.72	.06	.61	.82	22
Total	.71	.07	.53	.82	32

Table 7: Efficency of robit farmers by technology

Tech	mean	sd	min	max	N
Pulley	.73	.06	.60	.82	20
R&W	.68	.07	.53	.81	12
Total	.71	.07	.53	.82	32

Table 8: Efficency of Dangila farmers

Tech	mean	sd	min	max	N
Pulley	.65	.07	.49	.74	11
R&w	.73	.06	.60	.81	11
Total	.69	.08	.49	.81	22

The ordered logit model (proportional odds model) result indicated the existence of some policy manipulation tools to achieve a desirable level of efficiency. Table 9 shows the coefficients of the regression output and the odds ratio for the variable included in the model.

The odds of being in a higher efficiency level is increases by about 13% for male headed households and married household found to have 1.2 times more odds of being in a high efficiency level as compared to non-married farmers in the involved in the project.

Table 9: Ordinal Logistic Rregression Table

Variables	Coefficients	Odds Ratio	p-value
Size of the family	0.00864	1.009	0.0019
Highest education of head of the house hold	0.0546	1.056	0.031
Age of head of the house hold	0.005	1.004	0.049
Type of crop cultivated	0.170	1.18	0.042
Type of irrigation technology installed	0.180	1.20	0.005
The size of the plot allotted for the experiment	0.005	1.00	0.002
Sex of head of the house hold	0.128	1.14	0.002
Distance to market	0.0318	1.03	0.044
Marital status of the house hold head	0.169	1.18	0.12
Income obtained from non-farm activities in 2006	0.00000527	1.00	0.049
cut1	-0.887		
cut2	1.281		

The choice of technology also matters as to how much efficiency to achieve. All the farmers in Robit Bata kebele who took rope-and washer water lifting technology requested us to uninstall it all for the coming irrigation season. Labor is very expensive in this kebele as compared to Dangishit where they still tolerate to irrigate using Rope-and-Washer. Thus Choosing appropriate technology for could have a significant implication towards improving the lives of farmers.

Age is a variable included to estimate the impact on efficiency. It is believed that age can serve as a proxy for farming experience. Hence the larger the age, the greater the farming experience the farmer has. The expectation is supported by a positive coefficient for this variable as is the case in most of the literature reviewed in this paper.

The variable education which serves as a proxy for managerial input is also hypothesized to affect efficiency. Higher level of efficiency may lead to better assessment of the importance and complexities of good farming decision, including efficient use of inputs. In addition to age which is a proxy for farming experience, education enhance a farmer's ability to seek, decipher and make good use of information about production inputs As the result of intensive support provided by the project the impact of education and the levels of income they got from farm activities seem to have economically insignificant effects on the efficiency levels.

Male-headed households, it is hypothesized, will take care to use their production inputs efficiently. This is so because Females in the rural community takes all the burdens of the family caring which puts significantly huge pressure apart from the farm activities. The estimated value of this variable is positive suggesting strengthening the hypothesis.

5 Conclusions and Recommendations

5.1 Conclusions

The central theme of this study was that efficient utilization of resources enhances productivity of irrigated farms.The research questions: are the farmers efficient? and what are the causes for inefficiency? were the stepping stones for this study. If inefficiencies exist, then increasing the efficiency level would be an effective means of increasing production. But, if farmers are efficient in utilizing the available resources with the existing technology, then there is a need to introduce new technologies so as to improve productivity.

The paper analyzed the level of efficiency of farmers (using population data) who are under the ILSSI project cultivating irrigated vegetables and fodder. to detect where the inefficiencies exist and what the possible sources are.

Following many of the previous empirical works, stochastic frontier production was employed to analyze the data. This method was used for its better ability to detect the level of efficiency through decomposing the error term into random noise and inefficiency effect.

The findings of the study generally indicated that the irrigated farms under study are suffering from series inefficiency in their agricultural practices. Those farmers who operated Rope & Washer water lifting technology were even more inefficient; hence, improving productivity requires better utilization of resource before looking for introduction of new technology.

On the other hand, female headed farmers are less efficient urging for strong affirmative actions in our rural communities for increased farm products.

5.2 Policy Recommendations

The most important policy implications drawn from this study include, among others, first increasing the productivity of farmers operating these two water lifting technologies is possible through improving their level of technical efficiency. This may be done through providing continuous technical and managerial skills to farmers. It is also possible to make them able to produce twice each dry season irrigation farming. Second, continuous professional support in identifying the right cross combination of crop type and technology with sex and other socio economic variables pays a lot towards increased production. Thirdly, farmers with less irrigation experience can increase their productivity if they can acquire the skill from experienced farmers, and this may be accomplished through arranging farmers' field days.

To help women get out from the multi-diamentional problem they are in, all rounded support is paying towards gender mainstreaming. The inefficient problem of women can be addressed when an attempt is done to bring them to the front in all spheres of the community's activity. Further expansion of production then might need introduction of new technologies.

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