EXAMINING THE INVERSE RELATIONSHIP BETWEEN FARM SIZE AND EFFICIENCY IN TANZANIAN AGRICULTURE

HAJI ATHUMANI MSANGI

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ABSTRACT

Agricultural sector in Tanzania and elsewhere in sub-Saharan Africa is dominated by smallholder farmers. This has made the smallholder-led growth strategy to be widely accepted as the pathway for achieving economic transformation and mass poverty reduction in Africa. Recently, however, concerns have been raised on the validity of favouring small farmers because small-scale farming in Africa has historically provided very low returns to labour. Also unlike earlier findings of the inverse relationship between farm size and efficiency, findings of recent studies have provided mixed findings which are not conclusive. This study was carried out to examine the Inverse Relationship (IR) between farm size and efficiency in Tanzanian Agriculture using National Panel Survey (NPS) data for 2008/09, 2010/11and 2012/2013. Specifically, the study intended to:(i) determine the average and farmer's level of technical efficiency, land and labour productivity; (ii) determine the relationship between farm size and three measures of efficiency (technical efficiency, land and labour productivities) and; (iii) identify factors other than farm size which influence farmer's technical efficiency and productivity. The study employed the Two-Step-OLS Regression technique in determining the relationship between farm size and the three measures of efficiency. The findings confirmed the presence of inverse relationship between farm size and the three measures of efficiency that were used in the study. However, when controlling for soil quality the strength of the inverse relationship between farm size and technical efficiency decreased from 0.50% to 0.34%. Similarly, when GPS data were used instead of farmer reported data, the strength of the inverse relationship between farm size and efficiency decreased from 0.51% to 0.47%. Apart from farm size, other factors found to have a significant positive influence on efficiency were farming experience, irrigation, use of fertilizer, household size and intercropping. Basing on the major findings of the study, the following are recommended: Firstly, the success of industrialization and inclusive growth in Tanzania depends on how effective are the agricultural and land policies, the study further recommends the use of GPS technology especially in large household surveys because it improves the accuracy of various analyses involving land variables. Secondly, since use of fertilizer and irrigation water have significant positive influence on efficiency, the study recommends that agricultural policies that consider sustainable use of fertilizer and irrigation water among smallholder farmers should be promoted in order to improve agricultural productivity particularly now when the government is promoting industrialization. Improvement of agricultural productivity is paramount for agro-based industries that will require raw materials and surplus labour from the agricultural sector.

DECLARATION

I, **HAJI ATHUMANI MSANGI** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

____________________________ ______________________

Haji Athumani Msangi **Date**

(MSc. Candidate)

The above declaration is confirmed by;

____________________________ ______________________

Prof. Ntengua S. Y. Mdoe **Date**

(Supervisor)

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DEDICATION

This valuable work is dedicated to my beloved mother Alia Msangi who laid down the foundation of my education which made me to be the person I am today.

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LIST OF ABREVIATIONS

AERC	African Economic Research Consortium
ASDP	Agricultural Sector Development Programme
DEA	Data Envelopment Analysis
FAO	Food and Agriculture Organization of the United Nations
GPS	Global Positioning System
ha	Hectare(s)
IR	Inverse Relationship
Kg	Kilogram
LP	Linear Programming
LR	Likelihood Ratio
MLE	Maximum Likelihood Estimation
NBS	National Bureau of Statistics
NPS	National Panel Survey
OLS	Ordinary Least Squares
SFA	Stochastic Frontier Approach
SPSS	Statistical Package for Social Science
T.E	Technical Efficiency
TZS	Tanzanian Shilling(s)
URT	United Republic of Tanzania

CHAPTER ONE

1 0 INTRODUCTION

1.1 Background

Smallholder farmers comprise the majority of farmers in Tanzania and other developing nations (World Bank, 2014). In these countries, most (about 80%) of the food consumed at home and supplied to the markets originates from the smallholder farmers (McMillan *et al.,* 2014). Owing to this significant contribution it has been a conventional wisdom that a smallholder-led growth strategy would be the best approach for agricultural and economic transformation with an ultimate goal of poverty alleviation in Tanzania and other African countries. However, like other African countries Tanzania has failed to cope with the Green Revolution Technologies.[PYM1] Like other African nations, Tanzanian farmers majority of which are smallholder farmers have been experiencing low agricultural productivity. The evidence from recent URT report indicates that the Agricultural Sector Development Programme (ASDP)'s targets of increasing agricultural productivity have not been achieved as shown in Tables 1 and 2. This low agricultural productivity has resulted into the sluggish growth of per capita food production, leading to increased food insecurity (UTR, 2014). Consequently, most of smallholder farmers in Tanzania and Africa as whole have been struggling in quest of better ways of improving their livelihoods. This has compelled most of them to diversify into off-farm activities or completely refraining from farming activities (Babatunde, 2015).

Table 1: ASDP targets and actual yields for the major crops in Tanzania

Crop	Yield (Kg/ha)		Gap (%)
	Targets	Achieved	
Cassava	7577.88	5684.20	33.31
Maize	1574.50	1175.00	34.00
Sweet potatoes	6420.45	4592.60	39.80
Sugar cane	147100.00	100000.00	47.10
Rice, paddy	2738.55	2088.90	31.10
Potatoes	10177.18	7428.60	37.00
Banana	4299.90	3300.00	30.30
Beans, dry	1284.44	884.60	45.20
Sunflower seed	1926.62	1337.00	44.10
Sorghum	1330.66	944.40	40.90
Groundnuts, with shells	1475.57	1060.80	39.10
Cotton	1699.10	1300.00	30.70

Source: URT (2014)

Table 2: ASDP targets and actual yields for livestock and fishery products in Tanzania

Target Livestock Product	Production Quantity (Tonnes)		Gap (%)
	Targets	Achieved	
Meat + (Total)	589170	410000	43.7
Fish, Seafood	513732	372000	38.1
Milk - Excluding Butter	2587647	1847000	40.1
Eggs	45696	34000	34.4

Source: URT (2014)

The low agricultural productivity and the desire for smallholder farmers to diversify with non-farm activities or completely refraining from farming, has recently made some researchers to question the viability of a smallholder-led growth strategy in Tanzania

(Chen *et al.*, 2009; Jayne *et al.*, 2014; Dercon and Collin, 2014; Dawson *et al.*, 2016; Cuevas and Anderson, 2016).

Despite the low productivity among smallholder farmers in Africa, there is substantial empirical evidence that smallholder farmers in Africa are more efficient than large scale farmers. This argument became a stylized fact of rural development and attracted the interest of researchers after Sen (1962) who observed an inverse relationship (IR) between farm size and output per hectare in Indian agriculture, suggesting that small scale farmers are relatively more efficient than large scale farmers. Several further studies, since then, have been undertaken to test this argument. The study by Sen (1966) on the IR between farm size and productivity concluded that smaller farms were more productive. Zyl *et al.* (1995) in their study on the relationship between farm size and efficiency in South African Agriculture concluded that there was an IR between farm size and efficiency despite the history of South Africa's agricultural policies discriminating in favour of large scale mechanized farmers, the IR became stronger and even more accentuated as these policy distortions were removed. Similar conclusion in favour of small farmers was drawn in several other studies (Adesina *et al.*, 1996; Irz and Stevenson, 2014; Muyanga and Jayne, 2016; Mazumdar, 1965; Rosset, 1999; Thapa, 2007).

The explanations for the IR between farm size and efficiency are more or less the same between different studies. The first explanation is related to imperfections in the factor markets especially the markets for land, insurance, credit and labour. The failure or absence of these markets leads to suboptimal allocation of resources at farm level which in turn deters productivity. The labour market imperfections results into inefficiencies due to its cost implications on high labour supervision, as hired labour is said to be less motivated and ineffective which, in turn, requires more productive part of family labour to supervise hired labour (Cuevas and Anderson, 2016). This reduces the overall productivity of labour at farm level. Therefore, the IR exists because majority of small scale farmers use family labour which make them relatively more productive due to relative cost effective advantage. For example, the use of family labour reduces the monitoring and supervision costs as compared to the use of hired labour by most large scale farmers. In that regard, many incentive associated problems could be minimized with the use of family labour. The second explanation for IR between farm size and productivity is that, small farmers till their land more intensively with higher degree of diversification which results into higher returns per hectare in a year relative to large scale farmers whose majority depends only on one or two crops per year (Thapa, 2007). The third explanation is related to the relative scarcity of labour and land. Where the land is scarcer than labour which is actually the case in most developing countries then small scale farmers become more efficient relative to large scale farmers (Cuevas and Anderson, 2016). However, this argument could only be valid in the short term because as the country grows the labour becomes more expensive which in turn weaken the viability of small farms. Other arguments in favour of IR between farm size and productivity is related to higher land conservation efforts devoted by small farmer to their farms (Byiringiro and Reardon, 1996).

Despite a plethora of studies favouring the IR between farm size and efficiency, the findings are still inconclusive due to a number of studies that have been cited in dissent of this inverse relationship in many countries especially developed countries. The first argument advanced against this stylized fact of the IR between farm size and efficiency is related to the presumed existence of economies of scale (Binswanger and Rosenzweig, 1997). Despite the fact that analyses indicate that the empirical evidence for existence of scale economies in agricultural production is very weak, the overall conclusion of researchers on economies of scale in agriculture is that they do not exist, except for very special situations (Kumar *et al.*, 2015). A recent study by World Bank asserts that the most important possible source of economies of scale in agricultural production arises from lumpy inputs (Ali and Deininger, 2014). Complex farm implements and machinery such as combine harvesters, threshers, tractors, harrowers and motorized sprayers are all lumpy inputs which in fact attain their least per unit cost of operation when used to relatively large areas. With the introduction of agricultural mechanization, it was believed that the economies of scale associated with mechanization would be so large that the family farming would become outdated. The argument was that smallholder farmers would not be able to meet the expenses of the relatively efficient but expensive equipment (Keslev and Peterson, 1982). In some cases, however, small farmers can rent or hire machinery to circumvent the benefits of economies of large scale farming associated with holding such expensive farming equipment.

Another key argument against the IR studies includes mis-specification issues (Bhalla and Roy, 1988). The main reason advanced under this argument is that due to its measurement difficulties, most researchers ignore the unobservable effect of soil quality aspects on agricultural efficiency, that is, the IR between farm size and efficiency could be attributable to the differences in soil quality aspects such as soil fertility and agro-ecological zones. The omission of these variables from the estimated equation may lead to biased coefficients which may in turn strengthen and overstate this IR. However, the study by Barret (2010) concluded that the soil quality is not a cause of this IR. Also, other researchers such as Bhalla and Roy (1988) concluded that the IR could not occur if the factor markets were efficient and well-functioning (Bhalla and Roy, 1988). This could explain why most of studies favouring inverse relationship are from developing countries where the factor markets are highly imperfect. The third argument against IR is that the IR between farm size and efficiency remain existent in traditional agriculture which is always the case in most developing countries and that is why most of studies which supported the IR hypothesis are from developing countries where agricultural is mostly traditional and subsistent. A study by Thapa (2007) indicates that the earlier adoption of agricultural technologies by large scale farmers weaken and may even invalidate the IR argument. This has been proven by most of studies done in areas with high rates of adoption of agricultural technologies (Bangladesh, China and Peru) where the IR argument had been rejected (Chen *et al.*, 2009). On the other hand, rapid changes in agricultural technologies and development of high level of commercialized farming have changed this fact in favour of small farmers. This has led into declining of the IR over time due to the fact that the transformation from local to modern farming practices associated with adoption of capital intensive technologies such as use of machines and industrial fertilizers and chemicals for improvement of agricultural productivity has a cost implication. In that regard, most small farmers cannot manage to afford purchasing these modern inputs and therefore, fail to compete with large farmers.

1.2 Statement of the Problem and Justification

The importance of enhancing agricultural productivity is critical for increasing rural incomes ensuring economic growth, boosting industrial development, improving food and nutrition security and reducing poverty in Tanzania where the population is projected to grow to more than double the 2012 population census figure of 49.08million by 2050 (NBS, 2014). This rapid population growth will obviously exert pressure on agricultural land hence reducing the land holding size per household. As land holding declines, sustenance of farm income, food security and livelihoods as a whole will depend on increasing land productivity through application of modern farming technologies such as improved seeds and fertilizers which is currently limited by several factors including lack of credit, farmers’ education level, inadequate extension services, limited irrigation water supply and limited access to information (Nkonya *et al.*, 1997; Kaliba *et al.*, 2000; Shiferaw *et al.*, 2008; Kassie *et al.*, 2013; Ndah *et al.*, 2015). In an attempt to promote use of improved technologies to improve agricultural productivity, agricultural policy makers have implemented a range of alternatives such as reform of the prevalent land policies and subsidization of modern farming technologies such as seeds and industrial fertilizers among smallholder farmers (Salami *et al.*, 2010; Ndah *et al.*, 2015) .

The policy support to smallholder farmers in Tanzania is not only based on the experience from Asia that has made the smallholder-led growth strategy to be widely accepted as the pathway for achieving economic transformation and mass poverty reduction but also because smallholder farmers constitute the majority of farms in these countries. Furthermore, earlier empirical research findings on the relationship between farm size and productivity have shown that small farms are relatively more productive than large farms, implying IR between farm size and productivity (Adesina *et al.*, 1996; Irz and Stevenson, 2014; Muyanga and Jayne, 2016; Thapa, 2007). The earlier empirical research findings have renewed interest in the Inverse Farm Size-Efficiency Relationship (IR) among development economists. The increasing interest in testing the validity of IR has made the IR to remain inconclusive due to some findings reporting positive relationship between farm size and efficiency (Binswanger and Rosenzweig, 1997; Ali and Deininger, 2014; Kumar *et al.*, 2015). In this regard, further testing of the IR in different situations is necessary to obtain results that can appropriately guide land reform and agricultural policies. Also, further empirical studies to test the IR hypothesis take on even greater policy importance in light of recent concerns on the viability and even the objectives of promoting small-scale agriculture in Africa. For example the study by Collier and Dercon (2014) contend that "favouring small farmers is romantic but unhelpful". Therefore, more research is required to broaden the understanding on the farm size-efficiency relationship in order to appropriately advice the policy makers on developing effective Agricultural and land policy instruments to increase agricultural productivity. Also, good understanding of the farm size-efficiency and productivity relationship will enable farmers to make well informed and optimal production decisions which, in line with good policies, will enable them improve their productivity and hence achieve food security and create surplus for trade. Msuya *et al.* (2008) recommended that “Further analysis on farm size-efficiency analyses should be done in Tanzania to broaden the understanding of efficiency in agriculture so that the appropriate policy interventions could be recommended for agricultural efficiency improvement.

Apart from the aforementioned, most studies on testing the IR hypothesis have used small ranges of farm sizes, between 0 and 10 hectares (Muyanga and Jayne, 2016). According to Jayne *et al.* (2014) and other empirical studies (Binswanger and Mclntire, 2009: Obeng-Odoom, 2012: Muyanga and Jayne, 2016) asserts that “Most recent land reforms in Africa involve the re-distribution of the farms sizes ranging between 5 and 100 hectares”. In that regard, testing of the IR over a small range of farm size and under only one crop cannot provide findings that appropriately inform policy decisions regarding allocation of available land to achieve high productivity. In an attempt to address this particular concern, this study examined the relationship between farm size and efficiency over a wider range of farm sizes. Furthermore, most of the previous studies on IR have used physical units of output in measuring productivity (Sen, 1962; Masterson, 2007 and Msuya *et al.,* 2008). This approach essentially looks at what farmers harvest at the end of the production season and ignores the cost of production which is an important factor to consider when measuring productivity. For example, a farmer may have higher physical output per hectare relative to others and hence considered to be more productive which may not necessarily be true when taking into account the cost incurred to produce that output. Therefore, the use of gross value of output in measuring productivity makes very little or no sense when used to compare productivity across farmers, crops and regions.

Some recent studies such as Gucheng Li *et al.* (2013) and Dercon (2014) have tried to address this problem by considering the value of output instead of using the physical units of output in measuring productivity. However, most of these studies have only used the gross value of output and ignore the cost of production in measuring productivity.

Ignoring production cost makes this approach inadequately address the problem because relatively high gross value of output per acre, may not necessarily indicate higher productivity since the cost of production may be extremely high. Some recent studies such as Stevenson (2014) and Cuevas and Anderson (2016) have tried to address this challenge by accounting for production cost when measuring efficiency. However, majority of these studies focus on variable costs of production and ignored the fixed cost in estimating production cost as a result these studies tend to overstate the efficiency of farmers with high level of fixed cost of labour and land (Muyanga and Jayne, 2016). It is, therefore, plausible to think of productivity measures that account for production costs and incorporate both variable and fixed costs in estimating production costs. As an attempt to address this challenge, this study used the Net value of output in measuring productivity such as Net value of output per acre as a measure of land productivity and Net value of output per unit of labour as a measure of labour productivity. The study incorporates both variable and fixed cost of production and, therefore, avoiding the problem of overstating the efficiency of those farmers with higher level of fixed cost of production

1.3 Objectives of the Study

1.3.1 Overall objective

The overall objective of the study is to examine the inverse relationship between farm size and efficiency in agricultural production in Tanzania.

1.3.2 The Specific objectives of this study are:

i. To determine farmers' level of technical efficiency, land and labour productivity in agricultural production

ii. To determine the relationship between farm size and various measures of efficiency (technical efficiency, land productivity and labour productivity)

iii. To identify factors other than farm size which influence farmers' technical efficiency and productivity

1.4 Study Hypotheses

H_0: Farmers are not productively and technically efficient in agricultural production.

H_0: Farm size has no influence on productivity and technical efficiency in agricultural production.

H_0: Factors other than farm size have no influence on farm production efficiency.

CHAPTER TWO

2. 0 LITERATURE REVIEW

2.1 Theoretical Framework

Theoretically this study is informed by the theory of the firm (production) with the main assumption that producers/firms are rational and aim at maximizing profit. By definition, production is the transformation of goods and services (raw materials) into finished products of value and this is applied to every production process (Oyewo *et al.,* 2009). Since the sole purpose of existence of the firms is making rational production decisions in favour of profit maximization, they strive to maximize their objective with minimum effort, this is technically known as efficiency. On the other hand, efficiency is the act of exploiting materials and human resources and coordinating these resources to achieve better management goal. Ferrell (1957) distinguished between technical and allocative efficiency as a measure of production efficiency through the use of frontier production and cost function respectively. He defines technical efficiency as the ability of a firm to produce a given level output with a given minimum quantity of input under certain technology. With Ferrell framework, economic efficiency (EE) is an overall performance measure and it is a product of Technical efficiency (TE) and allocative efficiency (AE) that is EE=TE * AE. Therefore technical and allocative efficiency are the necessary condition for achieving economic efficiency (Abdulai and Huffman, 2000).

This study focused its attention on technical efficiency. A farmer is said to be technically efficient if he/she produces a given level of output using minimum resource possible. For a given resource limit, a technically efficient producer/firm will be operating along an isoquant Q as shown in Figure1. On the other hand, any farmer who operates below an isoquant Q is regarded as a technically inefficient farmer. For a fully technically efficient firm TE = 1. This means that actual output level is equal to expected output level when the firm is technically efficient. On the other hand, for all inefficient firms, a TE less than 1 (actual output is less than expected output when the firm is technically efficient) is achieved implying that a farmer is operating below the frontier. The difference between the estimated TE and 1 depicts the proportion by which the firm should reduce the ratios of both inputs used to efficiently produce a given level of output (Gelan and Muriithi, 2010). On the other hand, an attempt towards profit maximization can be explained in terms of productivity (Dewett, 1966). Agricultural productivity is defined as ratio of agricultural output to agricultural inputs. While individual products are measured using weight or volume, their variations in densities make it difficult to measure an overall productivity for multiple agricultural outputs (Griliches, 1998). In that regard, the market value of final output is used in measuring productivity. Agricultural productivity can either be expressed as partial factor productivity (PFP) that is land productivity (output per unit of land) and labour productivity (output per unit of labour) or total factor productivity (TFP). The land and labour have been often times used in expressing productivity due to their vast importance among the most limiting factors in agricultural production.

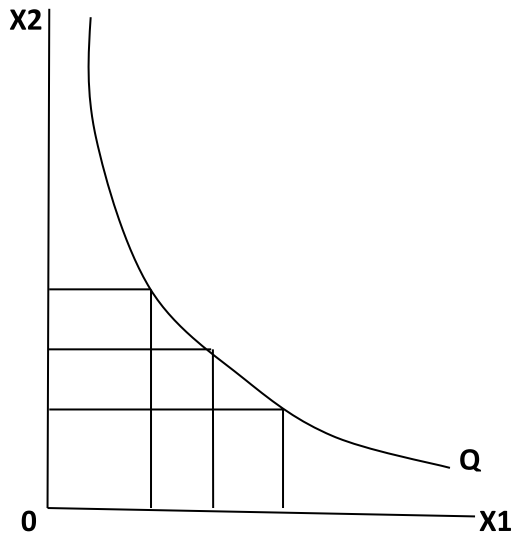

Figure 1: Technical Efficiency of Firms in Relative Input Space

Source: Ferrell (1957)

2.2 Empirical Studies Farm Size and Efficiency

The farm size-productivity analysis in developing countries has attracted the interests of many stakeholders in academics and policies in analyzing the agrarian structure. The study by Dyer (1996) on the IR between farm size and productivity geographically using two-way fixed effect model finds that the IR exists in the traditional agricultural sector, but he concludes that the IR has been wiped out in some areas where the green revolution has taken place. More or less similar conclusion was arrived by Ghose (1979) on his study on farm size-efficiency relationship and the contribution of farm organization in Indian agriculture where he concluded that the small farms are more allocatively efficient relative to large farms. The explanation for an IR is local technology and inefficient markets especially in areas where capital intensive technologies and factor markets are not well developed, small farmers (especially those with abundant labour and who use farmyard manure) appeared to have more advantage. However, Ghose assumed that this advantage would disappear with technological advancement.

Binswanger and Mclntire (1987) advanced the argument that labour as a major factor of production is associated with the cost of supervision, maintenance, hiring and direct payment. Labour supply is characterized by different incentive problems especially in a situation of information asymmetry. This could reduce the productivity per worker. Solving or minimizing this incentive problem is an added cost of labour to the farmer (labour supervision cost). This is especially common to hired labour and the cost increases with farm size due to the fact that the bigger the size of farm the higher is the amount of labour required completing farm operations. With higher number of hired workers, the supervision becomes less effective and time consuming (Dyer, 1996). In that regard, the small farmers would be more efficient due to labour cost saving advantages as they mostly use family labour which in most cases tend to devote more effort on work because of being part of whatever (whether good or bad) outcomes of production. The study by Bhalla and Roy (1988) using a two-way fixed effect model observed the IR between farm size and productivity and the explanation for this is due to omitted variables such as soil quality. They argue that, most researchers who have done their studies on farm size-productivity relationship do not have the accurate and precise measures of soil quality attributes such as nutrient content, moisture content, soil texture and pH of the soil. Many studies which confirmed the IR between farm size and productivity ignored the soil quality variable and some other unobservable effects, leading to biased coefficients (Chadha, 1978; Deolalikar, 1981; Chattopadhyay and Sengupta, 1997).

The study by Bhalla and Roy (1988) reveals that under the control of soil quality variable between farms the inverse relationship disappeared. Dyer (1997) also confirmed the existence of IR between farm size and productivity due to soil quality variables but the argument was slightly different from that of Bhalla and Roy (1988). He contends that "Since most farmers tend to cultivate the fertile land first and they (farmers) will tend to choose lower quality land as they increase the farm size, it is likely that the larger farms will have lower productivity on average relative to small farms which entails the IR between farm size and productivity. Under the same argument of soil quality variables, it is sometimes established that small farms are more productive than large farms since owner-operators tend to cultivate their most fertile land first and then sell or rent out less fertile land (Larson *et al.*, 2013). Since most of the large farms are either bought or rented, it turns out that most of these farms are less fertile than most small farms which may in turn reinforce the IR hypothesis.

Gucheng Li *et al.* (2013) used two way fixed effect model of panel data and the Battese and Coelli stochastic frontier analysis model to re-examine the IR between farm size and efficiency using farm-level panel data obtained from Hubei province in China from 1999 to 2003. The farm size-production efficiency relationships derived from the multiple measures of production efficiency indicators such as land productivity, labour productivity, profit ratio, TFP and TE were estimated. The findings confirmed the inverse relationship between land productivity and farm size, as in many other studies. Conversely, the study established that the relationship between farm size and other measures of agricultural efficiency is mixed implying that it might be positive, negative or even uncorrelated depending on how the farm efficiency is defined. Based on this finding the study concluded that any relevant agricultural policy reform should proceed with caution.

A World Bank commissioned study by Muyanga and Jayne (2016) revisited the IR hypothesis over a wider range of farm sizes (from 1hectare to 100 hectares) classified into small scale (below 5ha), medium scale (5 to 50ha) and large scale (over 50ha) farmers to check whether it still holds that small farmers are more productive in Kenya. Using a Cobb Douglas production function and Two Step Least Square technique, various measures of productivity were estimated. The findings indicate that there is a positive relationship between farm size and all measures of productivity. Conversely, when a separate analysis was done between three categories of farm size, the relationship was different. In a sample of small scale farmers the inverse farm size-productivity relationship was observed while a positive farm size-productivity relationship was observed in a sample of medium scale farms. In the case of large scale farms, no defined pattern was observed and the IR does not hold for a farm size range between 1 to 50 hectares. The study therefore, concluded that the medium scale famers were having more advantage over the small scale farmers in terms of productivity. However, having more advantage does not necessarily mean that policy reforms should favour medium scale farmers over small scale farmers because there are several other criteria to be considered when undertaking policy reforms.

The study by Rosenzweig and Binswanger (1993) on IR in India established that the IR hypothesis does not hold. The explanation for this is that the farmer with higher operational holding as well as higher ownership holding has an added advantage in terms of access to credit since the land serves as collateral. The larger the size of ownership the cheaper it is to access credit (Rosenzweig and Binswanger, 1993). Also, large farmers are in a better position to easily adopt new agricultural technologies which may in turn increase productivity per acre. Similar results were obtained by Olson and Vu (2009) with the same explanations. However, they had an additional explanation that larger farmers are likely to have a higher risk taking propensity in production relative to small farmers. This could increase the expected profit per acre. Dorward (1999) found a strong positive relationship between farm size and efficiency suggesting that large scale farmers were more efficient. He found that, small farmers incur higher transactions costs in participating in factor and product markets relative to large scale farmers who have higher access to market information, benefits from different discounts when purchasing higher input quantities, premium prices when selling their outputs at higher quantities and can exert higher bargaining power both in input and output markets. Also, due to food security anxiety small farmers decide to devote most of their resources to less profitable staples which in turn result into them being less productive relative to large scale farmers (Lipton, 2006).

2.3 Measurement of Efficiency

Theoretical methodologies of agricultural efficiency analysis is comprised of two main approaches, namely, parametric approach and non-parametric approach under which two competing methods namely parametric stochastic frontier analysis and the nonparametric data envelopment analysis-DEA are often used (Mugera, 2011). These efficiency measurement approaches were all developed around the same period. Before invention of these two approaches, the Index numbers (IM) technique was predominantly used in agricultural productivity and efficiency studies (Darku *et al.*, 2013).

2.3.1 Parametric approach

The parametric stochastic frontier models incorporate an error term which is a component of statistical noise and technical inefficiencies (Timmer, 1971). The main advantage of this technique is its ability to disintegrate the error term into random error and inefficiency. The random errors are assumed to be independently and identically distributed. It also assumes a stochastic relationship between inputs and the output produced. Thus, it allows the assumption that deviations from the frontier are due to inefficiencies and noise in the data (Battese and Coell, 1992). However, the assumption of a priori distributional forms for the inefficiency component and the imposition of an explicit functional form for the underlying technology is a major weakness of the stochastic frontier analysis.

2.3.2 Non-parametric approach

The Data Envelopment Analysis (DEA) approach was developed after Charnes *et al.* (1978) who developed the measures of efficiency in Agricultural production based on the works of Debreu (1951) and Farrell (1957). This approach was also put forward as a substitute to computing the total factor productivity as well as a substitute of the Index Number (IM) techniques of technical efficiency measurement. The DEA approach uses Linear Programming (LP) method in determining the Technological efficiency overtime and the resulting efficiency indices are used to identify the most limiting inputs in achieving technological efficiency. Since DEA is nonparametric it does not require any parametric assumptions on the structure of technology or the inefficiency term. Another advantage is that as long as inputs and outputs are measured in the same unit of measurement, an assumption about complete homogeneity of the economic agents included in the analysis is not needed (Henderson and Zelenyuk, 2007). However, DEA also has some drawbacks. The major drawbacks of this approach includes high sensitivity of results to outliers and sampling variation, non-specification of functional form and inability to distinguish between technical inefficiency and Statistical noise effects (Cesaro *et al.*, 2009). Also, DEA does not provide a room for hypothesis testing about the significance of the coefficients estimated. Based on these drawbacks, the DEA approach does not have a solid statistical meaning (Wilson, 2000).

2.3.3 Parametric Stochastic Frontier versus Data Envelopment Analysis

When comparing stochastic frontier model and DEA in terms of their appropriateness in different agricultural studies, stochastic frontier seems to be more appropriate because of its ability to deal with stochastic noise, accommodate traditional hypothesis testing, and allow single step estimation of inefficiency effects (Kumbhakar and Lovell, 2000). Although the stochastic frontier method lacks a priori justification for the selection of a particular distributional form for the one-sided inefficiency term, it remains to be the most appropriate model for many agricultural related studies (Kumbhakar and Lovell, 2000). This study, therefore, used stochastic frontier approach (SFA) in determining the technical efficiency in agricultural production in Tanzania. The justification for adopting this approach is its flexibility and its ability to decompose the error term into two components, symmetric component which captures stochastic effects of farmer’s control and the component of technical inefficiency of the farmer.

2.4 Lessons Learned From Review of Existing Literature on IR

The evidence from existing literature shows that the farm size-efficiency relationship may be positive, negative or mixed. It is, therefore, important to clearly define methodologies adopted in investigating the relationship between farm size and the efficiency of farms based on the particular region. It is also important to clearly specify the variables under consideration as well as proper measurement of such variables in order to come up with unbiased coefficients. Also, it has been recommended that in testing the farm size-productivity relationship, it is important to include a wide range of farm sizes so that the study findings could be more meaningful in terms of policy implications. Another concern from the literature is that most empirical studies on farm-size productivity analysis are based on the partial measures of productivity such as gross output or yield per unit of land. This would result into inappropriate conclusion. To address this gap, this study employed various measures of productivity such as land productivity and labour productivity.

CHAPTER TREE

3.0 METHODOLOGY

3.1 Theoretical Model

Cobb-Douglas and Translog are two major functional forms that have been widely used under the stochastic frontier production functions in modeling agricultural production relations. From the literature, it is indicated that each of these two functional forms has its own strengths and weaknesses. One of the strengths of Cobb Douglas production function over Translog is its simplicity in interpretation of the estimated coefficients whereby the coefficients of input variables are interpreted as elasticity of production in a log-log Cobb Douglas production function. In spite of its simplicity in interpretation of coefficients, Cobb Douglas production function is limited to constant returns to scale. Unlike Cobb Douglas function, the Translog function does neither impose the assumption of constant elasticity of production nor elasticity of substitution between input variables. It therefore, allows data to impose the right curvature of the function instead of establishing a prior assumption about the curvature. The main weakness of Translog function is that when it is used, all the variables must be transformed by dividing all variables by their mean so that the estimated coefficients of the input variables could be interpreted as elasticity of production. Also, large number of variables in Translog may lead to problems if the available data set is not sufficient which may in turn leads to problems in degrees of freedom. In such case, more restrictive assumptions must be imposed to enable estimation. The two functional forms, Cobb-Douglas and Translog are shown below:

(i) Cobb-Douglas production function

Cobb-Douglas production function is generally expressed as;

$Y_{it} = A{x_{ik}}^{\beta_k} e^{\varepsilon_i}$ .... (1)

Where A is a measure of the efficiency with which inputs are converted into output. Also, A is a measure of total factor productivity which is a function of other factors such as education, age, sex, marital status and others which are not in the model. The parameters α and β are the partial output elasticities with respect to factor *K* and *L* respectively.

(ii) Translog production function:

The incorporation of quadratic terms and interaction terms into the Cobb-Douglas function results into Translog function as shown in (2).

$$lnY_{it} = lnA_i + \beta_i \ln x_i + \frac{1}{2}\beta_{ij}(\ln x_i \ln x_j) + \varepsilon_i \quad (2)$$

3.1.1 Technical efficiency

The above equations (1) and (2) are used to estimate the expected output levels which are then used to estimated technical efficiency under Stochastic Frontier Approach (SFA). This is generally expressed as;

$$Y_i = f(x_i, \beta_i)e^{(v_i - u_i)} \quad (3)$$

Technical efficiency was estimated as ratio of observed (actual) output level to frontier (expected) output level as shown below:

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(x_i, \beta)\exp(-u_i)}{f(x_i, \beta)} = -u_i \quad (4)$$

Where Y_i = output for the i^{th} holding, f ( ) = appropriate functional form, x_i= vector of inputs, β=vector of unknown parameters associated with explanatory variables in the production function, v_i= random error term and u_i= non negative one sided error term that measures inefficiency.

3.2 Empirical Model Specification

The two functional forms, Cobb-Douglas and Translog have been specified to include variables under consideration as shown below:

3.2.1 Cobb-Douglas stochastic production function model specification

For the purpose of estimation, simple Cobb-Douglas function equation (1) is further modified to include more variables in the data set. The resulting equation (5) was transformed into linear form (7) by using natural logs as shown below;

$$Y_{it} = A_i {x_{i1}}^{\beta 1} {x_{i2}}^{\beta_2} {x_{i3}}^{\beta_3} {x_{i4}}^{\beta_4} e^{\varepsilon_i}, \qquad (5)$$

Where $\varepsilon_i = v_i - u_i$

$$Y_{it} = A_i {x_{i1}}^{\beta 1} {x_{i2}}^{\beta_2} {x_{i3}}^{\beta_3} {x_{i4}}^{\beta_4} e^{(v_i - u_i)} \qquad (6)$$

A_i= f(social economic factors)

On transformation into linear form:

$$lnY_{it} = lnA_i + \beta_1 ln(x_{i1}) + \beta_2 ln(x_{i2}) + \beta_3 ln(x_{i3}) + \beta_4 ln(x_{i4}) + (v_{it} - u_{it}) \qquad (7)$$

$$lnY_{it} = \beta_0 + \beta_1 ln(x_{i1}) + \beta_2 ln(x_{i2}) + \beta_3 ln(x_{i3}) + \beta_4 ln(x_{i4}) + (v_{it} - u_{it}) \qquad (8)$$

3.2.2 Translog stochastic production function model specification

The Translog functional form was specified as follow;

$$lnY_{it} = \beta_o + \beta_1 \ln x_{i1} + \beta_2 \ln x_{i2} + \beta_3 \ln x_{i3} + \beta_4 \ln x_{i4} + \beta_{12} (\ln x_{i1} \ln x_{i2}) + \beta_{13} (\ln x_{i1} \ln x_{i3}) + \beta_{14} (\ln x_{i1} \ln x_{i4}) + \beta_{23} (\ln x_{i2} \ln x_{i3}) + \beta_{24} (\ln x_{i2} \ln x_{i4}) + \beta_{34} (\ln x_{i3} \ln x_{i4}) + \frac{1}{2}\beta_{11} (\ln x_{i1})^2 + \frac{1}{2}\beta_{22} (\ln x_{i2})^2 + \frac{1}{2}\beta_{33} (\ln x_{i3})^2 + \frac{1}{2}\beta_{44} (\ln x_{i4})^2 + (v_{it} - u_{it}) \qquad (9)$$

Assuming symmetrical conditions holds that $\beta_{ij} = \beta_{ji}$

where:

- *ln* is a natural log
- Y_i is a quantity of output in kg for i^{th} farmer

- x_{i1} is farm size in acres
- x_{i2} is labour supply in adult equivalent Man-days of the i^{th} farmer
- x_{i3} is the amount of fertilizer in kg
- x_{i4} is the amount of seeds in kgs
- A_i is the total factor productivity for the i^{th} farmer
- β_1,β_2, β_3 and β_4 are the parameters that were estimated
- ε_i is an error term (v_i-u_i) which is made of two component, v_i and u_i

where v_i is a random error term that is assumed to be independent and identically distributed $N(0, \sigma_v^2)$ and independent of u_i, and u_i is inefficiency parameter which is non-negative and is also assumed to be independent but half-normally distributed with $N(0, \sigma^2)$. When i^{th} holding attains a maximum potential output for a given production technology, the value of u_i becomes zero and, therefore, the higher the magnitude of u_i is the lower the technical efficiency.

The inefficiency component (u_i) represents a variety of features that reflect inefficiency such as firm-specific knowledge; the will, skills, and effort of management and employees, work stoppages, material bottlenecks, and other disruptions to production (Aigner *et al.*, 1977). Table 3 summarizes the hypothesized relationship between dependent and independent variables in equations (8) and (9).

Table 3: A priori expectations between explanatory variables and dependent variable

Description	Variable	Unit of measurement	Expected sign
Size of Cropped Area	x_{i1}	Acres	-
Labour Supply	x_{i2}	Adult Equivalent man-days	+
Amount of fertilizer used	x_{i3}	Kgs	+
Amount of seeds used	x_{i4}	Kgs	+

Source: (Own construction)

The relationship between agricultural inputs (land, labour, fertilizer use and seeds) and is expected to be positive. That is, the more farmer increases the use certain inputs especially at lower level of input use, the higher the output will results and hence higher efficiency. For example the study by Mazumdar (1965), Ghose (1979), Rosenzweig and Binswanger (1993), Thapa (2007), Binswanger and Mclntire (2009), Obeng-Odoom (2012) and Jayne *et al*. (2014) found that the amount of labour, seeds, fertilizer used in production had positive effect on production efficiency for many crops especially at lower levels of use of these inputs. However, all these studies found the IR between farm size and efficiency indicating a negative effect of amount of cropped land on efficiency. In light of these studies and a plethora of other studies on IR, the argument that "small is beautiful" became a conventional wisdom and that's why the hypothesized relationship between the size of cropped area and efficiency is negative.

3.2.3 Choice of the functional form

Hypothesis testing was conducted for the parameters of the stochastic production frontier in order to get the best functional form that would adequately represent the data set. This was done under the null hypothesis that Cobb-Douglas production function provides an adequate representation of the data set that is, the parameters that corresponds to the interaction terms and square terms that are not statistically different from zero. The null hypothesis testing with regard to the appropriateness of the Cob-Douglas functional form was conducted using the generalized likelihood ratio (LR) test as shown below:

H_0: $\beta_{ij} = \beta_{ii} = \beta_{jj} = 0$

That is H_0: $\beta_{12} = \beta_{13} = \beta_{14} = \beta_{23} = \beta_{24} = \beta_{34} = \beta_{11} = \beta_{22} = \beta_{33} = \beta_{44} = 0$

$$\lambda = -2\left[\frac{ln(H_0)}{ln(H_1)}\right] \quad (10)$$

$$\lambda = -2[ln\,L_0 - lnL_1] \quad (11)$$

Where:

- $ln\,L_0$ = Natural log likelihood of the restricted model (Cobb-Douglas Stochastic Production function)
- lnL_1= Natural log likelihood of the unrestricted model (Translog Stochastic production function)
- λ= Test statistic that was calculated

The calculated value of λ (9.412) was then compared to the critical value of the chi-square distribution table at α=0.05% level of significance (25.188) and appropriate degree of freedom equal to the number of restrictions (10) under the null hypothesis model. The study failed to reject the null hypothesis that ($\beta_{12} = \beta_{13} = \beta_{14} = \beta_{23} = \beta_{24} = \beta_{34} = \beta_{11} = \beta_{22} = \beta_{33} = \beta_{44} = 0$) and therefore, the Cobb-Douglas function was an adequate representation of the data set. In that, the Cobb-Douglas functional form was employed in this study.

3.2.4 Estimation of technical efficiency and estimation technique

The technical efficiency of each individual farmer was estimated using stochastic frontier production function which is generally expressed as;

$$Y_i = f(x_i, \beta_i)e^{(v_i - u_i)}$$

Where:

- Y_i = output for the i^{th} holding
- f ( ) = appropriate functional form
- x_i= vector of inputs
- β_i=vector of unknown parameters associated with explanatory variables in the production function

- v_i= random error term and
- u_i= non negative one sided error term that measures inefficiency.

The technical inefficiency scores from the chosen functional form (Cobb Douglas production function) was estimated by maximum likelihood estimation (MLE) method using Frontier 4.1 computer software developed by Coelli (1996b) and maximum likelihood estimates of the production function was obtained from the following log likelihood function:

$$lnY = \frac{n}{2} ln\left(\frac{\pi}{2}\right) - \frac{n}{2} ln\sigma^2 + \sum_{i=1}^{n} ln\left[1 - f\left(\frac{\varepsilon_i\sqrt{\gamma}}{\sigma\sqrt{1-\gamma}}\right)\right] - \frac{1}{2\sigma^2}\sum_{i=1}^{n}\varepsilon_i^2 \quad \text{.........................} (12)$$

Where:

- ε_i are residuals based on Maximum likelihood estimates
- n is the number of observations, $f(.)$ is the standard normal distribution function,

$\sigma^2 = +\sigma_u^2 + \sigma_v^2$and $\gamma = (\sigma_u^2 / \sigma^2)$.. (13)

Using the FRONTIER Version 4.1 computer program, developed by Coelli (1996b), the maximum likelihood (ML) estimates, β_0,β_1,β_2, β_3,β_4, $\sigma^2 = \sigma_u^2 + \sigma_v^2$and $\gamma = (\sigma_u^2 / \sigma^2)$ average and farm level technical efficiency scores were obtained. FRONTIER4.1 software, also, provides the estimate for μ when the symmetric error term follows a truncated normal distribution.

3.3 Determination of Farm Productivity

As pointed out earlier, this study used land productivity and labour productivity as the measures of productivity. By using the collected data from the different areas of Tanzania, each of these measures were determined as shown in the next subsections.

3.3.1 Determination land productivity

In this study, land productivity is defined as Net value of output per acre. The Net value of output per acre was computed as follows;

$$\text{Land productivity } (P_{land}) = \frac{\text{Net value of output}}{\textit{Size of cropped land in Acres}}$$

$$\text{Land productivity } (P_{land}) = \frac{\text{Gross value of output} - (\text{Variable input costs} + \text{Fixed cost})}{\textit{Size of cropped land in Acres}}$$

3.3.2 Determination of labour productivity

The labour productivity from this study is defined as the Net value of output per unit of labour (labour-age equivalent). This was computed as shown below;

$$\text{Labour productivity } (P_{lb}) = \frac{\text{Net value of output}}{\textit{Amount of labour used in production}}$$

$$\text{Labour productivity } (P_{lb}) = \frac{\text{Gross value of output} - (\text{Variable input costs} + \text{Fixed cost})}{\textit{Amount of labour used in production}}$$

3.4 Analyzing the Relationship between Farm Size and Efficiency

This study adopted the two-stage estimation procedure whereby the first stage involves the determination of the farm level efficiency scores for the three suggested measures of efficiency. The first stage was accomplished in sections 3.2.4, 3.3.1 and 3.3.2. In the second stage the estimated farm level efficiency scores for each measure of efficiency was regressed on farm size using ordinary least square (OLS) method to check the how do each measure is related to farm size as shown in the next equations. It would plausible to include other explanatory variables which have been hypothesized to influence production efficiency.

- Technical efficiency;

The technical inefficiency effect model was used to model the relationship between farm size and efficiency. The technical inefficiency model is generally expressed as;

$$u_{it} = \delta_0 + \theta x_3 + \delta_i Z_{7_i} + v_{it}$$

$$u_{it} = \delta_0 + \theta x_3 + \delta_1 Z_{i1} + \delta_2 Z_{i2} + \delta_3 Z_{i3} + \delta_4 Z_{i4} + \delta_5 Z_{i5} + \delta_6 Z_{i6} + \delta_7 Z_{i7} + \delta_8 Z_{i8} + v_{it} \text{.......... (14)}$$

- Land productivity;

$$P_{l(and)t} = \delta_0 + \theta x_3 + \delta_1 Z_{i1} + \delta_2 Z_{i2} + \delta_3 Z_{i3} + \delta_4 Z_{i4} + \delta_5 Z_{i5} + \delta_6 Z_{i6} + \delta_7 Z_{i7} + \delta_8 Z_{i8} + \varepsilon_{it} \text{ .... (15)}$$

- Labour Productivity;

$$P_{(lbr)t} = \delta_0 + \theta x_3 + \delta_1 Z_{i1} + \delta_2 Z_{i2} + \delta_3 Z_{i3} + \delta_4 Z_{i4} + \delta_5 Z_{i5} + \delta_6 Z_{i6} + \delta_7 Z_{i7} + \delta_8 Z_{i8} + \varepsilon_{it} \text{ .... (16)}$$

Where $\delta_0, \theta, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7, \delta_8$, are the parameters to be estimated.

Table 4 summarizes the hypothesized relationship between explanatory and depend variables in equations (14), (15) and (16).

Table 4: A priori expectations between explanatory variables and dependent variable

Description	Variable	Unit of measurement	Expected sign
log Cropped Area	x_{i3}	Acres	–
Intercroping_D1	Z_{i1}	Dummy, 1 if farms is Intercropped 0 if otherwise	+
Log_Age of HH head	Z_{i2}	Age of household in years	+
Sex of HHhead	Z_{i3}	Dummy, 1 if a HH is male 0 if otherwise	+
Soil_Quality_D1	Z_{i4}	Dummy, 1 if soil quality is rated “good” 0 if otherwise	+
Soil_Quality_D0	Z_{i5}	Dummy, 1 if soil quality is rated “poor” 0 if otherwise	–
LogExperience	Z_{i6}	Number of family members	+
Plot_Irrigated_D1	Z_{i7}	Dummy, 1 if farms is irrigated 0 if otherwise	+
Log_Dist.(Home to farm)	Z_{i8}	Kilometres	–
Log_ hh_size	Z_{i9}	Number of members of household	+

Source: Own Construction

3.4.1 Description of hypothesized relationship between variable

The hypothesized relationship between dependent variables and independent variables in above Table 4 is based on economic theory and/or literature as follow: The hypothesized IR between farm size and efficiency is based on a plethora of studies supporting the IR between farm size and efficiency which has resulted into development of a "stylized fact" that small farmers are more efficient than large farmers. The relationship between intercropping and efficiency is expected to be positive because it reduces risk of total failure. On the other hand intercropping reduces risks and uncertainty especially if the intercropped crops are uncorrelated. Intercropping gives higher yields in a given season and greater stability of yields in different seasons compared with sole cropping (Willey, 1979a). Another hypothesized relationship is the age of household head and efficiency which is expected to be positive implying that the older he/she is the higher the efficiency. This is because the older household heads are expected to have acquired a lot of experience in farming which can help them improve their efficiency. Also, it is expected that male household heads are more efficient than their female counterparts since in many Sub-Saharan Africa countries, female households have relatively limited access to important production resources such as credit facilities, education, land ownership and time (Ogunlela and Mukhtar, 2009). Another hypothesized relationship is that good soil quality has a positive effect on efficiency. The study by Thierfelder and Wall (2012) contends that "poor soil quality lower the efficiency with which other agricultural inputs are converted into output". This implies that good soil quality such as appropriate soil pH, soil porosity, soil texture, soil profile is a necessary condition for the productivity of other inputs. Nevertheless, the distance from home to farm is expected to be negative on efficiency because under normal circumstance, a farmer may waste a lot time and energy to walk from their residence to the farm. This may interfere with production efficiency.

3.5 Data

This study used three waves (2008/09, 2010/11 and 2012/13) of the farm level National Panel Survey (NPS) data. All the three survey rounds were implemented by the Tanzania National Bureau of Statistics (NBS) with a sample based on the National Master Sample frame, but largely a sub-sample of households interviewed for the 2006/07 Household Budget Survey. These Panel Surveys are nationally representative household surveys that assemble data on a wide range of topics with regard to agricultural production and key social-economic indicators such as non-farm income generating activities, consumption expenditures and socio -economic characteristics.

The 2008/09 NPS covered 3,280 households from 410 Enumeration Areas (2,064 households in rural areas and 1,216 urban areas). In the 2010/2011 NPS sample design; a total sample size of 3,265 households was covered for 409 Enumeration Areas (2,063 households in rural areas and 1,202 urban areas).The sample for the 2011/12 NPS grew to 5,010 households. The increase in the sample was due to tracking and interviewing household members from split households. About 96% of the 2010/11 NPS households were successfully found and then interviewed during the 2011/12 NPS; hence the attrition rate is 4%, which is still exceptionally low. The attrition rate for the 2010/11 was 3%.

This study used the agricultural data from the 3,280 households covered during 2008/09 NPS where annual crop production data including farm outputs and their values as well as inputs such as labour supply, size of cropped land, fertilizer, equipment and chemicals particular were extracted. Also, the study used household data to extract variables such as sex of head of household and other family members, education, age of household head, family size, land ownership and experience in farming. These helped description of characteristics of the farmers in relation to the agricultural production patterns as well as farmers' level of efficiency and productivity. In addition to farm size data which were reported by respondents or farmers (farmer-reported farm size), the NPS data contains farm size data measured using GPS. These data were used in the analysis of the relationship between farm size and efficiency.

3.6 Data Analysis

Three data analytical tools namely Excel, Frontier 4.1 and SPSS were employed to analyse the data described in section 3.5. Firstly, the Excel computer software was used to compute cost of production where major cost structures such as land preparation cost, land and land rental cost, cost of fertilizers, cost of seeds and pesticides and other chemicals, irrigation cost, cost of tools, equipment and machines and labour cost (hired labour and imputed cost of family labour) from the panel data were used to obtain total production cost. In computing the fixed cost, the value of each farm asset was computed as the difference between annual use value (computed as the acquisition cost of each asset less estimated number of years of useful life) and its depreciation expense.

The straight line method (the commonly used method in Tanzania) was used to compute depreciation of assets. After accounting for depreciation, new values of fixed assets were then summed up to get total fixed cost. Total fixed costs were then added to total variable costs to obtain the total production cost. The total production cost was subtracted from the total value of output to obtain the net value of production. Secondly, the Frontier 4.1 computer software developed by Coelli (1996b) was used to determine the average and individual farmer's technical efficiency levels whereby the output (amount of output in kg) and input variables (land size in acres, fertilizers in kilograms, labour supply in man-days, amount of seeds in kilograms) variables transformed into natural logarithms using excel were transferred to Frontier4.1 software. Using this software, stochastic frontier estimation was run to obtain the average and individual values of technical efficiency and inefficiency. Maximum likelihood parameters of the stochastic frontier production function model were also estimated using Frontier4.1 computer software.

Lastly, the SPSS computer software was used to regress technical efficiency, land productivity and labour productivity on farm size and other factors which are likely to influence households' production efficiency. The data from excel were transferred to SPSS and used in analyzing the relationship between farm size and technical efficiency, labour productivity and land productivity.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results of Descriptive Analysis

4.1.1 Social economic characteristics of household head

The findings in Table 5 show that most (78.1%) of household heads were male. The higher percent of male headed households implies that most of agricultural production activities were led by men. This might have profound implications on production efficiency. Also Table 5 shows that majority (about 67.2%) of household heads fall under age category of between 31 years and 60 years. This might have implication on efficiency in farming since the households of these age categories (31-40 and 41-60) are expected to be energetic and perhaps to have gained great farming experience that can enhance efficiency in production.

With regard to education, the findings in Table 5 show that majority of household members (about 84%) had attained primary level education. This implies that majority of the farmers have basic ability of acquiring new skills and adopting technology for improvement of their productivity in farming.

Table 5: Social economic characteristics of household heads

Variable name	Percentage
Sex	
Male	78.1
Female	21.9
Age category(years)	
<18	1.6
18-30	11.2
31-40	26.8
41-60	40.4
61<	20.0
Education level	
Did not go to school	3.2
Not competed primary education	12.8
Completed primary education	84.0
Beyond primary education	9.4

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.1.2 Social economic characteristics of household members

4.1.2.1 Sex of household members

The findings in Table 6 indicate that among the sampled population, 53% of all household members were male and the rest 47% were female. This shows that although the number of male households was greater than female households but the difference in percentage between male and female household is small. This might have implication on participation on farming activities between men and women.

4.1.2.2 Age of household members

The age of household members was categorized into five categories as shown in Table 6. This categorization was adopted from previous Tanzania household budget survey reports. From the table it can be seen that the crop farming sector is dominated by the middle age.

This might have implications on efficiency in farming since these age groups are ideally made of energetic people who are perhaps the most productive and hence good source of labour in agriculture.

4.1.2.3 Education level of household members

The results in Table 6 show that majority (81.4%) of all households have completed primary education. This might have profound implication on productivity in farming as this group is the major source of labour in farming activity. Also, it can be relatively easy and less expensive to train these household members with primary school education (majority of which are able to read and write) on basic farming skills as compared to those (about 6.1% as shown in Table 6) who did not got school at all.

Table 6: Social economic characteristics of household members

Variable name	Percentage
Sex	
Male	53
Female	47
Age category(years)	
<18	19.6
18-30	23.7
31-40	18.2
41-60	20.4
61<	17.0
Education level	
Did not go to school	6.1
Not competed primary education	15.3
Completed primary education	81.4
Beyond primary education	6.6

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.1.3 Household head's experience in farming

The overall average number of years that farmers have been engaging in farming is 23.1 as shown in Table 7. This average number of years of experience in farming indicates that majority of farmers have engaged in farming for quite many years enough to clearly understand various production patterns such as seasonal trends, common pests and diseases around the farms. When the experience is analyzed across scale, the average number of years of experience is almost the same for small farmers and medium farmers (23.13 and 23.47 respectively as indicated in Table 7). However, the large farmers have few years of experience (10.50 years) relative to their counterparts.

Table 7: Household head's experience in farming (years)

Experience in farming	Across scales of farming			Full Sample
	Small scale	Medium scale	Large scale	
Average	23.13	23.47	10.5	23.1
Maximum	113	112	17	113
Minimum	0	1	4	0
Standard Deviation	9.79	8.22	9.19	8.80

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.1.4 Household size

The overall average size of households is 6 while the average household size across scale is 6, 5 and 5 for small, medium and large farmers respectively as shown in Table 8. Although the average is 5 for both medium farmers and large farmers, the overall average is 6 which is similar to the small farmers' average. This could be due to large number of small farmers that constitute about 91% of all farmers. The size of household has implications on production efficiency due to the fact that these members of household are the source of labour in production activities as it is the case for most smallholder farmers in developing countries which the major source of labour for their production activities is family.

Table 8: Household size

Household size	Across scales of farming			Full sample
	Small scale	Medium scale	Large scale	
Average Household Size	6	5	5	6
Maximum	30	13	6	30
Minimum	1	1	4	1
Standard Deviation	3.18	2.51	1.16	3.17

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.1.5 Household farm size

The data on household land holding was available as farmer-reported and as measured by GPS devices. The results indicate that about 90% of all farmers own the land between 0 and 5 Acres as shown in Table 9. This means that majority of farmers are small scale in accordance with the standard classification of land holding by the World Bank and FAO.

The average household farm size was 2.48 acres and 3.29 Acres under GPS measurement and farmer-reporting respectively as indicated in Table 9. Since the average GPS measured farm size is less than average farmer-reported farm sizes, it implies that farmers might incorrectly report their farm size which may impair on the accuracy of various analyses that involve land variables. Also, when comparison was made across different land holding categories, an interesting result was that the small farmers tend to underestimate their farm size and large farmers tend to overestimate their farm. This might have implication on land productivity since it is expressed as a net value of production per acre. Farmers with holding size below five acres cultivates about 90% of their total owned farm while on average farmers with holding size of more than 20 acres cultivate only 52%

of their total owned farms. This implies that small farmers use their land more intensively than large scale farmers. These findings are consistent with the literature on farm size and land productivity.

Table 9: Household's average farmer-reported and GPS measured farm sizes across farm size categories

Land holding category (Acres)	Land holding in Acres		Number of farmers		As % of total	
	GPS	**Farmer Reported**	**GPS**	**Farmer Reported**	**GPS**	**Farmer Reported**
less than 1	0.46	0.42	2 012	2 212	41.01	29.91
1-5	2.31	2.07	2 333	4 447	47.55	60.14
6-10	7.66	7.59	311	479	6.34	6.48
11-20	14.58	15.07	162	178	3.30	2.41
21-50	28.60	34.85	64	56	1.30	0.76
51-100	62.80	75.22	18	16	0.37	0.22
over 100	164.54	220.00	6	7	0.12	0.09
Total	**2.48**	**3.29**	**4,906**	**7,395**	**100.00**	**100.00**

Source: NPS Tanzania (2008/09, 201o/11, 2012/13)

4.1.6 Crop production costs

4.1.6.1 Variable costs

The results on variable cost in Table 11 indicate that labour cost forms 27.54% of total production cost per acre which is the highest share of production costs per acre and this is one of the major sources of production cost differences between small and large scale farm categories. The small farmers incur less labour cost as compared to medium and large scale farmers. This could be due to higher use of family labour by small farmers which most of them are not associated with other costs such as supervision and hiring. Another significantly large share of cost is the cost of fertilizers. Small farmers incur lower cost of fertilizer than other farmers. The difference in fertilizer cost between small and large scale farmers reflects the intensity of fertilizer use since the cost of fertilizers slightly differs in different areas of the country.

There was no a clear trend on other per acre cost components such as land preparation, planting, weeding and harvesting when compared across different sizes of planted area. On the other hand, the results show that for small farmers especially those owning less than two acres, about 73% of their source of labour is family. Unlike a decreasing trend of family labour as size of planted area increases, the results show that the cost of hired labour increases with the size of planted area. The land renting costs, also, show a decreasing trend across scale of farming as shown in Table 11. This may be due to advantages like price discounts that may accrue as one rent a large farm size. The cost of seeds shows an increasing trend across scales of farming that is small farmers have lower cost relative to medium and large scale farmers. The lower cost of seeds incurred by small farmers could be due to the use of local agricultural technologies such as local seeds by most small farmers in Tanzania most other Sub-Sahara African countries as cited in literature. The use of local seeds which are, in most cases, less productive and cheaper than improved seeds may reduce the cost of seeds to these farmers.

4.1.6.2 Fixed Costs

Fixed production cost was estimated as sum of annual use value of farm assets and their corresponding depreciation expenses. The annual depreciation was computed as the difference between original value of an asset and its salvage value multiplied by respective asset depreciation rate (computed as 1 devided into number of years of useful life of the asset) devided by its corresponding expected years of useful life (as estimated by NBS for each class of farm asset) was divided by The asset's annual used value is the asset's current value devided by its useful life. The computation of annual depreciation for the fixed farm assets is shown in Table 10. The results in Table 10 indicate that fixed form about 11.4% of the total cost. This implies that ignoring fixed costs may impair with may results into invalid conclusions which may in turn impairs with the reliability of findings farmers with less than two acres incur more (about twice as much compared to large farmers with more than 20 acres). This means that large farmers would be able to spread their fixed costs over their large farms.

4.1.6.3 Total production cost

The total production costs were estimated as a sum of total variable cost and total fixed cost for the overall sample and across farming scale to see how they vary across holding size categories. The results show that, on average, the total production costs per acre is TZS 701 575 as shown in Table 11. When the costs are compared between scales of farming, the results show that small farmers are most cost effective relative to others. Although the medium scale farmers have highest production cost but their costs differ slightly from large farmers' cost of production. This increase in cost implies that there are diseconomies of scale in farm production.

Table 10: Estimation of annual depreciation for the farm assets

Name of asset	Original cost ('000'TZS)	Estimated salvage value ('000'TZS)	Estimated life span	Depreciation rate	Estimated annual depreciation ('000'TZS)
Bicycle	60	12	5	0.2	1.9
Disc Plough	3 000	300	10	0.1	27.0
Harrow	2 800	280	10	0.1	25.2
OX-Cart	160	16	10	0.1	1.4
Oxen	800	160	5	0.2	25.6
OX-Plough	70	14	5	0.2	2.2
Planter	3 000	300	10	0.1	27.0
Sprayer	80	16	5	0.2	2.6
Stores	600	60	10	0.1	5.4
Tractor	15 000	600	25	0.04	23.0
Tractor Trailer	3 000	150	20	0.05	7.1
Truck	20 000	1 000	20	0.05	47.5
Water pump	600	120	5	0.2	19.2
Water tanks	420	84	5	0.2	13.4
Hand hoe	40	8	5	0.2	1.3
Combine harvester	21 000	1400	15	0.07	87.1

Source: Computed NPS Data for 2008/09, 2010/11, 2012/13

Table 11: Household crop production cost in Tanzanian Shillings ("000")

Name of the cost	Scale sample						Full sample	
	Small		Medium		Large			
	Cost per	Percentage of the total	Cost per	Percentage of the total	Cost per	Percentage of the total	Cost per	Percentage of the total
Total Labour cost	83.94	21.04	151.49	25.28	203.76	34.17	146.39	27.54
-Family labour	61.16	15.33	78.60	13.12	50.97	8.55	63.57	11.96
-Hired labour	22.78	5.71	72.89	12.16	152.79	25.62	82.82	15.58
Fertilizer	82.76	20.74	140.49	23.45	173.68	29.13	132.31	24.89
Seed	56.68	14.21	128.79	21.49	86.43	14.49	90.63	17.05
Land renting	55.90	14.01	48.38	8.07	28.38	4.76	44.22	8.32
Land reparation	42.56	10.67	65.36	10.91	64.07	10.74	57.33	10.79
Variable costs	321.83	80.66	534.50	89.20	556.32	93.29	470.88	88.59
Fixed costs	77.19	19.35	64.72	10.80	39.99	6.71	60.63	11.41
Total costs	**399.01**	**100.00**	**599.21**	**100.00**	**596.31**	**100.00**	**531.51**	**100.00**

Source: Computed NPS Data for 2008/09, 2010/11, 2012/13

4.2 Technical efficiency, Land productivity and Labour productivity

4.2.1 Technical efficiency

The maximum likelihood parameter estimates of the stochastic production function are presented in Table 12. From the maximum likelihood estimation of stochastic frontier production function, technical efficiency scores and other parameters were estimated. The mean technical efficiency was 0.724 which implies that, on average, farmers have 0.286 chance of improving their technical efficiency with the currently available technology and with the same input levels. Also the technical efficiency scores was computed across years and scales of farming and the results reveal that small farmers were more technically efficient on average followed by large scale farmers and then medium scale farmers as indicated in Table 13. Furthermore, when the technical efficiency scores were compared across time an increasing tendency was revealed as shown in Table 13. This increasing tendency of technical efficiency across time might imply that farmers are improving their farming practices such as adoption of modern farming techniques in the course of time. The Likelihood Ratio (LR) 46.492 which was statistically significant at 1% level of significance implying that the land size in acres, labour supply in Man-days, amount of fertilizer used in kilograms and amount of seeds used in kilograms significantly explain the farmer's level of technical efficiency even at small samples.

The parameter for the variance (γ) associated with inefficiency terms was 0.656 which is statistically significant at 5% and 1% levels of significance. From this value it means that farmers are significantly technically inefficient. This value of variance (γ) parameter implies that random inefficiency component (u_i) strongly surpass the random disturbance term implying that about 65.6% of the total deviation of farmers' output from the expected (frontier) output level is attributable to factors that are within the farmers' control. In that regards, the null hypothesis that "farmers are technically efficient" is rejected. The elasticities of production with respect to all inputs were positive and significant at 5% level of significance except for pesticides which was also positive but not significant at all.

Table 12: Summary of stochastic frontier regression results

Variable	**Parameter**	**Coefficient**	**(Std. Err.)**
Intercept	B_0	2.266***	(0.005)
log_CroppedArea	B_1	0.545***	(0.001)
log_Fertilizer	B_2	0.364*	(0.002)
log_Labour	B_3	0.033**	(0.001)
log_Seeds	B_4	0.002**	(0.001)
Log-likelihood	-918.851		
Likelihood Ratio (LR)	46.492***		
Average T.E	0.724		
Variance (γ)	0.656***		

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

Table 13: Summary of average technical efficiency scores across time and scales of farming

Year	Small	Medium	Large
2008/2009	0.711	0.694	0.685
2010/2011	0.733	0.714	0.721
2012/2013	0.769	0.741	0.749
Average	0.738	0.716	0.718

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.2.2 Land productivity

The land productivity was computed as ratio of net value of production to the size of cropped land in acres under farmer-reported and GPS measured farm sizes. The average land productivity in farmer-reported and GPS measured farm was observed to be TZS 522 554.00 per acre and TZS 20 5801.69 per acre respectively as shown in Table 14. This divergence in land productivities between farmer-reported and GPS measured plot sizes could be due to that tendency of farmers to underestimate or overestimate their plot sizes which in turn results into artificially higher or lower values of land productivity respectively. The reason as to why farmers underestimate or overestimate their farm size could be due to the fact that most farmers do not use standard approaches and units of area measurement rather they use local methods of area measurement such as paces (assuming one pace equals to one meter) in measuring the size of their farms. Since there is a great variation of the size of paces between farmers, the use of pace in measuring size of the farms may results into serious measurement errors that may lead to farmers underestimating or overestimating their farm size. Land productivity between farmer-reported and GPS farm sizes was measured across small, medium and large scale farmers as shown in Table 15. From the results it can be clearly seen that, on average, small scale farmers are more productive than medium and large scale farmers under both farmer-reported plot sizes and GPS measured plot sizes. However, the difference in productivity between small scale and other scales of farming is extremely high under farmer-reported plot sizes than in GPS measured plot sizes. This implies that farmers tend to, knowingly or unknowingly, underestimate or overestimate their plot sizes which could in turn triggers the inverse relation between farm size and efficiency.

Table 14: Land Productivity for farmer-reported and GPS farm size

	Mean (TZS/Acre)	Std. Error
Farmer-Reported	522 554.00	1999.83
GPS	205 801.69	784.48

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

Table 15: Land productivity for farmer-reported and GPS farm size across scales of farming

	Land productivity		
Scale of farming	**Farmer-reported TZS/Acre**	**GPS TZS/Acre**	**Bias (%)**
Small (Ac <5	454165.87	230670.31	49.21
Medium (5<Ac≤50)	207196.66	195413.58	5.68
Large (Ac >50)	202197.76	191498.18	5.29

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.2.3 Labour productivity

The labour productivity is computed as a net value of production per man-day. On average, the labour productivity was TZS 8 005 per man-day for male labourers and about TZS 6 660 per acre for female labourers as indicated in Table 16. With these results, male labourers are more productive than their female counterparts. This could be due to the fact that in addition to farming, female household members participate more in other household managing activities such as cooking, cleanliness, fetching water, child care and others, most of which are time consuming and hence may reduce their chance to equally participate in agriculture as male household members. The comparisons regarding labour productivity is made across scales of farming and the results indicate that small scale farmers are more labour productive than medium and large scale farmers as shown in Table 16. This could be explained by the reason that majority of small farmers used family labour as indicated in Table 17, and therefore, these farmers incurred less or no cost on labour. The low values of labour productivity by some medium and many large scale farmers could be due to drawbacks such as shirking and the cost of hiring, training and supervising labourers which are associated with the use of family labour as stipulated in the theory.

Table 16: Labour productivity as Net value of production per Man-day (TZS/Adult Equivalent Man-day)

	Labour productivity (TZS/Man-day)		
Scale	**Male**	**Female**	**Full Sample**
Small (Ac <5)	8866.25	8946.25	8906.25
Medium (5<Ac≤50)	7085.00	5667.50	6376.25
Large (Ac >50)	8061.27	5367.50	6716.88
Full Sample	8005.83	6660.42	7333.13

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

Table 17: The average ratio of hired labour per acre to household labour per acre (TZS/Adult equivalent man-day)

Scale	**Hired Labour/Family labour**	**Std. Error**
Small (Ac <5)	180.43	1.967
Medium (5<Ac≤50)	1070.83	3.624
Large (Ac >50)	289361.70	8.754

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.3 Relationship between Farm Size and Efficiency

4.3.1 Farm size and technical efficiency

Two models were estimated under this section. In the first model technical inefficiency scores were regressed against only farm size as a regressor and the value of estimated coefficient for farm size was 1.147*** which means that there is a significant positive relationship between farm size and inefficiency. On the other hand, the average technical inefficiency will increase by 1.147% if the size of cropped area is increased by 1% keeping all other factors constant. Another independent variable (Intercropping D1) was added in the first model then another OLS regression equation was estimated and results indicate that the coefficient for farm size decreased to 0.511***. Also, most of these added variables (irrigation dummy, intercropping dummy, farming experience, distance from home to farm and household size) were significant and therefore, ignoring these factors may increase the strength of the IR between farm size and technical efficiency.

In an attempt to check the effect of soil quality on technical inefficiency, the soil quality dummy was added to model 2 and the third regression equation was run. From the results the coefficient for farm size further decreased to 0.467. The decrease in this coefficient from 0.511 to 0.467 might imply that ignoring the role of soil quality on efficiency may trigger the IR. From the results soil quality, therefore, has significant positive effect on efficiency. However, this variable has been ignored in most of previous IR studies such as (Muyanga and Jayne, 2016 and Thapa, 2007). Furthermore, despite the fact that the information on soil quality was obtained from farmers’ perception on their farms, still it reveal that exclusion of soil quality contributes to the IR. Other variables such as distance from home to the farm, intercropping, experience in farming, household size and irrigation dummy have significant influence on efficiency as shown in Table 18.

Table 18: OLS regression of farm size and technical inefficiency

Variable	Parameters	Regr1	Regr2	Regr3
Intercept	δ_0	3.089***	2.914***	2.111***
log_CroppedArea	θ	1.147***	0.511***	0.467***
Intercroping_D1	δ_1		-0.608*	-0.603*
Age_of_HHhead	δ_2		-0.131**	-0.130**
Male_head	δ_3		0.017*	0.018*
Soil_Quality_D1	δ_4		-0.274**	-0.277**
Soil_Quality_D0	δ_5		0.263*	0.268*
Experience	δ_6		-0.073*	-0.073*
Plot_Irrigated_D1	δ_7		-0.173**	-0.181**
Dist.(Home to farm)	δ_8		-0.032**	-0.035**
Hhsize	δ_9		-	-0.028*
R^2		0.141	0.395	0.421
$F_{(10\ 9137)}$		16.244*	30.858**	53.051
		* p<0.1 , ** p<0.05,*** p<0.01		

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.3.2 Farm size and land productivity

The results from OLS regression indicate that there is a significant inverse relation between farm size and net value of production per acre of GPS measured plot size (-0.34) as shown in Table 19. This means that, the average net value of production per acre will decrease by 0.34% if the size of cropped area is increased by 1%, other factors remaining unchanged. It has been revealed from the previous section that, due to round-off, estimation errors and other factors, most of small scale farmers tend to underestimate their farm size which results into them having artificially higher net value of production per acre and opposite case applies to large farmers. To check whether this measurement error could explain the IR between farm size and net value of production per acre, another OLS regression of net value of production per acre in which the farmer-reported plot sizes were used instead of GPS farm size. The results in Table 19 indicate that the coefficient of the size of cropped area is still negative and significant but it has increased to (-0.50) meaning that on average 1% increase in amount of cropped area reduces the mean net value of production per acre by 0.50% *Ceteris paribus*. This confirms that farmer's failure to accurately report their farm size results into these farmers inaccurately reporting either higher (by small farmers) or lower (by larger farmers) output per acre and hence higher net value of production amplifies the IR between the farm size and efficiency.

Table 19: OLS regression of land productivity and farm size

Variable	**Parameter**	**Coefficient (GPS_plot)**	**Coefficient (farmer_reported_plot)**
Intercept	δ_0	1.801***	1.914***
log_CroppedArea	θ	-0.342***	-0.495***
Intercroping_D1	δ_1	0.258***	0.243***
Age_of_HHhead	δ_2	0.106*	0.104*
Male_head	δ_3	0.360*	0.357*
Soil_Quality_D1	δ_4	0.311**	0.314**
Soil_Quality_D0	δ_5	-0.506**	-0.505**
Experience	δ_6	0.362**	0.362**
Log_Total_land/Irrigated	δ_7	1.021***	1.017***
Distance_(Home to farm)	δ_8	-0.173**	-0.191**
Hhsize	δ_9	0.032*	0.030*
R^2		0.462	0.341
$F_{(10,9137)}$		38.001	27.022

* p<0.1 , ** p<0.05,*** p<0.01

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.3.3 Farm size and labour productivity

From results of regression of net value of production per Man-day the coefficient of the log of cropped land is negative and significant (-0.31) as shown in Table 20. This means that the smaller the size of cropped land is the higher the net value of production per man-day that is on average, one percent increase in farm size will reduce labour productivity by 0.31%. In that regards, an additional variable (hired labour to family labour ratio) and as shown in the results, the coefficient for this variable is -0.46 as shown in Table 20. This means that one percent increase in the ratio of hired labour to family labour will reduce the average labour productivity by 0.46% *Ceteris paribus*. On the other hand, there is a significant negative relationship between the log of hired labour to family labour ratio and net value of production per man-day (labour productivity). The findings from Table 20 show that small farmers have a far lower ratio of hired labour to family labour than large scale farmers which in accordance with these results small farmers would be more labour productive than larger farmers and hence this could be the cause of the observed IR between farm size and labour productivity.

The higher use of hired labour by larger farmers may be associated with a lot of additional costs such as supervision, payment of labour and other challenges such as incentive related problems such as shirking which may in turn reduce the quality of work done by hired labour and hence reduce the productivity of labour. This result is similar to the findings of the study by Thapa (2007). The distance from home to farm also has a significant negative influence on labour productivity as shown in Table 20. This means the longer the distance from home to farm the lower the productivity of labour and the reason might be that if farmer travels a long distance from home to farm, it is likely that he/she will be tired and less effective at working which may in turn reduce labour productivity.

Table 20: Regression of labour productivity and farm size

Variable	Parameter	Coefficient	(Std. Err)
Intercept	δ_0	0.314***	0.140
log_CroppedArea	θ	-0. 31***	0.061
Intercroping_D1	δ_1	-0.003**	0.215
Age_of_HHhead	δ_2	-0.130	0.708
Male_head	δ_3	0.018**	0.119
Experience	δ_4	0.073*	0.669
Log_Total_land/Irrigated	δ_5	0.003**	0.102
Distance_(Home to farm)	δ_6	-0.013*	0.088
Hhsize	δ_7	0.007*	0.501
Hired/Family_Lab	δ_8	-0.46**	0.130
SOIL_Q_Dummy1	δ_9	0.034**	0.144
SOIL_Q_Dummy2	δ_{10}	-0.109**	0.084
R^2		0.34	
$F_{(11, 9137)}$		56.59	

* p<0.1 , ** p<0.05,*** p<0.01

Source: NPS Tanzania (2008/09, 2010/11, 2012/13)

4.3.4 Summary of the key findings of the study

The findings from this study reveal that about 90% of all farmers are smallholders cultivating the farms between 1ha to 5ha. The study has confirmed the existence of Inverse relation between farm size and all indicators of efficiency (technical efficiency, land productivity and land labour productivity) used in the study and therefore supporting the IR hypothesis. However, after controlling for soil quality the strength of inverse relation between farm size and land productivity decreased from 0.51% to 0.47% but it was still statistically significant. Also, when GPS data on farm size were used instead of farmer reported farm size data, the strength of IR decreased from 0.50% to 0.34% using farmer-reported farm size data. This could probably due to small farmers' failure to estimate their farm sizes leading to higher land productivity for small scale farmers than land productivity for large scale farmers. Other than farm size, factors such as farming experience, irrigation, fertilizers, household size and intercropping had significant positive influence on efficiency.

CHAPTER FIVE

5.0 CONCLUSION, CONTRIBUTION OF THE STUDY AND RECOMMENDATIONS

5.1 Conclusion

This study was carried out to examine the inverse relationship between farm size and efficiency as an attempt to understand the viability of smallholder-led agricultural growth strategy in Tanzania as in other developing countries characterized by rapid population growth and an ever increasing pressure on agricultural land. The study used NPS data for 2008/09, 2010/11and 2014/2013 from National Bureau of Statistics. The conclusion drawn from the major findings of the study is that Inverse relationship was found between farm size and all three measures of efficiency (technical efficiency, land productivity and labour productivity) used in the study. However, when controlling for soil quality the strength of the inverse relationship between farm size and efficiency decreases. Comparison of mean farm sizes estimated using GPS farm size data with those estimated using farmer-reported farm size data show decrease in the strength of the inverse relationship between farm size and efficient with the use of GPS farm size data, implying. This suggests existence of the problem of underestimation and overestimation of farm size by small farmers and large farmers respectively, leading into an artificially higher net value of production per acre among smallholder farmers and lower net value of production per acre among large farmers.

On the other hand, the study findings indicate that factors such as farming experience, irrigation, fertilizer use, household size and intercropping have a significant positive influence on efficiency and productivity.

5.2 Recommendations

5.2.1 Policy recommendations

The existence of the inverse relationship between household farm size and efficiency is of substantial policy implications for Tanzania that seeks to transform her agricultural sector from subsistence to a commercial sector. This will in turn help to transform the economy into industrial economy through provision of raw materials for agro-industries. In that regard, the study recommends the following:

Firstly, the use of farmer-reported farm size data has been shown to contribute to the misleading results on efficiency indicators especially land productivity and, therefore, triggers the strength of the IR between farm size and efficiency. Therefore, this study recommends that the government and development partners should support and promote the use of GPS technology especially in large household surveys as it provides accurate and reliable land holding size data that can produce farm productivity and efficiency measures that can correctly inform policy making.

Secondly, the findings indicate that application of fertilizers and irrigation water have significant positive influence on efficiency and productivity, suggesting that the efficiency of small farms can be enhanced by the use of fertilizers and irrigation water. Therefore, any agricultural policy that considers the importance of fertilizer and irrigation should be promoted in order to improve agricultural productivity particularly now when the government is promoting industrialization. Improvement of agricultural productivity is paramount for agro-based industries that will require raw materials from agriculture. Apart from increasing productivity, irrigation is crucial in the face of unreliable rainfall due to climate change as it will ensure reliable supply of agricultural raw materials for the agro-industries. Also increase in agricultural productivity would release surplus labour for the industries.

5.2.2 Contribution of the study and suggestions for further research

5.2.2.1 Contribution of the study

The study contributes to the current worldwide debate on IR between farm size and efficiency in the following ways:

Firstly, the study confirmed the presence of inverse relationship between farm size and efficiency in Tanzania using National Panel Survey data. Secondly, while most of the previous studies on IR have been conducted over small range of farm sizes (between 0 to 10Ha), this study examined the inverse relationship between farm size and efficiency using a wider range of farm sizes which can appropriately inform policies on land redistribution. Thirdly, unlike previous studies most of which used farmer-reported data on farm size which may increase the chance of committing errors due to approximation, this study used GPS data on farm sizes in examining the relationship between farm size and efficiency. The GPS data are more accurate than farmer-reported data and hence minimize the estimation errors which in turn increase the reliability of the study findings. Fourthly, while most of the previous studies on inverse farm size-efficiency relationship ignored the effect of soil quality in examining the relation between farm size and efficiency, this study controlled for the effect of soil quality in examining the relationship between farm size and efficiency as an attempt to address the weakness of the previous studies which contribute to the observed IR between farm size and efficiency in a plethora of these studies.

5.2.2.2 Suggestions for further research

This study examined the relationship between farm size and only three indicators of efficiency namely technical efficiency, land productivity and labour productivity using National Panel Survey data. It is recommended that further IR studies should widen the scope of indicators of efficiency and be undertaken using different data sets from different areas of Tanzania and covering a wider range of farm sizes.

Although this study has controlled for the soil quality, failure to control for measurement errors and technological differences among farmers have been argued to be among the causes of strong IR between farm size and efficiency. It is therefore suggested that future studies should control for these aspects in testing the IR between farm size and efficiency. This will broaden the understanding about the relationship between farm size and efficiency which will in turn help the policy makers to properly design policy actions for better impacts on agricultural and economic development as a whole.

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