FARM SIZE AND AGRICULTURAL PRODUCTIVITY ACROSS MAIZE CROPPING SYSTEMS IN MAIZE PRODUCING DISTRICTS IN TANZANIA MAINLAND

SEVERIAN, NICKSON

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2019

ABSTRACT

The evidence over a negative relationship between farm size and productivity in large global literature is largely dependent on a narrow range of farm sizes excluding medium and large scale farms. This study was carried out to determine the relationship between farm size and agricultural productivity over a wider range of farm sizes across maize cropping systems in maize producing districts of Tanzania Mainland. Specifically, the study attempts to: (i) estimate the farmers' total factor productivity level across maize cropping systems, (ii) determine the relationship between farm size and total factor productivity level across maize cropping systems and (iii) identify factors other than farm size which influence agricultural productivity across maize cropping systems in the study districts. OLS Regression technique was employed to determine the relationship between farm size and the level of total factor productivity. Data for the study comprised of 1001 observations randomly selected from ASPIRES Project data set of 1200 observations comprising of small, medium and large scale farms. The data were collected during the 2015/16 cropping season from eight maize producing districts namely Mvomero, Kilombero, Njombe, Kiteto, Magu, Moshi Rural, Mkuranga and Liwale in Tanzania Mainland. The findings indicate variation in the level of total factor productivity (TFP) across maize cropping systems, ranging from 1.22 for maize-pure stand and 1.64 for maize-legumes intercropping systems. Contrary to the evidence in favour of inverse relationship between farm size and productivity, the regression results in this study indicate a significant and positive relationship between farm size and total factor productivity level across maize cropping systems. Moreover, other factors including household size, land slope, source of water and measurement errors had significant influence on the farm-level productivity across farm size categories and cropping systems. The study recommends review of the existing agricultural related policies,

strategies and/ or programmes to ensure that medium and large scale farms are also promoted instead of the currently emphasis on smallholder-lead agricultural growth as pathway to economic development in the country. Also the following are recommended in order to improve agricultural productivity and hence increase marketable surplus which is essential for ensuring adequate supply of raw materials for the agro-industries as the country is striving to become an industrialized and middle income country: (i) Review of the National Agriculture Policy 2013 and the Agricultural Sector Development Programme (ASDP II), (ii) Promoting land productivity enhancing mixed cropping systems, (iii) Promoting family planning strategies and actions, (iv) supporting low-cost irrigation strategies and programmes, (v) hastening the process of formalization of land rights and (vi) providing education on and promoting appropriate farming practices on hilly/high slope land.

DECLARATION

I, NICKSON SEVERIAN do at this moment declare to the Senate of the Sokoine University of Agriculture that this dissertation is my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Nickson Severian Date

(MSc. Candidate)

The above declaration is confirmed by

Prof. Ntengua, S.Y.Mdoe Date

(Supervisor)

COPYRIGHT

ACKNOWLEDGMENTS

I thank God for providing me with the strength, guidance, patience throughout my study period. I understand without Him this would not be accomplished. Firstly I would like to express my sincere appreciation to ASPIRES PROJECT-TANZANIA for financing this study. Special thanks are directed to my research supervisor Prof. Ntengua S.Y. Mdoe of the Sokoine University of Agriculture (SUA) for his wise advice, constructive comments, and tireless guidance. Without his efforts to making close follow-ups, my academic career goals would not be achieved. I am thankful to Prof. Gilead I. Mlay of the SUA for his valuable support particularly on modeling issues just at the start of data analysis. I also extend my sincere thanks to Prof. Milu Muyanga of Michigan State University (MSU) for his constructive comments especially on the methodology section which improved the analysis and the study in general. I express my sincere appreciation to my family and friends for their prayers and good advice from the first step up to the last point of this study.

DEDICATION

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AfDB	African Development Bank
ASDP	Agricultural Sector Development Programme
ASPIRES	Agricultural Sector Policy and Institutional Reform Strengthening
DEA	Data Envelopment Approach
GPS	Global Positioning System
Ha	Hectare
IR	Inverse Relationship
KG	Kilogram
NBS	National Bureau of Statistics
PFP	Partial Factor Productivity
SFA	Stochastic Frontier Analysis
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
TFP	Total Factor Productivity
UNCTAD	United Nations Center for Trade and Development
UNDP	United Nations Development Programme
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Small farms hold most of the economic livelihoods in Africa and the world at large. It is estimated that about 500 million farms in the world are no more than 2 hectares and these control about 98% of all farms and 53% of total agricultural land (UNCTAD, 2015; Lowder *et al.,* 2016). Similarly, majority of food production in Asia and the Pacific region is done on small farms of 2 hectares accounting for 80% of total farm land where as in Africa, Europe and Latin America, food produced on the small farms of 2 ha accounts for 8%, 4% and 1%, respectively (Graeub *et al.*, 2016).

In sub-Saharan Africa, Jayne *et al.* (2016) found that only 20%, 32%, 39% and 50% of total farmland in Kenya, Ghana, Tanzania and Zambia respectively is within a range of 5-100 ha. Since small-scale farms constitute a huge number of farms in Africa and since majority of the region's rural population obtain their livelihoods from farming, government leaders and agricultural economists have for decades conventionally believed and adopted a smallholder-led strategy as the best pathway to economic development in Africa (Hazell *et al*., 2007; Graeub *et al.,* 2016). Conversely, some researchers like Collier and Dercon (2014) have raised concerns on the sustainability of a smallholder-led growth strategy in Africa following the current efforts of African governments to transform their traditional agricultural sectors into more modern sectors to enhance economic transformation (African Development Bank, 2017). This has led to the emergence of medium-and large-scale farms with at least five hectares (Jayne *et al*., 2016), leaving majority of the farmers with their small plots and limited opportunity for expansion and productivity.

Based on yield per land size as a common measure of land productivity in most studies, the evidence indicates that majority of small farms' productivity in most of developing countries including Tanzania, is still the lowest, despite various programs like the Agricultural Sector Development Programs (ASDPs) in Tanzania, perpetuated to boost smallholder farmers (URT, 2010; UNDP and URT, 2014). As of recent, the yields for the major crops in Tanzania stand at only 1.2 t/ha for maize, paddy (1.7 t/ha), sorghum (0.8 t/ha), wheat (0.9 t/ha) and beans (0.6 t/ha) compared to 4.9 t/ha for maize globally (Karugia *et al.,* 2013; NBS, 2017). These yield data seem incongruent with the evidence on the inverse farm size-productivity relationship that is revealed in most studies. It has been generally found that small farms' productivity is higher than that of large farms (collectively referred to as farm size-productivity IR).

However, major observations in those studies constitute small-sized farms usually between zero and five hectares (Carletto *et al*., 2013). Since rapid changes in farm structure are being revealed in most parts of Sub-Saharan Africa (Jayne *et al.*, 2016), further studies to test the farm size-productivity relationship need to at least incorporate the medium farms with 5-100 ha and large farms with 100 ha and above to guide policy decisions.

Moreover, various cropping systems including mixed and sole cropping, are being practiced in Africa (Mkonda and He, 2016). The reasons for the choice of these cropping systems include agroecological factors like weather changes, proneness to infestations and soil fertility and economic factors like maximization of returns (Amos, Chikwendu and Nmadu, 2004; Sigh and Yadav, 2014; Arce and Caballero, 2015). This may lead to variation in land productivity across the cropping systems. While there is limited evidence particularly in Tanzania, on the influence of cropping systems on land productivity, this study contributes to fill this gap by studying the relationship between farm size and agricultural productivity across maize cropping systems in Tanzania Mainland.

Several studies in Africa have examined farm size-productivity relationship based on data that are generally considered representative of smallholder farms (Carletto *et al.,* 2013: 2015). Their findings in favor of IR hypothesis deserve recognition, but with caution as such studies can no longer address land and agricultural policy concerns about land distribution that are debated in Africa today.

For that matter, this study brings in empirical evidence to enrich the on-going debate on farm size-productivity IR in two major ways. First, the farm size-productivity relationship is studied over a relatively wide range of farm sizes including small-, medium-, and large-scale farms. Second, unlike most IR studies, the current study utilizes total factor productivity (TFP), an approach arguably considered more eloquent as it measures the returns on all factors of production and incorporates the production costs. The study uses data extracted from ASPIRES-Tanzania project data set comprising of 600 small scale farmers and 600 medium and large scale farmers, collected from eight maize producing districts of Tanzania Mainland.

Besides, the study estimates the influence of measurement errors on the relationship between farm size and productivity and finally, it provides evidence on-farm size-productivity relationship across maize cropping systems thought to influence farm size and its relationship with land productivity.

1.2 Problem Statement and Justification

A smallholder lead-growth development strategy has been key for development in most developing countries following the evidence that small farms constitute the majority and contribute significantly to the economies' well-being. However, some evidence from other areas are against the small farms' strategy and suggest that both farm sizes are crucial for sustainable development. Additionally, various measures of agricultural productivity have been used depending on the data constraints. Measures such as yield in kilograms per unit land area cultivated and/ or net value of output per unit land area cultivated, are some of the most common ones. However, the former has been widely used due to the challenges encountered in obtaining accurate price data for the majority of smallholder producers which limit the latter.

Moreover, smallholder farmers especially in rural Tanzania, practice multiple or mixed cropping systems and /or enterprise rotations as a strategy to mitigate production risks or improving the income portfolio. This makes use of crop yields less useful especially when the farm level aggregate measure of performance is desired. To this stance, total factor productivity (TFP) as opposed to partial factor productivity (PFP) per unit land area cultivated improves the productivity measurement.

Since mixed cropping systems embrace varied sources of livelihoods (Mdoe *et al*., 2015), their corresponding farm-level productivities will also vary accordingly (Dixon *et al.*, 2014; Baksiene *et al.*, 2014). However, there is little empirical evidence if any, on the analysis of farm size-productivity relationship across different cropping systems in SSA (Lokina *et al.*, 2011; Wineman and Jayne, 2018). Furthermore, there is limited empirical evidence on how measurement errors and soil quality variability across various cropping systems influence the IR of farm size- productivity (Savastano and Scandizzo, 2017).

To address this problem, this study calculates measurement discrepancies using self-reported and Global Positioning System (GPS) data on farm size to estimate their corresponding influence on farm/plot level productivity across a range of farm sizes and maize cropping systems.

Nonetheless, soil quality dummy variable is included in the analysis to capture the soil quality bias. Hence, the study's outcomes add to the existing empirical evidence on-farm size-productivity relationship across maize cropping systems and thereby providing useful information to stakeholders in the agricultural sector in determining the best routes to boost agricultural productivity.

1.3 Objectives of the Study

1.3.1 Overall objective

The overall objective of the study was to determine the relationship between farm size and agricultural productivity across maize cropping systems in eight maize producing districts of Tanzania Mainland.

1.3.2 Specific objectives of the study

The specific objectives of the study were to:

i. Estimate the farmers' total factor productivity level across maize cropping systems in the study districts,
ii. Determine the relationship between farm size and total factor productivity level across maize cropping systems in the study districts and
iii. Identify other factors than farm size which influence agricultural productivity across maize cropping systems in the study districts.

1.4 Study Hypotheses

The study has three hypotheses stated as follows:

H_{01}: The farmers' total factor productivity level across maize cropping systems in the study districts does not vary significantly.

H_{02}: Farm size has no influence on total factor productivity level across maize cropping systems in the study districts.

H_{03}: Factors other than farm size do not influence the level of total factor productivity across maize cropping systems in the study districts.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Framework

The study of agricultural productivity has its foundation in the theory of the firm with the assumption that economic entities are rational decision-makers. In this case, farmers are assumed to be rational in the way they make enterprise mix and production decisions in using their resource endowments. If they are more efficient or productive, they are expected to use fewer resources as possible without compromising their ultimate goal (s) including food self-sufficiency, profit maximization and/ or cost minimization. However, the measurement of efficiency depends on whether parametric or non-parametric approaches are used and whether a partial or total measure of productivity is used.

By controlling for cropping systems, this study adopted the parametric approach to estimate the TFP level as it depicts the overall measure of farmers' performance. This is illustrated using a two-input production function. The inputs are Capital (K) and Labour (L), and the corresponding output level is Q resulting from the combination of K and L and A is the efficiency of using the inputs as presented in equation (1).

$$Q = Af(K, L) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1).$$

Where; A measures the level of agricultural productivity (TFP) resulting from other factors than the growth or improvement in the level of use of inputs such as K and L, f(.) represents the functional form appropriate for the production of Q from K and L.

The literature provides two common approaches to estimate TFP in (1) above namely, parametric/econometric and non-parametric approaches. The major difference in these approaches is the assumption made about technical efficiency. While the latter assumes that production is always at the frontier, the former account for inefficiency which may influence the level of output. Also, there are two methods used to estimate TFP corresponding to the above approaches namely, Stochastic Frontier Analysis (SFA) and Data Envelopment Approach (DEA).

The SFA uses the econometric approach which accounts for the inefficiencies associated with measurement errors or noise in the system. The DEA, however, assumes that one can easily identify the best farmer from which others will be compared. Also, unlike the SFA, the DEA approach does not account for the possibility of other factors beyond farmers' control which may have a consequence on the level of TFP. Moreover, due to its ability to incorporate into the analysis of the inefficiency factor, the SFA in the parametric approach was chosen for this study. In the parametric approach, the Cobb-Douglass (C-D) and/ or Trans-log functional approaches are widely adopted as it conforms to most of the agricultural settings in the developing countries (Goksel and Ozden, 2007; Mburu *et al.*, 2014). Owing to this, the C-D function under the SFA approach was adopted in this study to estimate the farmers' level of TFP across maize cropping systems in the maize producing districts of Tanzania Mainland.

Borrowing from Goksel and Ozden (2007) and assuming that a production technology follows a conventional Cobb-Douglass production function, and that the gross values of output per household obtained using at least three basic inputs: land, labor and intermediate input (materials) could be calculated, the TFP index assuming zero time-variant (i.e. $t = 0$), was derived as in equations (2)-(5) below:

$$Qi = AL^{\alpha}D^{\beta} M^{\gamma}e^{u} \ldots \ldots (2).$$

$$TFPi = A = Qi/\sum_{i=0}^{n} L^{\alpha}D^{\beta} M^{\gamma}e^{u} \ldots \ldots (3).$$

Where 'A' in equations 2 and 3 measures the efficiency (TFP) with which inputs (land (L), man-days worked (D) and material inputs (M) were transformed into a gross value of total output per farm per household (Q) and 'u' accounts for the inefficiency factor (s). The parameters α, β, and γ are output elasticities estimated using equations 4 and 5 below:

$$InQi = InA + \alpha InL + \beta InD + \gamma InM + u \ldots \ldots (4)$$

$$lnA = lnQi - (\alpha InL + \beta InD + \gamma InM + u) \ldots \ldots (5)$$

Equation (5) implies that TFP is an increase in output not accounted for by the increase in the level of inputs usage and systematic error in the measurement as highlighted above. Under the above framework, the most productive farmer was expected to have a TFP level of 1 unit and any deviations accounted for inefficiencies.

2.2 Empirical Studies on Farm size-Productivity Relationship

2.2.1 Studies which support the IR hypothesis

The negative relationship between farm size and productivity has been a subject of debate among scholars for many decades now. This phenomenon is generally termed as farm size/plot size-productivity Inverse Relationship (IR). In this section, studies which confirmed negative relationship between farm size and productivity are reviewed. The pioneering work by Chayanov (1926) deserves recognition as being the first to observe that small farms in Russia tended to obtain higher crop yields per unit of land cultivated than large farms do. This evidence was then reinforced by Sen (1962: 1964) who also found similar results using Land Management Survey data of Asian Agriculture. Afterwards, there have been various attempts to test the farm size-productivity IR hypothesis across diverse studies as briefly presented below. Sial *et al.* (2012) tested the existence of inverse relationship between farm size and productivity by using yield approach and OLS estimation technique and a small data set with 302 observations from Central Punjab, comprising of small farms and large farms. A strong inverse relationship was confirmed in the small farms group and positive relationship was observed for the large farms group. Similar results were found Kian (2008) in Pakistanian agriculture he found a strong inverse relationship between yield and unit of land cultivated.

Additionally, Assuncao and Braido (2007) tested the relationship between yield per unit area cultivated and farm size using the ICRISAT/VLS survey data and found that the IR was upheld after controlling for modes of production and supervision costs which were formerly theorized to remove IR in farm size –productivity estimates. Concurrently, a strong negative relationship between farm size and productivity measured as yield per unit of land cultivated was upheld in rural Rwanda at least with studies of Ansoms *et al.* (2008); Ali and Deininger (2015) and Nilsson (2018). Moreover, the negative relationship between output per unit of land cultivated and farm size was also revealed in studies conducted in Zambia, Uganda, Malawi and Rural Ethiopia (Kimhi, 2006; Carletto *et al.*, 2013; Holden and Fisher, 2017; Desiere and Jollife, 2018).

Apart from the above studies, Msangi and Mdoe (2018) examined the Inverse Relationship between Farm Size and Technical Efficiency in Tanzanian Agriculture using National Panel Survey (NPS) data for 2008/09, 2010/11 and 2012/2013. Their findings confirmed the existence of inverse relationship between farm size and technical efficiency in Tanzanian agriculture. However, the strength of IR between farm size and technical efficiency decreased after controlling for soil quality and when GPS farm size were used instead of farmer reported farm size data. Likewise, Boulay (2018) used agricultural survey data on Tanzania, and introduced a crop/plot level analysis to test whether an inverse relationship exists for crops grown on a given plots. Various propositions including the statistical fallacy and cropping practices were controlled in the estimated models to see if the IR hypothesis could be reduced or eliminated. The findings revealed a strong inverse relationship across all crops studied including maize.

However, various explanations have been raised in favour of the IR hypothesis including omission of input costs particularly family labor, existence of imperfect factor markets in rural agriculture, costs of supervising hired labor relative to own family labor, presence of regular measurement errors and omitted variable issues, are often times been associated with the existing IR between farm size and productivity.

It has been argued that family labor are intensively used in small farms in developing economies and thus a low imputed opportunity cost of the same amplifies the net value of output per unit of land cultivated than the case in large farms (Hazell *et al.*, 2010), hence an inverse farm size-productivity relationship (IR).

Additionally, as residual petitioners to farm profits or outputs, owner-operators (family labor) tend to exert more efforts on managing and operating the farm than hired large farm managers. As Assuncao and Braido (2007) explained, the owner-operators tend to have a better knowledge of local soil and climatic conditions being accumulated over generations which give small farm operations an advantage over non-family operated large farms. Moreover, food self-sufficiency motive being accompanied by imperfect land and labour markets prevalent in rural areas, explain in part the existing IR between farm size and productivity (Ansoms *et al.* (2008). The other reason believed to explain the IR in farm size and productivity estimations is statistical fallacy or bad data especially on land size and farm output. Assunção and Braido (2007) and Boulay (2018) were of the view that, the lack of land quality issues amplifies the existence of inverse relationship between farm size and productivity. It is also argued that small farms appear to be more productive because owner-operators tend to farm their highest quality land and sell or rent out less fertile land (Larson *et al*., 2013). However, the IR consistently still holds even after controlling for land quality and unobserved effects using panel data (Barrett *et al.*, 2010; Foster and Rosenzweig, 2017).

The differences in land fragmentations, edge effect, cropping intensity and farm watering systems may explain in part the existence of farm/plot size-output IR (Imai *et al.*, 2015; Bevis and Barret, 2016; Reuben *et al.*, 2017). Moreover, other studies associate the prevalence of inverse farm size-productivity relationship with the edge effect that is dominant in most of the farming practices (Nkonde *et al*., 2015). Foster and Rosenzweig (2017) found that intensive use of modern technology like mechanization and precision farming relevant in large farms may reverse the inverse farm size-productivity relationship.

Furthermore, Carletto *et al.* (2013); Dillon *et al*. (2016) and Gollin (2017) and found that regular measurement errors in respondent-reported plot sizes explain in part the prevalence of IR hypothesis. However, Savastano *et al*. (2017) and Boulay (2018) used GPS plot data of rural Ethiopia and Tanzania, respectively, which were believed to be superior to self –reported plot data and still the slope for the relationship between farm size and productivity was steeper when GPS data was used than the case for self-reported data. However, most of the evidence in favour of IR hypothesis in farm size productivity studies is largely based on smallholder farmers.

2.2.2 Studies refuting the IR hypothesis

Besides the existing body of evidence in favour of the IR hypothesis, several studies have found positive relationship between farm size and productivity including (Kiani, 2008; Mburu *et al*., 2014; Singh and Yadav, 2014; Srinivasulu *et al*., 2015; Nilsson, 2018 and Muyanga and Jayne, 2019). In particular, Muyanga and Jayne (2019) used a relatively wider range of farm sizes in Kenya to test the inverse relationship hypothesis by using three different measures of productivity including profit per hectare and total factor productivity and found a strong positive relationship between farm size and productivity emerging within the 5 to 70 hectare range of farm sizes. However, across all the range of farm sizes studies, farms in the range of 20 to 70 hectares were found to be more productive than farms under 5 hectares.

On the other hand, other studies found a U-shaped relationship between farm size and productivity like Kimhi (2006), Foster and Rosenzweig (2017) and Milu and Jayne (2019) while other studies showed weaker inverse relationship including Desiere and Jollife (2018).

Despite the existing differences in methods and data leading to the above findings, these studies agree in common that IR can shield off if the data is large enough to cover for various farm sizes, and also if the estimation strategy is well formed based on theory. Other explanations underlying the above conclusions over the relationship between farm size and productivity particularly in this sub-section can be as similar as those of section 2.2.1 above. This study utilizes ASPIRES data collected from 600 small scale and 600 medium/large scale farmers across eight maize producing districts of Tanzania Mainland to examine whether the IR hypothesis is upheld even after controlling for cropping systems in maize farms.

2.3 Lessons Learned and the Study Gap from the Reviewed Literature

The existing evidence suggests a combination of SFA based on econometric theory and DEA based on optimization theory has been used in estimating agricultural productivity across farms. The choice of the two depends on the underlying assumptions about the distribution of the stochastic component and/ or functional forms under which the production process fits. However, in economic reality, stochastic noise, as well as measurement discrepancies are inevitable. Recognizing this fact, SFA has been superior over DEA in analyzing the farm size-productivity relationship.

On the farm size-productivity relationship, the evidence is largely mixed, suggesting differences in data, research methods, and modeling issues. Also, most of the previous studies on farm size-productivity have been inclined on partial productivities such as land and/or labour- productivity which may end up with biased conclusions especially in multiple or diverse cropping systems prevalent in rural SSA.

Furthermore, most of the evidence on-farm size-productivity relationship are based on national aggregates which do not capture differences in productivity across farming systems and/or cropping systems in various agro-ecological zones. However, even for the little evidence at the regional or district level, none have analyzed farm size-productivity relationship across maize cropping systems and with a considerable range of farm sizes. Therefore, the current study seeks to fill this gap by contributing empirical evidence on-farm size-productivity relationship across a range of farm sizes and maize cropping system in eight maize producing districts in Tanzania Mainland using the total factor productivity (TFP) approach.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Theoretical Model

Referring to section 3.1.1 in Chapter Three, the C-D functional form, as opposed to any others forms, was used in this study to estimate the level of TFP since it is easy to handle and above all, it conforms to the theory, data and design of the study. Equations (6-10) show how the TFP was estimated under the framework of the C-D production function.

3.1.1 Specifying the Cobb-Douglas production function and TFP

Cobb-Douglas production function was generally expressed as;

$$Qit = AX_{it}{}^{\beta k}e^{u} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6).$$

Where A measures the efficiency or TFP, Q is the gross aggregated value of maize output per season per year per farm unit. X is the vector of inputs used by the household per unit of the farm in the year of study and β is the vector of parameter coefficients which measure partial output elasticities while 'u' account for a stochastic component that may deter the efficiency with which Q is produced. From eq. (6) above, TFP of the i^{th} farmer was generated as in equation 7.

$$\mathrm{TFPi} = A = \frac{\mathrm{Qit}}{\sum_{i=1}^{n} X_{it}{}^{\beta k}e^{u}} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (7).$$

Thus, the magnitude of A in (7) above was thought to be 1 for the most efficient farmers and any deviations amounted to inefficiencies.

3.2 Empirical Model Specification and Estimation

The simple Cobb-Douglas function in equation 6 above was used to "estimate farmer's TFP level across maize cropping systems" and was expanded to include four variables denoted as X_{i1} to X_{i4} as indicated in equation 8. The TFP level of the i^{th} farmer was then estimated as in equations 9 and 10 below. The selected explanatory variables in the above models are supported by the existing empirical literature and the available data.

$$Qit = i\, X_{i1}{}^{\beta 1} X_{i2}{}^{\beta 2} X_{i3}{}^{\beta 3} X_{i4}{}^{\beta 4} e^{u} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8).$$

$$LnQit = \ln Ai + \beta_1 \ln(X_{i1}) + \beta_2 \ln(X_{i2}) + \beta_3 \ln(X_{i3}) + \beta_4 \ln(X_{i4}) + (\nu i - \upsilon i) \,.\,(9).$$

$$LnQit = \beta_0 + \beta_1 \ln(X_{i1}) + \beta_2 \ln(X_{i2}) + \beta_3 \ln(X_{i3}) + \beta_4 \ln(X_{i4}) + (\nu i - \upsilon i) \ldots (10).$$

Where Ln is the natural log and A_i is the efficient parameter (i.e. TFP) that was estimated as β_0 in (10). Q_{it} is the aggregated gross value of maize output (in Tanzanian Shillings (TZS) for the i^{th} farmer grown in the main season for the year 2015/2016 and X_1 to X_4 are the planted acres, amount of labour supply (adult equivalent man-days), cost of seeds (TZS) and cost of fertilizer (TZS) used in the production process while β_1 to B_4 is the estimated output elasticities. The term ν_i is a random error term assumed to be independent and identically normally distributed with $\mu = 0$ and δ_v^2 and $\upsilon_i >= 0$ is the inefficiency parameter which is also assumed to be independent but half-normally distributed with $\mu = 0$ and δ_v^2. If the i^{th} farmer attains a maximum potential output Q at a given production technology, the value of υ_i was assumed to be zero in absolute terms. So the presence of inefficiencies lowers the productive efficiency (i.e. TFP).

3.2.1 Estimation of the relationship between TFP, farm size and other socio-economic factors hypothesized to influence TFP

Equation (11) shows the empirical model estimated the relationship between TFP, farm size and socio-economic factors hypothesized to influence TFP.

$$\mathrm{LnTFPij} = \alpha 0 + \delta 1\mathrm{Di1} + \delta 2\mathrm{Di2} + \theta 1\mathrm{lnX_{i1}} + \phi 1\mathrm{Di1.lnX_{i1}} + \phi 2\mathrm{Di2.lnX_{i1}} + \beta 1\mathrm{lnEi1} + \alpha 1\mathrm{Di3} + \alpha 2\mathrm{Di4} + \alpha 3\mathrm{Di5} + \alpha 4\mathrm{Di6} + \alpha 5\mathrm{Di7} + \alpha 6\mathrm{Di8} + \alpha 7\mathrm{lnAge} + \alpha 8\mathrm{Di9} + \alpha 9\mathrm{Di10} + \alpha 10\mathrm{lnHHSize} + \alpha 11\mathrm{lnWT} + \alpha 12\mathrm{lnMF} + \varepsilon \mathrm{i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11).$$

In equation (11) above, TFP_{ij} is the j^{th} farm plot level TFP for the i^{th} maize farmer in the main farming season 2015/16, X_{i1} is the land area under maize planted in acres measured both as farmer-reported and GPS based plot size. The sign of the estimated parameter of the area planted (θ_1) was thought to explain the strength and magnitude of the relationship between the land area under maize and farm size. E_{i1} stands for the difference between GPS based-and the farmer's self-reported measures maize plot in acres which control for measurement errors in the estimation of the farm size-productivity relationship. $D_{i1}\ldots D_{i10}$ are dummies to control for cropping systems, farm-level characteristics as well as household heads' characteristics (see Table 1 and Appendix 1).

The parameters ϕ_1 and ϕ_2 were estimated to control for the possible interactions between cropping patterns and farm size in the estimation of TFP and the effects of other explanatory variables were estimated through parameters α_i. The terms HH Size, WT and MF stand for the household members, walking time in minutes from home to the farm, and months worked on the farm by the household head, respectively. The term ε_i is the error term incorporating random errors and inefficiency factors as explained in 3.2 above. Table 2 in appendix 1 shows the expected signs of the estimated parameters which are explained in section 3.3 below;

3.3 A priori Expectations for the Explanatory Variables in the Model

Table 1 shows the definition, measurement and expected signs for the variables included in the empirical model. The maize planted area measured in acres was used as farm size in this study to measure its relationship with farm level productivity measured as total factor productivity (TFP). Usually, a positive relationship between farm size and productivity is expected, however, the existing empirical evidence suggests mixed signs.

Since the ignorance of land measurement errors has been associated with the existing farm size-productivity IR, this study incorporated the measurement discrepancy (bias) as explained in section 3.2.1 above, to estimate its influence on farm-level productivity. The positive bias implies an underestimation of self-reported measures of land area planted (acres) and may accelerate the positive relationship between farm size and farm-level productivity and the opposite case for the negative bias.

Besides, if crops are grown on fertile soil under good conservation practices and being timely planted, then higher crop productivity per unit of land planted is expected. Additionally, it is expected that farms located near the homesteads will have close monitoring and minimum or no cases of crop losses due to theft and animal attacks and hence would produce higher levels of productivity, holding other factors constant.

Table 1: Definition, measurement and expected signs for the variables in the model

Variables	Definition and Measurement	Expected Signs
Planted land area (X_1)	Land planted with maize in acres	+/-
Land measurement error (E_{i1})	Measured as the difference between self-reported farm size and GPS farm size	+/-
Age of Household head (Age)	Measured as number of years since birth	-
Household size (Size)	Number of persons in a household	-/+
Months worked in farm (Months)	Number of months the head of household worked on the family farm.	+
Base/reference cropping system (Di_0)	Maize pure stand cropping system was treated as the reference cropping system	
Cropping system_1 (Di_1)	System dummy1: 1 if mixed maize with legumes, 0 otherwise	+/_
Cropping system_2 (Di_2)	System dummy2: 1 if mixed maize with non- legumes, 0 otherwise	_/+
Sex of household head (Di_2)	Dummy variable: 1 if male, 0 otherwise	+
Education of household head (Di_3)	Dummy variable: 1 if completed primary and above, 2 if otherwise	
Group membership of the household head (Di_4)	Dummy variable: 1 if Yes, 0 if No	+
Time taken from home to the farm in minutes (W_t)	Walking distance in minutes from homesteads to the farm	_
Use of fertilizer (Di_5)	Dummy variable: 1 if applicant of fertilizer, 0 if non applicant	+
Slope of the farm (Di_6)	Dummy variable: 1 if flat/moderate slope, 0 if other slope patterns	+/_
Fertility status (Di_7)	Dummy variable: 1 if fertile, 0 if not	+
Tenure status (Di_8)	Dummy variable: 1 if the farm is owned, 0 otherwise	+
Source of water for the maize crops (Di_9)	Dummy variable: 1 if rain-fed, 0 if other sources like irrigation by pipes, gravity, manual or both rainfall and irrigation were used	_
Experience on crop losses (Di_{10})	Dummy variable: 1 if the farm field ever experienced any crop losses, 0 if not	_

Moreover, if the farm fields are used to experience crop losses or shocks, then the resulting level of productivity per farm/plot will be low and vice versa for the case when there are limited or no cases of crop losses due to either failure, drought, heavy winds, floods, crop theft or unlawful animal grazing (Madau, 2011; Mburu *et al.*, 2014). Also, practicing mixed cropping systems reduces the risk of crop failures which then brings a positive influence on farm-level productivity.

Moreover, farms of household heads allocating enough time to work on their farms are expected to perform better in terms of productivity than their counterparts. Hence, under *ceteris paribus*, the more months a farmer allocates to work on his or her farm the higher the gross value of the resulting output and hence higher level of total factor productivity.

Similarly, the increase in the expenditure on intermediate inputs like fertilizers and seeds reduces farmer's efficiency in terms of profitability which then discourage input acquisitions to investment in farm production and hence low level of productivity (Madau, 2011). Additionally, the household head’s age used as the proxy for farming experience, is expected to have positive influence on productivity that is the older the farmer the higher the efficiency in farming and hence higher productivity.

Conversely, the larger the household size the lower the efficiency in farming due to the increased cost of taking care of the family, *ceteris paribus* (Madau, 2011). Additionally, Rangel and Thomas (2012) and Mukasa and Salami (2015) and hold the view that farms of households headed by male perform better in terms of efficiency than their female counterparts due to the differences in social and economic roles they play. If this is maintained, the current study findings are thought to give similar results.

Furthermore, if farmers are adequately educated/trained on the best farm practices, they will have proper knowledge and skills to enable them improve farm productivity. Likewise, this study expects a positive relationship between the level of education a farmer has and level of farm productivity, holding other influential factors the same.

3.4 Data, Data Processing and Analysis

3.4.1 Data

The study utilized the data set of ASPIRES project-Tanzania established in 2016. The data comprised of 600 small scale farmers and 600 medium/large scale farmers randomly selected from eight maize producing districts, namely Mvomero, Kilombero, Njombe, Kiteto, Magu, Moshi Rural, Mkuranga and Liwale of Tanzania Mainland. The data set comprises of socio-demographics as well as economic information that were important in this study. It also comprises of farm size measurements as reported by farmers at the household level as well as GPS estimates believed to control for possible measurement errors associated with the estimation by farmers. Since this study is concerned with farm size and productivity relationship in maize cropping systems, the sample for the study involved only 1001 farmers out of the 1200 farmers equivalent to 83.42% as they reported to have grown maize in the 2015/2016 main season. The data processing and analyses were manifested in various soft wares as outlined in the subsection below.

3.4.2 Data processing and analysis

The ASPIRES data set were stored in the SPSS file from where it was downloaded for various data manipulations/analyses. In order to estimate the total factor productivity (TFP) per household, the gross value of maize output was calculated as the sum of total maize harvested in kilograms per household multiplied by average farm gate price per kilogram as received by farmers in the 2015/2016 main farming season. Costs for seed, fertilizer, labour and land as major inputs used in production were considered in this study. The cost for seeds and fertilizer used in production, reported per acre of land cultivated were multiplied by the total area cultivated to get the total costs. Also, the cost of land cultivated were taken as the average imputed value of land cultivated per acre as reported by farmers multiplied by total area cultivated by an individual household in the sample. The labour input cost was calculated as the sum of household labour cost and hired cost per activity per acre cultivated multiplied by the total area under maize in acres per household. All the costs computations were manifested in the SPSS software and were reported in Tanzania Shillings (TZS). Moreover, the regression models as specified in the section 3.2 and sub-section 3.2.1 above were run using the SPSS commands and the results are presented in the following chapter.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socio-economic Characteristics of the Sample Households and Household Heads

Table 2 shows that household heads in the large maize farms category had an average age of 53.3 years which is higher than the rest of farm size categories. As it was expected, older household heads were found to own large farms than young household heads, probably because of having various savings and knowledge that were accumulated over time. Also, the results indicate that the mean months worked by the household head in the family’s farm in the large farms' category was approximately 1 month lower than the rest of farm size categories. This may be because large farms use modern equipment (capital-intensive) compared to small farms which are labour-intensive.

Table 2: Socio-economic characteristics of sample households and household heads by farm size

	Farm size categories (acres (A))				
Variables	**A<=2.5**	**2.5<A<=12.5**	**12.5< A<=50**	**A>50**	**Full sample**
Observations	308	487	181	25	1001
Age of HH head	50.09	48.7	48.1	53.3	49.63
Months worked in farm	6.95	7.3	6.7	6.05	6.75
Household Size	7.7	8.4	8.4	8.76	8.2
Sex of HH head: Male	93.5%	93.4%	96.1%	96.0%	94.0%
Female	6.5%	6.6%	3.9%	4.0%	6.0%
Education of HH head:					
Primary and above	59.3%	60.4%	63.0%	68.0%	60.8%
Other levels	40.7%	39.6%	37.0%	32.0%	39.2%
Membership in farmer					
group: Yes	69.5%	63.9%	59.7%	56.0%	64.6%
No	30.5%	36.1%	40.3%	44.0%	35.4%

Similarly, the average household size across all farm size categories of 8.76 persons corresponding to large farmers (with farms of over 50 acres) is about 1 person more the size of the very small farmers (with farms between 0 and 2.5 acres). Moreover, it was found that male heads dominated all groups of farm size by over 93%, which implies that most of the farm activities are controlled by male heads and this may lead to higher farm productivity as males are expected to have more time to invest on management and control of the farm resources to improve farm productivity than female households heads who normally have other roles to play in the family compared to male heads.

On the other hand, 68% of household heads in the large farm category reported to have completed primary education and above compared to 63%, 60% and 59% corresponding to medium, small and very small farms categories, respectively. The relatively high literacy level observed in the large farm category may be implied in the relationship between farm size and productivity that will be accounted for later in this study.

Furthermore, 69.5% of household heads of very small farms were members of farmer groups/associations compared to 63.9-, 57.9-, 56% for small farms, medium and large farms, respectively. This means that the majority of heads in the study area have chances to learn from others and gain new knowledge through various training programs which may boost their farm performance in terms of productivity.

4.2 Farm (field) Characteristics

Irrespective of farm size categories, Table 3 shows that, over 90% of the sample farmers owned the land they cultivated in 2015/2016 farming season. This is important especially in increasing interest over investing in good land management practices that may result in improved land productivity for the current and future use of the same. On the other hand, the owners of medium and large maize farms spent between 50 and 60 minutes to travel form their homesteads to their farms compared to the 37 to 40 minutes spent by owners of small farms. This could be due to such reasons as land scarcity, physical infrastructural change and other demographic-based facts like animal and human population increase which may locate large pieces of farms away from people's homes.

Table 3: Farm (field) characteristics across farm size categories

	Farm Size (acres (A))				
Farm characteristics	**A<=2.5**	**2.5<A<=12.5**	**12.5<A<=50**	**A>50**	**Full Sample**
Tenure status: Owned	95.1%	94.0%	93.4%	92.0%	94.2%
Others	4.9%	6.0%	6.6%	8.0%	5.8%
Time taken from homestead to farm (proxy of distance)	37.1	43.4	50.9	50.6	43.02
Slope: Flat/moderate	87.3%	91.2%	92.3%	92.0%	90.2%
Others	12.7%	8.8%	7.7%	8.0%	9.8%
Fertility status: Fertile	82.8%	86.7%	80.7%	72.0%	84.0%
Not fertile	17.2%	13.3%	19.3%	28.0%	16.0%
Use of fertilizer: Yes	9.1%	5.7%	6.6%	12.0%	5.7%
No	90.9%	94.3%	93.4%	88.0%	94.3%
Sources of water: Rain-fed	99.0%	98.8%	99.4%	100%	99.0%
Others	1.0%	1.2%	0.6%	0.0%	1.0%
Crop losses :Yes	85.4%	84.4%	84.5%	64.0%	84.2%
No	14.6%	15.6%	15.5%	36.0%	15.8%

Besides time taken to reach the farm, Table 3 show that over 87% of maize farms between 0 and 2.5 acres were located on a flat/moderate slope compared to over 90% for the rest of the farm size categories. This variation in the pattern of slope of the farm fields may as well influence land productivity as because soil erosion that can take soil nutrients away from the field is likely to occur on fields with steeper slope compared with fields on flat land.

Like the field slopes, fertility status of the fields varies across farm size categories, from 72% in the large farm size category to about 87% in the farm size category of between 2.5 and 12.5 acres. This is contrary to the expectation because the field slopes in the small farm size category were steeper compared to those in the large farm size category which are flats with the high likelihood of retaining soil nutrients. With the exception of the large farm size category, however, there is no significant difference in fertility status of fields in the rest the farm size categories of 50 acres and below. It can therefore be generalized that majority of the farms in the study districts were regarded as being naturally fertile and hence limited need for productivity enhancing technologies. As observed in Table 3, 12% of the household heads in the large farm size category reported to have applied fertilizer on their farms compared to less than 10% reported in other farm size categories with relatively high fertile farms.

With regard to source of water for the maize crop, majority of the farmers irrespective of the farm size category depended on rainfall as the source of water for their maize crops. This poses risk of reducing maize output and hence low productivity during seasons with little or low rainfall regimes.

Besides source of water for the maize crop, famers were asked to indicate if they experienced any crop losses in the 2015/16 farming season. As can be seen from Table 3, farmers with farms falling under farm size categories of 50 acres and below reported higher rate of experiencing crop losses which is above 80% compared to 64% of farmers with farms in the farm size category of above 50 acres. These losses were due to either natural calamities like floods, drought and diseases, or some unfair practices by neighbours like grazing on others' farms by pastoralists or on farm crop theft. Whatever the cause, these losses lead to reduction in crop harvest and consequently low farm productivity.

4.3 Land Area Planted and Measurement Errors

The findings in Table 4 indicate that, an average farmer in the first, second, third and fourth farm size categories in the study districts planted 1.63, 6.09, 24.83 and 107.63 acres of maize, respectively. While farmers with farm sizes falling in the first and second farm size category were the majority, these results imply that the small farms are likely to influence the resulting farm size-productivity relationship. Taking into account the measurement discrepancies across farmers' categories, the study found that on average very small farmers with farms between 0 and 2.5 acres underestimated their farm sizes by 5.49 acres compared to 1.17 acres for small farmers with farms between 2.5 and 12.5 acres. On the contrary, maize farmers in the medium-scale (12.5-50 acres) overestimated their plots' size by only 0.06 acres compared to 15.24 acres for large farmers (with farms above 50 acres). This may have implications on the relationship between acres planted and productivity as observed in the next section.

Table 4: Land area planted and area measurement errors by farm size categories

Farm Size Category	Average area planted with maize (acres)	Acreage measurement errors (acres)
Less than 2.5 acres	1.63	-5.49
Between 2.5 and 12.5 acres	6.09	-1.17
Between 12.5 and 50.0 acres	24.83	0.06
50 acres and above	107.63	15.24
Whole Sample	10.64	-1.87

4.4 Relationship between Productivity and Farm Size

4.4.1 Total factor productivity across farm size categories

The findings presented in Table 5 indicate that on average, the TFP of farmers who planted at least 50 acres of maize was 5.23 which is more than five times for those who planted at most 12.5 acres, and close to three times and five times for those who planted 12.5 to 50 acres and the whole sample, respectively. This implies that medium farmers with 12.5 to 50 acres of land owned and large farmers with farms of over 50 acres, who constituted about 20% of all observations, were more productive than their counterparts. These findings are contrary to the previous evidence over inverse relationship between productivity and farm size.

Table 5: Average total factor productivity across farm size categories

Farm size categories	Total Factor Productivity
Less than 2.5 acres	0.4
Between 2.5 to 12.5 acres	0.93
Between 12.5 to 50 acres	1.85
50 acres and above	5.23
Whole sample	1.04

4.4.2 Relationship between TFP and land area under maize

4.4.2.1 Graphical analysis of the relationship between TFP and maize area planted

The graphical presentation in Figure 1 shows different patterns in the relationship between the mean TFP and land area under maize (acres). The figure portrays a zig-zag pattern for maize areas of 0 to 80 acres for farmer-based data and 0 to 60 acres for the GPS based data. A gentle increase and sharp increase in TFP occur for farm sizes ranging from 100 to 200 acres for the farmer-based data while for the GPS data, a gentle decline in TFP is displayed for farm sizes in the range of 130 to 200 acres. Also using the same

GPS data, the figure shows that farmers in the range of 120 to 200 acres recorded almost no change in TFP despite the increase in farm size.

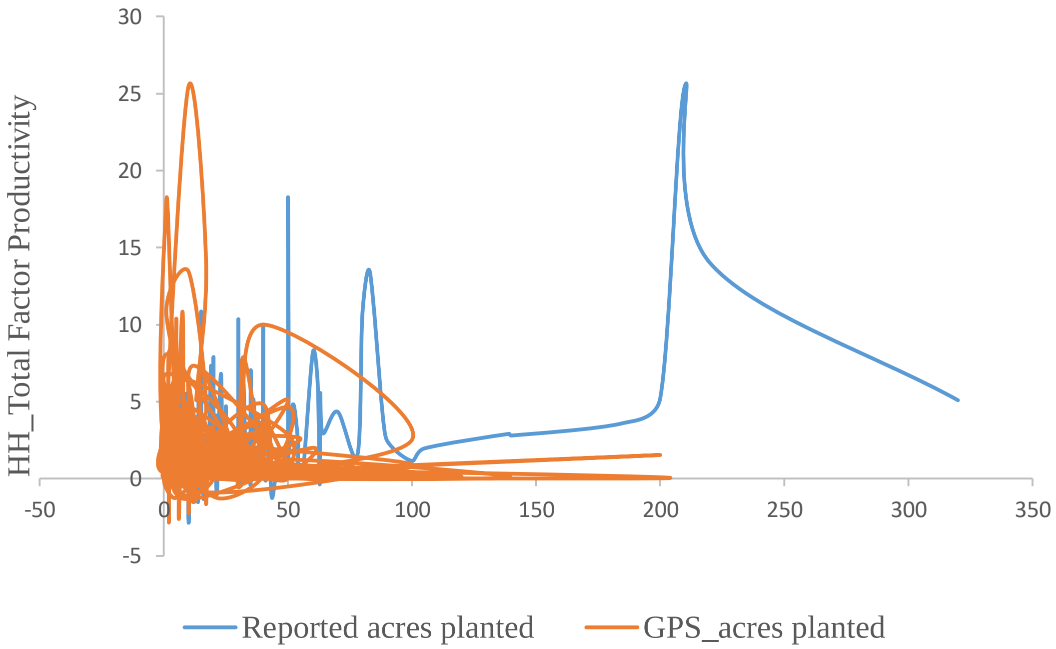

Figure 1: Relationship between Farm Size and Productivity

It is interesting to note that, the inverse relation between productivity and farm size occurs in farm sizes above 200 acres when the farmer-based data is used. This is probably due to diseconomies of scale resulting from inefficiency in management of farm resources. The findings presented here are close to those of Larson *et al.* (2013) and Carletto *et al.* (2013). Unlike the graphical evidence, the Pearson correlation coefficient (ρ=.513) for farmer-based data indicates that maize productivity (TFP) and area under maize (acres) are positively correlated while for the GPS data, the correlation coefficient (ρ=-.017) is negative though it is weak (see Figure 1). This evidence has shown that examining farm size-productivity relationship across a range of farm sizes, improves the prior inverse relation hypothesis and even refuting it.

4.4.2.2 Total factor productivity and area planted across maize cropping systems

Table 6 shows that, on average, the maize and legumes intercropping system performs better with TFP of 1.64 compared to 1.57 and 1.22 registered in maize-non legumes and maize-pure stand cropping systems, respectively. These findings are not surprising as it is expected that cropping systems involving legumes are likely to do better in terms of land productivity due to soil nutrients conversion ability rooted in leguminous plants. In terms of the average area planted with maize, the results reveal great variation both with farmer-reported plot sizes and GPS-estimated plot sizes, respectively. However, non-legumes maize cropping system occupied a large area compared to its counterpart systems due to its nature in the growth patterns which require large space.

Table 6: Average total factor productivity and area under maize across maize cropping systems

Variable	N	TFP	Area planted_ (acres)	Area planted_ (acres)
			(Farmer reported_ plot size)	(GPS based plot size)
Pure standers	524	1.22 (3.25)	7.94 (21.22)	12.07 (20.06)
Maize-legumes intercrop	75	1.64 (4.65)	10.24 (17.45)	8.32 (13.75)
Maize-non legumes intercrop	402	1.57 (3.49)	12.91 (21.27)	12.20 (16.58)
Total	1001			

Note: Values in parentheses are standard errors of the means.
N stands for the number of observations, TFP is the Total Factor Productivity

4.4.2.3 Validity of the results of the TFP and farm size across maize cropping systems

The validity of descriptive results for the relationship between farm size and TFP across maize cropping systems and farm size categories were examined.

The tests carried out include test of the normality and homogeneity assumptions and the following are the outcomes.

First, the assumption of normality of data was evaluated for the estimates of TFP across cropping systems. A Shapiro-Wilk's test with ($\rho>.05$) was tenable for both maize-non legumes and maize-legumes intercrop patterns. The assumption of homogeneity of error variance for the dependent variable (log of TFP) was found tenable using Levene's test, $F_{(2, 998)} = 1.569$, $\rho = 0.209$. However, it was unfortunate that the overall ANOVA was statistically insignificant, $F_{(2, 998)} = .452$, $\rho = .637$ implying that there were no statistically significant differences among mean TFP across the three cropping systems.

Second, the normality assumption was evaluated for the farm size categories. A Shapiro-Wilk's test ($\rho>.05$) was tenable for the first three farm-size categories (less than 2.5 acres, between 2.5 to 12.5 acres and between 12.5 to 50 acres) and a visual inspection of their histograms, normal Q-Q plots and box-plots showed that the household means levels of TFP were approximately normally distributed. A one-way analysis of variance was conducted to evaluate the null hypothesis that there is no significant difference among means of TFP across farm size categories. The independent variable, farm size categories had four groups: (below 2.5 acres, N=308), (between 2.5 to 12.5 acres, N=487), (between 12.5 to 50 acres, N=181) and (50 acres and above, N=25). The homogeneity assumption was also tested and found tenable using Levene's test, $F_{(3, 997)} = .526$, $\rho = .664$. The overall ANOVA was significant, $F_{(3, 997)} = 65.002$, $\rho = .000$, $\eta^2 = .164$. Thus, it suffices to conclude that there are significant differences among mean TFP levels across groups of farm sizes. However, the actual difference in mean scores between the groups is relatively small (16.4%).

4.5 Results of Econometric Analyses

4.5.1 Relationship between farm size and productivity across various plot size categories

The results in Table 7 indicate that, at 1% level of significance, the true mean maize productivity (TFP) in the study area is estimated to increase by 0.608%, 0.690%, 0.572%, and 0.750% respectively, if the area under maize in the farm size categories of between 0 and 2.5 acres, 2.5 and 12.5 acres, 12.5 to 50 acres and above 50 acres is increased by 1%, ceteris paribus. For the whole sample, the findings show that a 1% increase in area under maize will increase the estimated mean productivity (TFP) by 0.774%, holding all other factors the same. The estimated impact of area under maize on the mean TFP for the whole sample is higher by almost 0.1% for the first three farm size categories (Between 0 and 2.5 acres, 2.5 and 12.5 acres, and 12.5 to 50 acres) and lower by 0.6% for maize farms greater than 50 acres.

The above evidence shows that the estimated relationship between area under maize (acres) and productivity (TFP) is positive when each farm size category is analyzed separately and when observations are combined. The above findings are consistent with the recently published work by Desiere and Jollife (2018) and Muyanga and Jayne (2019) and inconsistent to Msangi and Mdoe (2018). Also, this study found that 1% increase in farm size measurement errors will respectively lower the estimated mean TFP by 0.45%, 0.52%, 0.69% and 0.56% across farm size categories, and by 0.53% for the whole sample (see Table 7), keeping other factors unchanged. This implies that if farm size measurement systems are improved in the study area such that errors in farm sizes are significantly reduced, the estimates of productivity per unit of land will improve accordingly, *ceteris paribus*.

Table 7: OLS regression estimates for total factor productivity across farm size categories

Variables	Farm size categories (acres (A)) Model1 (A<=2.5)	Model2 (2.5<A<=12.5)	Model3 (12.5<A<=50)	Model4 (A>50)	Full sample
Intercept	-0.248	-0.419	4.332**	0.225	0.139
Log_acres planted	0.608***	0.690***	0.572***	0.750***	0.774***
Log_measure_discrep.	-0.453***	-0.526***	-0.691***	-0.564***	-0.533***
Log_walk_time (min.)	-0.052	0.034	-0.065	0.003	-0.016
Log_months in farm	0.052	0.019	0.055	0.048	0.046
Log_household size	-0.290*	-0.325**	0.113	-0.219*	-0.240**
Log_age of HH head	0.268	0.117	-0.542	-0.045	0.028
Dummy_sex of HH head	-0.182	0.293	0.637	0.311	0.167
Dummy_HH head educ.	0.161	0.060	-0.011	0.044	0.078
Dummy_apply fertilizer	-0.061	-0.675**	-0.907**	-0.807***	-0.810***
Dummy_slope pattern	-0.653***	-0.266	-0.152	-0.222	-0.370***
Dummy_fertility status	0.086	0.257	-0.317	0.101	0.089
Dummy_tenure status	0.062	-0.323	0.991**	-0.024	0.004
Dummy_watering syst.	-0.446	-0.656	-3.680**	-0.985*	-0.815*
Dummy_shock/loss exp.	-0.657***	0.145	-0.390	-0.040	-0.226*
Observations	**308**	**487**	**181**	**25**	**1001**
R Square	**0.186**	**0.185**	**0.321**	**0.271**	**0.320**
F statistic	**4.446*** **	**7.110*** **	**5.211*** **	**16.816*** **	**30.963*** **

Note: *** significant at 1%, ** significant at 5%; * significant at 10%
A is planted maize area in acres

Additionally, the results show that, other factors than farm size namely; household size, status of fertilizer application, slope pattern, tenure status, source of water, and crop losses were also found to significantly influence the estimated level of TFP across farm size categories as it is explained here. In particular, the estimated mean TFP is estimated to decrease by .29% (ρ*>0.1), .325% (ρ*>0.05) and .219% (ρ*>0.1) if the household size for farmers with farm size of between 0 to 2.5 acres, 2.5 to 12.5 acres and above 50 acres increased by 1%, holding other factors the same. This implies that the larger the household size the lower the level of TFP at least across the above farm size groups. Similarly, at 5% significance level and maintaining levels of other factors, farmers who planted between 2.5 and 12.5 acres of maize and applied fertilizer (9.1%) were found to attain 49.08% of the mean TFP than non-fertilizer applicants who attained 90.9%, while farmers with farms of 12.5 to 50 acres and above 50 acres planted with maize were respectively found to attain 59.62% and 55.38% of mean TFP than that of their counterparts. Likewise, when considering the full sample, the true estimated mean TFP of farmers who applied fertilizer is 55.51% ($\rho>0.01$) lower than farmers who did not apply fertilizer, holding everything else fixed. These results seem unusual at least in this study probably because the farmers who reported to have applied fertilizer on their farms did not have adequate skills on the proper use of fertilizer given soil characteristics and other management practices of the crop under the field. It seems also that non-fertilizer applicants were used to believe on the natural soil fertility of their farms and other organic methods to improve soil fertility which earned them an edge in terms of productivity than their counterpart farmers who depended on inorganic fertilizers.

Furthermore, farms below 2.5 acres and located on a flat or moderate slope were found to produce 47.95% lower mean of TFP compared to similar farms located on other slope patterns like terraces, steep or up land slopes. Likewise, when the whole sample is analysed, the findings reveal that, farms located on a flat/moderate slope attained 30.93% lower mean of TFP compared to farms in other slope patterns. This implies that for the farmers with very small plots to realize higher productivity of maize they should consider cultivating on upland or terraced sloped land to increase productivity of their farms.

Moreover, at 5% level of significance and fixed levels of other factors, the study found that owned farms of maize with 12.5 to 50 acres attained over 169% of mean TFP than non-owned farms. This means that farmers who own farms have more control of their farms which give them ample chance to improve the land quality and hence productivity as compared to farmers renting in land. On contrary, at 5% and 10% levels of significance, rain-fed maize farms with 12.5 to 50 acres and 50 acres and above were estimated to produce 97.43% and 62.66% lower mean ratio of TFP, respectively than those farms which depended on other sources of water, holding other factors fixed. These findings are important especially now when the government of Tanzania is promoting industrialization policy of which most of the raw materials or inputs for the agro-industries will be derived from agriculture. Nonetheless, as expected the experience on crop losses especially on the field reduced estimated mean TFP for the small scale maize farms (below 2.5 acres) by 48.16% at the level of significance of 1% compared to 20.23 % at the level of significance of 10% for the whole sample, *ceteris paribus*. This means that maize crop losses either due to rodents, unlawful animal grazing as well as natural hazards like floods, drought and diseases contribute to reducing total farm productivity.

4.6 Relationship of Farm Size and Total Factor Productivity across Maize Cropping Systems

The OLS regression results in Table 8 indicate a positive and significant relationship between acres under maize and Total Factor Productivity (TFP) across both cropping systems and the whole sample. It is estimated that the true mean TFP among maize farmers would increase by 0.783%, 0.849%, and 0.834%, respectively if the land area under maize-pure stand-, maize-legumes- and maize-non legumes-intercropping systems are each increased by 1%, holding other factors fixed.

For the whole sample, the evidence reveals that a 1% increase in the area planted with maize leads to an increase in the estimated mean TFP by 0.745%, holding other factors unaltered. As expected, the estimated impact of an area under maize on the mean TFP for the whole sample is lower than when the three cropping systems are analyzed separately. On the contrary, a 1% increase in the farm size discrepancy leads to a decrease in the estimated mean TFP by 0.449% (p*>0.01) for pure stand, 0.452% (p*>0.01) for maize-legumes intercrop, 0.654% (p*>0.01) for maize-non legumes intercrop and 0.534%

(p*>0.01) for the whole sample, leaving other factors the same. Hence, the increase of accuracy in measuring farm-plot sizes will improve the farm level productivity (TFP), *ceteris paribus*.

Also, this study found that holding everything the same, a 1% increase in the number of persons in a household practicing maize pure stand system reduces the estimated mean TFP by 0.365% which is 0.137% less than the estimated mean TFP for the whole sample. Also, it is estimated that the mean TFP for male-headed households is 54.8 % higher than that of female headed households in the maize pure stand intercropping system, holding other factors fixed.

Table 8: OLS Regression Estimates for Total Factor Productivity across Maize Cropping Systems

Variable Observations	Coefficients MPS 524	Coefficients ML 75	Coefficients MNL 402	Coefficients Full sample 1001
Intercept	-0.997	2.788	0.921	0.243
Log_acres planted	0.783***	0.849***	0.834***	0.745***
Log_measurement discrep.	-0.449***	-0.452**	-0.654***	-0.534***
Log_walk time (minutes.)	-0.024	0.046	-0.011	-0.018
Log_month worked in farm	-0.035	-0.035	0.037	0.042
Log_family size (no. persons)	-0.365***	-0.566	-0.083	-0.228***
Log_HH head’s age	0.293	-0.165	-0.127	0.012
Dummy_sex of HH head	0.437*	0.667	-0.274	-0.149
Dummy_HH head's Educ.	0.082	0.318	0.032	-0.315**
Dummy_HH head’s assoc.	0.051	-0.497	0.114	0.067
Dummy_apply fertilizer	-1.001***	-2.255*	0.855	-0.855***
Dummy_slope pattern	-0.424***	-1.036	-0.157	-0.354***
Dummy_fertility status	0.185	-0.179	-0.056	0.101
Dummy_tenure status	-0.154	-1.435	0.258	0.004
Dummy_watering system	-0.489	-0.069	-1.558	-0.770*
Dummy_shock/loss experience	-0.193	-0.579	-0.203	-0.208*
Maize-legumes dummy_ D_1				-0.149
Maize-non legumes dummy_ D_2				-0.315**
Dummy1_cross_acres planted				0.056
Dummy2_cross _acres planted				0.109
R^2	**0.33**	**0.37**	**0.36**	**0.32**
F statistic	**16.67*** **	**2.354*** **	**14.68*** **	**24.67*** **

Note: *, ** and *** stands for 10%, 5% and 1% level of significance, respectively.
MPS stands for Maize pure stand, ML stands for Maize-legumes intercrop and MNL Stands for Maize-non legumes intercrop

Additionally, at fixed levels of other factors, it is estimated that the mean TFP for farmers who applied inorganic fertilizer is 63.24%, 89.51%, 57.47% of those who did not apply the same in the maize pure stand, maize and legumes intercrop and for the whole sample, respectively. These findings are not expected, probably because most farmers (close to 90%) did not apply any fertilizers and therefore depended on the natural soil fertility of their farms and other indigenous field-crop management practices which gave them an edge over those who depended on inorganic fertilizer to improve fertility of their farms. The other reason for the unexpected influence of fertilizer on productivity could be lack of proper skills on soil characteristics and fertilizer attributes among fertilizer applicants. Moreover, holding other factors fixed and at a 1% significance level, it is estimated that flat or moderate sloped maize farms attained 34.56% and 29.81% of the mean TFP than farms located in other slope patterns for maize pure stand cropping system and the full sample, respectively. This means that maize cultivated as a stand-alone crop on hilly/slope or terraced land had more chances to perform better in terms of higher productivity level per unit land area than those in flat/moderate slope within the same locality.

However, it was also found that, at fixed levels of other factors and 10% level of significance, the estimated mean TFP for rain-fed farms and which experienced crop losses is 53.69% and 18.78% of their counterpart systems, respectively for the whole sample. This means that if all other factors are held constant, maize farmers depending on rains as the source of water attain lower levels of productivity (mean TFP) than those farmers depending on various sources like irrigation by pipes, gravity, manual, or both (irrigation and rains). Also good management of the maize crop from field to market reduces crop losses and hence ensures higher levels of productivity.

Furthermore, farmers practicing mixed maize farming system with non-legumes intercrop are estimated to attain 27.02% of mean TFP which is lower than farmers in pure stand system. This means that holding everything the same, farmers growing maize in pure stand system are estimated to perform better in terms of TFP than those in the maize and non-legumes intercropping system.

4.7 Summary of the Key Findings

The findings from this study reveal that more than 79% of maize farms are between 0 to 12.5 acres, suggesting that the majority of the farmers in 2015/2016 season were small scale farmers. The findings show existence of variability in Total Factor Productivity (TFP) across farm size categories with mean TFP of 0.40, 0.85, 1.85 and 5.23 corresponding to farms in farm size categories of between 0 to 2.5 acres, 2.5 to 12.5 acres, and 12.5 to 50 acres and above 50 acres, respectively.

Similarly, mean TFP across cropping systems were found to vary considerably with maize mixed with legumes cropping system recording higher levels of TFP of 1.64 compared to 1.57 and 1.22 for pure stand cropping system and maize mixed with the non-legumes cropping system. The relationship between farm size (measured as acres planted with maize) and productivity (measured as TFP) was significantly positive both across a range of farm size categories and across maize cropping systems and therefore refuting the inverse relation (IR) hypothesis. However, the graphical analysis (Figure 1) shows mixed patterns of relationships including; a zig-zag pattern for farms of 0 to 80 acres, U-shaped pattern for farms in the range of 100 to 200 acres and an inverse relationship for farms beyond 200 acres when the farmer-based data was used while for the GPS based data a zig-zag pattern was noted for farms of 0 to 60 acres and an inverse relationship was noted for farms of 130 to 200 acres. This means that the well-established inverse farm size-productivity relationship does not generally hold when a wide range of farm sizes including a mixture of small, medium and large farmers is considered.

The farm size measurement discrepancy determined by comparing farmer based and GPS based data was found to reduce the mean TFP by 0.45%, 0.52%, 0.69% for farms of 0-2.5 acres, 2.5-12.5 acres, and 12.5-50 acres, respectively, compared with 0.53% for the whole sample with average farm size of 10.64 acres. Likewise, if land planted with maize is not accurately measured, then a 1% increase in errors of planted area would reduce estimated TFP by 0.449%, 0.452%, and 0.654% in pure stand, maize-legumes and maize-non legumes-intercropping systems, respectively. This implies that land size measurement errors lead to lower reported productivity per farm/plot and hence inaccurately supporting the IR hypothesis.

Apart from farm size, other factors like household size, sex of household head, use of fertilizer, land slope pattern, tenure system, source of water and crop losses incurred significantly influence the farm level productivity (mean TFP) both across farm size categories and cropping systems, respectively.

CHAPTER FIVE

5.0 CONCLUSIONS, CONTRIBUTION OF THE STUDY, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER STUDIES

5.1 Conclusions

This study was carried out to determine the relationship between farm size and agricultural productivity across a range of farm sizes and maize cropping systems in Tanzania Mainland. It was motivated by the existing conventional wisdom of Inverse Relation (IR) hypothesis for land productivity and farm size and the fact that despite the numerous studies carried out using different methods to measure farm efficiency, little evidence is provided on the magnitude and strength of the relationship between farm size and productivity across cropping systems.

The study tested three hypotheses as they are restated hereunder. Firstly, to test whether the farmers' total factor productivity level across maize cropping systems in the study districts does not vary significantly. Secondly, to test if farm size has no influence on total factor productivity level across maize cropping systems and lastly, to test if factors other than farm size do not influence total factor productivity level across the maize cropping systems in the study districts in Tanzania Mainland.

The first hypothesis was rejected. Contrary to the hypothesized relations, the findings of the study show variation of TFP by both cropping system and farm size. Regarding variation across cropping systems, the maize-legumes cropping system stood out with higher levels of TFP followed by maize and non-legumes and maize pure stand cropping systems. Similarly the second hypothesis was rejected. Contrary to the hypothesis that farm size has no influence on farm productivity, the study found that the relationship between farm size and TFP was significantly positive across maize cropping systems. These findings contribute to the emerging empirical evidence on positive relationship between farm size productivity which is contrary to the IR hypothesis that has been supported by several studies for many decades. Like the other two hypotheses, the third hypothesis that factors other than farm size do not influence the total factor productivity level across the maize cropping systems, the findings of the study show that household size, sex of household head, use of fertilizer and slope of the farm influenced significantly the mean TFP across the maize cropping systems.

5.2 Contribution of the Study

The study contributes to the on-going debate on IR between farm size and efficiency or productivity in terms of empirical evidence in four different ways. Firstly, the study defied the presence of the inverse relationship between farm size and maize productivity (TFP) using cross-sectional data from a wide range of farms including small, medium and large farms in eight maize producing districts in Tanzania Mainland. While most of the previous evidence on IR was based on a narrow range of small scale farms, this study has revealed various patterns of relationship across the wide range of farm sizes including zig-zag, inverse and positive relationships.

Secondly, using the cross-sectional data set, the study provides empirical evidence on influence of cropping systems on farm-level productivity. It was found that mixed maize-legume cropping system performs better in terms of TFP than other cropping systems. Thirdly, the study enforces the existing empirical evidence on the influence of farm size measurement errors on productivity both across a range of farm sizes and cropping systems. The study found that, farm size measurement discrepancy reduces the estimated mean TFP, implying that ignorance of errors in measurement of farm size may lead to inappropriate conclusions. Lastly, unlike most of the previous IR studies, this study used TFP approach to test the IR hypothesis arguably more eloquent than use of partial productivity measures such as yield or gross margin per unit of land or labour.

5.3 Recommendations

Based on the major findings of the study and conclusion, the recommendations and suggestions for further studies are put forward:

5.3.1 Review of the current National Agriculture Policy and the Agricultural Sector Development Programme (ASDPII)

The evidence of a positive relationship between farm size and agricultural productivity across a range of farm sizes suggests that the current agricultural policy and the Agricultural Sector Development Program (ASDPII) which are largely emphasizing promotion of small-scale agriculture in the country should be reviewed. While supporting smallholder farmers who are the majority, the country's agricultural land policies and programmes should also promote medium and large scale farms which have large multiplier and employment effect as well as the potential to produce surplus of agricultural products required as raw materials for the agro-based industries and hence enable the country to realize its vision of becoming and industrialized and middle income country by 2025.

5.3.2 Promoting land productivity enhancing mixed cropping systems

The maize-legume cropping system was found to have higher TFP than the maize pure stand and maize-non legume cropping systems. In order to ensure higher crop productivity levels, the government should provide education on mixed cropping systems that enhance land productivity such as the cereal-legume cropping system. Adoption of these cropping systems mutual could be promoted through Farmer Field Schools (FFS) and farmer managed demonstration trials facilitated the government extension officers at the ward and village levels.

5.3.3 Promoting family planning strategies and programmes

The findings of the study show inverse relationship between household size and productivity in maize production i.e. the larger the household, the low the productivity. Therefore, public health interventions and programmes to promote family planning should be supported in rural areas with the aim of controlling the number of dependents per household. This will ensure use of available household resources on improving farm productivity instead of spending them of family care.

5.3.4 Supporting low cost irrigation strategies and programmes

It was found that farmers who depended solely on rains as the source of water for their maize farms had lower levels of productivity compared to farmers who depended on other sources of water like surface irrigation, manual irrigation, sprinkler irrigation (for medium and large scale farms) and sprinkler irrigation (for medium and large scale farms)n and ran-fed). It is therefore recommended here that, the government should support strategies and programmes that promote low cost and hence sustainable improvement of agricultural productivity.

5.3.5 Hastening the process of formalizing land property rights

The findings of the study show that maize farmers owning land attained higher productivity (TFP) levels compared to farmers who rented similar farm size fields. Since the normal process of land surveys for formalizing land rights expensive and relatively slow, the government in collaboration with other stakeholders should ensure that the process of formalizing land rights through the Customary Rights of Occupancy (CRO) of land stipulated in the Village Land Act No. 4 of 1999 is hastened and widely used to ensure security of land for farming in the rural areas.. This will encourage farmers to invest in good land management practices that would improve productivity.

5.3.6 Providing education on and promoting appropriate farming practices on hilly/slope land

The findings show unexpected negative relationship between the slope of the farm and productivity in maize production for pure stand cropping system. Therefore, education on the appropriate land management practices including terraces, cover crops, need to be provided to farmers especially those in highlands whose majority of their maize farms are on hilly/slope land to reduce soil erosion and loss of soil nutrients and ensure sustainable higher productivity. These land management practices should be promoted through various famer managed farm trials to show the benefits of adopting these practices.

5.3.7 Building Capacity for Extensive use of Geographical Information Systems and Technology (GIS/GIT)

The study found a significant negative influence of the farm size measurement error on farm productivity. Therefore, the National Bureau of Statistics (NBS) need to build capacity among staff so that they may extensively use the GIS/GIT especially on collecting information on farm size among the agricultural households in Tanzania Mainland. This would improve the farm size data used for research as well providing implications from the research findings which would then help to make better policy decisions.

5.4 Suggestions for Further Studies

With the current evidence, the study recommends that forthcoming studies in the area of farm size-productivity relationship should consider various cropping systems and a wider range of crops to improve the existing empirical evidence on farm size-productivity relationship as well as bringing more evidence that may serve as cornerstones for further policy interventions.

REFERENCES

African Development Bank. (2017). Feed Africa: The Road to Agricultural Transformation in Africa. High Five Brief #2, African Development Bank.

Ali, D. A. and Deininger, K. (2015). Is There a Farm Size–Productivity Relationship in African Agriculture? Evidence from Rwanda. *Land Economics* 91(2): 317–343.

Amos, T.T., Chikwendu, O.D. and Nmadu, J. (2004). Productivity, technical efficiency and cropping patterns in the Savanna zone of Nigeria. *Food, Agriculture and Environment* 22: 173-176.

Ansoms, A., Verdoodt, A. and Van Ranst, E. (2008). The inverse relationship between farm size and productivity in rural Rwanda, (January). pp. 1–36.

Arce, C.E. and Caballero, J. (2015). Tanzania: Agricultural Sector Risk Assessment. Washington, DC. 45pp.

Assunção, J. J. and Braido, L. H. B. (2007). Testing household-specific explanations for the inverse productivity relationship. *American Journal of Agricultural Economics* 89(4): 980–990.

Baksiene, E., Razukas, A., Repeckiene, J. and Titova, J. (2014). Influence of different farming systems on the stability of low productivity soil in Southeast Lithuania. *Zemdirbyste-Agriculture* 101(2): 115–124.

Barrett, C. B., Bellemare, M. F. and Hou, J.Y. (2010). “Reconsidering Conventional Explanations of the Inverse Productivity-Size Relationship.” *World Development* 38 (1): 88-97.

Bevis, L. E. M. and Barrett, C. B. (2016). Close to the Edge : Do Behavioral Explanations Account for the Inverse Productivity Relationship? 1–82.

Boulay, B. (2018). Revisiting the old debate: on the relationship between size and productivity in Tanzania. 56pp.

Carletto, B. C., Savastano, S. and Zezza, A. (2016). Measurement, Farm Size and Productivity How Does Use GPS Data Affect Yield. 879pp.

Carletto, C., Gourlay, S. and Winters, P. (2015). “From Guess estimates to GPS estimates: Land Area Measurement and Implications for Agricultural Analysis,” *Journal of African Economies* 24 (5): 593–628.

Carletto, C., Savastano, S. and Zezza, A. (2013). “Fact or Artifact: The Impact of Measurement Errors on the Farm Size Productivity Relationship.” *Journal of Development Studies* 103: 254-261.

Chayanov, A. V. ([1926] 1991). *The Theory of Peasant Co-operatives.* Columbus: Ohio State University Press. 45pp.

Collier, P. and Dercon, S. (2014). “African Agriculture in 50 Years: Smallholders in a Rapidly Changing World?” *World Development* 63: 92-101.

Desiere, S. and Jolliffe, D. (2018). Land productivity and plot size: Is measurement error driving the inverse relationship? *Journal of Development Economics* 130(August 2016): 84–98.

Dillon, A. Gourlay, S., McGee, K. and Oseni, G. (2016). "Land Measurement Bias and its Empirical Implications: Evidence from a Validation Exercise." World Bank Working Paper, Washington, DC. 67pp.

Dixon, J., Stringer, L. and Challinor, A. (2014). Farming System Evolution and Adaptive Capacity: Insights for Adaptation Support. *Resources* 3(1): 182–214.

Foster, A.D. and Rosenzweig M.R. (2017). Are There Too Many Farms in the World? Labor-Market Transaction Cost, Machine Capacities and Optimal Farm Size. Yale University. Economic Growth Center Discussion Paper No.1059.

Goksel, A. and Altug, O. (2007). Determinations of Total Factor Productivity with Cobb-Douglas Production Function in Agriculture: The Case of Aydin-Turkey. *Journal of Applied Sciences* 7: 499-502.

Gollin, D. (2017). Heterogeneity, Measurement Error, and Misallocation : Evidence from African Agriculture. 77pp.

Graeub, B. E., Chappell, M. J., Wittman, H., Ledermann, S., Kerr, R. B. and Gemmill-Herren, B. (2016). The State of Family Farms in the World. *World Development* 87: 1–15.

Hazell, P., Dorward, A., Poulton, C. and Wiggins, S. (2007). "The Future of Small Farms for Poverty Reduction and Growth." Discussion Paper No. 42, International Food Policy Research Institute 2020, IFPRI, Washington, DC. 89pp.

Hazell, P., Poulton, C., Wiggins, S. and Dorward, A. (2010). "The Future of Small Farms: Trajectories and Policy Priorities." *World Development* 38(10): 1349-1361.

Holden, S.T. and Fisher, M. (2017). Can Area Measurement Error Explain the Inverse Farm Size Productivity Relationship? *Centre for Land Tenure Studies Working Paper*. *Agricultural Economics* 45(3): 355-367.

Imai, K. S., Hasan, M. F. and Porreca, E. (2015). Do Agricultural Extension Programmes Reduce Poverty and Vulnerability? Farm Size, Agricultural Productivity and Poverty in Uganda. 46pp.

Jayne, T. S., Chamberlin, J., Traub, L., Sitko, N., Muyanga, M., Yeboah, F. K., Kachule, R. (2016). Africa's changing farm size distribution patterns: the rise of medium-scale farms. *Agricultural Economics (United Kingdom)* 47: 197–214.

Karugia, J., Massawe, S., Guthiga, P. and Macharia, E. (2013). Agricultural Productivity in the EAC Region (1965-2010) Trends and Determinants. *International Symposium and Exhibition on the Agricultural Development in the EAC Partner States at the 50 Years of Independence. 4th to 8th November 2013 Kampala*, *Uganda*. 89pp.

Kiani, A. K. (2008). Farm size and productivity in Pakistan. *European Journal of Social Sciences* 7(2): 42–52.

Kimhi, A. (2006). "Plot Size and Maize Productivity in Zambia: Is there an Inverse Relationship?" *Agricultural Economics* 35(1): 1-9.

Larson, D., Otsuka, K., Matsumoto, T. and Kilic, T. (2013). "Should African rural development strategies depend on smallholder farms? An exploration of the inverse productivity hypothesis." Policy Research Working Paper 6190. Washington, DC. World Bank.78pp.

Lokina, R., Nerman, M. and Sandefur, J. (2011). Poverty and Productivity : Small-Scale Farming in Tanzania, 1991-2007. Working paper 8/0896: 1–56.

Lowder, S. K., Skoet, J. and Raney, T. (2016). The Number, Size and Distribution of Farms, Smallholder Farms and Family Farms Worldwide. *World Development* 87: 16–29.

Madau, F. A. (2011). Parametric estimation of technical and scale efficiencies in Italian citrus farming. *Agricultural Economics Review* 12(1): 91–111.

Mburu, S., Ackello-Ogutu, C. and Mulwa, R. (2014). Analysis of Economic Efficiency and Farm Size: A Case Study of Wheat Farmers in Nakuru District, Kenya. *Economics Research International* 2014: 1–10.

Mdoe, N.S.Y., Mlay, G.I. and Kadigi, M.L. (2015). Farming Systems in Tanzania: Empirical Evidence of Changes in Livelihood Patterns and Poverty among Smallholder Farmers. In: Lal R., Singh B., Mwaseba D., Kraybill D., Hansen D., Eik L. (eds) Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa. Springer, Cham 67pp.

Mkonda, M. Y. and He, X. (2016). Production Trends of Food Crops: Opportunities, Challenges, and Prospects to Improve Tanzanian Rural Livelihoods. *Natural Resources and Conservation* 4(4): 51–59.

Msangi, H. and Mdoe, N.S.Y. (2018). Examining the Inverse Relationship between Farm Size and Technical Relationship in Tanzanian Agriculture. 167pp.

Mukasa, A. N., Salami, A. O., Kayizzi-mugerwa, S. and John, C. (2015). Gender productivity differentials among smallholder farmers in Africa : A cross-country comparison (231): 45.

Muyanga, M. and Jayne, T. S. (2019). Revisiting the Farm Size-Productivity Relationship Based on a Relatively Wide Range of Farm Sizes: Evidence from Kenya. *American Journal of Agricultural Economics* 101(4): 1140–1163.

NBS (2017). National Panel Survey Wave 4, 2014 – 2015, (February): 1–104.

Nilsson, P. (2019). The Role of Land Use Consolidation in Improving Crop Yields among Farm Households in Rwanda. *Journal of Development Studies* 55(8): 1726–1740.

Nkonde, C., Jayne, T.S. Richardson, R.B. and Place, F. (2015). Testing the farm size-productivity relationship over a wide range of farm sizes: Should the relationship be a decisive factor in guiding Agricultural Development and land policies in Zambia? *Journal of the International Society for Southeast Asian Agricultural Sciences* 18(1): 49–61.

Rangel, M. A. and Thomas, D. (2012). Gender, Production and Consumption : Allocative Efficiency within Farm Households. *Redistribution: Toward Greater Consensus*, Washington D.C.: World Bank. 44pp.

Reuben, M. J. K., Japhet, J. K., Agnes, S., Felix, K., Anna, S. and Winfred, M. (2017). Land fragmentation, agricultural productivity and implications for agricultural investments in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) region, Tanzania. *Journal of Development and Agricultural Economics* 9(2): 26–36.

Savastano, S. and Scandizzo, P. L. (2017). Farm Size and Productivity: A "Direct-Inverse-Direct" Relationship. *Global Indicators Group, Development Economics*, (June). pp. 78-97.

Sen, A. K. (1962). An aspect of Indian agriculture. *Economic Weekly* 14(4-6): 243-246.

Sen, A. K. (1964). Size of Holdings and Productivity. *The Economic Weekly*, (February): pp.323–326.

Sial, M. H., Iqbal, S. and Sheikh, D. (2012). “Farm size – productivity” relationship. Recent evidence from Central Punjab 50(2): 139–162.

Singh, J. and Yadav. H.S. (2014). Farm Size, Cropping Pattern and Productivity Variation in Punjab: The Analysis of Mansa and Jalandhar Districts. *International journal of management and information technology* 7(3): 22-37.

Srinivasulu, R., Victor, A. S., Daniel, K. K., Richard, M., Dannie, R., Magesa, A. M., Radegunda, F. K. (2015). Technical efficiency of traditional African vegetable production: A case study of smallholders in Tanzania. *Journal of Development and Agricultural Economics* 7(3): 92–99.

UNCTAD (2015). Evolution of the international trading system and its trends from a development perspective. *The role of smallholder farmers in sustainable commodities production and trade.* 23pp.

UNDP and URT (2014). *Tanzania Human Development Report 2014. Economic Transformation for Human Development.* [https://doi.org/978-9987-770-00-7]. Site visited on 3/2/2019.

URT (2010). National Strategy for Growth and Reduction of Poverty II: NSGRP II. *Ministry of Finance and Economic Affairs Tanzania*, (July). 168pp.

Wineman, A. and Jayne, T. S. (2018). Factor Market Activity and the Inverse Farm Size-Productivity Relationship in Tanzania. Conference, July 28-August 2, 2018, Vancouver, British Columbia 277030, International Association of Agricultural Economists. 47pp.

APPENDICES

Appendix 1: Dummies for Maize Cropping Patterns

Type of Pattern	**Dummy**	**Description**
Maize pure stand	D_{i0}	This is the base/reference group
Maize and legumes	D_{i1}	1 if maize cropped with legumes, 0 otherwise
Maize and non-legumes	D_{i2}	1 if maize cropped with non-legumes, 0 otherwise