ANALYSIS OF FACTORS AFFECTING THE TECHNICAL EFFICIENCY OF SMALLHOLDER DAIRY FARMERS IN NJOMBE DISTRICT

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF BUSINESS ADMINISTRATION OF THE OPEN UNIVERSITY OF TANZANIA

2013

CERTIFICATION

I hereby certify that I have read this thesis prepared under my supervision and recommend that it be accepted for examination.

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Dr. Felician Mutasa

(Supervisor)

Date……………………………………...........

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DECLARATION

I, Peternus M. Mbehoma, do here by declare that this thesis is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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Date……………………………..

DEDICATION

I dedicate this thesis to my wife Joha Karagwe Mrua, and all my sons and daughter for nursing me with affections and love and their dedicated partnership in the success of my life.

ACKNOWLEDGEMENTS

First and foremost let me praise and honor the almighty God for the opportunity and capacity given to me to realize my aspiration.

Several individuals and organizations deserve acknowledgement for their contributions to the study. I am greatly indebted to my advisor Dr. Felician Mutasa (Ph.D) for he unreserved help, advice, directing, insight guidance, critical review of my thesis manuscript, invaluable support and suggestions as without his professional help it was difficult to be successful in my academic, research work and thesis write up. I am also deeply grateful to Njombe District Council my employer for grating me permission to participate in postgraduate studies.

I acknowledge the help received from the extension workers and smallholder farmers in the study area during data collection. Their cooperation is highly appreciated.

Last but not least, I am very grateful to my beloved wife, Joha Karagwe Mrua our children Jovianus Mgizi, Johannes Karagwe Nyekomize and Joyline Kokuhumbya who showed patience and love and gave me tireless encouragement throughout the study.

ABSTRACT

This study was conducted in nine dairy cattle keeping villages of Njombe District Council (NDC) with the overall objective of estimating Technical Efficiency (TE) and analyzing factors influencing Technical Inefficiency (TI) of smallholder dairy farmers. Cobb-Douglas stochastic frontier production function in which the parameters for the production frontier and for the inefficiency model were estimated jointly using the maximum likelihood technique on cross section data of 81 smallholder dairy farmers. The estimated TE ranged from 13% to 99% with a mean of 45.46% and SD of 24.113%. Analysis of TE results revealed that majority of respondents (61.7%) had TE below 50%. The implication of these findings is that majority of the respondents were technically inefficient and that the value of dairy production could be increased by 54.54% through better allocation and use of available resources. In addition, it was found that TI of smallholder dairy farmers is positively related to farmer's age, gender, education level, experience, selling to processor, membership in dairy production and marketing group, off farm income and dairy herd size and negatively related to farmer's marital status, use of hired labour, dairy training, extension contact and selling on credit. It is suggested that any policies that would attract young and married people to enter or remain into dairy production business would lead to improved TE in smallholder dairy production. TE could improve more if such policies are directed at attracting and encouraging more women to participate in business, implemented in areas where off farm employment opportunities are limited, more farm labour are available and selling is done on credit to reliable buyer allowing timely lump sum payments.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ASDP	:	Agricultural Sector Development Strategy
DALDO	:	District Agricultural and Livestock Development Officer
DEA	:	Data Envelopment Analysis
DPLO	:	District Planning Liaison Officer
FAO	:	Food and Agriculture Organization
FDH	:	Free Disposal Hull
GDP	:	Gross Domestic Product
ILRI	:	International Livestock Research Institute
LR	:	Likelihood-Ratio
ML	:	Maximum Likelihood
MLE	:	Maximum Likelihood Estimate
MoAC	:	Ministry of agriculture and Coorperative
NDC	:	Njombe District Council
OLS	:	Ordinary Least Square
PFP	:	Partial Factor Productivity
RTS	:	Return to Scale
SD	:	Standard Deviation
SPF	:	Stochastic Production Frontier
SPSS	:	Statistical Package for Social Scientists
SUA	:	Sokoine University of Agriculture
TE	:	Technical Efficiency

TFP	:	Total Factor Productivity
TI	:	Technical inefficiency
TSHS	:	Tanzanian Shillings
UK	:	United Kingdom

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Agricultural Sector is the leading sector of the economy of Tanzania. It accounts for over half of the GDP and export earnings. Over 80% of the poor live rural areas and their livelihood depend on agriculture accounting for about 70 percent (ASDS, 2001).

Smallholder farmers predominates agricultural sector in Tanzania and has been characterized by low productivity (Lwelamira et al, 2010). According to R&AWG (2005) and Msuya (2007), increasing agricultural productivity is crucial for improving the livelihoods of smallholder farmers, who makes the majority of the rural poor in Tanzania. Msuya (2008: 291) shows that, low productivity is one of the primary causes of low and unstable value added along the value chains leading to a stagnant rural economy with persistence of poverty. Hence, increasing productivity of smallholder farmers is crucial for improving the livelihoods in the country.

Livestock production is among the major agricultural sub-sectors in Tanzania. According to FAO (2005), livestock production makes up around 13% of the GDP and 30% of the agricultural GDP. Of the latter, about 40% is beef production, 30% milk and dairy production 30% is poultry and small stock production (National Livestock Policy 2005). Out of the 4.9million households, 35% are engaged in both crop and livestock production while 1% is purely livestock keepers (Njombe and

Msanga, 2008). Livestock production is therefore an important component of local economies at both national and farm household level where cattle constitute the main livestock species kept by farmers.

1.2 The Context of the Study

Smallholder dairying is one of the fast growing enterprises in the livestock industry in Tanzania. Smallholder dairy production though limited in size has been receiving more emphasis in investment and improvement because of four main reasons namely: improvement of nutritional status of the society through increased milk consumption, increased cash income for dairy farmers, saving in terms of reduced dairy import and contribution to market oriented economy (National Livestock Policy, 2006). In Tanzania, dairy development effort focuses its attention in high potential areas mostly located in the highlands. Northern and Southern highlands have been identified as ideal places for dairy production (Maganga, 1995). Government has joined hands with donor agencies in these areas in order to implement its dairy development policies (Muren, 1981 and Lauren and Centres, 1990).

Despite government and donor efforts to improve milk production, production of milk and other dairy products has not kept pace with population and urbanization growth, (Sumberg 1997). Total milk production from indigenous cattle and improved cattle is currently estimated at 1.6 billions litres (Budget Speech, 2009). The overall per capita milk availability is low (42 litres/annum) compared with

Kenya (80 litres/annum), the average for Africa (35 litres/annum) and the world average (105 litres/annum) (Kurwijila, 1995).

According to the MoAC/SUA/ILRI (1998) milk demand projections to the year 2010 (base on consumption level of 22 litres per-capita per annum, urbanization level of 5% per annum, a population growth rate of 2.3% per annum, an overall income elasticity of dairy products of 0.8 and modest real GDP growth of 1% per annum) demand is estimated to increase by 60% annually or per-capita consumption of 44 and 30 litres per annum respectively in urban and peri-urban areas, while milk production (under assumptions that: no change in cattle herd productivity and structure, an increase in indigenous cattle population of 1.7% per annum and dairy herd expansion of 46% per annum) would increase by 43% resulting in short fall of some 17%. These observations suggest that without substantial effort to improve the performance of dairy sector, Tanzania will face severe shortage of milk and dairy products.

1.3 Statement of the Research Problem

As income, population growth and urbanization are expected to substantially increase the demand of dairy products in 21st century, Tanzania has not achieved self-sufficiency in production of milk and other dairy products and the contribution dairy sub sector to income and nutrition has been very limited (Kurwijila, 1995). This may be due to fact that most smallholder farmers practice subsistence farming with low and varied productivity. This may be attributed to both high technical and allocative inefficiencies. Although some of the factors that lead to low productivity have been identified, socio-economic and institutional factors that are expected to have significant influence on technical efficiency of smallholder farmers are still not well empirically established due to the fact that few studies have been carried out in this area. Few studies that have analyzed efficiency in Tanzania no study have estimated technical efficiency of smallholder dairy farmers and analyzed the determinants of their inefficiencies.

While Msuya and Ashimogo (2006) determined the technical efficiency of smallholder farmers, they focused on sugarcane production (a cash crop). Shapiro and Muller, (1977) also focused on a cash crop (cotton), Sesabo and Tol (2005) examined the technical efficiency of small-scale fishing households and Msuya et al., (2008) focused on maize (food crop). This research work therefore intends to fill this knowledge gap.

1.4 Research Objectives

1.4.1 General research objective

The general objective of this study is to estimate technical efficiency and analyse factors influencing technical inefficiency of smallholder dairy farmers in NDC.

1.4.2 Specific Objectives

The specific objectives of the study are:

i. To characterize socio-economic and institutional attributes of smallholder dairy farmers in NDC.
ii. To estimate the level of technical efficiency of smallholder dairy farmers in

the district.

iii. To identify the variables affecting their current levels of technical efficiency.

1.5 Hypotheses of the Study

i. Smallholder dairy farmers in NDC are technically efficient as result no productivity gains linked to the improvement of technical efficiency may be realized in dairy production under current technologies and available resources.

ii. Socio-economic and institutional variables specified in the inefficient model do not influence technical efficiency of smallholder dairy producers in Njombe district.

1.6 Conceptual Framework

The level of technical efficiency of a particular farmer/firm is characterized by the relationship between observed production and some ideal or potential production (Greene, 1993), often measured as a ratio between the output of a particular farmer/firm and the maximum possible output obtainable (frontier) using a given set of inputs under a given technology. The gap can be closed if the limiting factors are identified and addressed. This study is sought to estimate technical efficiency and analyse factors affecting technical efficiency of smallholder dairy farmers in NDC.

All smallholder dairy farmers in Njombe District Council keep improved dairy cattle and they face similar conditions with regard to infrastructure and marketing institutions for inputs and farm produce. It is therefore, safe to assume that they all use very similar technology for dairy production. However, smallholder dairy farmers have different socio-economic and institutional factors which include farmers' education, training, age, and experience in the dairy business, herd size, household size, marital status, access to extension service, record keeping and membership in mutual aid groups.

They also face different institutional environment which includes issues like the transaction costs in milk marketing in terms of search for buyers and market information, contractual arrangements, monitoring the contracts and binding costs. These socio-economic and institutional factors interact with each other and together they influence managerial capacity of the farmer which in turn influences his technical efficiency. Thus, it is postulated that, the performance differences among smallholder dairy farmers within a village, in terms of technical efficiency can be attributed to socio-economic and institutional factors. It is further postulated that, correlation exists between these factors and technical efficiency. If such correlation can be identified, then efforts to improve the farmer's technical efficiency can specifically target at changing most critical factors for optimum productivity.

1.7 Significance of the Research

This study is both of a practical and theoretical importance. At practical level, measuring technical efficiency of dairy production, and identifying the factors that affect it may provide useful information for evaluation of existing interventions strategies and formulation of economic policies likely to improve farmer's technical efficiency. Moreover, from microeconomic standpoint, identifying and analysing the factors that may improve farm efficiency is of major significance since, by using information derived from such studies, farmers may become more efficient and hence more profitable.

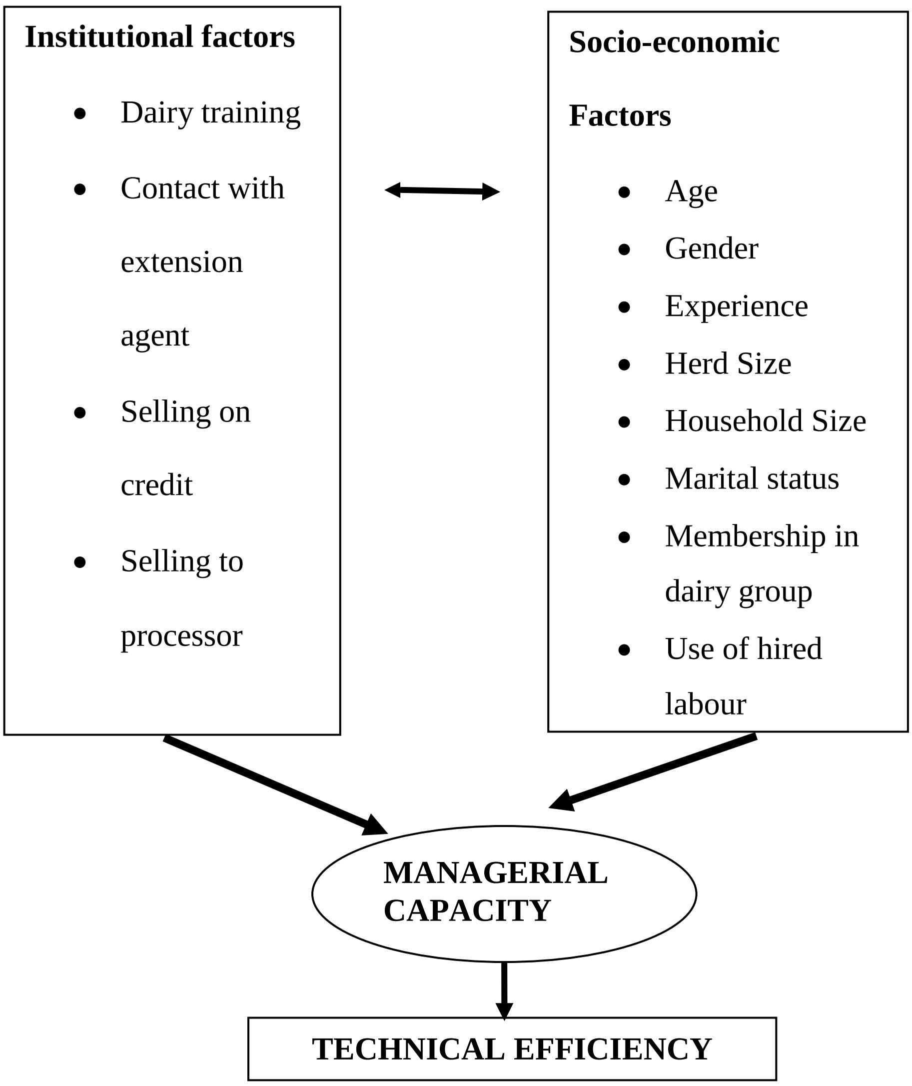

Figure 1.1: ConceptualFramework Underlying the Study
Source: Kalirajan, (1990).

At the theoretical level, the study aims to bring some contribution to the understanding of dairy farmer's technical performance in Tanzania and Njombe district in particular and factors that influence their technical efficiency.

1.8 Scope and Limitation of the Study

The inefficiency in small holder dairy production may be resulting from low genetic potential, livestock diseases and existing government livestock and trade policies. This study however, did not investigate these issues. Instead the study investigated socio-economic and institutional variables to analyze the influence of these variables on technical efficiency small holder dairy producers in NDC.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Literature Review

2.1.1 Basic Efficiency Concepts

2.1.1.1 Production

Production is the process of transforming inputs into output. Production technology can be described by using production function, cost function, profit function and revenue function.

2.1.1.2 Production Function

A production function describes the technical relationship between inputs and outputs of a production process. According to Beattie and Taylor (1985), a production function is the maximum output attainable from given level of inputs and given technology. Production function is usually represented by a mathematical function or by a graph.

A general way of writing a production function in mathematical form is given as:

$$Y = f(X)$$

Where Y is an output, X is a vector of inputs and f(.) is a suitable functional form.

Assumptions of a Production Function

A typical production function is based on the following assumptions (Beattie and Taylor, 1985):

1. Production activity of a firm is so arranged that production in one time

period is totally independent of the production in preceding and subsequent time periods.

2. All inputs and outputs of a firm are homogeneous.
3. The production function is twice continuously differentiable.
4. The production functions, output prices and inputs prices are known with certainty.
5. There is no limit to input availability.
6. The objective of a firm is to maximize profit or to minimize cost for a specified output level.

2.1.1.3 Productivity and Efficiency

The terms productivity and efficiency are often used interchangeably but they are not precisely the same things. Productivity is an absolute concept and is measured by the ratio of outputs to inputs while efficiency is a relative concept and is measured by comparing the actual ratio of outputs to inputs with the optimal ratio of outputs to inputs.

Productivity can be divided into two sub-concepts: Partial Factor Productivity and Total Factor Productivity. Partial Factor Productivity is the average productivity of a single factor, measured by total output divided by the quantity of a factor applied. Total Factor Productivity is the productivity of all factors taken together. The efficiency of a firm is defined as the actual productivity of a firm relative to a maximal potential productivity (Farrell, 1957). Maximal potential productivity (also known as best practice frontier) is defined by the production frontier. Measurement of efficiency involves measurement of the distance from observed data point to that frontier (Lissitsa, et al. 2005).

Efficiency is an important economic concept and is used to measure the economic performance of a production unit. Efficiency in production is usually referred as economic or productive efficiency of a firm which means it is successful in producing as much output as possible from a given set of inputs. Production efficiency is concerned with the relative performance of the process used in transforming inputs into outputs. According to Farrell (1957) drawing from the former work of Debreu (1951) and Koopmans (1951), efficiency has two components: technical efficiency and allocative efficiency. Technical efficiency is the ability of a firm to produce a maximal output from a given set of inputs or it is the ability of a firm to use as modest inputs as possible for a given level of output. The former is called input oriented measures and the latter is known as output-oriented measures of technical efficiency.

A producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in at least one input requires an increase in at least one other input or a reduction in at least one output (Koopmans 1951). Allocative efficiency is the ability of a firm to use inputs in optimal proportion, given their respective prices and the production technology. The use of an input is allocatively efficient if the value of marginal product is equal to its price. According to Lovell (1993), a firm working allocatively efficient combines inputs and output in optimal proportion in the light of established prices. Allocative inefficiency arises when factors of production are used in proportion that does not minimize the cost of producing a given level of output. In other words, allocative inefficiency arises when a firm is failed to equate the ratio of marginal product of inputs to the ratio of market prices. Economic efficiency is the product of technical and allocative efficiency. If a firm is both technically and allocatively efficient is said to be an economically efficient firm.

2.1.2 Technical Efficiency Measurement

The evaluation of a firm's technical efficiency level results from the estimation of a frontier production function. Two main approaches are used to construct efficiency frontiers. The first of these is the nonparametric approach. In this approach, estimation methods are based on envelopment techniques. Distinct among them are the free disposal hull (FDH) and data envelopment analysis (DEA) methods. The FDH method was developed by Deprins et al. (1984), while the DEA method was initiated by Farrell (1957) and transformed into estimation techniques by Charnes et al. (1978). DEA is based on linear programming and consists of estimating a production frontier through a convex envelope curve formed by line segments joining observed efficient production units. No functional form is imposed on the production frontier and no assumption is made on the error term. Nevertheless, this method is limited because it:

i) Lacks the statistical procedure for hypothesis testing.

ii) Do not take measurement errors and random effects into account; in fact, it supposes that every deviation from the frontier is due to the firm's inefficiency.

iii) Is very sensitive to extreme values and outliers.

The second approach is the parametric approach. It is based on econometric estimation of a production frontier whose functional form is specified in advance. In this approach, the stochastic frontiers method is the most popular. Also referred to as "composed error model", the stochastic frontiers method has the advantage of taking into account measurement errors or random effects. Criticism of this method resides in the need to specify beforehand the functional form of the production function and the distributional form of the inefficiency term. The stochastic frontiers method is used in this study. This choice is made on the basis of the variability of livestock production, which is attributable to climatic parameters, and animal genetic factors, on the one hand, and, on the other hand, because information gathered on production is usually inaccurate since small farmers do not have updated data on their farm operations.

In fact, the stochastic frontiers method makes it possible to estimate a frontier function that simultaneously takes into account the random error and the inefficiency component specific to every firm. The stochastic frontiers production method was proposed for the first time by Aigner et al., (1977) and Meeusen and Van den Broeck (1977). It is defined by equation:

$$\text{Ln } y_j = f(X_{ij\,;}\, ß) + \varepsilon_j$$

Where y_j denotes the outputs of production unit j being evaluated, X_{ij} is the vector of quantities of factors of production i used by farm j and ß's are the parameters to be estimated. The residual ε_i is composed by a random error v_i and an inefficiency component u_i. Further details on both approaches can be obtained from books edited by Fried, Lovell, and Schimidt (1993) and Coelli, Rao and Battese (1998).

2.1.3 Method for Identifying Technical Efficiency Determinants

In the literature, two main approaches are used to analyse the determinants of technical efficiency from a stochastic frontier production function. The first approach, called the two-step approach, first estimates the stochastic frontier production function to determine technical efficiency indicators. Next, indicators thus obtained are regressed on explanatory variables that usually represent the firms' specific characteristics, using the ordinary least square (OLS) method. This two-step approach has been used by authors such as Pitt and Lee (1981), Kalirajan (1981), Parikh, Ali and Shah (1995), and Ben-Belhassen (2000) in their respective studies.

The major drawback with the two-step approach resides in the fact that, in the first step, inefficiency effects (u_j) are assumed to be independently and identically distributed in order to use the Jondrow et al. (1982) approach to predict the values of technical efficiency indicators. In the second step, however, the technical efficiency indicators thus obtained are assumed to depend on a certain number of factors specific to the firm, which implies that the u_j's are not identically distributed unless all the coefficients of the factors considered happen to be simultaneously null.

After becoming aware that the two-step approach displayed these inconsistencies, Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) developed a model in which inefficiency effects are defined as an explicit function of certain factors specific to the firm, and all the parameters are estimated in one step using the maximum likelihood procedure. By following this second approach Huang and Liu (1994) developed a non neutral stochastic frontier production function, in which the technical inefficiency effects are a function of a number of factors specific to the firm and of interactions among these factors and input variables introduced in the frontier function.

Battese and Coelli (1995) also proposed a stochastic frontier production function for panel data in which technical inefficiency effects are specified in terms of explanatory variables, including a time trend to take into account changes in efficiency over time. By following the one-step approach the model of technical inefficiency effects is specified in the following manner:

$U_j = Z_j^{\delta} + W_j$;

Where Z_j is the vector of characteristics specific to farm j**,** δ is a vector of parameters to be estimated, and W_j is the random terms assumed to be independently and identically distributed. It is defined by the truncation of the normal distribution with zero mean and unknown variance σ_w^2, such that u_j is non negative.

The one-step approach has since been used by such authors as Ajibefun et al. (1996), Coelli and Battese (1996), Audibert (1997), Battese and Sarfaz (1998), and Lyubov and Jensen (1998) in their respective studies to analyse the factors affecting the technical efficiency (or inefficiency) of agricultural producers.The one-step approach will be used this study. In effect, relative to the two-step approach, the one-step approach presents the advantage of being less open to criticism at the statistical level, and helps in carrying out hypothesis testing on the structure of production and degree of efficiency.

2.2 Empirical Literature Review

2.2.1 Review of Empirical Efficiency Studies from Developed and Developing countries

Bravo-Ureta and Evenson (1994) measured technical, allocative and economic efficiencies of peasant farmers in Eastern Paraguay by using a decomposition technology. Separate Cobb-Douglas production frontiers were estimated for 87 cotton and 101 cassava farmers. Average technical, allocative and economic efficiency was 58, 70 and 41 percent respectively for cotton farmers. Average technical, allocative and economic efficiency was estimated at 59, 89 and 52 percent, respectively for cassava farmers. The analysis of the relationship between efficiency and five socioeconomic variables (farm size, operator's age, education, extension contacts and credit) revealed a very weak association between efficiency and socio-economic characters.

Battese and Coelli (1995) used a stochastic frontier production function to investigate technical inefficiency effects on paddy rice farmers in India. The authors used panel data for 10 years. Results of the study indicated that the older farmers were less technically efficient than the younger ones. Farmers with higher education level were more efficient than the farmers with less education level but declined over the time period.

Xu and Jeffery (1998) used a stochastic frontier and neoclassical cost frontier to measure technical, allocative and economic efficiency of Chinese hybrid and conventional rice production. Cross-sectional data for a sample of 90 hybrid rice households and 90 conventional rice households were collected from the Jiangsu province. Average technical, allocative and economic efficiency for conventional rice were higher than for hybrid rice. Average technical efficiency for hybrid rice for south, central and north region was 0.85, 0.78 and 0.74, respectively. Average technical efficiency for conventional rice for south, central and north region was 0 .94, 0.91 and 0.87, respectively. Average economic efficiency for hybrid rice for south, central and north region was 0.61, 0.52 and 0.49, respectively and for conventional rice was 0.83, 0.80 and 0.74, respectively. Average allocative efficiency for hybrid rice and for conventional rice for south, central and north was 0.72, 0.67, 0.66 and 0.88, 0.86 and 0.85, respectively.

The authors concluded that the results were consistent with the ‘poor but efficient’ hypothesis. The small farmers were more efficient in allocating their inputs for convention rice production than for hybrid rice production. Education was significantly related with the technical efficiency. The authors also concluded that a positive relationship existed between land size and economic and allocative efficiency in modern agricultural regions (south) while the opposite was true for traditional agricultural areas (north).

Bravo-Ureta and Pinheiro (1997) used a stochastic production frontier to estimate technical, allocative and economic efficiency of peasant farmers in Dominican Republic. The authors used a maximum likelihood (ML) procedure to estimate the Cobb Douglas functional form. The average technical, allocative and economic

efficiency was 70, 44 and 31 percent, respectively. Results of the second stage analysis revealed that the younger farmers were technically, allocatively and economically more efficient than older ones. The authors concluded that contract farming and medium size farms had a statistically positive impact on allocative and economic efficiencies of farms in
Dominican Republic.

Seyoum, et al. (1998) estimated technical efficiency of maize farmers within and outside the Sawakawa-Global 2000 project in Eastern Ethiopia. The authors used a translog stochastic production frontier. The mean technical efficiency of farmers within the project was 0.937 while outside the project was 0.794. It was found that farmers with more years of schooling and those obtained technical advice from extension agents were technically less inefficient. The authors concluded that the younger farmers were technically more efficient than the older farmers. Wilson, et al. (1998) estimated technical efficiency of potato farmers in UK by using a stochastic frontier production function. It was found that the mean technical efficiency across regions ranged from 33 to 97 percent. The authors concluded that experience and small-scale farming were negatively correlated with the technical efficiency of potato farmers in UK.

Jaforrullah and Whiteman (1999) calculated technical and scale efficiency of the New Zealand dairy industry by a non-parametric data envelopment analysis (DEA) method for a sample of 264 dairy farms for the year 1993. The average technical efficiency of dairy farms was estimated at 83 percent. It was found that more farms were operating at below optimal scale. The authors suggested that trends towards larger farms Kibaara (2005) used a stochastic frontier production function to estimate technical efficiency in maize production in Kenya. The mean technical efficiency of maize farmers was 49 percent. The author concluded that use of hybrid maize seed increased technical efficiency by 36 percent, use of tractor for land preparation increased technical efficiency by 26 percent and an additional year of school increased technical efficiency by 0.84 percent. It was also found that male-headed households were technically more efficient than female-headed households.

Ajibefun, et al. (2006) estimated technical efficiency of rural and urban small scale farmers in Nigeria by using a stochastic frontier production function. Data were collected from 200 food crop farmers from rural and urban centers in Ondo State of Nigeria. Results of the study showed that farmers from rural centers were technically more efficient than urban farmers. The mean technical efficiency of rural framers was 0.69 as compared to 0.58 of urban farmers. The authors concluded that the education and farming experience were found to increase the level of technical efficiency of farmers in both rural and urban centers.

Wubeneh and Ehui (2006) analyzed the inefficiency of smallholder dairy producers in the central Ethiopian highlands with the stochastic production frontier technique. Their results confirmed the existence of systematic inefficiency in milk production. The average efficiency level of the farmers was only 79% implying that milk output could be increased on average by 21% with the existing technology by training farmers better production techniques. They also found that the efficiency in production of individual farmers can be improved by training farmers in proper feeding calving, milking, cleaning of cows, storing milk, marketing as well as other management skills. The variables that were found to influence technical efficiency include literacy level of the farmers, livestock training, age of the farmer, access to credit, expenditure on veterinary services and amount and concentrate and forage fed to cows.

2.2.2 Review of Empirical Efficiency Studies From Tanzania

Elibariki and Ashimogo (2005) determined and compared the level of technical efficiency of outgrower and non-outgrower Sugar cane farmers in Turiani Division, Mvomero District, Morogoro Region, and examined the relationship between levels of efficiency and various farm specific factors using stochastic production frontier technique. The results of the estimation showed that there were significant positive relationships between age, education, and experience with technical efficiency. Sesabo and Tol (2005) examined the technical efficiency of small-scale fishing households in Tanzania using data from two coastal villages (Mlingotini and Nyamanzi). A stochastic frontier (with technical inefficiency effects) model was specified and estimated. The estimated mean technical efficiency of small-scale fishing households is 52%. Results showed that the efficiency of individual fishing households is positively associated with fishing experience, size of farming land, distance to the fishing ground, and potential market integration and negatively related to non-farm employment and bigger household sizes.

In this chapter many efficiency studies have been reviewed from developed and developing countries of the world. These studies show that farmers of developing countries like Tanzania are inefficient both technically and allocatively. It is also evident from the review of literatures that few such studies have been done in Tanzania. According to intensive literature review conducted, no study has been conducted in Tanzania which investigated technical efficiency in agriculture and focused on smallholder dairy production. Therefore, it becomes imperative to investigate technical efficiency of smallholder dairy producers in Tanzania to fill this gap. This study is designed to measure the technical efficiency of small holder dairy producers in Njombe district. The study also identified and analyse various socio-economic and institutional related factors responsible for technical inefficiency inherent in smallholder dairy production in the district.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 The Study Area

3.1.1 Geographical Location

This study was carried out in Kichiwa, Ibumila Nyombo, Matiganjola, Mtwango and Ikelu villages of Makambako Division and Mlevela, Lusisi, Mhadzi and Nyumbanitu villages of Mdandu Division in Njombe District Council. Njombe District Council is located in the Southern Highlands of Tanzania between $8^0$8 and $9^0$8 South of Equator and $33^0$5 to $35^0$8 Longitudes. In the Southern part the district Council boarders Njombe Town Council, in the East it boarders Morogoro region, in the West it boarders Makete district and Mbeya region and in the North it boarders Mufindi district.

3.1.2 Climatic Zones, Vegetation and Soil

Njombe District Council is divided into two major climatic zones: highland zone and lowland zone.

3.1.2.1 Highland Zone

This is the continuation of the Southern highlands that form the undulating hills and plateaus. The highland zone lies between 2000 - 2500 meters above sea Level and covers areas of Lupembe, Imalinyi, and Mdandu Divisions. The soils are volcanic and the area forms the upper catchments for Rufiji and Lake Nyasa basins. The temperature in this zone is humid and lies below 15^0 C and rainfall is above 1000mm per annum. Planted and natural forest trees, fruit trees, scattered shrubs and grasslands cover most of the area.

3.1.2.2 Lowland Zone

Lowland zone is the area that borders the Great Rift Valley. The zone lies between 900-1200m above sea level. The zone receives annual rainfall between 900-950mm. The average annual temperature is 25^0 C. the zone is covered by gravel sandy soils. Thorny bushes and grasslands cover most the area. The lowlands zone experience hot and dry weather conditions with unreliable rainfall.

Table 3. 1: Population Size in the Study Villages

Village	Population	Males	Females	Number of Households
Kichiwa	1970	946	1024	440
Ibumila	1973	947	1026	635
Nyombo	1989	935	1054	642
Matiganjola	2416	1160	1256	631
Mtwango	5352	2569	2783	1534
Ikelu	2763	1326	1437	505
Mlevela	3257	1563	1694	526
Nyumbanitu	2240	1075	1165	493
Mhadzi	3816	1832	1984	854
Lusisi	1943	933	1010	395

Source: Population census 2002 (URT, 2002)

3.1.3 Population

According to the 2002 population and housing census, Njombe district had total population of 282 071 people of whom 133 150 were males (47.2 %) and 148,921 females (52.8%). The district has a growth rate of 1.5% annually during 1988 to 2002.The population in the study villages is 27,719 people with 6,655 households (Table 3.1).

3.1.4 Socio-Economic Activities

All households in the study villages practice mixed farming system, where by crop production is the major socio-economic activity of the communities followed by livestock keeping and petty business. Maize, Irish potatoes, sunflower and beans are the main crops grown. The livestock kept include cattle, pigs, goats and chicken. Villages that participated in this study were selected purposively because are potential for dairy production and were under the programme for agricultural and natural resource transformation for improved livelihood project, which aimed to develop an integrated and sustainable dairy production system.

3.1.5 Social Services

Social services available in the study villages include primary and secondary schools, churches, water tapes, dispensary and roads that facilitate transportation of agricultural crops and other produce.

3.2 Research Methods

3.2.1 Analytical Framework

Since the dairy production activities are largely characterized by many stochastic elements, especially for cases of smallholder dairy production. Hence, the Stochastic Production Frontier (SPF) approach was found as an appropriate method for examining the technical efficiency of smallholder dairy production in this study. A general stochastic production frontier model can be given by:

$$\ln q_i = \beta \ln x_i + v_i - u_i \qquad (1)$$

where q_i is the output produced by farmer i, x_i is a vector of factor inputs of the ith farmer, and β is a vector of estimated parameters. The term v_i is a random variable that accounts for random effects (beyond the control of the farmers), which is assumed to be an independent and identically distributed (*iid*) N (0, σ^2_v), independent of u_i, and it can be positive or negative.

The term u_i is a non-negative random variable, accounts for pure technical inefficiency in production, which is assumed to be independently and identically distributed and truncations (at zero) of the normal distribution (Aigner et al., 1977) with mean, μi-measures the technical inefficiency relative to the frontier and describes the distance of farmer *i*th from the frontier output (Coelli et al., 1998), and variance, σ^2_u (| N (μ_i, σ^2_u |). Additionally, the other distributional assumptions of the error term (*ui*) have also been proposed such as an exponential distribution (Meeusen and van der Broeck, 1997), a half-normal distribution truncated at zero (Jondrow et al., *1982*), or a two-parameter Gamma distribution (Green, 1990), and all have advantages and disadvantages (Coelli et al., 1998). However, Pascoe and Mardle (2003) believed that the truncated normal distribution is a more general specification. The assumption of independent distribution between u_i and v_i allows the separation of the stochastic (statistical noise) and inefficiency effects in the model (Bauer, 1990). This is considered as one of the advantages of assessing technical efficiency by the SPF model.

The method of the maximum likelihood is proposed for estimating the parameters of the stochastic frontier equation 1. The parameters to be estimated involved β and variance parameters such as $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2 / \sigma^2_u$ (Battese and Corra, 1977).Where, σ^2 is the sum of the error variance, while γ measures the total variation of output from the frontier attributed to the existence of random noise or inefficiency. Note that the value of γ lies between zero and one. The inefficiency is not present when γ=0, it means that all deviations from the frontier are entirely due to random noise, and against if γ=1 then the deviation is completely caused by inefficiency effects (Battese and Coelli, 1995).

Based on the Battese and Coelli (1995) model, the random variable associated with technical inefficiency, u_i, was further assumed as a function of various socio-economic and institutional variables that are hypothesized to influence technical inefficiencies as:

$$u_i = z_i \delta + w_i \qquad (2)$$

where z_i is a vector of explanatory variables associated with the technical inefficiency of production of the *i*th farmer, δ is an unknown vector of coefficients that is to be estimated, and w_i is a (*iid*) random error term, which is defined by the truncation of the normal distribution with zero mean and variance, σ^2_u, such that the point of truncation is

$-z_i\delta$, i.e., $w_i \geq -z_i\delta$. These assumptions are consistent with u_i being a non-negative truncation of the $N(z_i\delta, \sigma^2_u)$-distribution.

It should be noted that both the frontier model (Equation 1) and the inefficiency model (Equation 2) may include intercept parameters if the inefficiency effects are stochastic and have particular distributional properties (Coelli and Battese, 1996). Hence it is necessary to test the following null hypothesis:

i) $H_0: \gamma = \delta_0 = \delta_1 = \delta_2 .... = \delta_{14} = 0$ which specifies inefficiency is absent from the model.

ii) $H_0 : \gamma = 0$, which specifies that the inefficiency effects are not stochastic,

iii) $H_0: \delta_0 = \delta_1 = \delta_2 \ldots = \delta_{14} = 0$ which stipulates that, the coefficients of the explanatory variables in the inefficiency models are simultaneously zero,

iv) H0: $\delta_1 = \ldots = \delta_{14} = 0$, which state, that the coefficients of the variables in the model for inefficiency effects are zero.

The tests of these hypotheses for the parameters of the frontier were conducted using the generalized likelihood ratio statistics (Coelli and Battese, 1996), defined as;

$$LR = -2\{\ln[L(H0)] - \ln[L(H1)]\} \quad (3)$$

where ln{*L(Ho)*} and ln{*L(H1)*} are the values of the log-likelihood function under the null *(Ho)* and alternative *(H1)* hypotheses, respectively. The restrictions form the basis of the null hypothesis, while the unrestricted model being the alternative hypothesis. LR has a Chi-squared (χ 2) distribution with the number of degrees of freedom provided by the number of restrictions imposed except cases where the null hypothesis also involves the restrictions of $\gamma = 0$. In such cases, the asymptotic distribution of the likelihood ratio test statistic is a mixed-χ 2 distribution and therefore the appropriate critical values are drawn from Kodde and Palm (1986) at q + 1 degrees of freedom, where q is the number of parameters to be estimated.

Based on the model estimations, the output for each farmer could be compared with the frontier level of output that is known as the best output given the level of inputs employed, and this deviation indicates the level of inefficiency of the firm.

Therefore, the technical efficiency score for the *i*th farmer in the sample (TE_i) under equations (1) and (2) that would be defined as the ratio of observed output to the corresponding best output is given by (Coelli et al., 2005):

$TE_i = q_i / exp(lnßx + v_i) = exp(lnßx + v_i - u_i) / exp(lnßx + v_i) = exp(- u_i) / (-z_i\delta - w_i)$

(4)

where TE_i is relative technical efficiency of the firm ($0<TE<1$). Note that, when u_i = 0 then the *i*th farmer lies on the stochastic frontier and known as technically efficiency. If

$u_i >0$, the farm *i* lies below the frontier, which means that the farm is inefficient.

3.2.2 Model Specification

There are several potential functional forms that can be used to specify the stochastic frontier. However, the first-order flexible Cobb-Douglas form is adopted for this study. This functional form is widely used in frontier production studies (e.g. Dawson and Lingard 1989; Kalirajan and Flinn 1983; Coelli and Battese 1996). Given the objective of this study, Cobb-Douglas production function and the stochastic frontier is thus expressed as:

$$\text{Ln } Y_i = \beta_o + \beta_1 \text{ Ln } X_1 + \beta_2 \text{ Ln } X_2 + \beta_3 \text{ Ln } X_3 + \beta_4 \text{ Ln } X_4 + \beta_5 \text{ Ln } X_5 + V_i - U_i \qquad (5)$$

where *i* and *Ln* are the *i*th farmer and the logarithm to base *e*, respectively; *Y* denotes the value of dairy outputs in TSHS; X1 is veterinary costs; X_2 is concentrate feed costs in TSHS; X_3 other costs in (TSHS); X_4 Lactating in numbers; X_5 daily hours spent on dairy Activities in hours; V_i and U_i are random variables defined earlier.

The model for various operational and farm-specific variables hypothesized to influence technical inefficiencies of smallholder dairy farmers:

$Ui = \delta0 + \delta_1 (Age) + \delta_2 (gender) + \delta_3 (Marital\ status) + \delta_4 (Education\ level) + \delta_5(Experience) + \delta_6 (household\ size) + \delta_7 (Group\ membership) + \delta_8(Off\ farm\ income) + \delta_9(Herd\ size) + \delta_{10}(Dairy\ training) + \delta_{11}(Contact\ with\ extension\ agent) + \delta_{12}(Hired\ labour) + \delta_{13}(sale\ on\ Credit) + \delta_{14}(Selling\ to\ processor) + wi$ (6) where *w* is defined earlier; *Age* represents age of the primary decision maker.

Gender is a dummy variable which has the value of one, if farm decision maker is a male, zero if she is a female; *Marital status* is a dummy variable which has the value of one, if farm decision maker is married, zero if otherwise; *Education level* denotes number of years spent on formal schooling for a farm decision maker; *Experience* denotes number of years engaged in dairy production by the decision maker; *Household size* is total number of people in household; G*roup membership* is a dummy variable which has the value of one, if the farm decision maker is the member of dairy production and marketing group, zero if not member; *Off farm income* is income generated out of farm business by household measured in TSHS; *Herd size* is the number of cattle household own; *D*airy t*raining* is a dummy variable which has the value of one, if the farm decision maker has any dairy training, zero if not; *Contact with extension agent* denotes number of extension visit made by extension agent to household for dairy advisory purposes; *Hired labour* is a dummy variable which has the value of one, if the farm decision maker use hired labour in dairy production, zero if not; *sale on Credit* is a dummy variable which has the value of one, if milk sales payments are effected monthly, zero if not and *Selling to processor* is a dummy variable which has the value of one, if milk produced are sold to processor, zero if sold to other outlets.

3.3 Research Design

This is survey type of research. The research design that was employed in this study is that of cross-sectional study. A cross-sectional study is one that studies a cross-section of the population at a single point in time, and data collection is done once. It is very advantageous in that time is saved and a very big sample can be used (Kotharii, 2004).

3.4 Sample Size and Sampling Technique

A sample of 81 smallholder dairy farmers was selected from the population of the smallholder dairy farmers in the selected villages of Njombe District Council (NDC). The following formula was employed to come up with an appropriate sample for the study.

$n = z^2.\delta^2/e^2$ (Kothari, 2004) (7)

Where n is the sample size, z = standard variation at a given confidence level (α = 95%), e =acceptable error (precision) and δ = standard deviation of the population Z = 1.96, e = 0.05, δ=0.23. Standard deviation is estimated from previous studies.

Using the population list of smallholder dairy farmers from selected villages, the intended sample size was determined proportionally to population size of smallholder dairy farmers in selected villages. Then representatives were randomly selected from each village using random sampling technique (Table 3.2).

3.5 Methods of Data Collection

This research work used both primary and secondary data. The primary data was collected through questionnaire survey and involved collection socio-economic data of the respondents. Secondary data were collected through documentary review.

Table 3. 2: Sample Distribution of Smallholder Dairy Farmers

Name of Village	**Smallholder dairy farming households**	**Sample households**
Kichiwa	27	9
Ibumila	19	6
Nyombo	43	14
Matiganjola	21	7
Mtwango	10	3
Ikelu	39	13
Mlevela	33	11
Nyumbanitu	30	10
Mhadzi	15	5
Lusisi	9	3
Total	**246**	**81**

Source: DALDO’s office

5.1 Primary Data Collection

Questionnaire survey method was used. A semi structured questionnaire containing both closed and open ended questions was used in face to face interview (Sample questionnaire in Appendix 1). Open –ended questions helped to get the respondents’ views regarding the problem under the study while in closed-ended questions, respondents were provided with alternative answers. Open-ended questions served the purpose of disclosing the system of knowledge and structuring of ideas central to respondent’s own view of the study problem.

A sampling unit for questionnaire survey was a household. The household is defined as a unit consisting of one or more persons related or unrelated who live together in one or more housing and have a common catering arrangement (World Bank, 1995). A random sampling technique was used to select owners of dairy enterprise in the study villages for interview.

3.5.2 Secondary Data Collection

Secondary data were collected through documentary reviews of both published and unpublished documents from Njombe District library (text books, journals, and pamphlets), village offices in the study area, DALDO's office, DPLO's office and different websites.

3.6 Methods of Data Analysis

Two methods of data analysis were used to analyze data. These are: (i) Descriptive statistics consisting of simple percentages and proportions. This was used to examine the socio-economic characteristics and technical efficiencies of the respondents. The Statistical Package for Social Sciences (SPSS version 12.0) was used for this purpose. (ii) The Stochastic Frontier Production Function. This was used to estimate the technical efficiencies of respondents and to identify the sources of inefficiencies. This was done using Frontier version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation developed by Coelli (1996).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Descriptive Analysis of Socio-economic and Institutional Characteristics of the Smallholder Dairy Farmers

The socio-economic characteristics of the respondent smallholder dairy farmers are presented in Table 4.1:

4.1.1 Age of the Respondents

Table 4. 1: Age of the Respondents (N = 81)

Age Category of Respondent (Years)	Frequency	Percentage
21.00 - 30.00	10	12.3
31.00 - 40.00	31	38.3
41.00 - 50.00	25	30.9
51.00 - 60.00	13	16.0
61.00 - 70.00	1	1.2
71.00 – 80.00	1	1.2
Minimum	23.00	
Maximum	75.00	
Mean	41.7284	
Std. Deviation	10.25428	

Source: Survey data 2012

The age of respondents (enterprise owners) ranged between 23-75 years with mean and standard deviation of 41.73 and 10.25 years respectively (Table 4.1). The results indicate that 12.3% of respondent were in age category of 21-30 years, 38.3% were in age category of 31-40 years, 30.9% were in age category of 41-50 years, 16% were in age category of 51-60 years, 1.2% were in age category of 61-70 years and 1.2% were in age category of 71-80 years (Table 4.1). These results show that most (97.5%) of the respondents were below the age of 61 years. This implies that majority of the respondents were not very old and could participate fully in production activities.

4.1.2 Gender of the Respondents

Table 4.2: Gender of the Respondents (N = 81)

Parameters	**Frequency**	**Percentage**
Male	42	48.1
Females	39	51.9

Source: Survey data 2012

From the study 51.9% of the respondents were male where as 48.1% were female (Table 4.2). These results show that men have more interest in milk production. Similar observations have been reported in Tanga by Mulangila et al (1997), in Turian Morogoro region by Mollel et al (1999) and in Morogoro municipality by Urassa and Raphael, (2002). This might be due to fact that women have limited access to and control over household resources and means of production due to an array of factors including socio-cultural traditions, the existing political economy, as well as institutional constraints.

4.1.3 Education Level of the Respondents

Table 4. 3: Education Level of the Respondents (N = 81)

Parameters	**Frequency**	**Percentage**
No formal Education	2	2.45
Adult Education	2	2.45
Early Standard IV	5	6.2
Primary Education	64	79.0
Secondary Education and above	8	9.9
Years of schooling (YEARS)		
Minimum	0.00	
Maximum	18.00	
Mean	7.0741	
Std. Deviation	2.61141	

Source: Survey data 2012

Results in Table 4.3 present the education level of respondents. The education level of the respondent ranged from those who attained no formal education 2.45%, adult education 2.45%, early standard IV 6.2%, and primary education 79.0% to those attained secondary education and above 9.9%. Years of schooling ranged from 0-18 years with mean and standard deviation of 7.07 and 2.61 years respectively. The results indicate that majority of respondents (97.55%) had some form of adult and primary education and can therefore hardly cope with the complexity of dairy farming.

4.1.4 Household Size of the Respondents

Table 4. 4: Household Size of the Respondents (N = 81)

Household Size (Person)		
Household Members (Number)	**Frequency**	**Percentage**
2.00 - 3.00	8	9.9
4.00 - 5.00	34	42.0
6.00 - 7.00	29	35.8
8.00+	10	12.3
Minimum	3.00	
Maximum	10.00	
Mean	5.4938	
Std. Deviation	1.55019	

Source: Survey data 2012

Table 4.4 indicates that household size of the respondents ranged from 3-10 people with mean of 5.49 people and standard deviation of 1.55 people. Results show that 27.2% of respondents had household size of 3-4 people, 50.6% had household size of 5-6 people, 19.8% had household size of 7-8 people and 2.5% had household size of 9-10 people (Table 4.2). These findings suggest that there could be no enough members who can provide labour for dairy production activities.

Dairy herd size of the respondents ranged from 1-8 dairy cattle with the mean of 2.56 and standard deviation of 1.36 (Table 4.5). The results indicate that 61.7%. of the respondents had dairy size of 1-2 dairy cattle, 28.4% had dairy herd size of 3-4 dairy cattle and 9.8% had dairy herd size of 5-8 dairy cattle.

4.1.5 Dairy Herd Size of the Respondents

Table 4. 5: Dairy Herd Size of the Respondents (N = 81)

Dairy Herd Size (Number)	Frequency	Percentage
1.00 - 2.00	50	61.7
3.00 - 4.00	23	28.4
5.00 - 6.00	7	8.6
7.00+	1	1.2
Minimum	1	
Maximum	8	
Mean	2.56	
Std. Deviation	1.36	

Source: Survey data 2012

Dairy production experience of the respondents ranged from 1-18 years with mean of 6.29 years and standard deviation of 3.69 years (Table 4.6). Results further indicate that 61.7% of the respondents (Table 4.6) had experience of more than five years of dairy keeping experience while 38.3% had experience of 1-4 years. These findings suggest that majority of the respondents (61.7%) and had some experience of dairy farming.

4.1.6 Dairy Production Experience of the Respondents

Table 4. 6: Dairy Production Experience of the Respondents (N = 81)

Dairy Production Experience (Years)	Frequency	Percentage
1.00 - 4.99	31	38.3
5.00 - 8.99	25	30.9
9.00 - 12.99	21	25.9
13.00 – 16.99	3	3.7
17.00 – 20.99	1	1.2
Minimum	1.00	
Maximum	18.00	
Mean	6.2901	
Std. Deviation	3.68516	

Source: Survey data (2012)

Household income ranged from 150,000-7,210,000 Tanzanian shillings per year with mean and standard deviation of 2,267,100 and 1,475,440 shillings respectively (Table 4.7). Table 4.7 shows that 90.1% of respondent households had annual income in the category of 150,000-4,149,999 Tanzanian shillings and 9.9% had annual income in the category of 4,150,000 Tanzanian shillings and above.

4.1.7 Income of the Respondent Households

Table 4. 7: Income of the Respondent Households (N = 81)

Income of Respondent (TSHS)	**Frequency**	**Percentage**
150000.00 - 1149999.00	13	16.0
1150000.00 - 2149999.00	36	44.4
2150000.00 - 3149999.00	18	22.2
3150000.00 - 4149999.00	6	7.4
4150000.00 - 5149999.00	2	2.5
5150000.00 - 6149999.00	3	3.7
6150000.00 - 7149999.00	1	1.2
7150000.00+	2	2.5
Minimum	150,000	
Maximum	7,210,000	
Mean	2,267,100	
Std. Deviation	1,475,440	

Source: Survey data (2012)

Results in Table 4.8 indicate that 76.55% of respondent households their main livelihood sources constituted of crop farming, livestock rearing and dairy production, 11.11% constituted of crop farming, livestock rearing, dairy production and off farm activities, 8.64% constituted of crop farming, dairy production and off farm activities and 3.70% constituted of crop farming and dairy production. These findings suggest that dairy production is the main livelihood source for all respondent households but not necessarily the sole source of their livelihood.

4.1.8 Livelihood Sources

Table 4. 8: Livelihood Sources of the Respondents (N = 81)

Livelihood Sources	Frequency	Percentage
Crop farming and dairy production	3	3.7
Crop farming, livestock rearing and dairy production	62	76.55
Crop farming, dairy production and off farm activities	7	8.64
Crop farming, livestock rearing, dairy production and off farm activities	9	11.11

Source: Survey data (2012)

Dairy training of the respondents ranged from 0 to 20 days of training with mean of 3.64 days and standard deviation of 4.433 days (Table 4.9). The results in Table 4.9 indicate that 9.9% of respondents had no dairy training while 71.6% had one to four days of dairy training and 18.6% had seven to twenty days of dairy training. Results in that table also indicate that 81.5% of respondents were trained between one and five times while 8.6% were trained more than five times. These results suggest that respondents had minimal dairy training.

4.1.9 Dairy Training

Table 4. 9: Dairy Training of the Respondents (N = 81)

Dairy Training (days)	Frequency	Percentage
0	8	9.9
1	21	25.9
2	20	24.7
3	12	14.8
4	5	6.2
5	2	2.5
7	2	2.5
11	2	2.5
14	8	9.9
20	1	1.2
Minimum	0	
Maximum	20	
Mean	3.64	
Std. Deviation	4.433	

Source: Survey data (2012)

The extension visits made by extension agent to respondent dairy farmers for advisory purposes per year range from 0 visits to 12 visits with mean of 3.63 visits and standard deviation of 2.69 visits (Table 4.10). 4.9% of the respondents had no extension visit, 8.6% reported one visit per year, 19.8% reported two visits per year, 14.8% reported three visits per year, 27.2% reported four visits per year, and 9.9%

reported 5 visits per year and 14.7% reported between 6 to 12 visits per year (Table 4.10). These results suggest that the respondent dairy farmers had limited access to dairy extension services.

4.1.10 Extension Services

Table 4. 10: Extension Visits (N = 81)

Extension Services (Number of Visits)	**Frequency**	**Percentage**
0	4	4.9
1	7	8.6
2	16	19.8
3	12	14.8
4	22	27.2
5	8	9.9
6	4	4.9
7	1	1.2
8	1	1.2
10	2	2.5
12	4	4.9
Minimum	0	
Maximum	12	
Mean	3.63	
Std. Deviation	2.69	

Source: Survey data 2012

4.2 Descriptive Analysis of Dairy Management Practices by the Respondents

Dairy cattle management practices examined were rearing system, feeding system, calf milk feeding system, improved fodder production, record keeping and disease control. The results are presented in Table 4.11.

4.2.1 Rearing System

Table 4.11: Dairy Cattle Rearing System (N = 81)

Rearing System	Frequency	Percentage
Zero Grazing	81	100
Partial grazing	0	0

Source: Survey data 2012

The results of the study show that all respondent dairy farmers (100%) used zero grazing system to rear their cattle (Table 4.11). Farmers mostly prefer the zero grazing system as it reduces diseases challenge especially tick borne diseases and a very strict isolation of the exotic stock from indigenous cattle (De wit, 1990).

4.2.2 Feeding System

Table 4. 12: Dairy Cattle Feeding System (N = 81)

Feeding System	Frequency	Percentage
Individual feeding	22	27.2
Group/Collective feeding	59	72.8

Source: Survey data 2012

It was observed that 72.8% of the respondents were using individual feeding system while 27.2% were using collective feeding system (Table 4.12). Individual feeding allows the opportunity to feed cows according to their requirements and to manage the amount and quality of feed cows are consuming.

4.2.3 Calf Milk Feeding System

Table 4. 13: Calf Milk Feeding System (N = 81)

Calf Milk Feeding System	Frequency	Percentage
Bucket/bottle feeding	15	18.5
Suckling	66	81.5

Source: Survey data 2012

Findings in Table 4.13 show that 81.5% of the respondents were using calf suckling system and 18.5%were using bucket/bottle feeding system. Majority of peasant farmers in the tropics allow the calf to suckle before milking in order to obtain a let-down of milk (Williamson and Payne, 1978). The practice is undesirable as it is both uneconomical and unhygienic and it can be stated quite categorically that it is not essential to suckle the calf in order to induce the dam to let down her milk. In addition majority of smallholder farmers do not prefer bucket feeding as the practice requires more equipments, and that all additional equipment has to be kept very clean, thus adding to the expense and the difficulties of management.

4.2.4 Improved Fodder Production

Table 4. 14: Production of Improved Fodder (N = 81)

Improved Fodder Production (Acre)	Frequency	Percentage
<= 0.00	19	23.5
0.01 - 0.50	29	35.8
0.51 - 1.00	25	30.9
1.01 - 1.50	3	3.7
1.51 - 2.00	4	4.9
2.01+	1	1.2
Minimum	0	
Maximum	2.5	
Mean	0.664	
Std. Deviation	0.556	

Source: Survey data 2012

Area under improved fodder production ranged from 0 to 2.5 acres with mean and standard deviation of 0.664 and 0.556 acre respectively (Table 4.14). 23.5% of the respondents had no area under improved fodder production, 35.8% had area under pasture production in the category of 0.01-0.5 acre, 30.9% had area under pasture production in the category of 0.51-1.00 acre and 9.8% had area under pasture production above 1 acre but less or equal to 2.5 acres (Table 4.14). It was observed that most of fodder plots were not properly managed and hence majority of the respondents depend on natural pasture and crop residues for dairy production. The cost and value of land has a significant effect on dairy production and can be one of the constraints towards dairy expansion. Land is the most important asset to the smallholder farmers. Its opportunity cost is high and makes the investment cost to dairying very high.

4.2.5 Dairy Record Keeping

Table 4. 15: Dairy Record Keeping (N = 81)

Dairy Production records Keeping	Frequency	Percentage
Record Kept	22	27.2
No record kept	59	72.8

Source: Survey data 2012

The results of the status of record keeping among respondents show that 27.2% of the respondents had written dairy production records while 72.8% had no written records (Table 4.3). This low rate of record keeping agrees with results in a case study of smallholder animal recording in Sri Lanka where Amarasekera (1998) indicated that smallholders having one or two cows very rarely keep individual production records. Also, Bachman (1998) indicated that most smallholder farmers having small herds of 1 to 2 cows have significant difficulties in recording adoption. The argument being that, in small herds, transactions are few and infrequent such that farmers are familiar with their herds and might account these to memory. However, memory recall is never accurate.

4.2.6 Disease Control

Table 4. 16: Disease Control (N = 81)

Deworming	**Frequency**	**Percentage**
Not Practicing	3	3.7
Once per year	8	9.9
every six months	14	17.3
Every four months	13	16.0
Every three months	43	53.1
Acaricide Application	**Frequency**	**Percentage**
Not using	0	0
Once per month	4	4.9
Twice per month	29	35.8
Four times per months	48	59.2

Source: Survey data 2012

All of the respondents claimed to practice tick control. 4.9% used acaricide once per month, 35.8% used acaricide twice per month and 59.2% used acaricide four times per month. Spraying using hand pump was the commonest method used. Prophylactic use of anthelminthics (deworming) was practiced by 96.3% of the respondents. 9.9% of the respondents reported to deworm their cattle once per year, 17.3% once every six months, 16% once every four months, 53.1 once every three months and 3.7% were not practicing (Table 4.16).

4.3 Descriptive Analysis of Dairy Production Parameters

The results of dairy production parameters examined are presented in Table 4.17.

4.3.1 Calving Interval

Table 4. 17: Calving Interval (N = 81)

Parameter	Frequency	Percentage
Calving Interval		
12 months	45	55.56
More than 12 months	36	44.44

Source: Survey data 2012

55.56% of the respondents reported average calving interval of their cows to be12 months and 45% reported calving interval of more than 12 months (Table 4.17). The recommended calving interval is 12 months.

4.3.2 Lactation Period

Table 4. 18: Lactation Period (N = 81)

Lactation Length	Frequency	Percentage
10 months	39	48.15
Less than 10 months	5	6.17
More than 10 months	37	45.68

Source: Survey data 2012

48.15% of the respondents reported average lactation period of their cows to be10 months, 6.17% reported lactation period of less than ten months and 45.68% reported lactation period of more than 10 months (Table 4.18). The recommended lactation period is 10 months.

4.3.3 Milk Marketing

Table 4. 19: Milk marketing (N = 81)

Milk Marketing	Frequency	Percentage
Selling to Processor	65	80.20
Selling to other outlets	16	19.80

Source: Survey data 2012

80.2% of the respondents were selling raw milk to milk processing factory and 19.2% were selling to final consumers and other market intermediaries (Table 4.19).

4.3. Payment Mode

Table 4. 20: Payment Modes (N = 81)

Mode of Payments	Frequency	Percentage
Cash sale	12	14.80
Credit Sales	69	85.20

Source: Survey data 2012

Regarding the mode of payment, Table 4.20 shows that 85.2% of the respondents were paid on monthly basis while 14.8% were paid on dairy basis. Mode of payment has saving implication.

4.4 Production Frontier Results

4.4.1 Hypothesis Testing

Tests of various null hypotheses associated with the models were carried out using likelihood-ratio (LR) statistics which have approximately χ^2 distribution , except cases where the null hypothesis also involves the restrictions of $\gamma = 0$. In such cases, the asymptotic distribution of the likelihood ratio test statistic is a mixed- χ^2 distribution and therefore the appropriate critical values were drawn from Kodde and Palm (1986). Table 4.21 presents the results of the hypothesis tested with generalized likelihood ratio tests.

Table 4. 21: Hypotheses Tests for Parameters of the Stochastic Frontier for Dairy Production

Null Hypothesis	**Test Statistic**	**Calculated Value**	**Critical Value**	**Degree of freedom**	**Decision at α = 1%**
H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 .... = \delta_{14} = 0$	χ2-test	105.097	31.353	16	Rejected
H_0 :$\gamma = 0$	χ2-test	42.970	39.664	22	Rejected
H_0 : $\delta_0 = \delta_1 = \delta_2 .... = \delta_{14} = 0$	χ2-test	62.127	30.578	15	Rejected
H_0 : $= \delta_1 = \delta_2 .... = \delta_{14} = 0$	χ2-test	38.314	29.141	14	Rejected

Source: survey data 2012

The first null hypothesis test that technical inefficiency effects are not present in the model i.e. smallholder dairy farmers are efficient and have no room for efficiency growth.H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 .... = \delta_{14} = 0$, The LR test statistic is asymptotically distributed as a mixture of chi-square distributions. This test statistic exceeds the 1% critical value $X^2_{0.99}$ (16) 105.097χ =, which is taken from Table 1 in Kodde and Palm (1986), so the LR test leads to reject the null hypothesis that there no exist a technical inefficiency in the stochastic production frontier (at the significant level of

5% or less), and also implying that the traditional average (OLS) function is not suitable for this study.

The second null hypothesis, $H_0 : \gamma = 0$, which specifies that the inefficiency effects are not stochastic, is again strongly rejected at 1% significant level and concluded that systematic influences that are unexplained by the production function are the dominant sources of random error.

The third null hypothesis considered in the model, H_0: $\delta_0 = \delta_1 = \delta_2 \ldots. = \delta_{14} = 0$ which stipulates that, the coefficients of the explanatory variables in the inefficiency models are simultaneously zero, is also rejected. It indicates that the combined effects of factors involved in the technical inefficiency model are responsible for explaining the level and variations in production of smallholder dairy farms in Njombe district, although individual effects of some variables may not be statistically significant.

The last null hypothesis considered, H0: $\delta_1 = \ldots = \delta_{14} = 0$, which state, that the coefficients of the variables in the model for inefficiency effects are zero, is also rejected. It reflects that all the coefficients of the explanatory model are significantly influenced by the hypothesized socio-economic, institutional and marketing variables in the inefficiency model.

4.4.2 Partial Elasticities and Return to Scale (RTS)

Because all input variables are measured in logarithmic form, the estimated coefficient values represent the partial output elasticities. The production elasticity measures the proportional change in output resulting from proportional change in i-th input level, with all other input level held constant. Presented in Table 4.22 are elasticity estimates and return to scale value.

Table 4. 22: Elasticity and Return to Scale for Smallholder Dairy Farmers in Njomber District

Inputs	**Elasticity**
Veterinary Cost (TSHS)	-0.1939
Purchased Feed Costs (TSH)	0.4923
Other Costs (TSHs)	0.2269
Number of lactating cows	0.4692
Daily hours Spent on Dairy Activities (HOURS)	0.4434
Return to Scale (RTS)	1.4379

Source: Analysed survey data 2012

All elasticities are positive and statistically significant at 1% level with the exception of veterinary cost which is negative and statistically significant at 5% level. This implies that the use and allocation of these variables are still under utilized and as such a unit increase in these inputs will eventually results in an increase in the value of dairy outputs of the producers. Similar results were obtained in Turkey by Alemdar et al., (2010). Of all input variable, purchased feed (concentrates) cost has the highest impact on dairy production with elasticity equal to 0.4923 that is 100% increase in concentrate feed purchased results in an estimated increase in dairy output of 49.23%. The next highest elasticity is for number of lactating cows in the herd (0.4692) followed by daily hours spent on dairy activities (0.4434) and other costs (0.2269). The negative sign of veterinary cost variable indicates an out of optimal usage of this input.

Analysis of the results in Table 4.22 shows that the RTS for the smallholder dairy farmers in Njombe District is 1.4379. This suggest that smallholder dairy farmers in Njombe district exhibit increasing return to scale and they are operating in the irrational zone of production (Stage 1) function with the implication that the resources are not efficiently allocated and used on their dairy farms.

4.4.3 Technical Efficiency Analysis

The maximum likelihood (ML) estimates of the parameters of the stochastic production frontier were obtained using the program, FRONTIER 4.1c (coelli, 1995). The results are presented in Table 4.23.

The sigma squared (σ^2) with value of 0.0964 is statistically significant and different from zero at $\alpha = 0.01$. This indicates a good fit and the correctness of the distributional form assumed for the composite error term. The estimated gamma parameter (γ) of frontier model is 0.9989 and significant ($P < 0.01$), indicates that systematic influences that are unexplained by the production function are the dominant sources of random error. This means that 99.89% of the variation in output among the smallholder dairy farmers was due to disparities in technical efficiency. Thus the model was used for estimation of technical efficiency levels of respondent smallholder dairy farmers.

Table 4. 23: Maximum Likelihood Estimate (MLE) of the Stochastic Frontier Production Function

Variables	Parameter Estimate	OLS Model			Frontier Model		
		Coefficients	**Standard-error**	**t-ratio**	**Coefficients**	**Standard-error**	**t-ratio**
Intercept	$ß_0$	7.703^{***}	1.2749	6.0419	7.6252^{***}	0.7881	9.6758
Veterinary Cost (TSHS)	$ß_1$	0.2776^{***}	0.0756	3.6702	-0.1939^{**}	0.0855	-2.2680
Purchased Feed Costs (TSH)	$ß_2$	0.2630^{***}	0.0846	3.1087	0.4923^{***}	0.0564	8.7205
Other Costs (TSHs)	$ß_3$	0.0209	0.0393	0.5306	0.2269^{***}	0.0749	3.0318
Lactating cows (Number)	$ß_4$	0.1858^{*}	0.1194	1.5551	0.4692^{***}	0.1615	2.9053
Daily hours Spent on Dairy Activities (HOURS)	$ß_5$	-0.0669	0.1204	-0.5556	0.4434^{***}	0.1438	3.0839
Variance Parameters and Diagnostic							
Sigma Square	$\sigma 2$	0.1362			0.0964^{***}	0.0227	4.2502
Gamma	γ	0.4600			0.9989^{***}	0.0031	323.3539
log likelihood function	λ	-31.0633			-9.5783		
LR test of the one-sided error		42.9700					

Source: survey data 2012

Table 4.24 shows the distribution of farmers according to their technical efficiency score. The table shows that the predicted farm specific technical efficiencies ranged from 13% to 99% with a mean of 45.46% and standard deviation of 24.113%. The table further shows that majority of respondents (61.7%) had technical efficiency of below 50%, indicating that more than half of the respondent farmers were relatively inefficient. The implication of the average TE of 45.46% from the analysis is that dairy production could be increased by 54.54% through better allocation and use of available resources.

Comparing the average TE from this study with other studies revealed that the TE from the study is not far from the findings of Ogunyinka and Ajibefun (2004) and Yao and Liu (1998) with an average TE of 58, 67% and 63%, respectively.

Table 4. 24: Frequency Distribution of Technical Efficiency Score (N = 81)

Efficiency Scores	**Frequency**	**Percentage**
10 - 19	8	9.9
20 - 29	21	25.9
30 - 39	13	16.0
40 - 49	8	9.9
50 - 59	7	8.6
60 - 69	8	9.9
70 - 79	8	9.9
80 - 89	3	3.7
90+	5	6.2
Mean	45.46	
Minimum	13	
Maximum	99	
Standard deviation	24.113	

Source: survey data 2012

4.4.4 Determinants of Technical Inefficiency of Smallholder Dairy Producers

Table 4. 25: Maximum Likelihood Estimates (MLE) for the Parameters of the Inefficiency Model

Variables	Parameter Estimate	Coefficients	Standard-error	t-ratio
Intercept	δ_0	1.3040***	0.9270	4.1067
Age	δ_1	0.0190***	0.0061	3.0974
Gender	δ_2	0.0155***	0.0042	3.6712
Marital Status	δ_3	-0.0147***	0.0045	-3.2542
Education Level	δ_4	0.5788**	0.2964	1.9525
Experience	δ_5	0.1464**	0.0696	2.1023
Household Size	δ_6	-0.0034	0.0029	-1.1806
Membership in Dairy Group	δ_7	0.0001	0.0004	0.31534
Off farm Income	δ_8	0.0073	0.0076	0.9519
Dairy Herd Size	δ_9	0.0582	0.1380	0.4217
Dairy Training	δ_{10}	-0.0051	0.0305	-0.1684
Contact with Extension Agent	δ_{11}	-0.0133	0.0261	-0.5102
Hired Labour	δ_{12}	-0.0650***	0.0203	-3.1964
Sale on credit	δ_{13}	-0.0885	0.0764	-1.1589
Selling to Processor	δ_{14}	0.0008***	0.0003	3.1197

* Significant at 10% level, ** Significant at 5% level and *** Significant at 1%

Source: Survey data 2012

Sources of inefficiency were examined by using the estimated δ-coefficients associated with the variables in inefficient model. The inefficiency variables were specified as those relating to farmer's socio-economic characteristics, institutional and marketing factors. They include the farmer's age, gender, marital status, level of educational attainment, experience, household size, membership in dairy product and marketing group, off farm income, dairy herd size, dairy training, contact with extension agents, use of hired labour, sales on credit and selling to dairy processor. Analysis of the estimated coefficients of the inefficiency variables of the inefficiency model tells us the contribution of the variables to technical efficiency. The coefficients have either positive or negative signs which indicate the effect of the variable on efficiency. A positive sign indicates that the presence of the variable has an increasing effect on inefficiency while a negative sign indicates a reducing effect on inefficiency. The results of the inefficiency model are given in table 4.25.

Results in Table 4.25 indicate that the coefficients of age, gender, marital status, hired labour and selling to processor were statistically significant at 1% level while coefficients of education level and experience were statistically significant at 5% level. On other hand the coefficients of family size, membership in dairy production and marketing group, dairy herd size, off farm income, dairy herd size, dairy training, contact with extension agent and sale on credit were statistically insignificant. All coefficients had expected sign except the coefficients for membership in dairy production/marketing group and selling to processors. This reveals the importance of these variables as sources of technical inefficiencies in smallholder dairy production.

The coefficient estimated for age variable has a positive sign and statistically significant at 1% level which indicates that older farmers tend to have more inefficiencies than younger ones. This could be explained in terms of adoption of modern technology. As the age increases, the farmers tend to be more risk averse and hesitate to adopt new technologies making the production process inefficient. Ogunniyi and Ajao, (2010) obtained similar findings and concluded that older farmers tend to be more conservative and less receptive to modern technologies. Another reason might be that dairy production is very strenuous giving younger farmers an advantage.

The gender coefficient measured as dummy variable with value of one for male and zero for women was found to be positive and highly significant at 1% level. This suggests that men were less technically efficient than women in dairy production. Women are key actors in the business of farming, both in terms of labour supply (Enete *et al*. 2002) and as decision makers (Enete and Amusa 2010). In many cases, farming is disproportionately their responsibility. They may therefore have acquired relatively more technical and managerial expertise on the job than men.

The coefficient for marital status was negative and statistically significant at 5 percent level of probability for the married farmers. This implies that smallholder dairy farmers who are married are more efficient than those who are either single, divorced, widowed or widowers. This might be due to the fact that marital status in most cases is considered important in household decision making where married people have always succeeded in decision-making (Kibirige, 2008). Also married farmers tend to be more technically efficient, probably reflecting more availability of labor, which is consistent with larger families having more labor at their disposal, thus contributing to higher TE (Oleke and Isinika, 2011). The education coefficient was found to be positive and statistically significant at 5 percent probability level. This implies that there is increased level of technical inefficiency as level of education increases.

These findings might be due to the fact that higher education opens up higher opportunities for livelihoods such as off-farm employment and, hence creates lower incentives to pay much attention to the performance of the dairy farm. Muhammad-Lawal *et al.,* 2009 obtained similar results and concluded that farmers with lower education are more likely to be limited in such opportunities and hence depend more on primary methods for their livelihoods therefore have acquired relatively more technical and managerial expertise on the job than higher educated ones with alternative livelihood options.

Experience may be defined as knowledge and skill gained by contact with facts and events (Nwaru, 2004). By its nature, it is a product of the past and therefore limited to and controlled by previous exposures. Number of years a farmer has spent in the farming business may give an indication of practical knowledge he has acquired on how to cope with the inherent farm production, processing and marketing problems leading to higher levels of technical efficiency. As result the number of years in dairy production was hypothesized to have a positive impact on technical efficiency of dairy farmers. Different with this expectation, the coefficient of dairy production experience was found positive and statistically significant at 5%. The positive sign shows that farmers with higher experience in dairy production tended to have higher technical inefficiencies. This could be that the experience the farmers had, was not geared towards the competency or skills needed for excellence in handling the available technologies required in smallholder dairy production. This could be due to fact that experience correlates with age, which would always associate with reduced energy and optimism necessary in dairy production. Age in this study was found positively related to inefficiency.

The coefficient of family size was observed negative but no statistically significant. The negative sign of this inefficiency parameter establish the fact that inefficiency of smallholder dairy farmers decreases with increase in household size. This may be due to the fact that increased household size means increasing available labour force for dairy production activities. Inability to find significant relationship could be attributed to fact that average household size of 5.49 people means that household sizes were not large enough to have more equitable labour distribution among farming and dairy production activities. Improved farm labour distribution will lead to concentration on the given task and thus improving technical efficiency (Kibirige, 2008).

Membership in dairy production and marketing group was expected to increase farmer’s interactions with fellow farmers, extension agent and other entrepreneurs in his locality. It was hoped that such interactions would help them to receive and synthesize new information on dairy production and marketing activities in his locality and even beyond. For instance, Okike et al., (2001) observed that the reduction of inefficiency effects through farmers belonging to farmer group is linked to group being source of good quality inputs, information and organised marketing of products. Contrary to a priori expectation the coefficient for membership in dairy production and marketing group was positive and statistically insignificant implying that membership in dairy production and marketing group has no relationship with technical inefficiency. As majority of the respondents (80.2%) were members of dairy production and marketing groups and were selling milk to dairy processor this could be accounted to low price paid by processor and delay in effecting payment as complained. As result dairy farmers may regard membership in dairy production and marketing group as a “public good” and not a “social good” where they fraternize not necessarily for production motives.

The coefficient for off farm income variable was positive and not statistically significant. Although not statistically significant, the positive sign of the coefficient indicates that farmers engaged in off-farm income earning activities tend to exhibit higher levels of inefficiency. This was probably due to fact that involvement in non-farm work are accompanied by reallocation of time away from farm related activities, such as adoption of new technologies and gathering of technical information that is essential for enhancing production efficiency. Also due to lower schooling levels and management skills, smallholder dairy farmers must make an effort in order to maintain their levels of production and productivity occupying much more time in the dairy production related activities. As a result, the efficiency is reduced when farmers do not depend on agricultural activity. Even though this result was expected, it contrasts with the findings of Villano and Fleming (2006), who argue that non-agricultural income can be used to purchase inputs and equipment for agriculture, positively contributing to improved efficiency. However, due to the lower socioeconomic conditions that characterize small farmers, they tend to look for a non-agricultural employment in order to complement agricultural income rather than obtain additional resources to be invested in the activity. Other researchers that made similar finding are: Huffman (1980); Awudu and Eberlin (2001); Liu and Zhuang (2000).

The coefficient for dairy herd size variable was positive but not statistically significant. Although not statistically significant the positive sign of the coefficient indicates that technical inefficiency increases as dairy herd size increases. Resources allocation and management in small herd size are less complex than in large herd size and do not require advance farm management knowledge, which could be lacking among small dairy herd size. The link between efficiency and farm size has been the subject of much discussion in the literature (Berry and Cline 1979). However, only a few studies using frontier function methodology have investigated this issue in developing country agriculture, but most have found no statistically significant correlation between size and technical efficiency (Bravo-Ureta and Evenson 1994; Huang and Bagi 1984; Kalirajan 1991; Ray 1985; Squires and Tabor 1991).

Dairy training and contact with an extension officer during the past year were positively related to efficiency but statistically insignificant. These findings are consistent with the findings of Feeder *et al.* (2004); Binam *et al.* (2004); Rahman (2003). Each of these studies involved farmers in developing countries. The inability to find statistical significance has been attributed to bureaucratic inefficiency, poor program design, (Feeder *et al.*, 2004; Binam *et al.*, 2004) and the use of a "top-down" instead of participatory approach (Braun *et al.*, 2002). Tanzanian's extension program has been characterized by a top down approach. Thus, the lack of a participatory approach may explain the insignificance of Tanzanian's extension program in terms of its impact on the efficiency of these Tanzanian smallholder dairy farms.

The coefficient of the dummy variable for use of hired labour is negative and statistically significant at the 10 percent level implying that smallholder dairy farms on which hired labour is used to supplement family are less inefficient than those that exclusively use family labour. This finding may reflect the economic use of hired labour resources for farm households that are constrained in terms of family labour.

The coefficient of the dummy variable for sale on credit is negative and statistically insignificant. Although statistically insignificant the negative sign of the coefficient shows those smallholder dairy farmers who sale milk on credit and after two weeks or one month receive payments in lump sum are less technically inefficient than farmers who receive daily payments. These findings may be probably due to fact that smallholder milk marketing is associated with sales of small quantity marketable milk surplus which limit the ability of the farmer to afford daily essential dairy production expenses for efficient management. Lump-sum payments may be intrinsically valuable where liquidity flow is required in lumps to match lumpy expenditures (Ngigi et al,. 2000). The inability to find significant relationship may be due to delay in payments as complained by majority of farmers who sale on credit to dairy processor. On other hand the coefficient for selling to dairy processor was positive and statistically significant at 1% probability level. These results indicate that smallholder dairy farmers who sell to dairy processor are more technically inefficient than those who sell to other outlets. This is contrary to a priori expectation probably because of the low price paid by processor and delay in effecting payment as complained by farmers.

CHAPTER FIVE

5.0 CONCLUSIONS, RECOMMENDATIONS AND FUTURE STUDIES

5.1 Conclusion

Agricultural productivity varies due to differences in technology, differences in the settings production occurs and differences in the efficiency in the production process. Efficiency measurement has been the concern of researchers with an aim to investigate the efficiency level of farmers engaged in agricultural activities. Identifying major determinants of efficiency levels is the major task in efficiency analysis.

Empirical studies suggest that farmers in developing countries fail to exploit fully the potential of a technology making inefficient decision. Policy makers have started to recognize that one important source of growth for agricultural sector is efficiency gain through greater technical efficiency.

This study attempts to analyse factors affecting technical efficiency of smallholder dairy farmers in Njombe district using a stochastic production frontier (SPF) methodology under Cobb-Douglas functional form and cross section data obtained from a household survey conducted on a sample of 81 smallholder dairy farmers. In SPF methodology, the parameters for the production frontier and for the inefficiency model are estimated jointly using the maximum likelihood technique. The findings of this research offer valuable information on the technical efficiency levels of smallholder dairy farmers and their determinants in Njombe district. In the rest of this section the main findings of this study are highlighted.

The analysis revealed that the sum of the partial output elasticities with respect to all inputs is 1.4379 which is greater than one. The implication of such a result is that smallholder dairy producers are operating at stage one in production curve. At this stage, marginal product of smallholder producer is greater than average product. This is an inefficient stage, because increase in the use of inputs will lead to more than proportional increase in the value of dairy output. This suggests smallholder dairy farmers in Njombe District can still benefit from economies of scale linked to increasing returns to boost production. The analysis further revealed that of all input variables, cost of purchased concentrates feeds had the highest contribution on increasing the value dairy outputs with elasticity equal to 0.4923 followed by number of lactating cows in the herd (0.4692), daily hours spent on dairy activities (0.4434) and other costs (0.2269). The veterinary cost input had negative elasticity of -0.1939 implying that this input was over utilized.

The mean technical efficiency index is estimated at 45.5%, and 61.7% of the respondent farmers have technical efficiency indexes below 50%. Furthermore, the estimated value of the variance parameter (γ) of 0.9989 for the stochastic frontier production function is not only close to one but also significantly different from zero at 1% probability level. These results confirmed the existence of high systematic technical inefficiency in dairy production indicating that 99.89% of the variation in the value dairy output among the smallholder dairy farmers was due to disparities in technical efficiency. On the average, smallholder dairy farmers can increase their value of dairy output by 54.5% provided they operate along their efficient frontier. Consequently, if all farmers efficiently use the available resources, the resulting increase in value of dairy output can partially offset production costs and thus improve productivity and increase their income.

Identification and analysis of the factors affecting technical efficiency of smallholder dairy farmers in Njombe district revealed that age, gender, education level, experience of the farmer and selling to processor are major factors having a significant and positive influence on the farmers' technical inefficiency while marital status and use of hired labour are the major factors having a significant and negative influence on the farmers' technical inefficiency. Other factors which were found to have positive influence on technical inefficiency but not statistically significant included membership in dairy production and marketing group, off farm income and dairy herd size. Dairy training, contact with extension agent and selling on credit are factors which were found to have negative impact on technical inefficiency but were also not statistically significant.

5.2 Recommendations

In order to protect, promote and develop the smallholder dairy production, the following recommendations need some due consideration by all stake holders in the dairy industry at all levels including both local and central governments.

i) Some productivity gains linked to improvements in technical efficient can still be realized in the smallholder dairy production sector in Njombe district. Moreover, smallholder dairy producers can still take advantage of scale economies linked to increasing returns to increase value of dairy output.

ii) Age, gender and off income are among the variables which showed negative influence on technical efficiency. On other and marital status and use of hired labour were found to have positive influence on technical efficiency. Hence any policies that would attract young and married people to enter or remain into dairy production business would definitely lead to improved technical efficiency in smallholder dairy production. Technical efficiency could even improve more if such policies are directed at attracting and encouraging more women to participate in business and if implemented in areas where off farm employment opportunities are limited and more farm labour are available.

iii) Selling to processor was also one of the variables that showed negative and significant influence on technical efficiency. This suggests that smallholder dairy producers that sold their milk to processing plant were relatively more inefficient compared to those who sold to other outlets. As this was attributed to low price paid and delay in effecting payments, any interventions that will lead processors to offer relatively higher price and timely effecting payment may have significant and positive impact on technical efficiency of smallholder dairy producers. These may include improving rural roads to facilitate milk collection; creating reliable source of power; review of dairy import policies in favour of domestic dairy value chain and review taxes imposed on imported dairy production, processing and marketing materials.

iv) Selling on credit was found to have positive and significant influence on technical efficiency of smallholder dairy farmers. Thus any strategies that will facilitate smallholder dairy farmers to sell on credit and receive payments in lump sum would lead to improved technical efficiency of farmers. However the buyer should be assessed in terms of profitability, timely effecting payment and sustainability.

v) This study found that dairy training and contact with extension agent had positive influence on technical efficiency though the relationship was not statistically significant. A potential explanation for this finding is that the Tanzanian's extension and training programme uses a top-down approach as opposed to participatory approach. The top-down approach may fail to capture the attention of farmers. Thus to have significant impact on improving technical efficiency of smallholder dairy farmers, Tanzanian's extension and training programme need to be revamped with the view of making it participatory and client based in nature.

5.3 Future Research

Considering that low productivity is a serious national issue for Tanzania, it is important the research on productivity and efficiency of smallholder dairy production continues. There is need for a follow up study. Such a study should include all the relevant variables important in explaining allocative and technical efficiency.

Furthermore efficiency analysis is based on a single year in this study. Therefore results should be extended to other periods. The use of panel data in future researches is suggested to reduce effects of some time related biases in efficiency measurements. In addition, as this study used Stochastic Frontier Technique such future studies may consider use of both Stochastic Frontier approach and DEA approach for comparison of results.

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APPENDICES

Appendix I: Questionnaire for Smallholder Dairy Farmers

I. Identification

1) Village: …………………………………………….……………………
2) Ward: …………………………………….……………………...
3) Division……………………………………..………………………
4) District Council…………………………….………………………….

II. Background Information

1) Name of the farmer…………………………………………………...
2) Age of the household head/owner of dairy enterprise in years…..……
3) Gender of the household head/ owner of dairy enterprise (Write1 if Male or 0 if female) ……………………………
4) Education status of the household head/ owner of dairy enterprise (Write 1 if formal education, 0 if otherwise) …………………….
5) If the answer to question 4 above is 1, what is the highest level of education attained? (1 if Adult Education, 2 if Early Standard IV, 3 if Primary Education and 4 if Secondary Education and above)………………………..
6) Indicate the total numbers of years spent on formal education………………………………………………………………
7) Marital status of the household head/owner of dairy enterprise (1 if single, 2 if married, 3 if divorced, 4 if widowed)……………………..
8) What is the size of your household?……..

ME……………KE……………..

9) Are you a member of dairy production and marketing group? (Write 1 if yes or 0 if no) ……………….

10) If you are a member of dairy production/marketing group how does the organization help you on dairy production and marketing? Tick where appropriate. (Facilitate contact with extension staff…….. Facilitate milk collection and market access……… Provide credit………… Aid in disease control …………. Aid in input acquisition.

11) Which of the following are your main livelihood sources? (Tick where appropriate)

Livelihood sources	**TICK**
Crop farming and dairy production	
Crop farming, livestock rearing and dairy production	
Crop farming, dairy production and off farm activities	
Crop farming, livestock rearing, dairy production and off farm activities	

III. Dairy production and management

1) How long have you been in dairy production? …………… years.
2) What was your dairy herd size last year (2011)? (Number of dairy cattle including Calves the owner has) ………………..
3) How many cows were lactating last year? ……………….
4) What were the average production of your cows and the length of lactation last year?

Cow number	Average production per day Litre/day	Lactation length

5) What dairy production system do you practice (Write 1 if zero grazing system only 0 if otherwise)……………….

6) If the answer in question 5 above is 1 what feeding system do you practice? (Write 1 if each cattle is fed individually, 0 if otherwise)………..

7) Do you supplement your dairy animals? (Write 1 if yes and 0 if no)………

8) If the answer in question 7 above is 1, why do you supplement your animals? (Write 1 if is because of forage/pasture shortage or 0 if you want to increase production)…………………….

9) If the answer in question 8 above is 0 what supplementary feeds do you use, (Tick where appropriate).

Component	Tick
Maize bran	
Sunflower seed cake	
Minerals	
Molasses	
Others (Specify)	

10) Do you have forage/pasture farm? ………… (Write 1 if yes, 0 if no).

11) If the answer in question 10 above is 1, what is the size of the farm in

acres………..

12) What calf feeding system do you practice? ………………. (Write 1 if bucket or bottle feeding system or 0 if otherwise)

13) At what age do you wean calves…………………..(months)

14) For what reason do you wean? Put tick where appropriate (Time to wean…….. Time to breed cow………. Need milk for sale)

15) Do you keep written farm records? …………….. (Write 1 if yes, 0 if no)

16) If the answer in question 15 above is 1 which record do you keep? Put a tick where appropriate

Type of record	**Tick**
Production records eg milk yield	
Breeding records eg mating record, heat records	
Sales records eg milk sold record, live animal, manure sales	
Feeds and Veterinary costs	
Disease records	

17) Doy you under take tick control in your dairy farm? (Write 1 if yes, 0 if no) ……………………….

18) If yes to question 17 above which method do you use? .... (Write 1 spraying 0 if dipping)

19) If yes to question 17 above, how often do you spray/dip your dairy cattle to control ticks? Tick where appropriate.

Item	**Tick**
Once per month	
Twice per months	
Once per week	
Not practicing	

20) If yes to question 17 above, how often do you deworm your dairy cattle to control worms? Tick where appropriate.

Item	**Tick**
Once per year	
Once every six months	
Once every four months	
Once every three months	
Not practicing	

21) What is the average calving interval of you dairy herd? .... (write 1 if more than 12 month or 0 if it is 12 month)

IV. Dairy marketing

1) What marketing channel did you use to sell your milk produced last year? (Write 1 if you sell to milk processing factory, 0 if you sell to other marketing outlets)…………….
2) How far is it to the main market for milk? ……………..kilometers
3) What was payment arrangement practiced? (Write 1 if bill, 0 if daily cash)……………….

4) If the answer to question 3 above is 1 how long it takes to receive payment? …………………..days

5) How many litre did you sell last year? ....

6) What was the average price per litre? …

V. Livestock Extension

1) Do you have an extension officer operating in your village? (Write 1 if yes, 0 if no)………………

2) If the answer to question 1 above is yes, does the livestock extension officer visit your farm/dairy group frequently or until approached? (Write 1 if frequently 0 if until approached)…………………..

3) If the answer to question 2 above is frequently, on average, how many times did he/she visit you/group for advice last year? ……………………………………………………………………

4) If he/she visits you when approached, how many times did you or your group called him/her for provision advice last year? ……………………………………………………………………

VI. Dairy Training

1) Have you ever participated in dairy production/marketing training for the past 3 years? (Write 1 if yes, 0 if no)………………………..

2) If the answer to question 1 above is yes, what was the duration of training? …………days

VII. Costs and income in dairy production

1) For last year what were costs for the?

COST ITEM	COST PER MONTH (TSH)	COST PER YEAR (TSH)
Spraying or dipping		
Procurement of mineral powders		
Maize bran		
Sunflower seed cake		
Mineral block		
Treatment of tick borne diseases		
Mastitis treatment and control		
vaccination		
deworming		
Hired labour wage		
TB na brucellosis testing		
Repair and maintenance of cow shed		
Breeding		
Dairy group contributions		
Maintenance of pasture farm		
Oil for milking		

2) What were the income from the following outputs from dairy production

Income source	Income per month (TSH)	Income per year (TSH)
Milk sales		
Manure sales		
Cattle sales		
Rent of bull for breeding purposes		

VIII. Sources of household Income

1) What were the income obtained from farm production and off farm sources in the following table

Sources	Quantity sold	Price	Income
Sales of crop produce			
Maize			
Sunflower			
Wheat			
Round potatoes			
Fruit and vegetables			
Tea			
coffee			
Beans			
Sales of livestock			
Local cattle			
pigs			
Sheep			
goats			
chicken			
Sales of livestock products			
Eggs			
Hide and skin			
Other sources			
Rent of land			
Small business eg kiosk			
Casual labourer			
Sales of local brews			
Formal employment			
Remittances			

IX. Labour Division in Management, Operation and Marketing of Dairy Related Activities

Fill the table below.

Activities	Family labour		Hired Labour	Average time spent on the activity (Minutes)
	Me	KE		
Cleaning the shelter of the dairy animals				
Milking				
Feeding				
Watering				
Transporting milk for sale				
Dipping/spraying for parasite control				
Fetching forages/ grasses				
Caring for calves				

Appendix II: Output from the program FRONTIER (Version 4.1c)

```
instruction file = terminal
data file =       eg1-dta.txt

 Tech. Eff. Effects Frontier (see B&C 1993)
 The model is a production function
 The dependent variable is logged


the ols estimates are :

              coefficient     standard-error    t-ratio

  beta 0        0.77031418E+01  0.12749487E+01  0.60419228E+01
  beta 1        0.27755178E+00  0.75622254E-01  0.36702395E+01
  beta 2        0.26298430E+00  0.84596088E-01  0.31087052E+01
  beta 3        0.20874278E-01  0.39341147E-01  0.53059658E+00
  beta 4        0.18575323E+00  0.11944591E+00  0.15551242E+01
  beta 5       -0.66924607E-01  0.12044656E+00 -0.55563736E+00
  sigma-squared  0.13616050E+00

log likelihood function =  -0.31063299E+02

the estimates after the grid search were :

  beta 0        0.79316361E+01
  beta 1        0.27755178E+00
  beta 2        0.26298430E+00
  beta 3        0.20874278E-01
  beta 4        0.18575323E+00
  beta 5       -0.66924607E-01
  delta 0       0.00000000E+00
  delta 1       0.00000000E+00
  delta 2       0.00000000E+00
  delta 3       0.00000000E+00
  delta 4       0.00000000E+00
  delta 5       0.00000000E+00
  delta 6       0.00000000E+00
  delta 7       0.00000000E+00
  delta 8       0.00000000E+00
  delta 9       0.00000000E+00
  delta10       0.00000000E+00
  delta11       0.00000000E+00
  delta12       0.00000000E+00
```

delta13 0.00000000E+00
delta14 0.00000000E+00
sigma-squared 0.17828419E+00
gamma 0.46000000E+00

iteration = 0 func evals = 20 llf = -0.30985831E+02
0.79316361E+01 0.27755178E+00 0.26298430E+00 0.20874278E-01
0.18575323E+00
-0.66924607E-01 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00
0.00000000E+00 0.17828419E+00 0.46000000E+00
gradient step
iteration = 5 func evals = 43 llf = -0.26709834E+02
0.79317210E+01 0.27833239E+00 0.26392085E+00 0.21354032E-01
0.18567762E+00
-0.66913313E-01-0.23520791E-04-0.87812479E-03-0.20599028E-02
0.36939488E-02
0.72149991E-04-0.79204044E-04-0.12941821E-02-0.17236644E-04
0.26504398E-03
0.36977048E-04-0.93235621E-05 0.20178664E-03-0.16186401E-02
0.73012607E-04
0.82656873E-03 0.17774027E+00 0.46004575E+00
iteration = 10 func evals = 69 llf = -0.24146651E+02
0.79328399E+01 0.27789100E+00 0.26519063E+00 0.21298903E-01
0.17980335E+00
-0.73604914E-01-0.12231415E-02 0.48144971E-03-0.28522065E-02
0.59878555E-02
0.28857114E-02-0.12754914E-03-0.15864804E-02-0.20724037E-03
0.72081190E-02
0.16891627E-02 0.42648013E-02-0.59462195E-02-0.47896995E-01
0.97589398E-04
0.94077464E-03 0.16175410E+00 0.46194757E+00
iteration = 15 func evals = 88 llf = -0.23455782E+02
0.79648428E+01 0.29041749E+00 0.25691174E+00 0.36928415E-01
0.10186161E+00
-0.20320084E+00-0.52406913E-01 0.12376004E-02-0.23247348E-02
0.68799236E-02
0.58704683E-01-0.52889026E-01-0.17439266E-02-0.52588912E-04
0.73132785E-02
0.57776045E-03 0.38113046E-02-0.66394038E-02-0.51708210E-01-
0.41238817E-01
0.10194061E-02 0.15963659E+00 0.44430431E+00

iteration = 20 func evals = 112 llf = -0.19516980E+02
0.85147790E+01 0.25935209E+00 0.25073037E+00 0.42524597E-01
0.19739708E+00
-0.26941803E+00-0.13424332E+01 0.36267658E-02 0.33174609E-02
0.92610625E-02
0.39486473E+00-0.11185930E+00-0.26080053E-02 0.10142658E-03
0.75730095E-02
0.17672157E+00 0.20925179E-01-0.63415969E-02-0.78454921E-01-
0.61046693E-01
0.10094217E-02 0.13281294E+00 0.59835304E+00
iteration = 25 func evals = 148 llf = -0.15282295E+02
0.84011168E+01 0.11716209E+00 0.29210225E+00 0.11589924E+00
0.33906762E+00
-0.80030732E-01-0.18617883E+01-0.38796200E-02 0.87179427E-02
0.13552224E-01
0.57673543E+00-0.17918395E-01-0.23959848E-02 0.34298430E-04
0.97936217E-02
0.91643955E-01 0.18109890E-01-0.21799477E-01-0.97034632E-01-
0.10329693E+00
0.10620641E-02 0.12347353E+00 0.61902152E+00
iteration = 30 func evals = 258 llf = -0.11227351E+02
0.80910041E+01-0.18091532E+00 0.46432539E+00 0.22455883E+00
0.44478959E+00
0.24909099E+00-0.11127834E+01-0.19715355E-01 0.13277918E-01
0.16090093E-01
0.58890893E+00 0.87356342E-01-0.29502342E-02 0.25900584E-03
0.72242573E-02
0.12924579E+00 0.12177416E-01-0.12695168E-01-0.65373102E-01-
0.89700633E-01
0.76194125E-03 0.98380846E-01 0.92416312E+00
iteration = 35 func evals = 358 llf = -0.99269013E+01
0.77375247E+01-0.19057743E+00 0.47914037E+00 0.23114368E+00
0.45405040E+00
0.42103711E+00-0.13008693E+01-0.18902431E-01 0.15280517E-01
0.15137313E-01
0.56227460E+00 0.14023888E+00-0.29718773E-02 0.11664240E-03
0.76342608E-02
0.55682834E-01 0.48736643E-02-0.14220898E-01-0.67975469E-01-
0.92778730E-01
0.83722058E-03 0.99073802E-01 0.99678094E+00
iteration = 40 func evals = 408 llf = -0.97076842E+01
0.76894234E+01-0.19304598E+00 0.48269747E+00 0.23216249E+00
0.45230680E+00
0.43800039E+00-0.13112146E+01-0.19098208E-01 0.15589715E-01
0.15057661E-01
0.55788353E+00 0.14593813E+00-0.29525554E-02 0.10662417E-03
0.75321794E-02

0.50538192E-01 0.43266859E-02-0.14519299E-01-0.67819478E-01-0.92198579E-01
0.84286239E-03 0.98674477E-01 0.99937861E+00
iteration = 45 func evals = 583 llf = -0.95783905E+01
0.76251810E+01-0.19392196E+00 0.49224571E+00 0.22695140E+00 0.46920691E+00
0.44341075E+00-0.13039460E+01-0.18976724E-01 0.15508840E-01 0.14665406E-01
0.57879500E+00 0.14637174E+00-0.33873383E-02 0.12060475E-03 0.72571729E-02
0.58199606E-01 0.51350837E-02-0.13319684E-01-0.64969170E-01-0.88551031E-01
0.82507597E-03 0.96353874E-01 0.99885266E+00
iteration = 47 func evals = 631 llf = -0.95782882E+01
0.76251511E+01-0.19391889E+00 0.49225264E+00 0.22694236E+00 0.46922279E+00
0.44341095E+00-0.13039614E+01-0.18976552E-01 0.15508957E-01 0.14664949E-01
0.57880796E+00 0.14637219E+00-0.33877505E-02 0.12062113E-03 0.72570026E-02
0.58209154E-01 0.51352051E-02-0.13319072E-01-0.64967773E-01-0.88548999E-01
0.82506949E-03 0.96353057E-01 0.99885235E+00

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.76251511E+01	0.78806758E+00	0.96757578E+01
beta 1	-0.19391889E+00	0.85504043E-01	-0.22679500E+01
beta 2	0.49225264E+00	0.56447694E-01	0.87205092E+01
beta 3	0.22694236E+00	0.74853324E-01	0.30318275E+01
beta 4	0.46922279E+00	0.16150817E+00	0.29052573E+01
beta 5	0.44341095E+00	0.14378455E+00	0.30838567E+01
delta 0	-0.13039614E+01	0.92698864E+00	-0.14066639E+01
delta 1	-0.18976552E-01	0.61265761E-02	-0.30974155E+01
delta 2	0.15508957E-01	0.42245230E-02	0.36711735E+01
delta 3	0.14664949E-01	0.45064515E-02	0.32542121E+01
delta 4	0.57880796E+00	0.29644190E+00	0.19525174E+01
delta 5	0.14637219E+00	0.69626062E-01	0.21022615E+01
delta 6	-0.33877505E-02	0.28695668E-02	-0.11805791E+01
delta 7	0.12062113E-03	0.38258678E-03	0.31527784E+00
delta 8	0.72570026E-02	0.76238901E-02	0.95187661E+00
delta 9	0.58209154E-01	0.13802662E+00	0.42172413E+00
delta10	0.51352051E-02	0.30488240E-01	0.16843232E+00
delta11	-0.13319072E-01	0.26108001E-01	-0.51015289E+00

delta12 -0.64967773E-01 0.20325008E-01 -0.31964451E+01
delta13 -0.88548999E-01 0.76406340E-01 -0.11589221E+01
delta14 0.82506949E-03 0.26447318E-03 0.31196716E+01
sigma-squared 0.96353057E-01 0.22670341E-01 0.42501813E+01
gamma 0.99885235E+00 0.30890372E-02 0.32335394E+03

log likelihood function = -0.95782893E+01

LR test of the one-sided error = 0.42970019E+02
with number of restrictions = *
[note that this statistic has a mixed chi-square distribution]

number of iterations = 47

(maximum number of iterations set at : 100)

number of cross-sections = 81

number of time periods = 1

total number of observations = 81

thus there are: 0 obsns not in the panel

covariance matrix :

0.62105051E+00 -0.59365512E-01 -0.14778936E-01 0.11178486E-01 0.16376482E-01
0.69283490E-01 0.12251816E+00 -0.20566524E-02 0.16427802E-03 0.82257109E-03
0.10388401E-01 0.23967783E-01 0.52232870E-03 -0.26498619E-04 0.52143104E-03
-0.52682905E-02 -0.19785573E-02 -0.24309229E-02 -0.30059744E-03 -0.74569871E-02
0.32666063E-04 -0.46518857E-03 0.41633449E-03
-0.59365512E-01 0.73109414E-02 0.10863686E-02 -0.19570196E-02 -0.28342478E-02
-0.10093232E-01 -0.10798113E-01 0.30460937E-03 -0.61295976E-04 -0.12182874E-03
-0.86471374E-03 -0.32208279E-02 -0.57010870E-04 0.23584979E-05 -0.50539557E-04
-0.45106810E-03 0.24201924E-03 0.29176264E-03 0.30787735E-04 0.49958011E-03
-0.41225262E-05 0.95784252E-04 -0.24868386E-04
-0.14778936E-01 0.10863686E-02 0.31863422E-02 -0.37297974E-02 0.69380326E-02
0.42780121E-03 -0.94749789E-02 0.83424846E-04 0.60477565E-04 -0.16995807E-03
0.68400100E-02 0.28498949E-03 -0.11254730E-03 0.37250570E-05 0.15526407E-04
0.16415618E-02 0.11811713E-03 0.16499508E-03 0.31248693E-03 0.44010189E-03
0.11873448E-05 -0.26375049E-03 -0.12630358E-03
0.11178486E-01 -0.19570196E-02 -0.37297974E-02 0.56030200E-02 -0.92309787E-02
0.50627539E-03 0.10588720E-01 -0.16324773E-03 -0.52607745E-04 0.26019637E-03
-0.94256369E-02 -0.20941870E-03 0.14794174E-03 -0.44726995E-05 -0.30645182E-04
-0.16243404E-02 -0.17806610E-03 -0.26251541E-03 -0.43085939E-03 -0.43440534E-03
-0.14553649E-05 0.35922041E-03 0.13723355E-03
0.16376482E-01 -0.28342478E-02 0.69380326E-02 -0.92309787E-02 0.26084888E-01
0.13556081E-01 -0.17005490E-01 -0.42007095E-04 0.23376636E-03 -0.43853633E-03

0.19894969E-01 0.49309821E-02 -0.24712528E-03 0.81107531E-05 0.11181449E-03
0.62301079E-02 0.13906239E-03 0.40302079E-03 0.92218337E-03 0.13933214E-02
0.80520990E-05 -0.10677570E-02 -0.22816845E-03
0.69283490E-01 -0.10093232E-01 0.42780121E-03 0.50627539E-03 0.13556081E-01
0.20673997E-01 0.54019179E-02 -0.46669291E-03 0.19028530E-03 0.25232518E-04
0.55421871E-02 0.65981386E-02 0.17570198E-04 -0.70071101E-06 0.96595559E-04
0.39033236E-02 -0.25818210E-03 -0.15814734E-03 0.24623248E-03 0.49587153E-03
0.83314991E-05 -0.57691145E-03 0.30156463E-04
0.12251816E+00 -0.10798113E-01 -0.94749789E-02 0.10588720E-01 -0.17005490E-01
0.54019179E-02 0.85930794E+00 -0.28481078E-02 -0.26644329E-02 -0.22309367E-03
-0.30785318E-01 0.12056456E-01 0.16568460E-03 0.68783503E-05 0.18765308E-03
-0.58766553E-01 -0.51180279E-02 0.82071901E-03 -0.11916579E-02 -0.98628742E-03
-0.75020479E-04 -0.10983705E-02 0.20704519E-03
-0.20566524E-02 0.30460937E-03 0.83424846E-04 -0.16324773E-03 -0.42007095E-04
-0.46669291E-03 -0.28481078E-02 0.37534935E-04 -0.58834106E-06 -0.88675311E-05
0.33529668E-04 -0.23326940E-03 -0.41749806E-05 0.27418450E-06 -0.40790932E-05
0.10208913E-03 0.33974732E-04 -0.40517691E-04 -0.10470225E-04 0.10322356E-04
-0.10891381E-06 0.95028753E-05 -0.36176781E-05
0.16427802E-03 -0.61295976E-04 0.60477565E-04 -0.52607745E-04 0.23376636E-03
0.19028530E-03 -0.26644329E-02 -0.58834106E-06 0.17846594E-04 -0.24359185E-05
0.28260455E-03 0.22331260E-04 -0.12314404E-05 0.11099608E-06 -0.26025843E-05
0.26796389E-03 -0.11993021E-04 -0.10429225E-04 0.72502367E-05 -0.13025107E-05
0.13660528E-06 -0.12629668E-04 -0.74200331E-06
0.82257109E-03 -0.12182874E-03 -0.16995807E-03 0.26019637E-03 -0.43853633E-03
0.25232518E-04 -0.22309367E-03 -0.88675311E-05 -0.24359185E-05 0.20308105E-04
-0.21212292E-03 0.18021552E-05 0.74695780E-05 -0.32172950E-06 0.67848027E-06
-0.10795336E-03 -0.30419110E-04 -0.89867503E-05 -0.25896368E-04 -0.91656892E-04
0.29353161E-06 0.21810772E-04 0.57123238E-05
0.10388401E-01 -0.86471374E-03 0.68400100E-02 -0.94256369E-02 0.19894969E-01
0.55421871E-02 -0.30785318E-01 0.33529668E-04 0.28260455E-03 -0.21212292E-03
0.87877799E-01 0.36117360E-02 -0.29148519E-03 0.29977124E-04 0.24206743E-03
-0.18870919E-02 0.95776146E-04 -0.67338202E-03 -0.59573532E-03 -0.12627372E-01
0.18120982E-04 -0.34286057E-03 -0.29760073E-03
0.23967783E-01 -0.32208279E-02 0.28498949E-03 -0.20941870E-03 0.49309821E-02
0.65981386E-02 0.12056456E-01 -0.23326940E-03 0.22331260E-04 0.18021552E-05
0.36117360E-02 0.48477885E-02 0.15099959E-04 -0.34484451E-06 0.22036220E-04
0.12412923E-02 -0.36349533E-03 -0.11775859E-03 -0.58564372E-04 0.65118672E-04
0.45409313E-05 -0.17532303E-03 0.77104023E-05
0.52232870E-03 -0.57010870E-04 -0.11254730E-03 0.14794174E-03 -0.24712528E-03
0.17570198E-04 0.16568460E-03 -0.41749806E-05 -0.12314404E-05 0.74695780E-05
-0.29148519E-03 0.15099959E-04 0.82344136E-05 -0.13140301E-06 -0.60508434E-06
-0.43301423E-04 -0.11775814E-04 -0.11183521E-04 -0.16388374E-04 -0.11016400E-04
0.63197623E-07 0.14780133E-04 0.52895094E-05
-0.26498619E-04 0.23584979E-05 0.37250570E-05 -0.44726995E-05 0.81107531E-05
-0.70071101E-06 0.68783503E-05 0.27418450E-06 0.11099608E-06 -0.32172950E-06
0.29977124E-04 -0.34484451E-06 -0.13140301E-06 0.14637264E-06 -0.10236735E-05
-0.13752207E-04 -0.80524603E-08 -0.32340256E-06 -0.91034995E-06 -0.79061538E-05
-0.27767063E-08 0.10153192E-05 -0.13503979E-06
0.52143104E-03 -0.50539557E-04 0.15526407E-04 -0.30645182E-04 0.11181449E-03
0.96595559E-04 0.18765308E-03 -0.40790932E-05 -0.26025843E-05 0.67848027E-06
0.24206743E-03 0.22036220E-04 -0.60508434E-06 -0.10236735E-05 0.58123700E-04

```
-0.82464585E-04  0.76522907E-04  0.42161330E-04 -0.94271006E-05 -0.26505683E-03
 0.32492366E-06 -0.28361696E-04 -0.44505980E-06
-0.52682905E-02 -0.45106810E-03  0.16415618E-02 -0.16243404E-02  0.62301079E-02
 0.39033236E-02 -0.58766553E-01  0.10208913E-03  0.26796389E-03 -0.10795336E-03
-0.18870919E-02  0.12412923E-02 -0.43301423E-04 -0.13752207E-04 -0.82464585E-04
 0.19051346E-01 -0.71830658E-03 -0.51910639E-03  0.83878909E-03  0.22705396E-02
 0.37467217E-05 -0.37524066E-03 -0.45628736E-04
-0.19785573E-02  0.24201924E-03  0.11811713E-03 -0.17806610E-03  0.13906239E-03
-0.25818210E-03 -0.51180279E-02  0.33974732E-04 -0.11993021E-04 -0.30419110E-04
 0.95776146E-04 -0.36349533E-03 -0.11775814E-04 -0.80524603E-08  0.76522907E-04
-0.71830658E-03  0.92953278E-03  0.24544053E-03 -0.15075287E-04  0.45506625E-03
-0.68508755E-06  0.56897266E-04 -0.67259632E-05
-0.24309229E-02  0.29176264E-03  0.16499508E-03 -0.26251541E-03  0.40302079E-03
-0.15814734E-03  0.82071901E-03 -0.40517691E-04 -0.10429225E-04 -0.89867503E-05
-0.67338202E-03 -0.11775859E-03 -0.11183521E-04 -0.32340256E-06  0.42161330E-04
-0.51910639E-03  0.24544053E-03  0.68162773E-03  0.23322944E-03  0.46452782E-04
 0.13572696E-05 -0.29769871E-04 -0.66489977E-05
-0.30059744E-03  0.30787735E-04  0.31248693E-03 -0.43085939E-03  0.92218337E-03
 0.24623248E-03 -0.11916579E-02 -0.10470225E-04  0.72502367E-05 -0.25896368E-04
-0.59573532E-03 -0.58564372E-04 -0.16388374E-04 -0.91034995E-06 -0.94271006E-05
 0.83878909E-03 -0.15075287E-04  0.23322944E-03  0.41310596E-03  0.20711604E-03
 0.57525694E-06 -0.19047988E-04 -0.14663638E-04
-0.74569871E-02  0.49958011E-03  0.44010189E-03 -0.43440534E-03  0.13933214E-02
 0.49587153E-03 -0.98628742E-03  0.10322356E-04 -0.13025107E-05 -0.91656892E-04
-0.12627372E-01  0.65118672E-04 -0.11016400E-04 -0.79061538E-05 -0.26505683E-03
 0.22705396E-02  0.45506625E-03  0.46452782E-04  0.20711604E-03  0.58379288E-02
-0.42579816E-05  0.71305029E-04 -0.91013909E-05
 0.32666063E-04 -0.41225262E-05  0.11873448E-05 -0.14553649E-05  0.80520990E-05
 0.83314991E-05 -0.75020479E-04 -0.10891381E-06  0.13660528E-06  0.29353161E-06
 0.18120982E-04  0.45409313E-05  0.63197623E-07 -0.27767063E-08  0.32492366E-06
 0.37467217E-05 -0.68508755E-06  0.13572696E-05  0.57525694E-06 -0.42579816E-05
 0.69946066E-07 -0.94895085E-07  0.18209851E-07
-0.46518857E-03  0.95784252E-04 -0.26375049E-03  0.35922041E-03 -0.10677570E-02
-0.57691145E-03 -0.10983705E-02  0.95028753E-05 -0.12629668E-04  0.21810772E-04
-0.34286057E-03 -0.17532303E-03  0.14780133E-04  0.10153192E-05 -0.28361696E-04
-0.37524066E-03  0.56897266E-04 -0.29769871E-04 -0.19047988E-04  0.71305029E-04
-0.94895085E-07  0.51394434E-03  0.12493453E-04
 0.41633449E-03 -0.24868386E-04 -0.12630358E-03  0.13723355E-03 -0.22816845E-03
 0.30156463E-04  0.20704519E-03 -0.36176781E-05 -0.74200331E-06  0.57123238E-05
-0.29760073E-03  0.77104023E-05  0.52895094E-05 -0.13503979E-06 -0.44505980E-06
-0.45628736E-04 -0.67259632E-05 -0.66489977E-05 -0.14663638E-04 -0.91013909E-05
 0.18209851E-07  0.12493453E-04  0.95421510E-05
```

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.99127910E+00
2	1	0.88963537E+00
3	1	0.33182002E+00
4	1	0.68495893E+00

5	1	0.76127488E+00
6	1	0.34539887E+00
7	1	0.45426456E+00
8	1	0.93498215E+00
9	1	0.60520391E+00
10	1	0.76499907E+00
11	1	0.21645781E+00
12	1	0.44528406E+00
13	1	0.56933668E+00
14	1	0.86480391E+00
15	1	0.35323587E+00
16	1	0.64647587E+00
17	1	0.33749735E+00
18	1	0.34294468E+00
19	1	0.63615436E+00
20	1	0.54449662E+00
21	1	0.65323488E+00
22	1	0.52603810E+00
23	1	0.30096130E+00
24	1	0.33155577E+00
25	1	0.28044808E+00
26	1	0.36565087E+00
27	1	0.20247502E+00
28	1	0.34093945E+00
29	1	0.20895326E+00
30	1	0.16020219E+00
31	1	0.17917058E+00
32	1	0.24654498E+00
33	1	0.23860012E+00
34	1	0.27691222E+00
35	1	0.31290051E+00
36	1	0.40572544E+00
37	1	0.25784671E+00
38	1	0.45898189E+00
39	1	0.29093767E+00
40	1	0.46368843E+00
41	1	0.25226503E+00
42	1	0.13005079E+00
43	1	0.51271275E+00
44	1	0.55919245E+00
45	1	0.21338046E+00
46	1	0.27457691E+00
47	1	0.15941099E+00
48	1	0.25830861E+00
49	1	0.72315543E+00
50	1	0.24107006E+00
51	1	0.28870900E+00

52	1	0.40354352E+00
53	1	0.24128797E+00
54	1	0.31131344E+00
55	1	0.71876339E+00
56	1	0.81579620E+00
57	1	0.78617266E+00
58	1	0.72435434E+00
59	1	0.23870004E+00
60	1	0.65059980E+00
61	1	0.99384075E+00
62	1	0.16800377E+00
63	1	0.53500746E+00
64	1	0.38470253E+00
65	1	0.64424665E+00
66	1	0.46653064E+00
67	1	0.17508346E+00
68	1	0.59091745E+00
69	1	0.17751984E+00
70	1	0.16822130E+00
71	1	0.28247845E+00
72	1	0.24846550E+00
73	1	0.20984916E+00
74	1	0.20289519E+00
75	1	0.30409354E+00
76	1	0.98904051E+00
77	1	0.45481775E+00
78	1	0.74674707E+00
79	1	0.90327373E+00
80	1	0.69042836E+00
81	1	0.77995899E+00

Mean efficiency = 0.45483651E+00