FACTORS AFFECTING PRODUCTION EFFICIENCY OF SMALLHOLDER DAIRY PRODUCERS IN CHOMA AND MONZE DISTRICTS

A Research Report presented to the Department of Agricultural Economics and Extension Education of the University of Zambia.

BY

IKABONGO IKABONGO

In Partial Fulfillment of the Requirements for the Degree of Bachelor of Agricultural Sciences

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LIST OF ACRONYMS

ACF	Agricultural Consultative Forum
CARPA	Center for Applied Research and Policy Analysis
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
FAO	Food and Agricultural Organisation
OLS	Ordinary Least Squares
MLE	Maximum Likelihood Estimators
WHO	World Health Organisation
ZDA	Zambia Development Agency

ABSTRACT

Factors Affecting Efficiency of Smallholder Dairy Producers in Choma and Monze Districts.

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The University of Zambia, 2013 — **Dr. G Tembo**

Understanding the factors affecting smallholder dairy farmers' production efficiency is essential to having a vibrant competitive dairy sector. To investigate some of the causes of inefficiency, a study on technical efficiency was carried out in southern province.

This study uses data from Center for Applied Research and Policy Analysis (CARPA), Data Envelopment Analysis (DEA) and Tobit regression analysis to measure and identify the factors influencing technical efficiency in 420 dairy farms, located in Choma and Monze district.

One output (milk in litres) and three input types (cows, labour, land, and feed) were used to calculate the efficiency scores for each farm. A two-stage analysis was conducted to measure and explain the efficiency scores. In the first stage, the efficiency scores were measured using the DEA approach which was implemented with a linear programming method. The efficiency indices ranged from 0.02 through to 1 while average technical efficiency was at 17 percent. Of the 420 farms, only 11 farms (2.62 percent) were fully efficient with unity efficiency scores. About 75 percent of the farms have efficiency scores below 0.25. Thus, three quarters of the dairy farms could expand dairy production by at least 75 percent from the current level without any increase in the level of the inputs.

In the second stage, a Tobit regression model was used to explain the efficiency scores by relating then to a range of explanatory variables. Empirical results from the regression analysis showed that the number of cows owned was statistically significant and positively influenced technical efficiency, whereas Socio-economic factors (such as sex of household head), and farm level factors (such as training and labour) were also statistically significant though influenced technical efficiency negatively.

Key words: Dairy farming; technical efficiency, two-stage efficiency, Data Envelopment Analysis, constant returns to scale.

CHAPTER ONE: INTRODUCTION

1.1 Background

Agriculture in Zambia has great potential for enhancing economic growth and reducing poverty. According to the Fifth National Development Plan (2006), a well-performing agricultural sector translates into significant improvements in the country's GDP, contributes to employment generation, and broadens the country's tax base. When well developed, the sector should contribute significantly to welfare improvement. Mainly, the livestock sub-sector is economically important in Zambia as it accounts for about 35 percent of total agricultural production. Zambia has an estimated total livestock population of 2.9 million cattle, 82,000 sheep and 954,000 goats. Approximately 84 percent, 96 percent and 64 percent of the national cattle, goat and sheep herds, respectively, are found in the traditional livestock sub-sector, which is dominated by subsistence farmers, most of whom are indigenous people who raise cattle on communal land (Muma et al. 2007).

The cattle industry is broadly divided into two main subsectors: commercial and small scale, both of which produce beef and dairy products. The dairy industry is one of the most rewarding agri-business activities in Zambia, and it is driven mainly by small-scale farmers who contribute 60 percent of total milk production in Zambia (ZDA, 2011). Small-scale dairy production was first introduced in the early 1970s under milk production schemes. These smallholdings are generally located near urban centres and away from the railway line, while commercial dairy production is undertaken along the old railway line by large- and medium-scale farmers.

Zambia has the potential to be a milk exporting country considering that it has abundant water, suitable land and favourable climatic conditions for the dairy industry to flourish. On average, small scale farmers' milk yield is 1-2 litres per cow per day while emergent, medium and large scale commercial farmers have yields as much as 10-15 and 15-25 litres per cow per day respectively (SNV, 2013). And unlike other African countries, 70 to 80 percent of all milk consumed in Zambia is sold directly to consumers in local, open markets and approximately 20-30 percent is processed by the commercial dairy processing industry (Valeta Alex, 2004). A dairy study commissioned by the Agricultural Consultative Forum (AFC) estimates that Zambia produces between 214 and 254 million litres of milk annually (ACF, 2012) of which only 15-18 percent passes through the formal marketing channels. The Regional Agricultural Trade Expansion Program (RATES) further estimates that smallholder farmers only account for 40 percent of all the marketed milk. It is estimated that Zambia is a net importer of milk and milk products by between 2.5 million and 3 million kilograms annually (Valeta, 2004). It is also estimated that, per capita consumption of milk is 19.5 litres which is 10 times lower than the recommended per capita consumption of 200 litres / annum by the World Health Organisation (WHO) and Food and Agriculture Organisation (FAO) of the United Nations (ACF, 2012). Thus, Zambia is a potentially big market on its own.

1.2 Statement of the problem

A number of studies done in the dairy sub-sector have mainly focused on performance and competitiveness of dairy (ACF, 2012), its viability (Mumba et al. 2012), the role of cooperatives and market access (Emeldah, 2012), production and marketing of milk (SNV, 2013). While they aim to contribute towards discovering and understanding ways of enhancing the subsector's performance and competitiveness, no study has sought to understand the sources of the huge productivity gaps among smallholder farmers. The few studies that have sought to determine productivity and identify sources of inefficiency in Zambia have mainly focused on crops (Chiona et al. 2012; Kabwe, Tembo and Kalinda 2012).

Elsewhere, a lot of work has been done on the production efficiency of the dairy sub-sector (Loren et al. 1984; DeeVon et al. 1989; Binici et al. 2006; Ayele et al. 2012; Majiwa et al. 2012). Most of these studies conclude using the stochastic production frontier approach that most farmers are operating inefficiently to a certain degree while identifying factors such as land size, access to extension service, infrastructure and the farmer's level of schooling as some of the determinants. However, many of these studies do not consider many of the farm-specific factors that would generally be expected to influence technical, allocative and economic efficiency of the smallholder dairy farmers.

The stochastic frontier approach also has a number of limitations, including the fact that it requires assumptions about the functional form or the distribution of the error terms of the frontier production function hence it imposes a specific structure on the technology a priori.

1.3 Rationale of study

This study is important as improving productivity in the dairy sub-sector is among the major policy objectives in Zambia. This is evident from the Fifth National Development Plan (2006) whose objective under livestock was to improve the productive efficiency of the livestock sector in a sustainable manner and support the marketing of both livestock and livestock products and contribute to food security and increased income.

It is also important as estimating the technical, allocative and economic efficiency in dairy production sector would nm establishing of economic performance indicators. These play an important role as they provide baseline data for policy makers, donors, development planners and farmers when making decisions related to the allocation and use of resources of smallholder dairy enterprises in Zambia. They are also important in issues relating to farm-level decision-making, policy and government programme evaluation, and performance analysis to smallholder dairy farming.

Understanding economic performance benchmarks such as milk per cow per day or costs per unit of milk produced, or household and farm specific characteristics influencing efficiency would help policy makers and other stakeholders formulate policy recommendations that will positively impact agricultural productivity. Improved agricultural productivity among dairy farmers has a multiplier effect on the sector. It is likely to improve income of dairy farmers and subsequently help to reduce poverty.

1.4 Objectives

The overall objective of the study is to determine the farm-level efficiency levels and to identify their determinants among Zambia's smallholder dairy farmers.

1.4.1 Specific objectives

- **i.** To determine technical efficiency indices of smallholder dairy farmers.
- **ii.** To identify the socio-economic and farm specific factors that influence technical efficiency among these smallholder dairy farmers.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature on efficiency studies that have been done in developed as well as developing countries. Subsection 2.1 highlights the productivity concepts while subsection 2.2 reviews the studies in which factors that influence technical, allocative and economic efficiency are determined. The chapter is concluded in subsection 2.3 by models that have commonly been used to measure efficiency in the reviewed literature.

2.2 Productivity Concepts

Technical efficiency is the effectiveness with which a given set of inputs is used to produce an output. It is the ability of a decision making unit to obtain maximum output from a given set of inputs (Farrell, 1957). 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 any input required an increase in at least one other input or reduction in at least one output (Koopmans, 1951). Therefore, a technically efficient producer could produce the same output with less of at least one input or could use the same input to produce more of at least one output. Technical efficiency is necessary for allocative efficiency.

Allocative efficiency is the ability of a firm or farm to use the inputs at its disposal in optimal proportion given their respective prices and production technology. When factors of production are used in proportions that do not minimize the cost of producing a given level of output, allocative inefficiency arises. The allocative efficiency index measures a production unit's ability to choose the input combination that minimizes cost given the best available technology. It is the ratio between the minimum costs if it were technically efficient. Because allocative efficiency implies substituting or intensifying the use of certain inputs based on their prices, inefficiencies may stem from unobserved prices, from incorrectly perceived price or from lack of accurate and timely information.

Economic efficiency is an indicator of total efficiency. It has the technical and allocative components. It is the product of technical and allocative efficiency.

2.3 Factors likely to affect efficiency of Smallholder dairy farmers

Studies aimed at determining efficiency of smallholder diary production have been carried out by many researchers. Efficiency levels and factors affecting efficiency were determined. A study aimed at identifying the determinants of technical efficiency of smallholder dairy farms of rural

Kenya done by Majiwa, et al (2012) revealed that the mean efficiency was 79 percent, which suggested that 21 percent of production was lost due to technical inefficiency.
Another study aimed at determining profit efficiency done by Nganga, et al (2010) showed that profit efficiencies of the sampled farmers in Kenya varied widely between 26 and 73 percent with a mean of 60 percent suggesting that an estimated 40 percent of the profit is lost due to a combination of both technical and allocative inefficiencies in the smallholder dairy milk production.

A nonparametric analysis of technical, allocative, scale, and scope efficiency of agricultural production carried out by Jean-Paul Chavas and Michael Aliber, (1993), on Wisconsin farmers indicated the existence of important economies of scale on very small farms, and of some diseconomies of scale for the larger farms.

Factors that influence efficiency were found to be land size, access to extension service, infrastructure and the level of schooling or education. (Majiwa et al. 2012; and Nganga et al. 2010). Experience and the size of the farm were also found to influence profit efficiency positively while profit efficiency decreased with age. Farmers who have more experience and farm size tend to exhibit higher levels of profit efficiency. However, completely in line with a priori expectation, a positive and statistically significant relationship was found between age of the farmer and profit inefficiency. This indicated that old tend to exhibit higher levels of profit inefficiency. Older farmers have acquired more human capital through their experiences, but they also may be less willing to adopt new ideas. (Nganga et al. 2010)

Binici et al (2006), identified two statistically significant factors that were associated with the variation in production efficiency: the type of feeding system used and herd size. Individual, instead of group feeding of cows, and larger herd gave a greater degree of efficiency. However, use of extension programs explained little of the variation in production efficiency.

Bailey et al. (1989) also established that Large and medium-sized farms were more allocative efficient than the small farms as a group, and the estimates of scale inefficiency showed that most of these farms were producing output at a level below the optimum.

2.4 Models that have commonly been used to measure efficiency

Production efficiency measurements are typically implemented by either parametric techniques or non-parametric techniques. Non-parametric techniques, also known as distribution free, include Data Envelopment Analysis (DEA), where the model structure is determined from the data available, not specified a priori. On other hand, parametric techniques assumes that the data has come from a type of probability distribution and makes inferences about the parameters of the distribution. This is inclusive of the Stochastic Frontier Analysis.

From the reviewed literature above, it is observed that most of the studies used the Stochastic Frontier Analysis, which has a lot of assumptions. More accurate and precise estimates can only be produced if the assumptions are correct. And if they are incorrect, they can mislead. This could have affected the obtained results. And for this reason, parametric methods are often not considered robust.

CHAPTER THREE: METHODOLOGY AND PROCEDURES

3.1 Introduction

This chapter begins with the study area and sample size. Section 3.3 gives the data collection and analysis. It is concluded with the theoretical framework in section 3.3.1.

3.2 Study area and sample size

This study was carried out by Food and Agriculture Organization (FAO) and Implemented by The Center for Applied Research and Policy Analysis (CARPA) in 2012. The area of study was Monze and choma districts of southern province, with a sample size of 420 farmer households.

3.3. Data Collection and Analysis

Secondary data about the dairy activities in the two districts were obtained from CARPA and analysed in Stata. The analysis was done in two stage. The first stage involved generating relative efficiency scores using data envelopment analysis (DEA) which involves running a mathematical programming model for each DMU.

In DEA, the envelopment surface differs depending on the scale assumptions that underpin the model. We assume constant returns to scale (CRS), which reflects the fact that output will change by the same proportion as inputs are changed. The DEA model was further configured to be input-oriented which determines quantities of inputs the firm could contract if used efficiently in order to achieve the same output level.

For the second stage, a regression model is used to identify the farmer and farm-level factors that could explain efficiency levels. We use the Tobit specification as the efficiency scores were heavily censored at one.

3.3.1 Theoretical framework

Data Envelopment Analysis (DEA) is a non-parametric data-oriented approach for evaluating the performance of a set of entities called Decision Making Units (DMUs), which convert multiple inputs into multiple outputs. In DEA, there are a number of producers. The production process for each producer is to take a set of inputs and produce a set of outputs. Each producer has a varying level of inputs and gives a varying level of outputs, meaning they are all producing at varying levels of efficiency. DEA evaluates producers relative to an average producer. It compares each producer with only the "best" producers hence attempting to determine which of the producers are most efficient, and to point out specific inefficiencies of the other producers.

Full efficiency (100%) is attained by any DMU if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs.

Relative Efficiency: A DMU is to be rated as fully (100%) efficient on the basis of available evidence if and only if the performances of other DMUs does not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs.

As introduced by Cooper et al. (2000), the ratio of outputs to inputs is used to measure the relative efficiency of the $DMU_j = DMU_o$ to be evaluated, relative to the ratios of all of the $j = 1, 2, \ldots, n$ DMU_j. In mathematical programming, this ratio, which is to be maximized, forms the objective function for the particular DMU being evaluated. Symbolically,

$$\max \theta = \frac{u_1 y_{10} + u_2 y_{20} + \cdots + u_r y_{r0}}{v_1 x_{10} + v_2 x_{20} + \cdots + v_r x_{r0}}$$

$$= \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{ri}}$$

Subject to the constraints that no service unit can be more than 100 percent efficient when the same values for u and v (coefficients) are applied to all other service units being compared. i.e.

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$$J=1,2,3,\ldots n$$

$$u_r,\ v_i \geq 0 \text{ for all } i \text{ and } r$$

where; j= number of service units

θ=efficiency rating of the service unit being evaluated by DEA

y_{rj}=amount of output r used by service unit j

x_{ij}=amount of input i used by service unit j

i= number of inputs used by the service units

r= number of outputs generated by the service units7

u_r=coefficients or weight assigned by DEA to output r

v_i= coefficients or weight assigned by DEA to input i

And the Tobit model,

$$y_i = \begin{cases} y_i^* & if \quad y_i^* > 0 \\ 0 & otherwise \end{cases}$$

where

$$y_i^* = \beta X + \mu_i \qquad \mu_i \neg N(0, \hat{\sigma}^2)$$

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This section presents the findings of the study as well as the interpretation and their discussion. We begin by first describing the demographic characteristics of smallholder dairy farmers, followed by the efficiency indices and then the regression of these indices on farm and farmer characteristics.

4.2 Household and farm characteristics of the dairy farmers

Table 1: Household and farm characteristics of the dairy farmers

Characteristic	Average
Socio-economic factors	
Proportion of male household heads	94%
Age of the household head	48.00
Household size	9.35
Head's level of schooling (years)	8.2
Off-farm income	1.87
Farm level factors	
Total Landholding (Hectares)	22.1
Received production training	1.59
Received a calf	1.75
No. of cows	9.0
Feed (kilograms)	114.4
Labour (minutes/day)	5.45

Source: CARPA (2014)

On average, most of the respondents that constituted the sample of the study were male (94%) as compared to females (6%). From the 420 dairy farmers, the minimum age of the farmers was 20 years while the maximum was 91 years, with a mean (average age of the farmers) of 48 years. In terms of education, most of the household heads barely completed primary and secondary education with a few reaching tertiary level. Most of these farmers are married monogamously while others were polygoumously married.

4.3 Technical efficiency in dairy production

From the linear programming, the results obtained indicated that technical efficiency of dairy production for the two districts was very low with an average of 17 percent. This implies that 83 percent is lost due to technical inefficiency. There is room for further increase in output without increasing the level and cost of inputs. **Error! Reference source not found.** summarizes the distribution of efficiency scores in the sample. Of the 420 households, only 11 households (2.62 percent) were fully technically efficient (100 percent) relative to all other farmers. That is, they had an efficiency score of one indicating full efficiency. About 93 percent of the households were 40 percent or less efficient.

Table 2: Distribution of technical efficiency in dairy production

Efficiency score category	Number of households	Percent
0 - 0.1	154	36.67
>0.1 - 0.2	172	40.95
>0.2 - 0.3	50	11.9
>0.3 - 0.4	17	4.05
>0.4 - 0.5	6	1.43
>0.5 - 0.6	8	1.9
>0.6 - 0.7	1	0.24
>0.7 - 0.8	1	0.24
>0.8 - 0.9	0	0
>0.9 – 1	11	2.62

Source: CARPA (2014)

4.4 Determinants of technical efficiency

The technical efficiency scores were then regressed on socio-economic and farm specific characteristics. The socio-economic factors included in the model were: gender of the household head, age of the household head, education level of the household head, off-farm income, whether or not training was received, and being a member of an association or a dairy cooperative. Then farm specific factors included were: total land used in dairy production, number of cows owned, labour and feed. The results of the Tobit regression are summarized in Table 3.

Table 3: Determinants of technical efficiency in dairy production

Variable	Coefficient		Standard error
Number of cows	0.0024	**	0.0008
Average total labour in minutes per day	-0.0038	*	0.0017
Land operated in hectares	-0.0002		0.0001
Education level of household head in years	0.0028		0.0033
Whether received a calf from an organisation (1=yes)	0.0044		0.0222
Member of a cooperative (1=yes)	-0.0098		0.0232
off-farm income	0.3381		0.0256
sex of the head (1=male)	-0.163	***	0.0392
Years in dairy business	-0.0002		0.001
Age of household head	-0.0007		0.0007
Average feed in kgs	0.00003		0.00004
Whether received training (1=yes)	-0.0253	**	0.023
Constant	0.2467		0.0784
Observations	420		

*, **, *** denote statistical significant at 10 percent, 5 percent and 1 percent respectively.

Source: CARPA (2014)

Among the demographic characteristics, number of cows owned, total labour, sex and training had a significant effect on efficiency. The number of cows owned was found to be both statistically significant and affecting technical efficiency positively as it is the source of the milk in the production. Labour had a negative effect on technical efficiency probably due to wages, in case of hired labour, thereby adding to the production costs. This also applies to training. The gender variable had a negative coefficient, meaning that it has a negative influence on technical efficiency too, probably due to that fact that most of these households are headed by males, who are known to attend meetings and workshops organized by extension officers relatively less than their female counterparts.

The influence of education on efficiency is usually attributed to the ability of more educated farmers to understand and adopt production practices that may enhance productivity. It can be used as a proxy for managerial input. Higher level of education could lead to better management of farming activities and that may have a positive influence on efficiency. This is because educated farmers are likely to access information easily, and use it to make well informed decisions. Access to extra income, from any other enterprise, credit or savings increases the liquidity of the household making it easier to finance the dairy enterprise.

The age of a household head matters in the way the household head makes farming decisions. Older household heads could be considered as being risk averse while younger household heads could be considered as risk takers. The farming decisions that might be taken by household heads with different age could have a different impact on technical efficiency. Age of a farmer can be expected to have a positive or a negative relationship with efficiency of the farm. This means that older farmers can be more experienced and efficient in doing their farm operations or that older farmers may be traditional and conservative and show less willingness to adopt new farming technology and hence could be less efficient.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION

5.1 Introduction

This chapter presents the conclusion and recommendations of the study based on the findings and interpretations of the study.

5.2 Conclusion

The primary objective of this study was to estimate the technical efficiency of smallholder dairy farmers in Zambia and to link the results to farmer and farm characteristics. According to the results from the DEA, technical efficiency levels among smallholder dairy farmers are very low, ranging from 0.02 through to1 while average technical efficiency stands at 17 percent. This suggests that there is room for further increase in output without increasing the level and cost of inputs.

The results from the tobit regression showed that sex of household head, labour and training were statistically significant at all 3 levels and influenced technical efficiency negatively, while number of cows owned was statistically significant and positively influenced technical efficiency. Education, age, years in dairy business, and land size operated on were not statistically significant but influenced technical efficiency.

5.3 Recommendations

Based on the empirical results obtained from this study, the following are the recommendations: Training was found to be significant, the government should come up with continuous seminars and training programs for the farmers on improved dairy practices and management. Extension workers should be able to reach out to each and every farmer on a regular basis and the extension education should not be directed towards production only but also towards encouraging the households to engage in income generating activities so that they can increase their financial security. This increased income can then be used to acquire cows and other implements.

Female participation in the dairy sector should also be encouraged. They would perform better than their male counterparts as they frequently attend training programs, seminars or workshops when they are called for, hence having the knowledge on management practices.

Ownership of cows also had a positive influence on the technical efficiency, therefore government, through lending institutions can come up with a scheme for loans specifically meant for cow purchasing, or enforcing the pass on a gift program where a female calf is given to one farmer, who is then expected to give another farmer when that calf matures and has a calf.

Future studies on allocative and economic efficiency of the dairy production should be conducted. Since this study used cross-sectional data; it would be interesting to look at technical efficiency, allocative efficiency and economic efficiency using panel data with at least key variables to evaluate how these efficiency categories would change over time.

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