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Indaba Agricultural Policy Research Institute (IAPRI)
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Any views expressed or remaining errors are solely the responsibility of the authors.

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EXECUTIVE SUMMARY

Cotton is produced by over 150,000 smallholder households, representing 10 percent of smallholder farmers in Zambia. The sector has grown in terms of production from less than 50,000 metric tonnes (mt) of seed cotton in 1994, to as high as 275,000 mt in 2012, with an average of 110,000 mt for the period 2005 to 2015. This is mainly due to the increase in number of ginning companies and investments in gins, from two to about 11 ginning companies with a ginning capacity of over 300,000 mt per annum in total. Despite all these positive strides, productivity of cotton smallholder farmers remains low.   Low productivity in cotton confines farmers to a perpetual vicious poverty trap and makes the sector grossly uncompetitive. Turning the sector around to make it more efficient, more competitive and more viable must be important for stakeholders and policy makers alike.

The primary data used in this study comes from the Post-Harvest Survey of 2010/11 conducted by the Central Statistics Office (CSO) and, the Ministry of Agriculture and Livestock (MAL). Using the Data Envelopment Analysis (DEA) and supplemented by the Stochastic Frontier Approach (SFA,) the study examined the technical efficiency of cotton farmers in Zambia. In the second stage, an Ordinary Least Squares (OLS) was used to determine the sources of efficiency among cotton farmers in Zambia. The study further examined the impact of technical efficiency on the welfare of cotton farmers.

The study highlights several key findings. First, the results show that Zambian cotton farmers are less efficient compared to farmers in other countries. On average, Zambian cotton farmers produce seed cotton at 43 percent level of efficiency. Only 20 percent of the cotton farmers produce at 50 percent or above efficiency whilst, the top 10 percent of produce cotton at 71 percent and above.

Secondly, female-headed households are more efficient than male-headed households when it comes to cotton production. On average, female-headed households produced cotton at 53 percent efficiency compared to the male headed households who produced cotton at 42 percent.

Thirdly, cotton farmers from Eastern and Southern Provinces are relatively more efficient than their counterparts from Central Province.

Fourthly, empirical results from the regression model show that efficiency of cotton farmers is affected by factors such as gender, age of household head (with age from 12 to 65 years), and government support of other crops such as maize. The results from the second regression on the welfare of cotton farmers show that gender and province (dummy variables) are important factors that affect their welfare.

There is need to develop strategies such as formation of study circles and farmer training programmes as platforms for disseminating extension message for cotton production and marketing as that is likely to encourage participation of male farmers. Cotton Association of Zambia (CAZ) and some ginning companies are implementing the study circles and cotton farmers' schools, however, all ginning companies are encouraged to form study circles/farmers schools as a way of training farmers and there is need to spread these interventions all cotton growing areas. Furthermore, relatively older farmers should be encouraged to grow cotton as experience counts in the production of the crop.

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ACRONYMS

CSA	Census Supervisory Areas
CSO	Central Statistics Office
DEA	Data Envelopment Analysis
DMU	Decision Making Units
FARA	Forum for Agricultural Research in Africa
MACO	Ministry of Agriculture and Cooperatives
MoFNP	Ministry of Finance and National Planning
OLS	Ordinary Least Squares
PHS	Post Harvest Survey
SEA	Standard Enumeration Area
SFA	Stochastic Frontier Approach
TE	Technical Efficiency
ZDA	Zambia Development Agency
ZMW	Zambian Kwacha (the symbol for rebased currency of Zambia)

1. INTRODUCTION

In sub-Saharan Africa (SSA), cotton is grown by over two million rural households who often depend on it as a source of income for their livelihood. Among the export crops with substantial smallholder farmer involvement in SSA, cotton ranks second in value only to cocoa, and notably, cotton production is spread more widely across the continent. The profitability of cotton production and processing in Africa has large and widespread impact on rural growth and poverty in the continent (Tschirley, 2009). In the case of Zambia, there are positive strides that have been associated with cotton production where over 150,000 smallholder households, representing 10 percent of the entire population of smallholder households depend on the crop for their livelihood. With an average size of the six people per household, the number of household members directly depending on cotton is close to one million, or approximately eight percent of the entire population of Zambia. The sector has grown in terms of production from less than 50,000 mt of seed cotton in 1994 to as high as 275,000 mt in 2012 with an average of 110,000 mt for the period 2005 to 2015. The sector has also seen an increase in the number of ginning companies operating in the sector during the same period. Immediately after privatisation in 1994, there were only two companies, but now there are about 11 companies supporting farmers with inputs (seed and chemicals) on credit, and offering extension service and guaranteed output market. At country level, the cotton sector contributes over US$60 million to the Zambian economy (ZDA 2011).

Despite the positive outcomes seen in the sector, productivity has remained very low, averaging around 850kg per hectare(ha) among cotton farmers in Zambia, as compared to the yield potential of over 2,500kg per ha of all the varieties of cotton found in Zambia (Kabwe 2012, Chita 2010, & Chapoto 2010). Worse still, the Zambian average seed cotton yield is less than that of Zimbabwe and West African countries which is over 1,000kg per ha (Tschirley 2009). This implies that the use of improved cotton varieties, use of approved insecticides, pesticides, herbicides, and the provision of effective extension advice have not widely translated into improved productivity among cotton farmers in Zambia. Therefore, there is need to find ways of improving productivity with the same level of inputs and access to extension information. According to Bravo-Ureta and Pinheiro (1993), that can be attained by improving the level of efficiency of farmers.

Numerous studies have been done in trying to understand production efficiency among cotton farmers and factors associated with their efficiency (Kabwe 2012, Mohammad 2009, Adanacioglu and Olgun 2012, Ngassam *et al.* 2010, Mevlut *et al*, 2009, Shafiq and Rehman 2000, Adzawla *et al.* 2013). A review of these studies shows that there is a knowledge gap on the socio-economic and farm level factors affecting efficiency of cotton farmers. Kabwe (2012) using DEA-generated technical efficiency indices without including key inputs such as chemicals (pesticides, insecticides) and micro-fertilisers as data on these variables were not captured in the survey. Technical efficiency was found at 46 percent. This paper builds up on the work of Kabwe (2012) and, uses more inputs variables for cotton production to estimate technical efficiency. Furthermore, it examines how technical efficiency affects household welfare. The researchers posit that there is currently no existing study assessing this aspect with more input variables to generate efficiency indices, in order to come up with appropriate policies.

2. EVOLUTION OF THE ZAMBIAN COTTON SECTOR

In 1994, as part of a broad-based effort to restructure Zambia's economy and in order to eradicate the inefficiencies experienced in the input provision and output market for cotton, Lint Company of Zambia (LINTCO) was sold to Lonrho Cotton/Dunavant[1] and Clark Cotton[2]. The sale was designed to limit regional competition between the companies. To this end, Lintco's gins in the centre and south of Zambia were sold to Lonrho, and those in Eastern Province were sold to Clark Cotton. Notably, both the private companies had regional cotton production interests.

After the liberalisation of the cotton sector, seed cotton production improved from as low as 20,000 mt in 1994, to the highest production of 275,000 mt in 2012. However, seed cotton production growth was observed between 1994 and 2005. This was as a result of innovations implemented in the provision of inputs and extension messages to the farmers by the private companies, more especially Lonrho/Dunavant and Clark Cotton the two leading companies. Over the same period, the nominal price of seed cotton was increasing until 2004. This trend changed dramatically in 2006 when the leading ginnery did not honour the pre-planting price of ZMW1.2/kg of seed cotton it had previously announced, instead, it paid only ZMW0.85/kg. This resulted in farmers reducing the area planted, and/or leaving cotton production completely. This in turn caused a reduction in the quantity of seed cotton produced in 2007. In the long-term, seed cotton production has been fluctuating, and the sectors growth has been less stable than was experienced between 2001 and 2006 (Figure 1). Information drawn from farmer narratives suggests that there exists a certain level of mistrust towards the ginners with respect to price setting, and the possibility of farmers being cheated out of earnings on the basis of prices paid to them.

Given this illustration, it is pertinent to note that when the nominal price paid to the farmers rebounded in 2010 and 2011 to over 100 percent, cotton farmers responded by increasing the area cultivated, and consequently production of seed cotton increased as well. In fact in 2012, Zambia produced the highest ever seed produced to a tune of 275,000 mt of seed cotton. Notably, the high in seed cotton production did not last long and reduced by over 100 percent in 2013. The main reason was that ginners paid cotton farmers in 2012 half the price they paid them in 2011 citing a reduction of lint price at international market. Farmers responded by reducing area for cotton and some farmers left the sector.

Figures 1 and 2 show that seed cotton production and area under cotton have a positive relationship with lagged price. Where the price of the previous season was high enough, farmers respond by increasing the area cultivated under cotton, and consequently this lead to increase in production. Figures 1 and 2 therefore suggest that, high seed cotton production in Zambia has not been as a result of improved productivity. Figure 3, shows that productivity of seed cotton has been hovering around 850 kg/ha.

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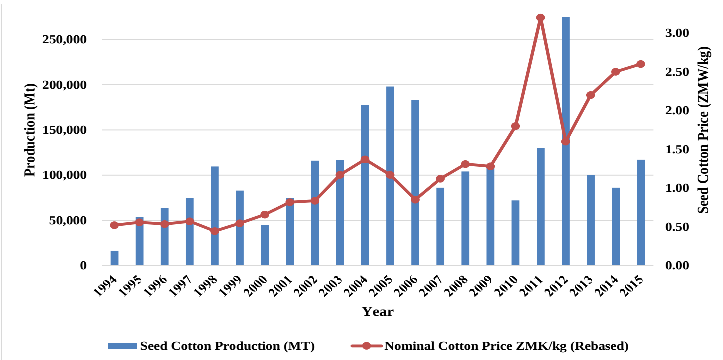
[1] Currently trading as NWK Agri Services

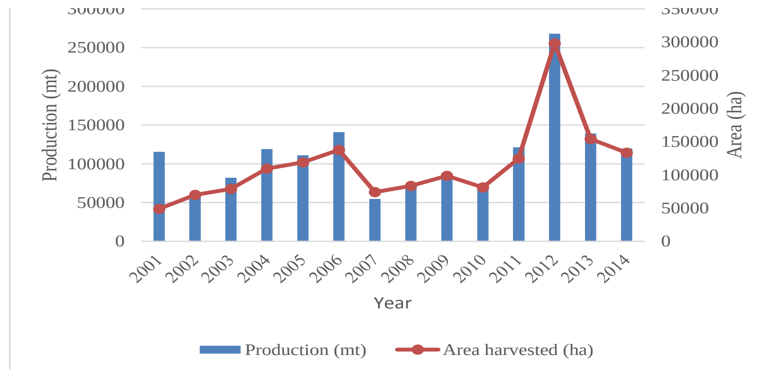
[2] Currently trading as Cargill

Figure 2: Trends in lagged price (ZMW/kg) and seed cotton production (mt) in Zambia



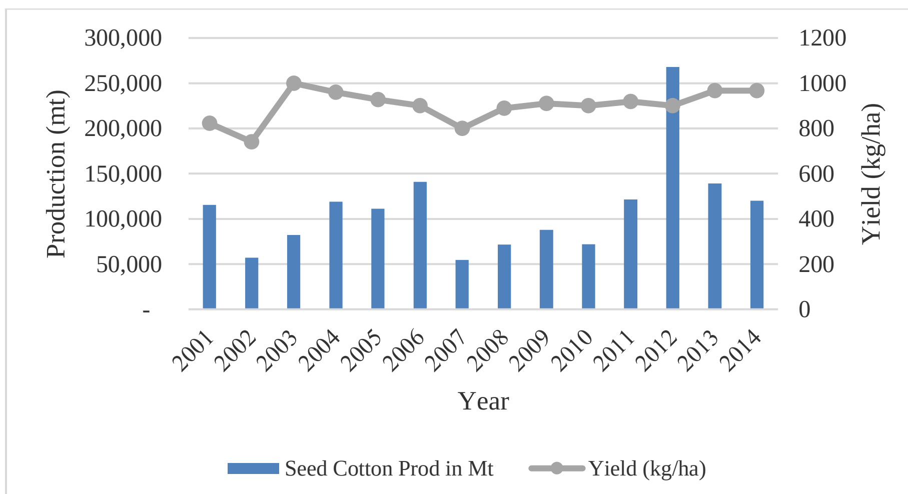
Source: Kabwe 2012, updated by Author using data from Ginners/CBZ, 2015

Figure 1: Trends in area harvested (ha) and seed cotton production (mt) in Zambia



Source: MA/CSO, various CFS 2001 to 2014

Figure 3: Trends of yield (KG/ha) and seed cotton production in Zambia



Source: MA/CSO, various CFS 2001 to 2014

If cotton production in Zambia has to be sustainable, there is need to improve productivity beyond 850kg/ha closer to the potential of available varieties of over 2000kg/ha through improved efficiency. This study assesses the technical efficiency of cotton farmers and the factors affecting technical efficiency, and seeks to determine if the technical efficiency has any impact on the value of productive assets.

2.1 Research Objective and Hypotheses

The broad objective of this study is to analyse the technical efficiency of cotton farmers. In order to achieve this broad objective, the following are the specific objectives;

i. To determine the technical efficiency of cotton farmers in Zambia;
ii. To determine the factors affecting technical efficiency of cotton farmers in Zambia;
iii. To determine if technical efficiency has any significant effect on the value of production assets.

2.1.1 Hypotheses

To achieve the above specific objectives, the following hypotheses were tested:

1. Technical efficiency of cotton farmers is positive related to some socio-economic and farm factors; gender (female=1, otherwise=0), age, education level of household head, farmer belonging to Dunavant/Cargill, growing seed cotton in Eastern/Southern in reference to Central Province, Farmers' access of inputs through Farmer Input Support Programme (FISP) and negatively related to off-farm income, size of the farm, selling of maize to Food Reserve Agency (FRA) and, growing seed cotton production in Central Province in relationship to Eastern/Southern Provinces.

2. Technical efficiency of cotton farmers is positively related to the welfare of cotton farmers.

2.1.2 Research questions

To achieve the above-stated specific objectives, the study answered the following research questions;

i. What socio-economic and farm characteristics relates significantly positive to technical efficiency?
ii. What are the key factors affecting the welfare of cotton farmers?

Following Section One and Two, Section Three discusses the theoretical framework under which the technical efficiency indices are generated. Data and methods are discussed in Section Four. Section Five discusses the descriptive and econometrics results and Section Six discusses the conclusion and the policy implications.

3. THEORETICAL FRAMEWORK

3.1 The Concept of Efficiency

Production efficiency is either measured by parametric[3] or by non-parametric[4] methods. Literature on efficiency measures has been shaped by the seminal work of Farrell, (1957) for non-parametric approaches and by Aigner *et al*. (1977) for parametric approaches. The principal behind efficiency measures involves comparison of the observed output with the potential (attainable) output. However, the potential output is not known in practice and thus must be estimated.

Production theory presupposes full efficiency among producers that firms are producing the maximum possible output for any combination of inputs. However, often times firms operate beneath their production frontier owing to a number of factors that affect their level of productivity, hence the need to estimate that gap. Two quantitative approaches are commonly used by researchers for frontier estimation; Stochastic Frontier Approach (SFA) (parametric approach) and Data Envelopment Analysis (DEA) (non-parametric approach) which involves econometric methods or a mathematic programming techniques respectively (Greene 2008). The major difference between the two approaches is that parametric approaches imposes a functional form on the production function and makes assumptions on the distribution of the error term while non-parametric approach does not impose any function form nor does it make assumptions about the distribution of the error term. The two methods both have their individual strengths and weaknesses[5]. This study used DEA method to generate the efficiency score. To validate efficiency scores generated by DEA, the study also used SFA to produce inefficiency scores. The efficiency score were computed by subtracting inefficiency scores from one (1). Then these were compared to the DEA scores. To determine the factors affecting efficiency, the efficiency scores generated from DEA were regressed with socio-economic and farm factors.

The literature suggests several alternative approaches to measuring production or technical efficiency. According to Farrell (1957), three measures are identified and these are: 1) technical efficiency; 2) price or allocative efficiency and; 3) scale efficiency (that is both price and technical efficiencies). This study focuses only on technical efficiency which is defined as the ability of a firm to produce a maximal output from a given set of inputs.

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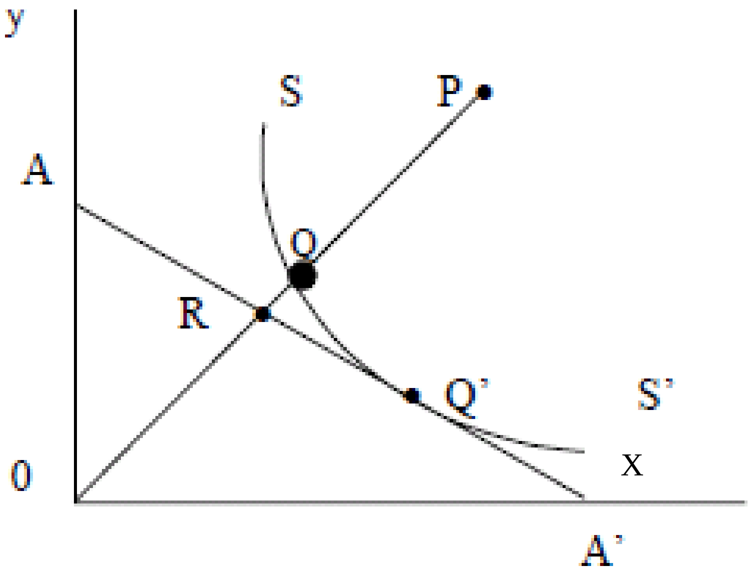
[3] Parametric is a model that can be described using a finite number of parameters (Cameron and Trivedi 2005)..

[4] Non-parametric model is one whose structure is not specified a prior but instead determined from the data (Cameron and Trivedi 2005).

[5] Stochastic frontier approach has the advantage of allowing for random shocks and measurement error and investigates the determinants of inefficiencies but the weakness is that it is risky to impose strong a priori assumptions on the production technology by choosing the functional form. It is also susceptible to specification errors. On the other hand, Data Envelopment Analysis has the advantage of minimal specification errors and can be used to estimate both multiple inputs and multiple outputs. However it is deterministic and attributes all the deviations from the frontier to inefficiencies (Cooper and Tone 1997).

Figure 4: Technical Efficiency



Source: Ajibefun (2008)

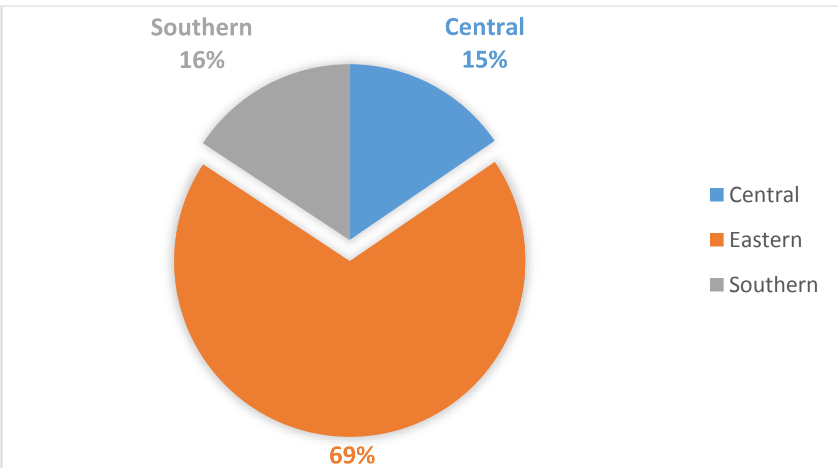
Using Figure 4 and considering two inputs *X* and *Y* to produce an output *P*, the ideas of technical efficiency determination are illustrated. The point *P* represents the inputs of two factors, per unit of output, that the firm is observed to use. The isoquant SS' represents the various combinations of the two factors that a perfectly efficient firm might use to produce a unit output. The point *Q* represents an efficient firm using the two factors in the same ratio as *P*. However, point *P* is a scatter point in terms of using the two factors. *Q* produces the same output as *P* using only a fraction OQ/OP as much of each factor. It could also be thought of as producing OP/OQ times as much output from the same inputs. Borrowing the definition of technical inefficient from Koopman (1951), a producer is technically inefficient 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 reduction in any input requires an increase in at least other input or a reduction in at least one output. Considering the definition and using Figure 4 above, technical inefficiency of a firm could be represented by the distance OP which is the amount by which all inputs could be proportionally reduced without a reduction in output. Thus, a technically efficient producer could produce the same output with less of at least one input, or could use the same inputs to produce more of at least one output. A technically efficient farmer/firm will have a ratio equal to one while an inefficient farmer will have a ratio less than one.

4. DATA SOURCES AND METHODS

4.1 Data Sources

This section describes the data sources that were used in this study and highlights the models used to estimate efficiency indices, and factors affecting efficiency in cotton production. The study used the 2010/11 Post Harvest Survey (PHS) data which is a nationally representative household survey conducted by the CSO and the Ministry of Agriculture (formerly Ministry of Agriculture and Livestock). A total of 12,168 sampled households were interviewed and after applying the sampling weights, a nationally representative 1,403,904 households were generated.

Figure 5: Percentage of household producing seed cotton by Province



Source: 2010/11 Post Harvest Survey

For the purpose of this study, the sample used for data analysis included cotton producing households from Central, Eastern, and Southern Provinces where most of cotton growing households are found (Figure 5). The cotton producing households in these provinces was 1,262 (unweighted). However, because of outliers in yield of seed cotton per hectare, 85 households representing 6 percent of the total households were excluded from the sample bringing the final sample used for analysis to 1,177 cotton households (unweighted). When this sample was weighted, the population of cotton producing households was 144,586 representing 8 percent of the agricultural households in Zambia.

4.2 Methods

This study used a two-step procedure used by many other researchers such as McDonald (2008); Hoff (2006); Banker *et al.*, 2008; Fletschner *et al.*, 2002; and Bravo-Ureta *et al.*, 1994. The first step estimates efficiency levels. DEA which is a non-parametric model and, SFA which is a parametric model were used to generate the efficiency levels. The second step involves determining the factors affecting efficiency. There are several methods to estimate the second

stage depending on method used to estimate the efficiency. For example, when efficiency scores are generated by censoring process, the most suitable model to use is the Tobit as highlighted by McDonald 2008; Bankers *et al.* 2008 and Hoff 2006. However, if efficiency scores are fractional data like the ones generated using the Data Envelopment Analysis (DEA) or production frontiers, Ordinary Least Squares (OLS) and Maximum Likely Estimator (MLE) are the most suitable models to use in the second stage since they are consistent estimators (McDonald, 2008). In this study, the researchers used DEA to generate the efficiency scores and as such the appropriate method for the second stage is OLS.

4.2.1 DEA Model (First Step Approach)

The non-parametric DEA method is used to determine the efficiency of the decision making units (DMUs) in this case the cotton farm. In this process DEA approach identifies DMUs based on the technical efficiencies. According to Fletschner *et al.* (2002) and Banker *et al.* (2004), technical efficiency for production unit *h* (TE^h) is found by comparing unit *h* with a combination of all other production units and establishing the minimum proportion of inputs that would allow unit *h* to produce the level of output actually being produced by *h*. The mathematical linear programming used to determine each household/farm technical efficiency measure is given as:

$$\min_{\lambda_t^h, TE^h} \sum_{h=1}^{z} TE^h \tag{1}$$

$$\text{s.t:} \quad \sum_{h=1}^{z} \lambda_t^h y_s^t \geq y_s^h \qquad \text{for } s = 1, \ldots.., m; h = 1, \ldots.., z, \tag{2}$$

$$\sum_{h=1}^{z} \lambda_t^h x_g^i \leq TE x_g^h \qquad \text{for } g = 1, \ldots.., n; h = 1, \ldots\ldots., z, \tag{3}$$

$$\sum_{\mathrm{h}=1}^{\mathrm{z}} \lambda_t^h = 1 \qquad \text{for h=1,.........,z,} \tag{4}$$

$$\lambda_t^h \geq 0, \qquad \text{for t} = 1, \ldots\ldots\ldots, z; h = 1, \ldots., z, \tag{5}$$

$$TE^h \geq 0 \qquad \text{for } h = 1, \ldots\ldots.., z, \tag{6}$$

Source: Fletschner et al. (2002), Fried et al. (2008)

Based on each individual equation above and where there are *m* output and *n* inputs, y_s^h is the s^{th} output of unit *h*, and x_g^h is the g^{th} input of unit *h*. The combination of units against which unit *h* is compared is given by the vector λ^h, where each element of vector $\lambda^h = (\lambda_1^h, \ldots.., \lambda_h^h, \ldots\ldots, \lambda_2^h)$ is the weight of each of the z units in the combination. In other words, λ^h is a vector of weights attached to each of the cotton farms (DMUs). The weighted outputs and inputs of these units against which unit *h* is compared are given by $\sum_{t=1} \lambda_t^h y_s^t$ and $\sum_{t=1} \lambda_t^h x_g^t$, respectively, where y_s^t 21 denotes the production of output *s* for each of the *t=1,………z* units, and x_g^t denotes the endowments of inputs *g* for each of the *t=1,….z* units. The first set of constraints of equation number 2 requires that the weighted average of the output of all cotton farms (DMUs) ($\sum_{t=1} \lambda_t^h y_s^t$), less the output of the h^{th} cotton farm be greater than or equal to zero. This means that, the output

of each cotton farm produced by the combination of production units has to be at least *h'*s output units. Similarly, the second group of constraint of equation number 3 requires that combining production units in the same manner, the inputs used do not exceed unit *h'*s level of inputs. The third constraint ($\sum_{t=1} \lambda_t^h = 1$) of equation number four guarantees unit *h'*s production frontier is weakly concave. This represents variable returns to scale.

The parametric model (SFA), which is the second part of the estimation procedure, is discussed in details in the next subsection. The model is adapted from the work of Ajibefun (2008).

4.2.2 The stochastic frontier production function

The theoretical definition of a production function has been based on expressing the maximum amount of output obtained from given inputs bundles. This is regarded as estimating average production function. This definition assumes that technical inefficiency is absent from the production function. However, in production not all units are produced at maximum outputs (Ajibefun 2008). Some units are produced below optimal points. To account for that, the stochastic frontier production function assumes the presence of technical inefficiency of production and is defined as:

$$Y_i = f(x_i, \beta)\exp(v_i - u_i) i = 1,2,......,N \qquad (7)$$

where v_i = random error associated with random factors not under the control of the producing unit. The technical efficiency of an individual producing unit is defined in terms of the ration of the observed output of the corresponding frontier output, given the available technology.

$$\begin{aligned} TE &= Y_i / Y_i^* \\ &= f(x_i;\beta)\exp(v_i - u_i) / f(x_i;\beta)\exp(v_i) \\ &= \exp(u_i) \qquad (8) \end{aligned}$$

where Y_i is the observed output and Y_i* is the frontier output. X_i is a vector of inputs in production while βs are parameters to be estimated. v_i is as defined earlier.

As indicated above, both the DEA and SFA were used in this study to estimate technical efficiency scores and technical inefficiency scores. The model in which the determinants of efficiency are incorporated was estimated simultaneously with a stochastic frontier model. The model is represented as follows:

$$LnY = f(x_i;\beta)\exp(v_i - u_i) \qquad (9)$$

where u_i which defines the inefficiency term is represented by:

$$u = f(z_s) \qquad (10)$$

where z_s are vectors of the determinants of technical efficiency.

4.2.3 Variables used in the DEA and SFA Models

The input variables that were used in the DEA and SFA models were output, and eight key inputs used in cotton production. The output variable is the quantity of seed cotton produced in kg. While the input variables included area planted, household labour proxied by the household members aged from 12 to 65 years and the quantity of cotton seed. The other inputs included quantities of chemical fertilisers, herbicides and pesticides used. Table 1 below shows the summary statistics of the variables used in the models.

Table 1: Summary Statistics for the Variables used in DEA and SF Models

	Mean	Std. Dev	Min	Max
Cotton harvested (kg)	742	730	12	9000
Area under cotton (ha)	0.95	0.88	.06	15
Household members aged 12 to 65 years	3	2	1	12
Cotton seed planted (kg)	17	14	1.0	200
Quantity of boll worm chemicals applied (litres)	1.2	1.7	0.0	30
Quantity of sucking pest chemicals applied (litres)	0.7	1.0	0.0	10
Quantity of folia fertilizer applied (litres)	1.7	1.9	0.1	30
Quantity of herbicides applied (litres)	2.0	2.7	0.0	20
Quantity of basal fertilizer applied (kg)	70	87	1	1000

Source: MAL/CSO 2010/11

4.2.3 Second Stage using the Ordinary Least Squares (OLS)

After calculating the efficiency indices, the next step is to express the efficiency indices as a function of socio-economic and farm specific factors. This is known as the second stage procedure. Based on MacDonald (2008), Hoff (2006), and Banker *et al.* (2008) recommendation, this study used OLS in the second stage to determine the socio-economic, farm specific and geographic factors that were likely to influence efficiency of smallholder cotton producers in Zambia. The Ordinary Least Squares model was used and is expressed as equation number 7:

$$Y = X\beta + \varepsilon \qquad (7)$$

where Y represents the efficiency scores, and X represents the socio-economic and farm specific factors that are likely to influence efficiency in cotton production. β represents the coefficients and ε is the error term which takes care of unobserved variables. As indicated before, the efficiency scores lie above 0 but less or equal to 1 denoted as: $0 < Y \leq 1$. When $Y = 1$, it implies that the cotton farm is technically efficient while if $0 < Y < 1$, it implies that he cotton farm is technically inefficient.

5. RESULTS AND DISCUSSION

5.1 Descriptive statistics

The descriptive characteristics of the cotton farmers was done and the results are shown in Table 2. The results show cotton farmers were relatively middle aged with a mean age of 43 years. Most of the cotton farmers' households where headed by males representing 88 percent. 72 percent of the household heads have attained primary level of education and only 1 percent have attained tertiary education. It was also observed that off farm income activities have a bearing on the agricultural productivity and 33 percent of farmers indicated that they engaged in off-farm activities to realise some income. The value of productive assets was used as a proxy to measure the welfare of cotton farmers. The mean value of productive assets was ZMW5,220 with a maximum value of ZMW497,000 and minimum value of zero.

Almost all cotton in Zambia is grown under contract farming through an out-grower scheme. Ginning companies recruit their own farmers whom they give inputs on credit and the monetary values is later deducted after harvest during the sale (marketing) of the crop. Dunavant (currently trading as NWK Agri-Service) and Cargill are the major ginning companies in Zambia. About 74 percent of cotton producing households indicated that they belong to either Dunavant or Cargill out grower scheme. The results show that the two companies had a combined market share in terms of its farmers' base in 2010/11 agricultural season of close to three quarters.

Cotton farmers cultivate 2.81 ha for all the crops. The average number of crops grown by cotton farmers was three. However, the average size of the cotton field was 0.95 ha, about 1.96 ha lower than the total cultivated area. The results also show that the majority of cotton farmers are found in Eastern Province, representing, about 71 percent of cotton farmers and only about 15 and 16 percent of cotton farmers are found in Central and Southern Provinces respectively.

Table 2: Socio-economic, Farm level and Geographical Characteristics of Cotton households

	Mean	Std. Dev	Min	Max
Socio Economic Factors				
Maleheaded households	.88	.32	0	1
Age of the household head	43	13	17	91
No education	0.16	0.37	0	1
Primary education level	0.72	0.45	0	1
Secondary education level	0.10	0.30	0	1
Tertiary education level	0.01	0.10	0	1
Did the household engage in off farm income activities?	.33	.47	0	1
Value of productive assets in ZMW (X 1,000)	5.22	21.36	22	497
Was the Farmer financed by Dunavant/Cargill?	0.74	0.44	0	1
Percent of hh that accessed extension	0.78	0.42	0	1
2009/10 district quantity of maize purchased by FRA	34,699	18,134	1,591	66,104
2009/10 district of fertiliser quantities in MT under FISP	3,365	1,775	164	6,448
Area in ha of all crops	2.81	2.31	0.13	32.50
Area in hectares of cotton	0.95	0.88	0.06	15.00
Number of crops grown by the household	3	1	1	13
Did the household use conservation tillage methods?	0.03	.16	0	1
Central	0.15	.39	0	1
Eastern	0.69	.45	0	1
Southern	0.16	.30	0	1

Source: Author calculation using PHS 2010/11

5.2 Technical Efficiency Level

The results from the DEA model show that out of 1,177 cotton farmers, only seven (7) percent cotton were technically fully efficient. These farmers produced more from a unit of output compared to their counterparts who were technically inefficient. Results from the DEA model at national level show that cotton farmers produce cotton at 43 percent efficiency. The low efficiency result is obtained at national level even with SFA where the technical inefficiency level was 0.69 (meaning farmers produced cotton at 31 percent efficiency level). The national mean of technical efficiency scores of cotton farmers from the DEA model varied from 0.11 to 1. Both models (DEA and SFA) show that cotton farmers from Southern Province are the most efficient cotton farmers but differ in showing the most inefficient farmers (Table 3). DEA model show that cotton farmers from Central Province are the most inefficient ones producing cotton at 36 percent while the SFA show that cotton farmers from Eastern Province are the most inefficient one producing at 29 percent efficiency. Overall, national technical efficiency results obtained from both models are comparable with one found in the earlier study by Kabwe (2012) where the mean efficiency of cotton farmers was at 46 percent even though the variables used for determining efficiency were very few as mentioned earlier.

The results suggest that cotton farmers in Zambia are technically inefficient, producing cotton at 43 and 31 percent efficiency respectively. The technical efficiency of 43 percent or 31 percent is way below the average technical efficiency of 58 percent and 60 percent in other developing countries such as Paraguay (Bravo-Ureta *et al.* 2007) and Cameroon (Ngassam *et al.* 2010) respectively. Therefore, there is room for improvement in technical efficiency with the current technology available. On average, cotton farmers can increase output by 57 percent if the results are based on DEA or 31 percent if the results are based on SFA with the same level of inputs as long as they improve the level of efficiency.

Table 3: Summary Statistics of Technical Efficiency by Province

	Technical efficiency DEA	Technical inefficiency SFA
Central	0.36	0.69
Eastern	0.44	0.71
Southern	0.47	0.62
National	**0.43**	**0.69**

Source: Authors calculation using PHS 2010/11

Furthermore, the analysis from the DEA and SFA models showed that female headed households were more efficient in the production of cotton than male-headed households (Table 4). Results from the DEA model showed that female-headed households produced cotton at 53 percent efficiency while the male headed households produced cotton at 42 percent efficiency. Similarly, the SFA model showed that female headed households produced cotton at 40 percent efficiency level compared to male headed households who produced seed cotton at 30 percent efficiency level.

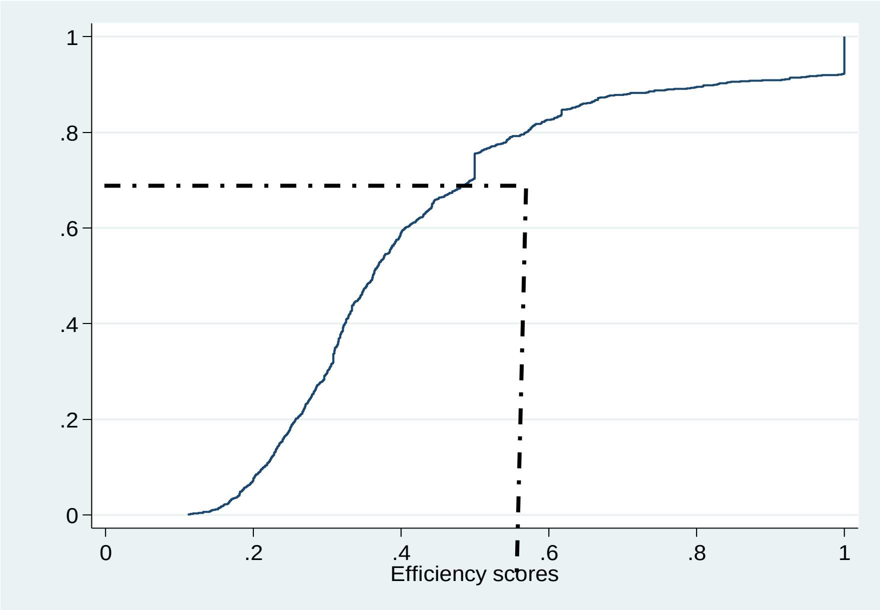
However, productivity of seed cotton per ha by gender shows opposite results compared to technical efficiency. Male headed households had a higher yield per ha than their female counterparts. Femaleheaded households use their given inputs more efficiently, but due to potential structure constraints of capital and labour, they tend to achieve lower yields.

Table 4: Technical efficiency and productivity by gender

	Mean quantity of planting cotton seed	Mean quantity of seed cotton produced per ha	Technical Efficiency Using DEA	Technical Inefficiency Using SFA
	-------------kg------------		Mean	Mean
Female	14	879	0.53	0.60
Male	20	995	0.42	0.70

Source: Author's computation

Figure 6: Cumulative Percent for Technical Efficiency



Source: Authors' computation

Figure 6 represents the cumulative percentages graphs of technical efficiency scores. It clearly shows that over 75 percent of cotton farmers fell between 0.10 to 0.50 technical efficiency. Only about 24 percent of the cotton farmers had their technical efficiency higher than 0.50 or farmers producing at 50 percent efficiency or more. Based on this analysis, the majority of cotton farmers in Zambia do not produce seed cotton efficiently. This could be one of the major factors influencing low productivity levels.

5.3 Determinants of technical efficiency

The low technical efficiencies observed in cotton production can be attributed to some socio-economic and farmer characteristics. Among the key socio-economic factors that affected technical efficiency significantly and positively included; gender (female=1, 0 otherwise), age squared of the household head, number of household members (12-65 years of age) squared, previous year's quantity of fertiliser supplied through FISP and producing of seed cotton in Southern in reference to Central Province. On the other hand, the factors that affected technical efficiency significantly and negatively were; age of the household head, number of household members (12-65 years of age) and log of previous year's quantity of maize purchased by FRA.

The positive and significant correlation between technical efficiency and gender implies that female headed households had a higher and significant technical efficiency than the male headed households. This may be explained by the commitment in attending meetings organised by extension officers exhibited by females compared to their male counterparts (Kabwe 2015). In that regard, they become more knowledgeable and adopt new techniques of cotton production as they are introduced. These results are in line with results from other studies (Kabwe 2012, Dolisca *et al.* 2008; Dhungana *et al.* 2004; Onyenweaku *et al.* 2005 and Mochebelele *et al.* 2000).

The coefficients of age and age squared were negative and positive at five percent significance respectively. This implies that the more years the producer gains, the more technically efficient one becomes. The explanation is that older farmers generally gain experience in cotton production and grow the cotton more efficiently. This result is in line with results obtained by Coelli and Battese (1996), Dangwa (2011), and Ngassam *et al.* (2012).

The coefficients for the number of household members aged 12 to 65 years and the same variable squared were negative and positive at five (5) and one (1) percent significance level respectively. The likely reason is that access to more family labour may result in under appreciation of the value of labour in production such that households with more members may over supply labour per unit area resulting in diminishing returns on labour. Similar results were found by Zahindul *et al.* (2011) and Chimai (2011). However, other studies such as Dolisca and Jolly (2010), and Mbanasor *et al.* (2008), found a positive relationship between large household size and technical efficiency. Their argument was that large household size enhances the availability of labour which may guarantee increased efficiency.

The log of lagged quantity of fertiliser distributed through FISP was found to be positive and significant at 1 percent confidence level with technical efficiency. The likely explanation is that there are some nutritional benefits cotton gets from residue fertiliser left in the soil when cotton is rotated with maize since cotton is a deep rooted crop. The coefficients of log of lagged quantities of maize bought through FRA was found to be negative and significantly at 1 percent. The relative higher price farmers receive when they sale maize to FRA is a motivation for them to pay attention on maize fields than other crops such as cotton. As a result, this affects the technical efficiency of cotton production.
The coefficients on the provincial results show that there was a positive and significant difference in technical efficiency between Central (a reference province) and Southern

Provinces. The coefficients on Eastern Province were not significant, as expected. Therefore the results show that cotton farmers of Southern Province were technically more efficient than those from Central Province. In general, farmers in Southern and Eastern Provinces had smaller cotton fields and those from Eastern and Southern Province cultivated an average of 0.99 and 1.31 ha respectively while Central Province farmers cultivated an average of 1.38ha. Further, cotton farmers from Southern Province had on average five cattle more than those from Central Province. This could explain why Southern Provinces cotton farmers were 4 and 19 percent more efficient than their Central Province counterparts respectively.

5.4 What are the key factors that affect the welfare of cotton farmers?

The value of productive assets was used as a proxy for estimating the welfare of cotton farmers. Productive assets are ones which the household uses in the production of the crops. The value of productive assets was considered because of the direct bearing assets have on crop production. The coefficients of the model are represented in the regression number 2 from Table 5. There were only two coefficients which were significant and these are gender and provincial dummy.

The coefficients on gender affecting technical efficiency was positive as shown in regression number 1. However, the coefficients on gender affecting welfare was negative and significant at 10 percent. The plausible reason is that female headed household are less endowed with productive assets. On average, female headed household had ZMW3,000 worth of productive assets while their male counterparts had ZMW5,500 worth of productive assets. This may explain why female headed households had a negative impact on welfare.

The coefficient on the provincial dummy shows that Southern Province has a negative and significant coefficient at 10 percent confidence level over Central Province on the value of productive assets. The negative sign was not what was expected because cotton farmers of Southern Province have on average ZMW14,000 worth productive assets compared to ZMW5,000 worth of productive assets for cotton farmers of Central Province. The plausible explanation could be that acquiring of a productive asset by cotton farmers in Eastern Province has more impact in relative terms compared to that of cotton farmers in Southern Province.

Table 5: Determinants of technical efficiency and welfare effect of cotton farmers

VARIABLES	Coefficients of Technical Efficiency	Coefficients of Welfare effect
Constant	0.879***	-4.926
	(0.159)	(13.95)
Female headed households	0.0601*	-2.725*
	(0.0323)	(1.394)
Age of the household head in yeas	-0.0101**	0.171
	(0.00469)	(0.216)
Age squared	0.000110**	-0.00207
	(4.56e-05)	(0.00227)
Number of household members (12-65 years)	-0.104***	1.443
	(0.0197)	(2.312)
Number of household members (12-65yrs) squared	0.00710***	0.0252
	(0.00199)	(0.164)
Education level attained	-0.00381	0.0339
	(0.00356)	(0.134)
Off-farm Income (ZMW)	0.0171	1.460
	(0.0210)	(1.494)
Log of value of production assets (ZMW)	0.000759	
	(0.000908)	
Was the ginning company Dunavant/Cargill?	0.00155	1.547
	(0.0227)	(1.425)
Did the household receive any extension advice?	0.00300	1.467
	(0.0193)	(0.939)
Log of previous year's quantity of maize purchased by FRA	-0.0800***	2.664
	(0.0298)	(2.521)
Log of previous year's quantity of fertilizer supplied through FISP	0.103***	-3.097
	(0.0347)	(3.066)
Did the household use any minimum tillage system?	0.0839	-1.417
	(0.0599)	(1.828)
Central Province (reference)		
Eastern Province	0.0385	-4.866
	(0.0245)	(3.786)
Southern Province	0.189***	-11.88*
	(0.0510)	(6.118)
Technical efficiency (DEA)		5.721
		(11.37)
Observations	1,177	1,177
R-squared	0.196	0.075

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' computation

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Enhanced productivity and efficiency among cotton farmers is very important in order to improve the competitiveness and sustainability of the cotton sector and can have huge bearing in smallholder household poverty reduction. Firstly, it is important to understand what efficiency is and how it can be improved.

Efficiency is the ability to attain outputs with a minimum level of resources. It is therefore related to productivity which is commonly defined as the ratio of outputs to inputs. In order to manage and improve efficiency, it has to be measured and the factors influencing it have to be determined.

Using a cross sectional data from the Post-Harvest Survey (PHS), the study examined the technical efficiency and determined the factors influencing technical efficiency and welfare of cotton farmers in Zambia. The technical efficiency results from DEA show that farmers have low level technically efficiency and produce seed cotton at 43 percent efficiency. This implies that they can increase output by 57 percent with the same level of inputs by just improving the level of technical efficiency. The high level technical inefficiency results from SFA of 69 percent confirms the results of low technical efficiency obtained from DEA. The other significantly important findings from this study in terms of technical efficiency are that; female headed households are more efficient in cotton production compared to male headed households. Thirdly, the cotton growing households from Southern and Eastern Provinces out performed their counterparts of Central Province.

Technical efficiency in seed cotton production is affected by a number factors. The main factors include: gender of the household head, age of the household head, number of family members aged 12 to 65 years of age the household has and, government support to maize (FISP and FRA). The main factors influencing welfare of cotton farmers was gender and the locality of the farmers i.e. where a farmers grows cotton in terms of province.

6.2 Recommendations

A sustainable cotton industry depends on the profitability of the sector. Profitability is affected by three factors, namely: productivity, price paid to the farmers, and the cost of production. Productivity is one factor which a farmer can manipulate and improve, whilst price paid to the farmers mainly depends on the international market price, of which farmers have no control. Therefore, to improve profitability, a farmer has to reduce production cost and one avenue is to improve productivity via enhanced efficiency. Based on the empirical results obtained from this study, stakeholders should devise strategies that can encourage and increase male participation in extension meetings (study circles and farmer schools) as that is likely to help them acquire knowledge of cotton production and subsequently improve efficiency in cotton production. Participation of relatively old farmers should be encouraged as they were found to influence technical efficiency positively. Furthermore, farmers should be encouraged to rotate cotton with

maize in order for cotton plant to benefit from residue fertilisers that might have been applied in maize fields.

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Appendix 1: Maximum likelihood estimates of stochastic frontier Production function

Independent variables	Coefficients Symbol	Coef.	Std. Err.	t-ratio
Production function				
Intercept	β_0	7.49	0.15	49.45***
Ln (labor)	β_1	0.04	0.07	0.57
Ln (planting cotton Seed)	β_2	0.13	0.02	5.88***
Ln (macro fertilizer)	β_3	0.02	0.04	0.568
Ln (micro fertilizer)	β_4	0.15	0.03	4.61***
Ln (herbicides)	β_5	0.02	0.04	0.62
Ln (boll worm chemicals)	β_6	0.03	0.01	2.54*
Ln (sucking Pest chemicals)	β_7	0.01	0.01	0.70
Variance parameters				
$\delta^2 = \delta_u^2 + \delta_v^2$		0.62	0.03	
$\gamma = \delta_u^2 / \delta^2$		1.4	0.07	21.55***
Log likelihood		-1204		
Number of observations		1177		
Inefficiency effects				
Constant	δ_0	-3.64	0.98	-3.71***
Was the household female headed household?	δ_1	0.14	0.08	1.85*
Age of the household head	δ_2	0.01	0.01	0.60
Age squared	δ_3	-0.00	0.00	-0.30
Number of household members between 15 and 65 years	δ_4	0.03	0.06	0.44
Number of hh members between 15 and 65 years squared	δ_5	-0.01	0.01	-0.87
Education level attained in years	δ_6	0.01	0.01	0.72
off farm income	δ_7	0.03	0.05	0.55
Crop Income (ZMW)	δ_8	-0.06	0.01	-11.00***
Was the ginning company Dunavant/Cargill?	δ_9	0.01	0.05	0.13
Did the household receive any extension advice?	δ_{10}	0.05	0.06	0.83
Log of previous year's quantity of maize purchased by FRA	δ_{12}	0.13	0.06	2.29
Log of previous year's quantity of fertiliser under FISP	δ_{13}	0.03	0.07	0.37
Did the household use any minimum tillage system?	δ_{14}	0.05	0.12	0.39
Central Province (Reference)				
Eastern Province	δ_{15}	-.22	.07	-3.31***
Southern Province	δ_{16}	-.10	.09	-1.11

*,**,*** Significant at 10% level (P<0.10), 5% level (P<0.05), 1% level (P<0.001) respectively

Source: Authors' computation