MEASURING EFFICIENCY OF SOYBEANS PRODUCTION IN ZAMBIA

BY

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In memory of my grandparents, John Mwanza and MaDhlamini Mwanza,

auntie Winnie and cousin Gertrude

ABSTRACT

As total hectarage and number of soybeans farmers increase in response to government programs, information is needed on use of resources in the production of soybeans. The objectives of this study are to measure and compare the efficiency of Zambian farms in the production of soybeans. Farms were classified into farm size categories using the farm management criteria. Personal interviews were conducted to collect cross section data specific to soybeans production on randomly selected farms in each farm size category.

Efficiency was approximated in terms of Tornqvist index numbers assuming a translog short run cost function and constant returns to scale in production. One capital and seven variable inputs were used in the efficiency calculations.

Results indicate the following ranking of farm size categories, from most efficient to least efficient: small (2-10 hectares), medium (10-40 hectares), traditional (<2 hectares) and commercial (>40 hectares) farms. Test results show significant differences in efficiency exist among the four farm size groups, with efficiency of small scale farms being the most significant. Econometric results suggest there are not constant returns to scale in the production of soybeans in contrast to the assumption used in calculating index numbers.

Results also show that the relatively high efficiency achieved by small scale farms cannot be explained singly by the extension support offered to these farms through the Lint Company of Zambia.

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CHAPTER 1.0 INTRODUCTION

The objective of this chapter is to provide an introduction to the agricultural sector in Zambia. This is followed by a discussion of the importance of oilseeds to the Zambian economy, the different oilseeds that are grown in Zambia, and a discussion of soybeans in terms of the potential for increased production. The problem statement and objectives for this thesis are provided in the last section of this chapter.

1.1 Background

The economy of Zambia is heavily dependent on the copper industry which occupies a pivotal role. The copper industry accounts for more than 92 percent of the total export earnings. The dependence of the Zambian economy on copper makes it highly vulnerable to external factors and thus necessitating the diversification of the country's economy away from the dominance of the copper industry to agriculture.

Despite recent production increases and some shift in the sources of output growth, the development of Zambian agriculture remains far below potential. The sector's contribution to the diversification of the economy has remained low as indicated by the share of the agricultural sector in GDP. In 1989, the share of the agricultural sector in GDP was only 13 percent (World Bank 1991).

Zambia has a considerable potential for agricultural development. It has an estimated 45 million hectares of arable land but only 16 percent was under cultivation during the 1984/85 season (World Bank 1984). To encourage increased agricultural production, the government has given incentives to farmers in the form of input subsidies, generous credit programs and also help from international funded projects. The population of Zambia, growing at 3.7 percent per annum, is currently estimated at 7.8 million (World Bank 1991). In 1990, 50 percent of the population was living in the urban areas. In addition, the urban population grew at 6.2 percent during 1980-90. This fact makes agricultural production of critical importance in view of the rapidly growing urban population. To feed this population requires expansion of the level of crop production to meet the basic needs. Furthermore the government wishes to develop domestic production and food processing to replace imports and to expand the role of agriculture in export earnings.

1.2 Importance of Oilseeds

There are four major sources of edible vegetables oil; cotton, groundnuts, soybeans and sunflower. These crops are mainly grown in the Central, Eastern, Lusaka and Southern provinces of Zambia.

Although groundnuts have oil content of about 38 percent, they are only for direct consumption and confectionary purposes, with very little surplus for oil processing. Cotton seed supplies only about 6 percent of national edible oil needs. Soybeans, the second most important oil source, provides only 17 percent of edible oil requirements. Sunflower supplies 15 percent of edible oil requirements. Table 1.1 shows the value of sales for major oilseeds grown in Zambia.

Table 1.1 Value of sales of oilseed crops in Zambia (current prices in million Kwacha*)

YEAR	SOYBEANS	SEED COTTON	SUNFLOWER
1982/83	2.8	1.8	2.6
1983/84	4.1	1.9	1.5
1984/85	18.7	1.1	0.6
1985/86	26.7	1.8	1.9
1986/87	41.7	1.6	5.0

Source:Ministry of Agriculture:Statistics Section, Zambia, 1988.
* Kwacha is the Zambian currency.

In addition to providing edible oil, these crops are important for their by-products, such as feed cake. Currently, only one third of the total edible oil requirement is produced domestically. To meet Zambia's edible oil requirement, at least 100 thousand tonnes of soybeans have to be produced annually (Ministry of Agriculture, Zambia 1989).

During recent years, dramatic changes have occurred in the dietary patterns in developing countries. These include an increasing role for soybeans as an important source of protein among the urban populations. Mixing soya meal with maize meal has provided a balanced diet for people of lower incomes, thereby reducing malnutrition. Soybeans are also used in rations for poultry, piggery and dairy production.

Soybeans production can generate foreign exchange earnings through exports to neighbouring countries. Earnings from tobacco, which used to be the most important foreign exchange earning agricultural commodity for Zambia, have declined due to contracting tobacco markets.

Zambia has had reasonable export market for day old chicks in neighbouring countries, but these have declined recently due to shortage of stock feed (Doris 1986). The Agriculture Investment Plan 1986 emphasised the need to increase the quantity of domestically produced stock feed. Increased soybeans production is expected to enhance the development of the livestock sector. The objective of the "Fourth National Development Plan" as regards oilseeds is to increase soybeans production in Zambia in order to meet the local raw material requirements for edible oils and stock feeds.

The strategies to achieve this objective are;

i) offering remunerative producer prices,

ii) increased extension advice to farmers,

iii) early delivery of inputs to local depots, and

iv) establishment of an oilseeds marketing system.

Inadequate information on production and marketing were identified by the Fourth National Development Plan as the major constraints in the oilseeds industry in Zambia.

1.3 Soybeans Production

The history of soybeans production in Zambia goes back to the 1930's when its plots were first introduced. The production of this crop was limited to commercial farmers, however, until the early 1980's.[1] Commercial farmers grew soybeans mainly as a protein source for livestock feed. However, there has been a steady increase in soybeans production in Zambia. Soybeans are mainly grown in the Central, Lusaka and Southern provinces of Zambia. The development of natural nodulating varieties led to the introduction of soybeans production among small holders.

In 1983/84, the Lint Company of Zambia (LINTCO) was directed by the government to promote this crop among small-scale farmers. The Lint Company of Zambia is responsible for providing credit, extension and distribution of inputs to an ever increasing hectares and number of smaller growers of soybeans. Table 1.2 shows the number of smaller!soybeans growers in the major soybeans growing areas.

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[1] The category of farmers is based on the type of technology used and the size of farm in terms of hectares. Traditional farms cultivate an average of 2 hectares, depend mainly on family labour and hand tools, and occasionally use oxen.Small scale farms (>2≤10 hectares) are moving away from subsistence cropping to producing cash crops. Mainly family labour and oxen are used but occasionally tractor services are hired.For medium scale farms, (>10≤40 hectares) cash crops are important. These farms mainly use hired services of tractors, labour and combines. Commercial scale farms (>40 hectares) involve capital intensive farming, often producing cash crops and livestock products. These are highly mechanized operations supplemented with hired labour. Some services, such as combines, are hired.

Table 1.2 Number of traditional and small scale soybeans growers in major areas.

YEAR	#	PROVINCE EASTERN	CENTRAL	SOUTHERN	LUSAKA	TOTAL
1983/84	GROWERS	838	716	733	1	2,288
	HECTARES	241	301	588	3	1,133
1984/85	GROWERS	1,597	988	1,074	123	3,782
	HECTARES	505	643	1,019	115	2,282
1985/86	GROWERS	3,525	1,757	1,056	325	6,663
	HECTARES	1,247	1,043	966	415	3,671
1986/87	GROWERS	5,305	3,267	697	256	9,525
	HECTARES	1,685	3,834	540	248	6,307

Source: Soybeans Development Division, Lint Company of Zambia Annual Report 1986/87.

Soybeans are also produced by large-scale farmers who grow soybeans in rotation with irrigated wheat. Rotation of soybeans with cereal crops like maize, wheat and sorghum increases yield of the cereal crop by 25 percent. In 1989/90 season, 80 percent of the total production of soybeans came from commercial farms and 20 percent from small-scale farmers (Ministry of Agriculture, Zambia 1989). Between 1980 and 1984 soybeans recorded an annual rate of growth of 45 percent. Increased soybeans production may be replacing some of the traditional oilseeds like cotton and sunflowers (see Table 1.3).

Table 1.3 Soybeans and Sunflower Production

YEAR	SOYBEANS		SUNFLOWER	
	HECTARES	PRODUCTION ('000 KGS)	HECTARES	PRODUCTION ('000 KGS)
1984/85	9,836	138,346	62,708	848,474
1985/86	13,854	176,732	57,200	611,533
1986/87	16,857	149,583	31,600	340,018
1987/88	20,273	235,829	44,555	315,456
1988/89	21,330	228,645	44,958	300,663
1989/90	29,814	297,677	44,289	399,313

Source:Ministry of Agriculture, Statistics Section 1990.

1.4 Problem Statement

Expansion of crop production to meet the growing demands of feeding the population, replacing imports, and expanding the role of agriculture in export earnings will require appropriate price incentives to producers. This calls for resources to be concentrated on policies and programs that can enhance the attainment of production targets. As agricultural production increases in response to government programs and incentives, more information is needed on producer behaviour, use as well as the allocation of resources in the production of agricultural commodities. One area where such information is required is the oilseeds industry.

Increase in production or total output of soybeans may be misleading because it ignores productive efficiency of this industry. Information on productive efficiency can provide an indication of how farm structures affect resource use and thereby of the likelihood of being able to achieve growth. The important question of policy is how efficient soybean production ranks in terms of productive efficiency. The efficiency of farms in producing a crop may be an illusion if national policies have consistently favoured a crop in such a way that their apparent relative efficiency is due to market imperfections in which specific public policies have played a crucial role.

Despite the increase in number of growers and area under soybeans production, no study has been carried out to measure farm efficiency in soybeans production. If economic planning is to concern itself with particular farm size categories, the research results should be able to provide information as to how much a given farm size group can be expected to produce its output efficiently, without absorbing further resources.

1.5 Objectives

The broad objective of this study is to analyse the efficiency in soybeans production. The specific objectives are to;

i) measure the overall productive efficiency of farms with respect to soybeans production;

ii) compare the productive efficiency of farms with respect to soybeans production; and

iii) determine the impact of farm size on efficiency in soybeans production.

CHAPTER 2.0 REVIEW OF LITERATURE

In this chapter, a review of literature related to measuring productive efficiency is presented in four sections. The introductory section discusses the importance of productive efficiency. This is followed by a section which defines the concepts of productive efficiency. This is important to understanding the subsequent analysis of productive efficiency. In the third section, several related studies on productive efficiency are explored. This section provides a critical review of various methodologies and approaches employed in measuring productive efficiency. The fourth section is a discussion of the specific approach used in this study.

2.1 Importance of Productive Efficiency

The measuring of productive efficiency of an industry is important to both the economic theorist and the economic policy maker. If the theoretical arguments as to relative efficiency of different economic systems are to be subjected to empirical testing, it is essential to be able to make some actual measurements of efficiency.

Productive efficiency (or productivity) is the relationship between output and the resource inputs used in production. Productivity is important in several ways. One way in which output per capita can be raised is by the growth of productivity. Other benefits that can be realized through increased productivity are; conservation of scarce resources per unit of output produced; and increase in international competitiveness of domestic production. It is worth mentioning that productivity advance is one of the chief variables contributing to rising real incomes per capita in economically advanced countries.

Productive efficiency changes can contribute to the changing industrial structure of the economy resulting in reallocation of resources and/or displacement of resources from specific occupations, firms industries or regions. Since productive efficiency has policy implications, it is important to understand it so that appropriate policies are adopted and made effective with less undesirable effects. For this study if we can measure productive efficiency of farms, we can then determine by how much farms are expected to produce output through appropriate reorganization without absorbing additional resources.

2.2 Productive Efficiency Concepts

As defined in the first section, productive efficiency is the relationship between output and the resource inputs used in production. Productive efficiency is made up of two components; technical and allocative efficiency. In 1957, Farrell introduced a technique with which the efficiency of a production activity could be decomposed into technical and allocative efficiency components.

Technical efficiency means maximization of output for a given input combination. Technical efficiency is achieved if production occurs on the boundary of the producer's production possibilities set. Any production that occurs in the interior of the production possibilities set is technical inefficiency. Allocative efficiency occurs when appropriate (minimum cost) input combination is used. The appropriate input combination is that for which the marginal product per dollar spent on each input is equal for all inputs used. Technical efficiency is said to be allocatively efficient if production occurs in a subset of the uncongested boundary of the production possibilities set that satisfies the objectives of the producer.

Technical efficiency and allocative efficiency when computed into a single measure imply overall productive efficiency. Differences in productive efficiency among firms may result from variations in either technical efficiency or allocative efficiency or both. The notion of an efficient unit isoquant provided a standard based on the best results in practice from which to gauge the efficiency of any sample observation. Farrell (1957) associated deviations from the frontier isoquant with technical inefficiency and deviations from the cost minimizing input ratios with allocative inefficiency.

Productive efficiency is a relative term defined in relation to a given set of firms and factors measured in a specific way and any change in these specifications will affect the measure. In measuring productive efficiency, the assumption is that all the ex ante production decisions have been made and all we see is ex post technology.

There are two approaches to measurement of productivity differences, one treats productivity differences as differences in maximum output conditional on a given level of inputs. This is output-based productivity measurement. The other approach treats productivity differences as differences in minimum inputs required, conditional on a given level of output; this is input-based productivity measurement.

2.3 Related Studies

Several studies have been done to measure productive efficiency. The earliest approach to productivity measurement was based upon ratios of a measure of aggregate output divided by the observed quantity of a single input, typically labour. These productivity ratios were normalized to some base year resulting in the calculated productivity ratio being used to measure aggregate productivity for the entire economy. This measure, based upon the use of a single input has the computational advantage given the availability of aggregate labour data. The disadvantage is that it is difficult to identify the causal factors accounting for observed productivity growth. In measuring productive efficiency, the approach employed clearly must refer to inputs that are both sufficient and necessary to produce the observed outputs. Therefore, the review of literature will concentrate on firm-level studies that utilized the inputs that were both necessary and sufficient to produce a given output.

The analysis of firm specific technical efficiency has received much attention in recent years with examples of studies by: Dawson 1985; Fare et al, 1985; Jondrow et al, 1982; Russell and Young, 1983; and Fare and Lovell (1978). Typically, the individual efficiency measures are obtained by comparing individual observations with reference to a particular level of output obtainable with a given level of inputs.

A variety of methods of measuring efficiency involve the construction of a best practice frontier and the measurement of efficiency is relative to the frontier. These methods are divided in three approaches. The first approach uses linear programming techniques to construct a non-parametric frontier. Technical efficiency of an observation is then measured relative to this frontier (Farrell, 1957). This approach has been extended to allow non-constant returns to scale and input congestion. This approach imposes no restriction on the functional form on the data.

An example of this approach is the study by Byrnes et al (1987) which measured technical efficiency of a sample of Illinois grain farms using the Farrell-type measures of technical efficiency. In their study, mathematical programming methods were used to construct the reference technology from observed inputs and outputs in the sample, thus a multiple output, multiple input technology relative to which the performance of individual farms was assessed. However, this method is susceptible to distortion introduced by outliers in the sample, random shocks or measurement errors.

The second approach uses linear programming techniques to construct a parametric frontier (Aigner and Chu, 1968; and Fϕrsund and Hjalmarsson, 1979). The second approach differs from the first approach in that the functional form is specified. Since no assumptions are made about the properties of the disturbance term, the parameters of the fixed frontier in these studies are not estimated in any statistical sense but merely computed through linear programming methods. Furthermore, when linear programming method is used, extreme observations can exert a large influence and only a small number of observations can determine the frontier. Technical efficiency values calculated with deterministic procedures will exhibit variability when derived from data obtained through repeated sampling (over time) even if there is no variability in true technical efficiency.

It has been found that deterministic procedures when estimating farm specific technical efficiency tend to overestimate the average level of technical efficiency though the extent of this bias is unknown. An improvement to deterministic procedures is a stochastic frontier model which enables the separation of random errors from deviations arising from technical inefficiency.

Thus the third approach involves the construction of a stochastic frontier. Aigner, Lovell and Schmidt, 1977; and Meeusen and van den Broeck, 1977; Schmidt and Lovell, 1980; and Huang, 1984; specified and estimated a stochastic production frontier which overcomes above problems. This approach allows one to distinguish between inefficiency and the effects of random shocks and data outliers, and measurement errors. It also assumes a specific distribution for the error term.

Bagi and Huang (1983) estimated production technical efficiency for individual farms in Tennessee. They criticized studies of empirical work based on economic engineering or synthetic firm analysis rather than actual farm level data analyses. Using the stochastic frontier approach, they estimated technical efficiency for individual observations in order to get a full picture of the variations in the level of technical efficiency across observations. They used the translog frontier production function in order to allow interaction between inputs. The farm level data used in their study was obtained from a stratified random sample. However, necessary input data to estimate separate production frontiers for crop and livestock enterprises was not recorded separately for each crop or livestock enterprise which resulted in two different enterprises being represented by a single production frontier.

Other stochastic frontier studies which used farm level data had limitations in that they estimated population technical efficiency. Both Huang (1979) and Kalirajan (1981) estimated a stochastic production frontier model using farm level data but failed to estimate the efficiency for individual farms in the sample. This is a major limitation in their models because the measure of average productive efficiency fails to remove the extent of variation in the level of technical efficiency across individual observations.

However, all models suffer from problems arising from omitted variables in the specification of the production function and measurement errors. Errors are always present in the statistical studies of technical efficiency. The measurement errors are magnified when individual rather than the average efficiency measures are derived from the residuals of estimated function. Specifying technical efficiency through the disturbance term or dummies also result in specification error of the disturbance term and hence inefficient estimates.

Therefore, the criteria for selecting a specific frontier methodology remain unclear. According to Broeck et al (1980), the choice between not specifying any efficiency distribution and then computing the frontier by programming techniques, and specifying a certain distribution and then applying maximum likelihood does not seem so clear cut. In addition, Aigner et al (1977) have concluded that it is not clear yet whether one approach dominates the other. However, the linear programming approach tends to be advantageous to estimate the frontier function because it is unique and straightforward measure of individual firm level efficiency.

The other general problem with most of the above studies is that productive efficiency was measured purely based on technical efficiency, thus avoiding data on prices. For a profit or cost minimizing firm, the observed output supply and input use will coincide with the profit maximizing or cost minimizing output and input demand if and only if the farm is technically, allocatively and scale efficient (Fϕrsund et al. (1980)). Kumbhakar et al (1989) observed that one cannot infer anything about total or economic efficiency simply by estimating technical efficiency as in Aigner et al. (1977), Bagi and Huang (1983), Huang and Bagi (1984).

Furthermore, utilizing a production function to measure productivity requires exact knowledge of the structure of the production technology. It also requires specific knowledge about the values of the parameters of the production function. Since it is difficult to have such information in practice, by using duality theory, measurement of productivity need not be specified in terms of the production function. In duality relationship, all economically relevant information can be recaptured from indirect objective functions such as cost or profit functions. The following are relevant examples of the studies that used the duality approach to measuring efficiency of firms.

Pescatrice and Trapani (1980) compared the productive efficiency of public and private utilities to determine if a significant cost differential results from differential objectives under the alternative modes of ownership. The procedure involved estimating simultaneously the cost function and input demand function of the public and private firms while accounting for differences in the cost of production. The results suggested that public firms minimize cost and had lower per cost unit than privately owned firms.

Garcia et al (1982) analyzed Illinois grain farms to determine whether differences in economic efficiency can be discerned for two important structural dimension of a sample. These dimensions are size of operation and the percentage of land input owned by farmer operators. Using the Seemingly Unrelated Regression method which accounts for the correlation in the error between the profit function and input function, they found that for cash grain farmers in Illinois, larger operators are not more economically efficient than moderate sized farms.

Lau and Yotopoulos (1971,1973) measured and compared performance of farm firms. They tested relative efficiency of small and large farms using a Cobb-Douglas profit function. In formulation of the test of equal relative economic efficiency, they used McFadden's profit function which expresses the firms' maximized profit as a function of prices of output and variable inputs of production. The results of this test was in favour of the small farms. Given the fixed factors of production (land and capital) and within the ranges of the observed prices of output and variable inputs, small farms had higher actual profits which implies they operate at a higher level of technical efficiency and attain higher levels of price efficiency. The use of Cobb-Douglas function is restrictive in that it does not allow for the interaction of inputs.

Sidhu (1979) measuring relative efficiency in wheat production of new to old varieties in the Indian Punjab found that there were no differences in the economic efficiency of small and large wheat farms. Labour, fertilizer, irrigation water, land, capital and number of years in school were the inputs used in this study. He used the profit function formulation used by Lau and Yotopoulos (1971, 1973). In this study, categorization of farms into small and large farms was arbitrary. In addition, the objective of large farms might be profit!but profit maximization assumptions on smaller farms might be questionable and too strong.

2.4 Approach of this study

To reiterate, the linear programming methods of measuring productivity involves no approximation errors and do not require restrictive assumptions about the functional form of the production technology. However, the major problem with the linear programming method is that the results are very sensitive to outliers which may arise from data errors for some observation. Thus when linear programming methods are used to measure efficiency, extreme observations can exert a large influence and only a small number of observation can determine the frontier. For example, in Dawson (1985), a mere six farmers out of fifty six determined the!linear programming frontier. In addition to the above problems, linear programming methods are a computational burden because individual farm efficiency value is calculated by running a linear programming problem for each farm; this, in our case means running 55 linear programming problems.

Productivity comparison based on econometric estimates of the structure of production have often been viewed as being more desirable than the index number comparisons. This view is based on the belief that index numbers are consistent only with restricted structures of production (Caves et al 1982). For example, it is necessary to assume either that all inputs are variable or there is constant returns to scale in production in order to implement the index number approach; but these assumptions are not necessary in an econometric approach. On the other hand, econometric model results are sensitive to many mispecifications. Therefore, it has been suggested that index number calculations should precede econometric studies of efficiency (Christensen (1975)).

Theoretical development has occurred in the area of index number theory. It is related to the basic problem of aggregation of input and outputs in productivity analysis. The work of Diewert (1976, 1978) and others in the area of exact or superlative index numbers has shown that there is a unique relationship between the index used to aggregate over outputs and inputs and the structure of the underlying technology. The importance of this work is that the linkage of production and profit or cost function to a suitable index number are dual to each other.

The following are some of the examples of studies that utilized the index number formulas to calculating productive efficiency. Caves and Christensen (1974) examined the relative efficiency of public and private firms in a competitive environment. Isolating the effects of property rights from effects of regulation on non-competitive markets, they measured relative efficiency or the comparative economic efficiency based on measures of total factor productivity. They found that there was no evidence of inferior performance by the government owned rail-road and concluded that any tendency toward inefficiency resulting from public ownership had been overcome by competition.

Caves, Christensen and Tretheway (1981) estimated the growth and relative levels of total factor productivity for the 11 U.S. trunk airlines over the period 1972-1977. Using an index-number approach and disaggregated measures of both passenger and freight service and five categories of inputs, they found results consistent with those of several other studies of airline efficiency.

Under the index number calculations of measuring productivity, two approaches are taken. One approach (non parametric) to measuring productivity is defined in terms of continuous time. This results in errors in approximation when discrete data is used on the index number defined in continuous time. In addition, these continuous time index number formulas assume that all inputs are freely variable and are at static long run equilibrium levels.

The other approach (parametric) does not require approximation of continuous time derivations. Writers from Solow (1957) to Diewert (1980) identified that the notion of productivity change is unambiguous for infinitesimal shifts in continuous time because actual productivity comparisons must be based on discrete data points. Since collected data are discrete, this study will use the parametric index number calculations which will be derived consistent with the discrete data.

Recently, Denny, Fuss and May (1981), and Caves, Christensen and Diewert (1982) have extended the index number formulas using the Tornqvist index to integrate the cross section and inter-temporal comparisons of productivity. In our study, we will adopt the approach developed by Denny and Fuss (1981, 1983) for comparing productivity levels across regions at a point in time. This theoretical framework has been applied on two interspatial comparisons which use the Tornqvist index. In the Denny and Fuss (1983) study on regional levels of cost efficiency for Canadian manufacturing, it was shown that the biases in the comparisons of the efficiency results from the use of Tornqvist index (Denny and Fuss (1980)) are negligible.

Based on the data collected in this study and the limitation of the other approaches, the index number approach as used in interspatial productivity comparisons becomes the natural choice for calculating productive efficiency. This approach can deal with large number of inputs and outputs. Since we only collected data for the 1990/91 cropping season on soybeans production, the interspatial approach of measuring productivity will be adopted because it does not require long time series or large data observations. The variable cost function will be used to calculate productive efficiency in soybeans production in Zambia. Since soybeans is grown by all farm size categories (traditional, small, medium or commercial farms), profit maximization objectives might be too strong under different objectives and marketing arrangements.

CHAPTER 3.0 THEORETICAL MODEL DEVELOPMENT

In this chapter, the standard theory of the firm will be explored in order to link the standard theory of the firm to efficiency discussion. This is followed with the discussion on the validity of efficiency assumption. The theoretical framework will be developed following the relaxation of the efficiency assumption in the theory of the firm.

3.1 Theory of the Firm

Economic profit is defined to be the difference between the revenue a firm receives and the costs it incurs. Both revenue and costs of a firm depend on the actions taken by the firm. These actions may be; actual production activities, purchase of factors of production and purchase of advertising. If a firm engages in a large variety of actions, each action at some appropriate level, then revenue can be written as a function of the level of operation of some n actions; $R(x_1,...,x_n)$, and costs as a function of these same n activity levels; $C(x_1,...,x_n)$.

The basic assumption of most economic analysis is that the firm acts so as to maximize profits in which the firm chooses activities $(x_1,...x_n)$ so as to maximize $R(x_1,..,x_n)$ - $C(x_1,..,x_n)$. The problem facing the firm can be written as:

$Max\ R(x_1,..,x_n)-C(x_1,..,x_n)$, differentiating this with respect to x, shows that an optimal set of activities; $x^* = (x_1^*,...,x_n^*)$ is characterized by the conditions;

$$\frac{\partial R(x^*)}{x_i}=\frac{\partial C(x^*)}{\partial x_i} \qquad i=1,...,n$$

Intuitively, these conditions mean that if marginal revenue were greater than marginal costs, it would pay to increase the level of activity. If marginal revenue were less than marginal costs, it would pay to decrease the level of activity.

The fundamental condition characterizing profit maximization has several interpretations. For example, one decision the firm makes is to choose the level of output. The level of output should be chosen so that the production of one more unit of output should produce a marginal revenue exactly equal to its marginal cost of production. Another decision is to determine how much of each factor of production to employ. The fundamental condition of profit maximization requires the firm to hire an amount of factor x such that marginal revenue from employing one more unit of x should be equal to the marginal cost of hiring that additional unit of x.

The revenue and cost function can be broken into more basic parts. Revenue is composed of quantities a firm sells of various outputs times the price of each output. Costs are composed of how much a firm uses of each input times the price of each input. A necessary condition for static profit maximization is static cost minimization i.e. at the profit maximizing level of output y and input prices w, the firm necessarily solves a cost minimization problem.

The firm's profit maximization problem reduces to the problem of determining what prices it wishes to charge for its output or pay for its inputs and what levels of output and input it wishes to use. In determining its optimal production, the firm faces two kinds of constraints; technological and market constraints. Technological constraint are simply those constraints that concern the feasibility of the production plan. Market constraints are those that concern the effect of actions of other agents on the firm. Each firm will be assumed to take prices as given, which are exogenous to the profit maximization. Thus the firm will be concerned only with determining the profit maximizing levels of output and inputs, hence, the firm has to choose the production plan given a configuration of market prices. A firm will produce outputs from various combinations of inputs.

3.2 Validity of the Efficiency Assumption

In view of the standard theory of the firm in which the level of output should be chosen where the marginal cost equals marginal revenue, Hicks (1946), Samuelson (1947), and Calson (1939) ignored and dismissed the possibility that producers might operate inefficiently. It is assumed that a producer successfully allocates all resources efficiently relative to the constraint imposed by the structure of; production technology; input and output markets; and relative to the behavioral goals of either profit maximization or cost minimization. Technology constraint on the producer's behavioral optimization problem is binding, thereby eliminating productive inefficiency. Satisfaction of the first order condition necessary for optimization eliminates behavioral inefficiency. Monotonicity and curvature assumptions on production technology sufficient to guarantee satisfaction of the second order conditions eliminates structural inefficiency. From assumptions on the structure of technology, markets, behavioral assumptions and on full efficiency, neoclassical economics derive testable hypothesis about producer behaviour (i.e. behaviour of efficient producers only).

Since modifying assumptions on the structure of technology as well as markets, and on behavioral motivation influences the richness of the resulting testable hypothesis, it is expected that relaxing the full efficiency assumption also reduce the richness of testable hypothesis of achieving profit maximization or cost minimization. Allowing relaxation of full efficiency assumption also opens the possibility of inefficient firms. In the theoretical framework section we will develop the measurement of the deviations from full efficiency assumption.

3.3 Theoretical Framework

This section of the study outlines the theoretical framework of measuring the productive efficiency as well as the conceptual basis of the relationship between productive efficiency and the technology. A key development in the economic theory of index numbers has been the demonstration that numerous index number formulas can be explicitly derived from particular aggregator functions. This development provides a powerful new basis for selecting an index number procedure. Rather than starting the selection process with a number of plausible index number formula, one can specify an aggregator function with desirable properties and derive the corresponding index number procedure. The resulting index is termed exact for that particular aggregator function.

Diewert(1976) makes a strong case for limiting the consideration of aggregator functions to those which are flexible, that is those which can provide a second order approximation to an arbitrary function. Diewert demonstrated that a class of index number comparison which he called the superlative can exactly represent various second order approximation to an arbitrary production or cost function.

Inter-temporal and inter-spatial comparison of productivity have utilized Diewert's results concerning superlative aggregate indexes using a quadratic lemma of the form

$$Y_i - Y_0 = F(\underline{Z}_i) - F(\underline{Z}_0) = \sum_n \frac{1}{2}\left[\frac{\partial F^i}{\partial Z_n} + \frac{\partial F^0}{\partial Z_n}\right][Z_{ni} - Z_{n0}] \tag{3.1}$$

Where $F(\underline{Z})$ is the underlying aggregator function, Z is a vector of components to be aggregated, and $\partial F/\partial Z_n$ is the partial derivative with respect to the continuous variable Z_n, evaluated at data point "i" or "0".

Inter-spatial and inter-temporal comparison require that a subset of the Z_n in (3.1) ce specified as discrete variables (usually binary dummy variables), which are not continuous. This specification is necessary in order that the underlying quadratic approximating aggregator function be permitted to have some different parameters at the two points of comparisons. Denny, et al (1981) noted that specifying the discrete variables to be binary variables implies that the function differs across comparisons in constant and linear terms but not in the quadratic terms. The quadratic lemma as used by Diewert can be generalized to the case of discrete variables. Denny, et al (1981) demonstrated that the quadratic lemma can still be applied without alteration, when a subset of the $\underline{Z}$ is a vector of non continuous variables by ignoring the discreteness of the variables. This provides the justification for applied inter-temporal and interspatial studies.

Consider the following aggregator function

$$y = F(\underline{X}, \underline{D}) \tag{3.2}$$

where $\underline{X}$ is a vector of continuous variables X_n, and $\underline{D}$ is a vector of binary variables D_i. D_i=0 for the reference data point 0, i≠0; and 1 otherwise.

A quadratic approximation to (3.2) takes the form

$$\begin{aligned} y_i = {} & \alpha_0 + \Sigma_{i\neq 0}\alpha_i D_i + \Sigma_n \Sigma_i (\alpha_{n0} + \alpha_{ni} D_i) X_{ni} \\ & + \frac{1}{2}\Sigma_n \beta_{nn} X_{ni}^2 + \Sigma_{n\neq l} \Sigma \beta_{nl} X_{nl} X_{li} \end{aligned} \tag{3.3}$$

where α and β are parameters of the approximation.

The reference or base point in the comparison can be represented by the following function

$$y_0 = \alpha_0 + \Sigma_n \alpha_{n0} X_{n0} + \frac{1}{2}\Sigma_n \beta_{nn} X_{n0}^2 + \Sigma\Sigma_{n\neq l} \beta_{nl} X_{n0} X_{l0} \tag{3.4}$$

The difference between any aggregate y_i and the reference point aggregate y_0 can be expressed as

$$y_i - y_0 = \Delta y = \alpha_i D_i + \Sigma_n (\alpha_{n0} + \alpha_{ni} D_i) X_{ni} - \Sigma_n \alpha_{n0} X_{n0} + \Delta g(\underline{X}) \tag{3.5}$$

where g is a quadratic function in $\underline{X}$(without constant or linear terms).

Since g is quadratic in continuous variables only, the quadratic lemma can be applied to yield

$$\Delta g = \tfrac{1}{2}\Sigma_n \left[\frac{\partial g^i}{\partial X_n} + \frac{\partial g^0}{\partial X_n}\right] [X_{ni} - X_{n0}] \tag{3.6}$$

The constant and linear terms of equation (3.5) can be written in the form

$$\frac{1}{2}[(\alpha_i+\Sigma_n\alpha_{ni}X_{ni})+(\alpha_i+\Sigma_n\alpha_{ni}X_{n0})][D_i] \\ +\frac{1}{2}\Sigma_i[2\alpha_{n0}+\alpha_{ni}D_i][X_{ni}-X_{n0}] \tag{3.7}$$

The non-continuous variables can be defined as

$$\frac{\partial F^0}{\partial D_i}=\alpha_i+\Sigma\alpha_{ni}X_{n0} \tag{3.8}$$

and

$$\frac{\partial F^i}{\partial D_i}=\alpha_i+\Sigma\alpha_{ni}X_{ni} \tag{3.9}$$

where the only difference between equation (3.8) and (3.9) is the point at which X_n is evaluated. Definitions (3.8) and (3.9) are required since D_i is a discontinuous variable and thus cannot be used to form a partial derivative. However, it is important to note that if we had ignored D_i being discontinuous and had differentiated F with respect to Di, we would have obtained (3.8) and (3.9).

Utilizing the results of the quadratic lemma in (3.6), we can combine (3.6) with (3.7), (3.8) and (3.9) and also noting that

$$\frac{\partial F^0}{\partial X_n}=\alpha_{n0}+\frac{\partial g^0}{\partial X_n} \quad \text{and} \quad \frac{\partial F^1}{\partial X_n}=\alpha_{n0}+\alpha_{ni}D_i+\frac{\partial g^i}{\partial X_n}\,.$$

The difference between any aggregate y_i and base point aggregate y_0 in (3.5) can be written in the form

$$y_i - y_0 = \frac{1}{2}\left[\frac{\partial F^i}{\partial D_i} + \frac{\partial F^0}{\partial D_i}\right][D_i - D_0] + \frac{1}{2}\Sigma_n\left[\frac{\partial F^i}{\partial X_n} + \frac{\partial F^0}{\partial X_n}\right][X_{ni} - X_{n0}] \tag{3.10}$$

where D_i=0(and D_i=1).

If we ignore the fact that D is not a vector of continuous variables, we would have obtained equation (3.10) by applying the quadratic lemma to (3.2). Thus the use of the quadratic lemma in the presence of discrete variables is justified.

The analysis of the preceding section can be applied to measuring productivity in a direct way in which two of the X_n (continuous) variables in (3.1) are the technological change indicator (e.g time) and an efficiency difference indicator [say the (0,1) dummy variable D_n], so that the (3.1) can either be interpreted as a production or cost function.

Denny and Fuss (1980) developed as framework for comparing productivity levels across regions at a particular point in time. Suppose the production process in region i at time t can be represented indirectly by a translog variable cost function,

$$C_{it} = G_{it}(W_{it}, K_{it}, Y_{it}, T_{it}, D) \tag{3.11}$$

where

C_{it} is the variable cost of production in region i at time t,

W_{it} is a vector of input prices in region i at time t,

K_{it} is fixed capital input in region i at time t,

Y_{it} is the output level in region i at time t, and

T_{it} is an index of technology in region i at time t.

The logarithm of the variable cost function G_{it} will be approximated by a quadratic function in the logarithms of W_{it}, K_{it}, Y_{it}, T_{it} and D. D is a vector (D_i) of dummy variables, where D_i=1 for every region other than a reference point and D_i=0 for the reference region. We may write the approximation as

$$\ln C_{it}=G(\ln W_{it},\ln K_{it},\ln Y_{it},T_{it},D) \qquad (3.12)$$

where G is a quadratic function.

The variable cost function is adopted because we believe the assumption of static long run equilibrium is unrealistic. Given the levels of fixed input, firms are always making short run decisions to produce output by minimizing cost. In addition, variable cost minimization is more realistic than profit maximization because the profit maximizing level of output may turn out different due to weather, output price risk etc.

Any method of measuring productivity (both cross sectional and inter-temporal comparison) without econometric estimation of the production technology implies the underlying technology has common elements. By replacing the function G_{it} in (3.11) with G in (3.12), the assumption is that the approximation of the variable cost function in each region (farm) has common elements. Differences in the regional (or farm) variable cost functions are maintained by the additional argument D in the variable cost function, which has the effect of permitting constant and linear terms in the quadratic approximation to differ across regions.

Suppose we wanted to know the differences in the cost of producing output in farm i at time s, and in farm 0 at time t. Since the logarithmic variable cost function is quadratic, we can apply Diewert's (1976) quadratic lemma to obtain the following equation

$$\begin{aligned}\Delta \ln C &= \ln C_{is} - \ln C_{0t} \\ &= \frac{1}{2}\left[\frac{\partial G^{i}}{\partial D_i} + \frac{\partial G^{0}}{\partial D_i}\right][D_i - D_0] \\ &+ \frac{1}{2}\Sigma_n\left[\frac{\partial G^{is}}{\partial \ln W_n} + \frac{\partial G^{0t}}{\partial \ln W_n}\right][\ln W_{nis} - \ln W_{not}] \\ &+ \frac{1}{2}\left[\frac{\partial G^{is}}{\partial \ln K} + \frac{\partial G^{ot}}{\partial \ln K}\right][\ln K_{is} - \ln K_{ot}] \\ &+ \frac{1}{2}\left[\frac{\partial G^{is}}{\partial \ln Y} + \frac{\partial G^{ot}}{\partial \ln Y}\right][\ln Y_{is} - \ln Y_{ot}] \\ &+ \frac{1}{2}\left[\frac{\partial G^{is}}{\partial T} + \frac{\partial G^{ot}}{\partial T}\right][T_{is} - T_{ot}]\end{aligned} \qquad 3.13$$

The cost differential across regions and time periods may be defined in terms of regional (or farm) effect, input price effect, an output effect and inter-temporal effect. The regional effect can be is

$$\theta_{i0} = \frac{1}{2}\left[\frac{\partial G^{i}}{\partial D_i} + \frac{\partial G^{0}}{\partial D_i}\right] \qquad (3.14)$$

and the inter-temporal effect is

$$\lambda_{i0} = \frac{1}{2}\left[\frac{\partial G^{is}}{\partial T} + \frac{\partial G^{1t}}{\partial T}\right] . [T_{is} - T_{0t}] \qquad (3.15)$$

Under constant returns to scale and with only one output, marginal cost equals average cost. This implies $\partial G/\partial \ln Y = \partial \ln C/\partial \ln Y = (\partial C/\partial Y).(Y/C)=1$, in turn $\partial G/\partial \ln Y = 1$. Perfect competition in factor markets and using Shephard's lemma results in the following, $\partial G/\partial \ln W_n = \partial \ln C/\partial \ln W_n = (\partial C/\partial W_n)(W_n/C) = X^n W_n/C = S^n$, the nth variable input's cost share.

We also know that $\partial \ln G/\partial \ln K = \partial \ln C/\partial \ln K = (\partial C/\partial K).(K/C)$ is the shadow price of capital input, which cannot be measured without recourse to econometric estimation of the factor demand equations. We can calculate the shadow price of capital input K without econometric estimation if we assume a single quasi-fixed capital input K and constant returns to scale, and also using Euler's theorem and assuming that the cost function is linear homogenous in Y and K.

If C(w,y,k) is linear homogenous in Y and K, then Euler's theorem implies

$$1.C(w,y,k) = (\partial C(w,y,k)/\partial Y)Y + (\partial C(w,y,k)/\partial K)K$$

Under short run profit maximization, marginal cost $(\partial C(w,y,k)/\partial Y)$ is equal to marginal revenue P. This implies

$$1.C(w,y,k) = PY + (\partial C(w,y,k)/\partial K)K$$

From the above expression, we can solve for the shadow price of capital good K as

$$\partial C(w,y,k)/\partial K = [C(w,y,k) - PY]/K$$

If we let the elasticity expression, $\partial \ln C/\partial \ln K$ be S_K and substituting $\partial C(w,y,k)/\partial K$ into the elasticity expression gives the following results,

$S_K = \partial \ln C/\partial \ln K = (\partial C(w,y,k)/\partial K)(K/C(w,y,k))=([C(w,y,k)- PY]/K)(K/C(w,y,k),$

$$S_K = [C(w,y,k) - PY]/C(w,y,k).$$

Equation (3.13) can be rewritten as

$$\begin{aligned}\Delta \ln C &= \ln C_{is} - \ln C_{0t} \\ &= [\ln Y_{is} - \ln Y_{0t}] \\ &+ \frac{1}{2}\Sigma_n [S_{nis} + S_{n0t}][\ln W_{nis} - \ln W_{n0t}] \\ &+ \frac{1}{2}[S_{Kis} + S_{K0t}][\ln K_{is} - \ln K_{0t}] \\ &+ \theta_{i0} + \lambda_{i0}\end{aligned} \tag{3.16}$$

The general expression (3.16) can be specialized to make a comparison of the efficiency levels across regions (or farms) at a point in time (t=s) as

$$\begin{aligned}\theta_{i0} &= [\ln C_i - \ln C_0] \\ &- [Ln Y_i - \ln Y_0] \\ &- \frac{1}{2}\Sigma_n [S_{ni} + S_{n0}][\ln W_{ni} - \ln W_{n0}] \\ &- \frac{1}{2}[S_{Ki} + S_{K0}][\ln K_i - \ln K_0]\end{aligned} \tag{3.17}$$

where

0 is the reference farm and i any other farm in the sample,

θ_{i0} is the logarithmic differential in the total variable cost of producing in farm i compared to farm 0,

C_0 is the total variable cost of producing output Y_0 in farm 0,

C_i is the total variable cost of producing output Y_i in the ith farm,

Y_0 is the output level of soybeans produced in farm 0,

Y_i is the output level of soybeans produced in the ith farm,

$S_{ni} = \frac{W_i^n X_i^n}{C_i}$ is the nth variable input's cost share in the ith farm,

$S_{n0} = \frac{W_0^n X_0^n}{C_0}$ is the nth variable input's cost share in farm 0,

W_{in} is the nth variable input price in the ith farm,

W_0^n is the nth variable input price in farm 0,

X_i^n is the quantity of nth variable input in ith farm,

X_0^n is the quantity of nth variable input in farm 0,

$S_{Ki}=\frac{(C_i-P_iY_i)}{C_i}$ is the cost share of aggregate capital input in farm i,

$S_{K0}=\frac{(C_0-P_0Y_0)}{C_0}$ is the cost share of aggregate capital input in farm 0,

P_i is the output price received at farm i,

P_0 is the output price received at farm 0,

K_i is the single aggregate capital input in the ith farm, and

K_0 is the single aggregate capital input in farm 0.

CHAPTER 4.0 EMPIRICAL MODEL AND DATA

The first part of this chapter presents the procedure that will be used to measure productive efficiency. This will be followed by a discussion of data collected during the 1990/91 cropping season.

In Zambian agriculture, total farm land cultivated and technology used on the farm are used in the classification of farm size. The farms will be ranked from the smallest to the largest farm size (in terms of hectares of soybeans planted). The largest farm was chosen as the reference farm since large farms are assumed to be more specialized, and thus more efficient. However, Caves and Christensen (1980) have proposed a compromise for binary comparisons that result in transitive comparisons thereby retaining a high degree of characteristicity. The transitive comparisons are achieved by using a constructed representative farm as the basis for making all possible binary comparisons in which any two farms are compared with each other by comparing them both with the representative firm. There are problems with transitive multilateral comparisons (Denny Fuss et al (1981)).

Caves et al (1982) have shown that in cross section data there is generally no natural ordering of the reference point. The choice of a reference point depends on the particular empirical investigation and no accepted general rules can be given.[2]

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[2] Caves, Christensten; and Tretheway (1981) used a constructed reference point based on the means of the variables in the interregional sample. On the surface, their procedure has the advantage of not requiring the use of any particular base as the reference point. However, there are a large number of possible mean points, each constructed from a subset of the sample, consequently the arbitrary nature of the reference region cannot be eliminated by the use of a mean reference region.

4.1 Empirical model

In the application to the sample of soybeans producers, 55 farm observations on 8 inputs and a single output were assembled. If we assume a variable cost function and short run competitive behaviour, thus all farms face different input prices, then the relative efficiency of every farm in the sample relative to the largest farm is calculated as

$$\begin{aligned}\theta_{i0} = & [lnC_i - lnC_0] - [lnY_i - \ln Y_0] \\ & -\frac{1}{2}\Sigma_{n=1}^{7}[S_{ni}+S_{n0}]\,[lnW_{ni}-\ln W_{n0}] \\ & -\frac{1}{2}[S_{Ki}+S_{K0}]\,[lnK_i-\ln K_0]\end{aligned} \tag{4.1}$$

where

0 is the reference farm and i is any other farm in the sample,

θ_{i0} is the logarithmic differential in the total variable cost of producing in farm i compared to farm 0 (the largest farm size in hectares of soybeans). If a farm is productive efficient compared to the reference farm, then θ_{i0} will be negative. Thus θ_{i0} for the reference farm will have a value equal to zero. Any value less than zero implies the farm is more productive than the reference farm. Farms less productive efficient relative to the reference farm will have a value of θ_{i0} greater than zero,

C_i is the variable input cost of producing output Y_i in farm i,

C_0 is the variable input cost of producing output Y_0 in farm 0,

Y_i is the output level of soybeans produced in farm i,

Y_0 is the output level of soybeans produced in farm 0,

S_{ni} is the ith farm's share of the variable input cost that can be attributed to the nth variable input,

S_{n0} is the reference farm's share of the variable input cost that can be attributed to the nth variable input,

W_{in} is the nth variable input price in farm i,

W_0^n is the nth variable input price in farm 0,

S_{Ki} is the ith farm's share of the capital input cost in soybeans production,

S_{K0} is the reference farm's share of the capital input cost in soybeans production,

P_i is the output price received at farm i,

P_0 is the output price received at farm 0,

K_i is the aggregate capital input that can be attributed to soybeans production in the ith farm, and

K_0 is the aggregate capital input that can be attributed to soybeans production in farm 0.

Since there are 55 farm observations, the direct use of (4.1) for comparisons of efficiency in soybeans production would result in 54 comparisons with the reference farm (the largest farm).

4.2 Discussion of Data

In this section, we provide a description of the sources and methods used in the construction of the data set. During the period June to August 1991, a total of 100 farmers were surveyed with the purpose of obtaining data on soybeans production. Central, Southern and Lusaka provinces were identified as major soybeans areas. Ideally, it would have been preferable to take a random sample of farms from all the soybeans growing areas of Zambia. However, this was not done because of the financial and transport constraints on the research. The approach taken was to select an area which would be representative of the major soybeans areas. In selecting the block to be sampled, the following factors were considered: farm type; farm size; variation in climate; and distance to the market. The research area was narrowed down to Central province primarily because of transport availability. In terms of number of farms and hectares of soybeans, Central province ranks among the top three major soybeans areas in Zambia (Table 1.2).

A list of farms growing a variety of crops, including soybeans, was made available from Commercial Farmers Bureau, Kabwe Regional Research Station and Lint Company of Zambia. Traditional and small scale farms were selected from a list of 150 village clusters provided by Lint Company of Zambia. Each village cluster was made up of about 20-25 farmers. In the first stage of sample selection process, 25 out of 150 clusters were selected. The 25 village clusters had 332 traditional farmers and 168 small scale farmers. From the Commercial farmers Bureau register, we had 516 medium scale and 287 commercial farms. The total number of farmers (traditional, small scale, medium scale and commercial scale) in the survey area was 1,303. Table 4.1 gives a summary of the break down of the number of farmers according to farm size category. In the second stage of sample size selection process, 100 farmers (25 from each farm size category) were randomly selected within the sample area to represent the population of farms growing soybeans. During personal visits of each of the 100 farmers selected for interviews, it was found out that 15 farmers did not grow soybeans during the 1990/91 cropping season. Information specific to soybeans production, which included input use, costs and output was collected from only 85 farmers. However, out of 85 farmers, a total of 55 usable questionnaires were obtained from the survey. The rest of the farmers could not provide reliable information or the questionnaires were incomplete.

Although the representativeness of the sample cannot be proved, the wide variations in size of farms, farm types, costs and output level would suggest that the sample is fairly representative. As a result of the difficulty in obtaining reliable time series data at farm level, we collected data for the 1990-91 crop year only which was the most recently completed crop year.

Table 4.1 Number of farmers in the selection of sample size

	Farm Size				
Stage	Traditional	Small	Medium	Commercial	Total
One	150 village clusters		516	287	-
Two	25 village clusters		516	287	-
Three	332	168	516	287	1303
Four	25	25	25	25	100
Five	19	20	22	24	85
Six	9	16	11	19	55

4.2.1 Hectares of soybeans

In Zambian agriculture, total farm land cultivated and technology used on the farm are used in the classification of farm size. Assuming hectares of soybeans planted are proportional to farm size, then the total hectares of soybeans planted is used as a proxy measure of farm size. Total hectarage of soybeans is defined as the average of the area planted and the area harvested of soybeans. The average of area planted and area harvested gives a better measure of hectares of soybeans.

4.2.2 Output

Soybeans output is the physical quantity of soybeans (kilograms) harvested from total hectares of soybeans. To construct the price of output, we employ the fact that the product price multiplied by quantity of soybeans produced must equal the value of output or revenue. Thus we constructed the output price as the ratio of total revenue from soybeans to the total soybeans output.

4.2.3 Inputs

Eight inputs were used to measure efficiency in soybeans production. There are seven variable inputs, fertilizer, lime, seed, chemicals, inoculum, labour, and materials, and one capital input. The total variable cost (C) of producing a level of soybeans output is the sum across the total expenditure on fertilizer, lime, seed, chemicals, inoculum, labour, and materials used in soybeans production on each farm in the 1990/91 cropping season.

Since we have different seed varieties, chemical brands, materials, labour categories or employee types, and capital goods, we need to construct a single aggregate input indexes for each of these input categories on each farm. Thus we have to come up with a single aggregate input index of seed, chemical, labour, materials, and capital. The single aggregate input indexes are constructed such that all values are shown relative to the reference farm.[3]

The stating point for the construction of single aggregate input indexes requires that we consider specific functional forms for the functions defining aggregate seed, chemical, labour and capital input. If aggregate seed, chemicals, labour and capital are translog functions of their components, we can express the differences between logarithms

[3] The reference farm will have an aggregate index equal to 0 for any aggregate input index constructed from different categories of that input.

of aggregate inputs for any two farms (any ith farm and the reference farm) in the form[4]

$$LnX_i - LnX_0 = \Sigma_{j=1}^{R} \frac{1}{2}(S_{ji} + S_{j0})\, Ln\left(\frac{X_{ji}}{X_{j0}}\right) \tag{4.2}$$

where

X_i is the aggregate index of input for the ith farm,

X_0 is the aggregate index of input for farm 0,

S_{ji} is the ith farm's share of the cost of aggregate input X that can be attributed to input of category j,

S_{j0} is the reference farm's share of the cost of aggregate input X that can be attributed to input of category j,

X_{ji} is the quantity of input in the jth category for the ith farm, and

X_{j0} is the quantity of input in the jth category for the reference farm 0.

The total variable cost of aggregate input X is the sum of costs across all the input categories of input X.

In principle, any index of aggregate input could be constructed from physical quantities of individual input components with weights based on expenses incurred on the use of each input component out of the total variable cost of producing a given level of output. However, this turns out to be infeasible because some farms employ only a subset

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[4] These expressions for aggregate inputs are also referred to as translog indexes of inputs (Jorgenson and Nishimizu (1978)).

of the categories of inputs and hence equation (4.2) is undefined if there are any zero quantities.[5]

However, the price dual to (4.2) is well defined because there is a positive price for each input even if the quantity is zero. Where the farm did not use a particular input, we quote the government announced price for that input to ensure we have a positive price for each input even if the quantity is zero.[6] Thus the price of an input faced by a farm is computed as

$$LnW_i - LnW_0 = \Sigma_{j=1}^{R} \frac{1}{2} (S_{ji} + S_{jo}) \; Ln(\frac{W_{ji}}{W_{jo}}) \tag{4.3}$$

where

W_i is the aggregate price index of input for ith farm in the 1990/91 cropping season,

W_0 is the aggregate price index of input for reference farm 0 in the 1990/91 cropping season,

S_{ji} is the ith farm's share of the cost of aggregate input that can be attributed to input of category j,

S_{j0} is the reference farm's share of the cost of aggregate input that can be attributed to input of category j,

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[5] Equation (4.2) is undefined for zero quantities because the logarithm of zero does not exit.

[6] Using the Government announced price where the farm did not use a particular input does not affect our results because the cost or expenditure share of that input will be zero. It just makes equation (4.3) defined.

W_{ji} is the price of input in the jth category paid by the ith farm, and

W_{j0} is the price of input in the jth category paid by the reference farm 0.

The total variable cost of aggregate input is the sum of costs across all the input categories of the aggregate input.

4.2.3.1 Fertilizer

Data on the physical amount of fertilizer applied to the total area covered by soybeans and expenditure on fertilizer was collected. Fertilizer is marketed in 50 kilogram bags. Despite the fact that fertilizer was a controlled product, farmers still paid the government announced price plus the cost of transport from the nearest depot to the farm. Fertilizer quantity is the amount (kilograms) of fertilizer applied by each farm.

The actual price of fertilizer paid by the farm is implicitly calculated price given the input quantity (amount of kilograms) and the total expenditure on fertilizer. If total expenditure on fertilizer is equal to the product of fertilizer price multiplied by the amount of kilograms of fertilizer applied, then the actual fertilizer price paid by each farm is computed as the ratio of total expenditure on fertilizer to the amount of fertilizer applied on soybeans. Each farm's share of the total variable input cost that can be attributed to fertilizer cost is calculated as the ratio of fertilizer cost to total variable input cost.

4.2.3.2 Lime

Physical quantities (kilograms of lime applied to total hectares of soybeans) and expenditure on lime were collected. The price of lime is calculated as the ratio of total expenditure on lime used on soybeans to the total amount of lime applied to the total hectares of soybeans. Each farm's share of the total variable input cost that can be attributed to lime cost is calculated as the ratio of lime cost to total variable input cost.

4.2.3.3 Seed

Three soybeans varieties (santa rosa, hernon and magoye) are used in soybeans production. Both seed quantity and expenditure data were collected directly from farms during the interviews. Some farms grew more than one variety in a cropping season. Instead of using three different seed prices, we constructed a single seed price index faced by each farm by aggregating the prices of three seed varieties into a single seed price.[7] The aggregate price of seed can be calculated as in equation (4.3)

where

W_i is the aggregate price index of seed in the ith farm,

W_0 is the aggregate price index of seed in the reference farm,

S_{ji} is the ith farm's share of the total seed cost that can be attributed to seed of the jth category,

S_{j0} is the reference farm's share of the total seed cost that can be attributed to seed of the jth category,

[7] We assume that aggregate seed is a translog function of its components (seed varieties).

W_{ji} is the price of the jth seed variety in the ith farm, and

W_{j0} is the price of the jth seed variety in the reference farm 0.

Total seed expenditure on each farm is tie sum across the expenditures incurred on each seed variety used on the farm. The farm's share of the total variable input cost that can be attributed to seed cost is calculated as the ratio of total seed cost to total variable input cost on each farm.

4.2.3.4 Chemicals

Different chemicals are used to control diseases in soybeans, however, we divided the chemicals into herbicides and pesticides. Expenditure and price data of each chemical used was collected. To avoid using different prices for different chemicals, we construct a single chemical input price given the expenditure and price data of each chemical type used on the farm. For farms that used a subset of the chemicals, we use the government announced price for that chemical type not used so as to avoid taking the logarithm of zero. For each farm we calculate an aggregate price index for chemical input using equation (4.3),

where

W_i is the price index of chemical input in the ith farm,

W_0 is the price index of chemical input in the reference farm 0,

S_{ji} is the ith farm's share of the total chemical expenditure that can be attributed to chemical of the jth category,

S_{j0} is the reference farm's share of the total chemical expenditure that can be attributed to chemical of the jth category,

W_{ji} is the price of chemical of the jth type used in the ith farm, and

W_{j0} is the price of chemical of the jth type used in the reference farm.

The total chemical expenses incurred in the production of soybeans on each farm is computed as the sum across all the expenditures on the different types of chemicals used. Each farm's share of the total variable input cost that can be attributed to chemical cost is calculated as the ratio of total chemical cost to total variable input cost.

4.2.3.5 Inoculum

Some varieties use inoculum to enhance nodulation in the roots. Physical quantities (kilograms) and expenditure data on inoculum were collected. The price of inoculum is computed from the quantity and expenditure data.

If we define total expenditure on inoculum as the price per kilogram of inoculum multiplied by the total kilograms of inoculum applied to total hectares of soybeans cultivated, then the price paid at each farm is the ratio of total expenditure on inoculum to the total quantity of inoculum used for the soybeans crop in the 1990/91 crop season. Each farm's share of the total variable input cost that can be attributed to inoculum cost is calculated as the ratio of total expenditure on inoculum cost to total variable input cost.

4.2.3.6 Labour

It was difficult to obtain data on the number of hours worked by employees on the farm. However, data on the total number of farm employees and total expenditure on labour were collected. For farms that grew more than one crop in a season, labour expenditure on soybeans was obtained by asking the farmer what proportion of the total expenditure on labour was attributed to soybeans.

Five categories of farm labour were identified:

i) farm manager - heads or occupies the managerial position on the farm. The farm manager could be the owner or a hired manager;

ii) Supervisors - these occupied the middle management on the farm.

iii) Regular farm labourers - this constituted the bulk of the labour force on the farm.

These workers are employed on the farm as regular workers and are paid a monthly wage based on an established wage rate between the owner or farm manager and the regular farm labourers.

iv) Casual workers - this is the group of farm labourers employed during the peak crop season to supplement the regular farm labourers. Casual workers are paid according to the work done at an agreed wage rate.

v) Family labour - Singh (1969) defined family labour to include members of the relation established between close relatives besides the members of the individual family who reside together and share responsibilities.[8]

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[8] The child (ages 8 to 15 years) labour units have been converted into adult units on the basis of two child units being equal to one adult units. One unit work of adult consist of eight hours.

Given wage rates (which for the purpose of this study are used as labour prices) and weights that reflect the labour cost of each category of labour, an aggregate labour price index can be constructed. On each farm, payment expenses on wages and benefits on each category of labour will be used as the shares of that category of labour to the total cost of labour. For farm managers, supervisors, regular and casual farmers, there are no complications on the wage rate paid out and expenditures incurred on each category.[9] On each farm, the wage rates for each category is calculated as the ratio of expenditure on that category to the number of employees of that category.

One of the vexing problems in formulating models for traditional agriculture in developing countries is the valuation of family labour, and thus in establishing its opportunity cost. Where off-farm work is readily available at a known wage, the problem is readily resolved by valuing family labour at the opportunity cost given by the off farm wage. It is however, not uncommon, particulary in developing countries to find that such alternatives are so limited that the wage is not a true measure of the opportunity cost. Since opportunities are limited, the wage used (the official minimum wage) is sufficiently high that all the labour needed will be forthcoming.

At the other extreme and a common practice in planning models is that a portion of the family labour is given a zero value. This carries with it an implicit assumption about the family's valuation of leisure and work which is not likely to be desirable for this study. The zero opportunity cost implies no suitable off-farm work is available.

[9] Large and medium scale farms are mostly operated by managers and/or supervisors, regular and casual workers whilst small farms are operated by family labour.

Moreover, from the zero opportunity cost, it can be inferred that utility is independent of leisure and work but assumption about utility function imply that a positive income is required to induce the farmer to give up leisure and to work more.

In this study, valuation of family labour was difficult to obtain and determine. Employment of family labour decreased with the increase in farm size. Farms owned by traditional farmers are mainly operated by family labour. To determine family labour wage rates, several considerations are made about traditional and small scale farms in general. During the peak season, to meet the heavy work load, family members practice exchange of labour. In the survey area, family labour is exchanged to meet the peak seasonal demands. In addition, soybeans is labour demanding at harvest time on small and traditional farms. Coupled with the fact that family labour can be exchanged among family members, it becomes logical to assume that family labour is variable in the sense that its availability can be increased or decreased by exchanges among family members.

Family labour wage rate is related to the availability of off-farm work (Winkerman 1972). If opportunities off the farm are limited, then the opportunity cost is low. If we assume that the opportunity cost is zero, then family labour should be treated as a fixed input which could complicate our model by working with zero prices. Other approaches in evaluating family labour assume that the marginal product of family labour is the same as that of salaried or hired labour. Assuming perfect competition in the labour market, labour is paid commensurate to its marginal product. Thus under these assumptions, family labour is valued the same as hired labour.

Despite opportunities off farms being limited, we assume the opportunity cost of family labour is low but not equal to zero. In addition, soybeans is mostly grown in Central, Southern and Lusaka provinces which are relatively close to the urban centres. On traditional and small farms, family labour is not compensated in the form of structured wage rates, but mainly through food supplements, thus expenditure on family labour is mainly on food. For this study, wage rates for family labour were calculated by the ratio of expenditure on family members to the number of adults available in the cropping season. Given the wage rate and expenditure on each category of farm employees, we can calculate an aggregate price index of labour for each farm using equation (4.3)

where

W_i in the aggregate price index of labour in the ith farm,

W_0 in the aggregate price index of labour in the reference farm 0,

S_{ji} is the ith farm's share of the total labour expenses attributed to labour of jth category,

S_{j0} is the reference farm's share of the total labour expenses attributed to labour of jth category,

W_{ji} is the wage rate of labour of jth category paid on the ith farm, and

W_{j0} is the wage rate of labour of jth category paid on the reference farm 0.

The total labour cost is computed as the sum across the five categories of labour. Each farm's share of the total variable input cost that can be attributed labour cost is calculated as the ratio of total labour cost to total variable input cost.

4.2.3.7 Materials

Materials include fuel (diesel) and grain bags. Data were collected on fuel expenditure, price of fuel, total number of grain bags, and the price of each bag. Total expenditure on grain bags was computed by multiplying the total number of bags by the price of each bag. The aggregate price index of material is calculated using equation (4.3)

where

W_i is the aggregate price index of material input in the ith farm,

W_0 is the aggregate price index of material input in the reference farm 0,

S_{ji} is the ith farm's share of the material expenditure attributed to material of the jth category,

S_{j0} is the reference farm's share of the material expenditure attributed to material of the jth category,

W_{ji} is the price of material of the jth type used in the ith farm, and

W_{j0} is the price of material of the jth type used in the reference farm 0.

The total material expenses incurred in the production of soybeans on each farm is computed as the sum across the expenditures on the two types of materials. Each farm's share of the total variable input cost that can be attributed to material expenses is calculated as the ratio of total material expenses to total variable input cost.

Since farms pay the same price for fuel and same price for grain bags, the difference of aggregate price index of ith farm to the reference farm is zero. This implies the product of the average share of the materials input multiplied by its aggregate price index between the ith farm and the reference farm will be zero.

4.2.3.8 Capital

One approach is to construct capital input from data on the services of capital stock and rental prices for capital services. Since capital services can be compensated at rental prices, the construction of capital input would require data on rental transactions in capital services but with lack of active rental markets in Zambia and lack of farm level data on rental transaction in capital services, it is not feasible to construct capital input using rental prices.

An alternative approach to construction of capital input is to infer the level of capital stock at each point of time from data on flows of investment up to that point. Rental prices required for the indexes of capital can be inferred from data on prices of investment goods. This approach, called the perpetual inventory method, is based on Christensen and Jorgenson (1969). Gollop and Jorgenson (1975) utilized the dual to the perpetual inventory method to provide the theoretical framework for measures of the rental prices of capital services. The dual approach requires data on nominal rate of return, rate of depreciation, capital gains or loss and tax structure.[10] It is difficult to obtain such information at farm level in Zambia.

Lower wage levels and higher capital costs in underdeveloped countries make a strong priori case for using equipment longer than in developed countries. In Zambia where credit and finance are relatively scarce for the small and medium scale farmers, farmers have no alternative but to buy equipment that wears out at a rate that amounts

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[10] Capital variable is to be measured by the annual rental value of the capital stock in which capital stock is the total value of capital components. Multiplying the value of capital stock by the rate of return on farm capital and the average rate of depreciation yields the capital input.

to higher costs of repair work. Lack of technological advance, however, means that equipment is replaced when physically worn out.

In Zambia, the use of old equipment is the most widespread way of adjusting production methods to scarce capital and abundant labour. Maintenance and repair permits capital goods to stay on the production line longer. Terborgh (1949) observed that maintenance and repair work is labour intensive and that high wage, low interest, large market economies abandon equipment earlier than in developing countries. Thus spending on maintenance and repair work is an alternative way of postponing replacement in developing countries.

On each farm, data were collected on the number of tractors, combines, oxen and other farm implements, hire payments on tractor, combine and oxen, and expenditure on maintenance and repair of tractors, combines, oxen and farm machinery. We also collected rough estimates as how much of each capital input was allocated or used on soybeans production.

Our model assumes single quasi-fixed capital input. For this reason, we have to construct a single capital input. From the data collected we cannot employ the perpetual inventory method to estimate the capital stock from investment data. There is a lack of data on investment in equipment and structures, price of investment goods and taxation structure.

However, we are able to construct our capital input using the approach of Yamada and Ruttan (1975). They aggregated the different traction methods into horsepower without weighting the different traction types. Modifications will be made to their approach to include the cost share (weight) of each of the different traction methods used in aggregating capital input.

For convenience in this study, the construction of capital input will include motive power only: tractors, combines and oxen. Buildings, farm structures and irrigation facilities are thus excluded due to incomplete data. The farm capital input is the aggregate horsepower of tractors, combines and oxen.[11] We assume that one horsepower work is the same across tractors, combines and oxen. This implies one horsepower of ox can do the same amount of work as one horsepower of tractor or combine. Aggregation using the horsepower also carries with it that the amount of horsepower on a farm is related to the size of the farm and implements used. The larger the implement, the more horsepower needed to perform work with that implement.

Construction of an index of capital input from the three categories of farm capital input requires weights that reflect the annual capital cost of each type of capital input. A substantial amount of repair and maintenance work is carried out on tractors and combines. Farmers who own tractors and combines incur capital costs in the form of replacing worn-out parts, spare parts, and other repair and maintenance work. In view of the high cost of capital inputs, particulary for combines and tractors, some farms hire tractors and combines. These farmers incur capital cost in the form of lease payments for tractor or combine hired. We estimate the annual cost of each type of capital input hired as the total lease payment.

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[11] One ox has 0.5 horsepower

Capital costs in oxen include dipping and other maintenance cost. Despite the fact that the total number of farms in the sample who own oxen is about 15 percent, the use of oxen is about 38 percent due to oxen hire. We estimate the annual oxen cost for farmers who do not own oxen as the total payments incurred for hiring oxen. On each farm, the capital cost incurred on each category of capital input is used as the share of that category on the total cost of capital input.

We can compute the aggregate capital quantity index for each farm using a modified version of equation (4.2) as[12]

$$LnK_i - LnK_0 = \sum_{j=1}^{3} \frac{1}{2}(S_{ji}+S_{jo})\ Ln\left(\frac{K_{ji}}{K_{jo}}\right) \tag{4.4}$$

where

K_i is the aggregate index of capital input in the ith farm,

K_0 is the aggregate index of capital input in the reference farm 0,

S_{ji} is the ith farm's share of the total capital input cost attributed to capital input of jth category,

S_{j0} is the reference farm's share of the total capital input cost attributed to capital input of jth category,

K_{ji} is the amount of horsepowers in the jth category in the ith farm, and

K_{j0} is the amount of horsepowers in the jth category in the reference farm 0.

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[12] Since farms use a subset of the three categories of capital input, and equation (4.2) is undefined if there are zero quantities, we will add one horsepower to all farms to avoid taking the logarithm of zero for capital input not used on a particular farm. This does not complicate our results because if the farm did not use a particular category of capital input, its cost share of that input is zero and the logarithm of one is zero.

Total cost of capital input on each farm is the sum across the expenses incurred in the three capital input categories. Each farm's share of the total variable input cost attributed to cost of capital input is calculated as the ratio of difference between total variable input cost and total revenue to the total variable input cost.

CHAPTER 5.0 ANALYSIS OF RESULTS

This chapter presents results of the efficiency calculation of each farm. Productive efficiency implies a larger amount of output is produced from a given quantity of inputs. This also means if a farm is efficient, lower levels of variable cost were required in the 1990/91 cropping season.

The calculated efficiency value of the reference farm is represented by 100 ($\theta_{i0}=0$) percent. In any other farm, a lower efficiency level relative to the reference farm is represented by a number greater than 100 ($\theta_{i0}>0$) percent. Higher efficiency level relative to the reference farm is represented by a number less than 100 ($\theta_{i0}<0$) percent.

For purposes of comparison, efficiency measures were calculated using two alternative bases. The largest farm (in terms of hectares) was used as the reference farm in scenario I, and an average farm was used as the reference point in scenario II. The theory of flexible functional forms suggests that more accurate measures of efficiency are obtained using the average farm as the base (scenario II). The translog specification of the cost function provides a second order Taylor series approximation to the unknown true cost function. This approximation is more satisfactory for small variations in data (arguments of the cost function) than for large variations in data (e.g. Diewert 1971). Variations between farms and the reference farm will generally be smaller when the base is defined as an average farm rather than as an extreme observation such as the largest farm. Therefore, a translog approximation generally leads to less serious specification errors when an average farm is selected as the reference point as in scenario II.

5.1. Scenario I

Scenario I uses the largest farm as the reference farm. The results describe a very remarkable difference in technology among the farms growing soybeans. The efficiency values of individual farms range from 0.41 to -2.91 with the overall mean efficiency value of the sample at -0.18 which implies that soybeans require lower levels of variable costs of production. At -0.18 efficiency value, these farms can produce soybeans at variable cost level 16 percent lower than the reference farm.

Breaking the sample overall efficiency value into percentage of sample farms with higher and lower cost levels, the results show that 48 percent of the farms have an efficiency level lower than the reference farm. These farms require higher level of variable costs relative to the reference farm. The percentage of the sample farms that are approximately as efficient as the reference farm, with efficiency values ranging from -0.03 to 0.03, is 13 percent. The efficiency differential of this range means the variable cost level of these farms is not less or greater than 3 percent of the largest farm variable cost level. Farms with higher efficiency relative to the reference farm account for 39 percent of the sample. Figure 5.1 will enhance our analysis of efficiency distribution in each farm size category.

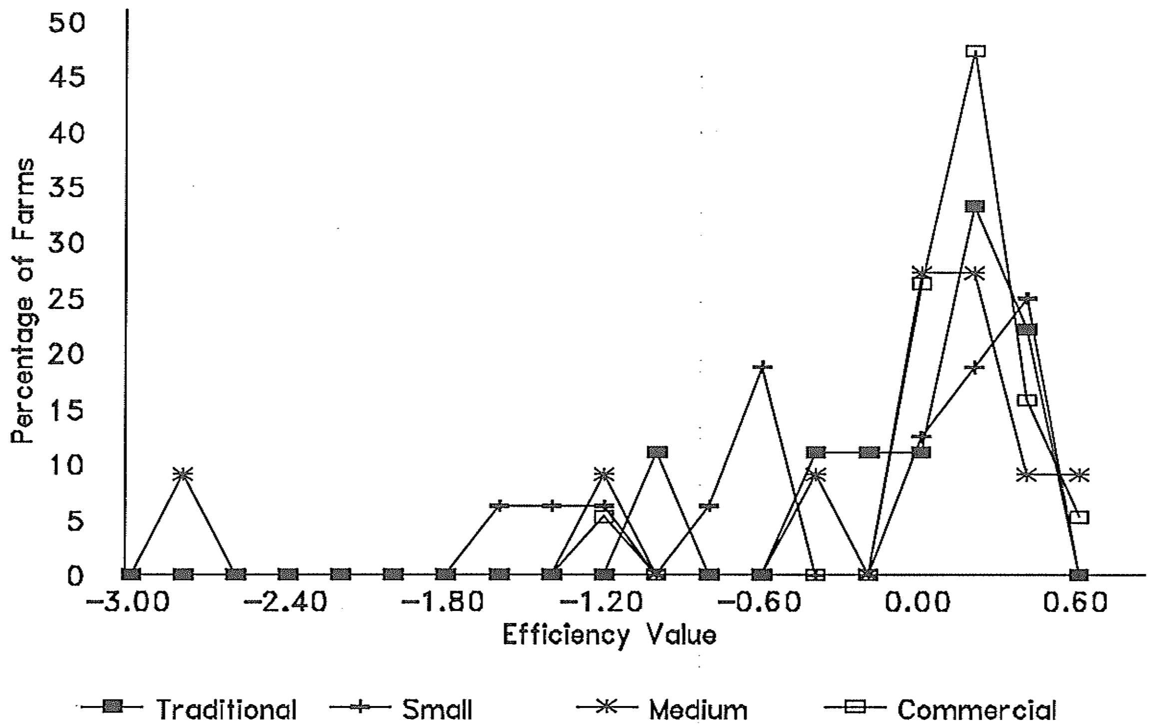

Figure 5.1 Efficiency distribution in each farm size category (scenario I).

Within the traditional farms, there are as many efficient farms as there are inefficient ones relative to the reference farm. In this group, efficient and inefficient farms each account for 44.4 percent while 11.2 percent of farms are as efficient as the reference farm. 56 percent of small scale farms are producing soybeans at relatively lower variable cost level and 38 percent of the farms in this category operate relatively inefficiently. The proportion of farms that are as efficient as the largest farm is 6 percent. The proportion of efficient medium scale farms is 46 percent. The percentage of high cost farms is 36 percent of the group. The farms whose efficiency value is almost that of the largest farm are 18 percent of the farms in this group. The fraction of high cost farms is higher in the commercial farm category, some 63 percent of the group. Those as efficient as the largest farm make up 21 percent and 16 percent of the farms are higher efficiency producers.

A comparison of mean efficiency values in each farm size group will likely reveal a pattern of the levels of efficiency. The mean efficiency values achieved in the sample generally decreases with farm size with the commercial farm size group being the lowest of all the four farm groups.The small scale farms (growing between 2-10 hectares) have the highest average efficiency value of -0.38. An average efficiency value of -0.38 means the variable costs of small scale farms are 32 percent lower relative to the reference farm. The medium scale farms, a category of farms cultivating 10-40 hectares, rank second with an average efficiency level 31 (θ= -0.37) percent higher than the largest farm. The traditional farms (0-2 hectares) ranking third have average efficiency level 10 (θ= -0.11) percent higher than the largest farm. The commercial scale farms growing more than 40 hectares rank least with average efficiency value of 0.05, which means variable cost level in soybeans production are 5 percent higher relative to the reference farm. Within each farm size group, we can investigate the individual farm level efficiencies as shown in table 5.1.

Table 5.1 Range of efficiency values by farm size (scenario I).

Farm Size (Hectares)	Number	Efficiency Value		
		Lowest	Highest	Average
0≤2	9	0.34	-1.12	-0.11
>2≤10	16	0.40	-1.62	-0.38
>10≤40	11	0.41	-2.91	-0.37
>40	19	0.41	-1.24	0.05
All Farms	55			-0.18

The highest efficiency level is achieved neither by the smallest nor the largest farm in the sample. The highest efficiency value is attained by a medium sized farm that grew 20 hectares in the 1990/91 cropping season. This most productive farm is 95 (θ= -2.91) percent more efficient compared to the reference farm.

Apparently two farms with the lowest productive efficiency level have the same efficiency value of 0.41. The two most inefficient farms are a medium size farm that grew 25 hectares while the other is a commercial farm that grew 45 hectares of soybeans in the 1990/91 cropping season. These farms are 50 percent inefficient compared to the reference farm.

It appears smaller farms have achieved higher efficiency in costs level. The use of the largest farm as the reference point could be the contributing factor in smaller farms revealing artificially higher efficiency levels. We can utilize the average farm as the reference point in the analysis of efficiency levels to reduce the variations. The average farm is not as extreme as using the largest farm. Moreover, the average farm adjusts, for changes in the relative importance of factors determining the efficiency level. As the divergency of the farm size becomes smaller, so too does the difference between the values of efficiency.

5.2 Scenario II

The reference farm in this case is the average farm constructed from all farms in the sample. The overall efficiency value of the sample does change drastically in terms of magnitude when the average farm is used as the reference point. The overall sample efficiency value in this scenario is -0.47. This means farms are relatively efficient with variable cost level 37 percent lower than the average farm. The overall sample efficiency level in scenario II is more than double the value in scenario I.

Farms with lower efficiency relative to the average farm account for 33 percent while 7 percent of the farms are as efficient as the average farm with efficiency values ranging from -0.03 to 0.03. The rest, 60 percent are efficiently operating at a lower variable cost level compared to the reference farm. Figure 5.2 shows the efficiency distribution in each farm size category in scenario II.

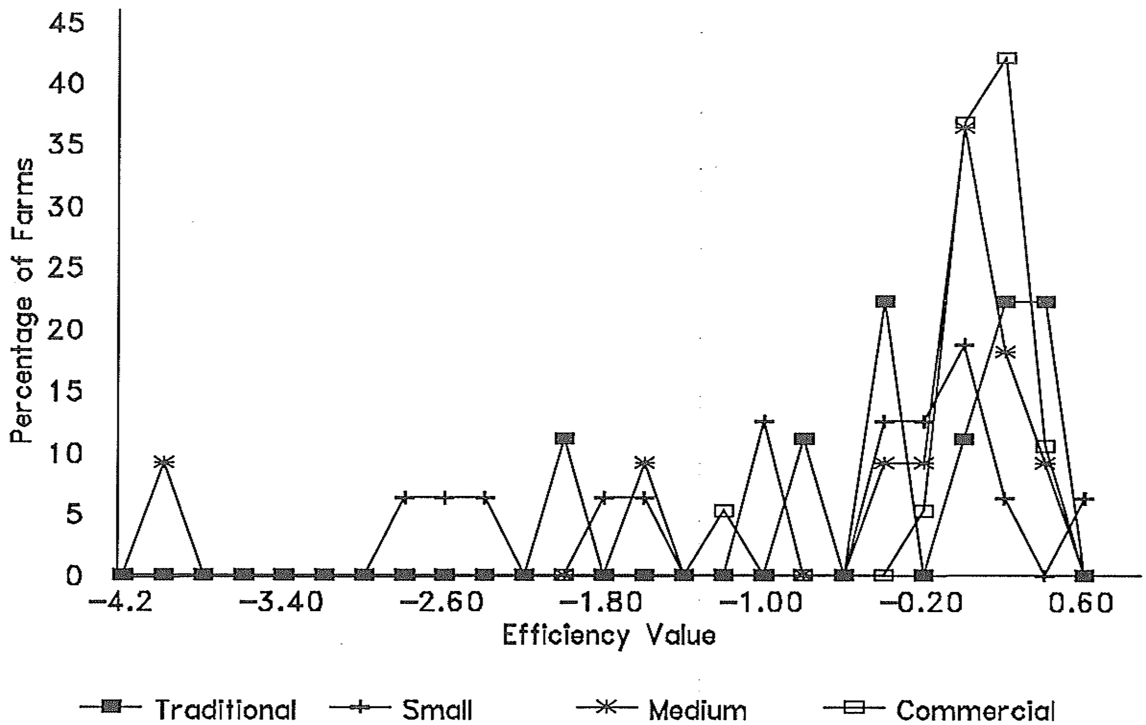

Figure 5.2 Efficiency distribution in each farm size category (scenario II).

In the category of traditional farms, 44 percent of the farms incurred higher variable costs than the average farm in the production of soybeans in the 1990/91 cropping season. The corresponding figure for efficient farms relative to the reference farm variable cost is 56 percent of the traditional farms. In the small scale farms, the fraction of farms in the lower cost level is 87 percent and 13 percent are in the higher cost level. Efficient farms in the medium scale category make up 73 percent of the farms. The higher cost level farms are 27 percent of the farms in the medium scale category. The commercial farms with higher efficiency level relative to the reference farm in the production of soybeans are 32 percent of the farms in this group. Inefficient farms are 47 percent and those as efficient as the reference farm are 21 percent of the farms. In scenario II, none of the farms are as efficient as the average farm in the traditional, small and medium scale farms.

The same picture is repeated in terms of mean efficiency values. The small scale farms are the most efficient. They are 62 (θ= -0.97) percent more efficient than the average farm. The medium scale farms rank second with average efficiency value of -0.57 which is 43 percent higher than the average farm. The average efficiency level of traditional and commercial farms rank third and fourth respectively. The average efficiency value of -0.35 means traditional farms are 30 percent more efficient than the average farm. However, the commercial farm category average efficiency level is now 5 percent higher than the average farm. Under scenario I, commercial farms were 5 percent inefficient relative to the reference point. The average efficiency values of all farm size categories has risen under scenario II compared to the values in scenario I. The average efficiency for traditional farms has increased from -0.11 to -0.35. For the medium farms, the average efficiency value is -0.57 as opposed to an average efficiency value of -0.37 in scenario I. The average efficiency level for the small scale farmers has risen to -0.97 from -0.38 under scenario I. Table 5.2 below shows the ranges of efficiency values on each farm size in scenario II.

Table 5.2 Range of efficiency values by farm size (scenario II).

Farm Size (Hectares)	Number	Efficiency Value		
		Lowest	Highest	Average
≤2	9	0.39	-2.11	-0.35
>2≤10	16	0.49	-2.89	-0.97
>10≤40	11	0.34	-4.08	-0.57
>40	19	0.27	-1.26	-0.05
All farms	55			-0.47

The lowest efficiency value of 0.49 is attained by a small scale farm that grew 3 hectares of soybeans as compared to the value of 0.41 in scenario I which was achieved by farms that planted 25 and 45 hectares of soybeans. In both scenario I and scenario II, a medium scale farm that grew 20 hectares ranked the most efficient relative to the reference point. However, under scenario II, this farm has efficiency value of -4.08 compared to -2.91 in scenario I.

5.3 Discussion of results

Although in both scenarios, the average sample efficiency value shows, farms are operating at higher efficiency level, there is wide variation in the level of efficiency for individual farms, and consequently the potential for minimizing the farm cost of production from the existing inputs also varies greatly across farms in the sample.

Even though there are variations in efficiency levels within the farm groups, the overall pattern is consistent. We notice that the highest productive efficiency in the sample are not restricted to the largest farm. On average, productivity declined from the small scale farm size group to the commercial farm size group.

It is not surprising that the traditional farm size group ranks third in efficiency. Traditional farmers are more subsistence and their venturing into soybeans, a cash crop, is to spread the possibility of bad events occurring and to supplement their incomes. On the other hand, the small scale farmers, who are emerging into cash crop production such as soybeans, have ranked first in efficiency level. These small farms are not as specialized as the commercial farms. They tend to be involved in a mixture of activities, thus soybeans is grown in addition to other crops in any one season. Another general characteristic of small scale farms is that they cannot afford the high cost of inputs; hence, research and extension services seek to make the cost of production affordable in the traditional and small scale farms. Small scale farms are also supported by the Lint Company of Zambia input credit scheme as a way of cushioning them from the high cost of inputs. Under this scheme, Lint Company of Zambia also provides, extension advice, and transportation of inputs to and produce from depots covered by this scheme. This could be a possible explanation for small scale farms ranking first in efficiency.

Commercial farms are highly specialized and supposedly require more management skills to operate. On larger farms, soybeans is mainly grown in the rainy season to be rotated with wheat in the cold dry season. Commercial farmers have relatively more access to commercial credit. The fact that at the time of survey inputs were subsidized, we suspect over application of inputs by the commercial farms in soybeans production. The question therefore, arises as to whether extension support (through Lint Company of zambia) is the explanation for the relatively higher efficiency among the small scale farms. Thus we will test the significance of extension support on efficiency of small scale farms.

5.3.1 Hypothesis Tests

We would like to consider formal statistical tests of differences of means among the four groups of farms. To test whether there are significant differences in efficiency among the farm groups, we use the following regression equation

$$\theta=\beta_0+\beta_1 D_{1t}+\beta_2 D_{2t}+\beta_3 D_{3t}+e$$

where

θ is the calculated efficiency value of each farm in the sample,

D_{1t} = 1 if t is in traditional farms, D_{1t} = 0 otherwise,

D2t = 1 if t is in small scale farms, D_{2t} = 0 otherwise,

D_{3t} = 1 if t is in medium scale farms, D_{3t} = 0 otherwise, and

e is the error term.

The null hypothesis ($H_0:\beta_1=0,\beta_2=0,\beta_3=0$) is that there are no significant differences in efficiency by farm size group. The results of tests of differences in efficiency are reported in table 5.3. Although we have reported test results from the two scenarios, we will only consider results from scenario II over those from scenario I. An F-test is performed in order to determine whether there are significant differences in efficiency among farm groups. Based on the results of this test, shown in table 5.3, the null hypothesis of no significant differences in efficiency among farm size groups is rejected at 95 percent level. In other words, the calculated F value of 3.23 is greater than the critical F value of 2.78. Thus, there are significant differences in efficiency among the four farm size categories. All the coefficients are negatively related to the calculated efficiency value. However, only the coefficient associated with the small scale group is significant at the 95 percent level. This means the efficiency level of small scale farms is the most significantly different from the other farm size categories.

Table 5.3 Test of differences in efficiency among different farm size groups.

Variable	Scenario I	Scenario II
D_{1t}	-0.16	-0.30
	(-0.64)	(-0.83)
D_{2t}	-0.43	-0.92
	(-2.01)*	(-3.06)*
D_{3t}	-0.42	-0.52
	(-1.76)	(-1.54)
Critical $F_{0.05,3,51\ d.f.}$	2.78	2.78
Calculated F-value	1.76	3.23*

t-statistics in parentheses, 51 d.f.

* indicates significance at the 95 percent level.

An issue that has generated interest is the relationship between farm size and efficiency. Since our efficiency measure is calculated under the assumption of constant returns to scale, it would be interesting to test whether there is internal consistency with the assumption of constant returns to scale. Another issue we would like to investigate is the impact of Lint Company of Zambia support on small scale farms.

There are two ways of carrying out tests related to returns to scale and extension. We can test constant returns to scale and the impact of extension on efficiency by utilizing two regression equations with the calculated productive efficiency measure as the dependent variable and either farm size in hectares of soybeans planted or farm size in capital (k) and output (y) as the independent variables.

We can write the first regression equation as

(1). $\theta = \beta_0 + \beta_1 Fs + \beta_2 D + e$

where

θ = calculated efficiency level of each farm,

Fs is farm size measured in hectares of soybeans planted in the 1990/91 cropping season,

D = 1 if small scale farm, and D = 0 otherwise. The dummy variable D is to capture the impact of extension on small scale farms supported by Lint company of Zambia.

1. Tests of Constant returns to scale

H_0: $\beta_1 = 0$

The null hypothesis of constant returns to scale implies that the efficiency values (θ) is constructed correctly regarding returns to scale and is consistent with our assumption of constant returns to scale. An implication of constant returns to scale is that there is no relationship between efficiency and farm size.

2. Test of significance of extension (D)

H_0: $\beta_2 = 0$, the null hypothesis is that (controlling for farm size) extension is not a significant explanatory variable for the high efficiency among small scale farms. Thus insignificant results imply that factors other than extension alone are responsible for small scale farms ranking first in efficiency.

Table 5.4 Test results from the regression equation 1, specified in hectares of soybeans planted

Variable	Scenario I	Scenario II
Farm size (Fs)	0.19E-02	0.31E-02
	(1.03)	(1.16)
Small scale dummy (D)	-0.17	-0.55
	(-0.82)	(-1.86)

t-statistics are in parentheses, 52 d.f.

All the coefficients are insignificant at 95 percent level. By this result, we accept the null hypothesis of constant returns to scale. Furthermore, insignificant results mean efficiency is independent of farm size. In terms of extension, we accept the null hypothesis that extension alone is not responsible for small scale farmers being the most efficient.

Within the framework of a variable cost function C(w,k,y) used in this study, constant returns to scale in production is defined by restrictions on the cost function in terms of k and y rather than in terms of hectares of soybeans. Therefore, a more appropriate and direct test of constant returns to scale is that θ is independent of k and y. Thus output y and capital k will be used instead of hectares of soybeans planted, to test for constant returns to scale and significance of extension in the following equation:

(2). $\theta = \beta_0 + \beta_1 k + \beta_2 y + \beta_3 D + e$

where

θ = calculated efficiency level of each farm,

k is the capital input on each farm,

y is the level of output produced on each farm, and

D as defined in the first equation.

1. Test of Constant Returns to scale

H_0: $\beta_1 = 0$, $\beta_2 = 0$ is the null hypothesis of constant returns to scale. Since our values of θ where constructed using k and y, by this test, we are also testing for internal consistency. Insignificant coefficients would mean efficiency (θ) was constructed properly regarding returns to scale and is consistent with constant returns to scale assumption. Insignificant results also suggest there is no relationship between farm size and efficiency.

2. Test of significance of extension (D)

H_0: $\beta_3 = 0$, insignificant results imply extension service provided by Lint Company of Zambia is not a primary explanation for the relatively high efficiency among small scale farms compared to other farm size categories.

An F-statistic is calculated to test for constant returns to scale in soybeans production. T-statistics is used to test for the significance of extension by Lint Company of Zambia on small scale farms. The results of the above tests are presented in the table 5.5 below.

Table 5.5 Test result from regression equation 2, specified in terms of k and y.

Variable	Scenario I	Scenario II
Capital input (K)	0.27	0.16
	(3.31)	(2.61)
Output (Y)	-0.11E-05	-0.88E-06
	(-0.93)	(-0.52)
Calculated F value	6.07*	4.13*
Critical $F_{v0.05,\ 2,51\ d.f}$	4.03	4.03
Small scale dummy (D)	0.14	-0.27
	(0.68E-01)	(-0.91)

t-statistics are in parentheses. 51 d.f.

* indicates significance at the 95 percent level.

At the 95 percent level of significance, we reject the null hypotheses of constant returns to scale in both scenarios (although the emphasis of the interpretation is on scenario II results for reasons mentioned earlier). This means we do not accept the null hypothesis of constant returns to scale. By this result, it is possible efficiency (θ) was not constructed properly and therefore there is no internal consistency with the assumptions made. Since testing for constant returns to scale using k and y is more direct than using hectares of soybeans planted, we will use the results from regression equation specified in terms of k and y to make deductions about internal consistency. Rejecting constant returns to scale also implies that productive efficiency is dependent on farm size measured in capital (k) and output (y). The test results are interesting in the sense that capital input coefficient has a significant t-statistics at 95 percent level. Capital input coefficient is also positively related to the dependent variable. This implies one percent increase in capital input reduces efficiency level by 16 percent. A possible explanation for the positive relationship with the dependent variable is that the shadow price of capital may have been over-estimated by calculations based on constant returns to scale. Alternatively, the contributions of farm family labour associated with low levels of capital may have been under-estimated.

The test of significance in extension support offered by Lint Company of Zambia to small scale farm shows insignificant results. This means we accept the null hypothesis that extension does not explain the high efficiency among small scale farms. Other factors combined with extension could be the possible explanation for better performance by small scale farms.

5.4 Limitation of model and data

The model we used to calculate the farm level efficiency had its own limitations.

The choice of reference point is arbitrary. In cross section studies of measuring efficiency, there is no natural ordering as in time series studies. However, it is worth highlighting that when the reference point was changed from the largest farm to average, it is only the magnitude of our values that changed not the pattern of results.

Expenditures were used as the choice of weighting the inputs. In some inputs, the allocation of the proportion of that input used on soybeans were just rough estimates from the farmers. Double counting is suspected especially in inputs like labour, fuel and chemicals.

The construction of inputs like capital also affected our results especially for the larger farms. Generally, larger farms are capital intensive compared to smaller farms but the use of horsepower on the farm as capital input measure might have overestimated amount of the capital input on the farm. The allocation of capital input as well as labour input to soybeans were just rough estimates purely based on the farmers's recollection especially in multiple cropping situation. The general quality of data can also be questionable especially when collected at a time of political uncertainties. Data on other variable inputs; electricity, irrigation, veterinary medicines and weather was not collected.

CHAPTER 6.0 CONCLUSION

Given the increase in the number of farms and hectares under soybeans production, the objective of this study was to measure and compare the efficiency of farms in soybeans production. The other objective was to determine the impact of farm size on efficiency.

The objectives were achieved by comparing farm level variable costs incurred in soybeans production in the 1990/91 cropping season. The model used was a Tornqvist index formula based on a translog short run variable cost function. The findings of this study indicate significant differences in efficiency levels in the production of soybeans exists among the different farm size categories.

Results indicate the following ranking of farm size categories, from most efficient to least efficient: small scale (2-10 hectares), medium (10-40 hectares), traditional (<2 hectares) and commercial (>40 hectares). Thus small farms tend to be most efficient, and commercial farms tend to be least efficient.

Tests of consistency show that there is inconsistency with the assumption of constant returns to scale. These tests suggest there is a general negative relationship between farm size (as measured by capital) and efficiency. The impact of extension on small scale farms supported by Lint Company of Zambia was assessed. We find that extension is not significant in explaining the high efficiency among small scale farms.

6.1 Policy Implications

The smaller farm sizes, despite practising multiple cropping within a growing season, have efficiencies higher than the larger farms. These smaller farms have an input credit scheme with Lint Company of Zambia, which also provides extension service to small farms. Small farmers by virtue of support by the Lint Company of Zambia, are required to sell their produce to the fore mentioned company. Commercial farmers have different marketing arrangements independent of Lint Company of Zambia. They can sell their produce anywhere. The emphasis on Lint Company of Zambia providing credit, physical inputs, and extension advice to smaller farms is not the only influential factor contributing to higher efficiency of small scale farmers in soybeans production. Our conclusion is that small scale farms, even though they rank first in performance, have achieved high efficiency because of other factors combined with the present input credit scheme. Although extension was not the only explanation for their high efficiency, as results show, the potential for producing soybeans at minimum cost favour small scale and medium sized farms rather than commercial scale farms. The present input credit scheme should be encouraged because it is targeted on the small scale farms who are the most efficient group of farmers.

Although the farm's efficiency level is measured relative to the performance of the other farms in the sample, making it impossible to draw any general conclusions on the efficiency of farms in soybeans production as a whole, we can make a few comments about the importance of this study in as far as soybeans production is concerned. Firstly, this study could be the foundation for which agricultural research and extension advice aimed at a particular farm group could be based especially if increased output at minimum resource cost is to be achieved by the targeted farm group. Even if we cannot generalize, the results of this study could enhance more analysis in research and extension services with regards to different farm categories.

Our results suggest that larger farms are not necessarily more efficient than small farms. Although the model and the data construction had short comings, the results of the study are important to the extent that it may be useful for policy especially in Zambia where it is normally argued that the policy environment is more favourable to larger farms than smaller farmers. If this is the case, with results indicating that large farms are not as efficient as is purported, then efforts to increase soybeans production by encouraging commercial farmers may be counter productive.

6.2 Recommendation for Future Research

It is generally argued that there is a tendency to over-estimate (in larger farms) and to under-estimate (in smaller farms) the level of costs, even though the extent of this bias is unknown. In view of the fore mentioned problem, a natural extension to this study would be to expand the data base so as to handle multiple outputs especially among small scale farmers who grow multiple crops in a season. One must, however, point out that we did not include all the variables used in soybeans production. Therefore, another suggestion is to include the missing variables such as electricity, irrigation, and weather, which in turn presumably would lead to improved measurement of efficiencies.

Constant returns to scale was the implicit assumption in the calculation of productive efficiency. Rejecting the assumption of constant returns to scale in soybeans production implies the possibility of other scales of operation. Our approach can be seen as being restrictive by implicitly assuming constant returns to scale. In applications where there are increasing or decreasing returns to scale, the index approach we used can result in biased results of efficiency. Econometric estimation of production technology becomes essential because of the importance of parameter estimates of the underlying substitution elasticities (allowing for interaction between inputs) and scale parameters. As part of future research we suggest econometrically estimating a production technology that should allow for the possibility that returns to scale vary with both output level and input mix; that is, regions of increasing, constant and decreasing returns to scale can exist. This will allow for the possibility that farms show differences in returns to scale as well as non-constant returns to scale.

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APPENDIX 1.0 FARM SURVEY QUESTIONNAIRE

STRUCTURE OF THE QUESTIONNAIRE

A: SOYBEANS PRODUCTION

VARIETY	AREA	OUTPUT	PRICE	TOTAL REVENUES

....

....

....

....

B: TOTAL COST OF PRODUCTION

VARIETY	AREA	TOTAL COST OF INPUTS

....

....

....

C: USE OF FERTILIZER ON SOYBEANS PRODUCTION

TYPE	AMOUNT	AREA COVERED	PRICE/UNIT	TOTAL COST

....

....

....

D: USE OF LIME ON SOYBEANS PRODUCTION

AMOUNT	AREA COVERED	PRICE/UNIT	TOTAL COST

....

....

E: SEED USE ON SOYBEANS

VARIETY	AMOUNT	AREA COVERED	PRICE/UNIT	TOTAL COST

....

....

....

F: USE OF CHEMICALS

TYPE	AMOUNT	AREA COVERED	PRICE/UNIT	TOTAL COST

....

....

....

G: USE OF INOCULUM

AMOUNT	AREA COVERED	PRICE/UNIT	TOTAL COST

....

....

H: FARM LABOUR

TYPE	NUMBER	OPERATION	WAGE RATE	TOTAL EXPENDITURE

....

....

....

I: MATERIALS

TYPE	AMOUNT	PRICE/UNIT	TOTAL EXPENDITURE

....

....

....

J: INVENTORY OF TRACTORS

a) If used own tractor,

TYPE	OPERATION	HORSEPOWER	TOTAL EXPENDITURE[13]

....

....

....

....

....

b) If tractor was hired,

TYPE	OPERATION	HORSEPOWER	HIRE RATE	TOTAL PAYMENTS

....

....

....

....

[13] Total expenditure on repair and maintenance (excluding fuel)

K: USE OF COMBINE

a) If use own combine,

TYPE OPERATION HORSEPOWER TOTAL EXPENDITURE

....

....

....

b) If combine was hired,

TYPE OPERATION HORSEPOWER HIRE RATE TOTAL PAYMENTS

....

....

....

....

L: USE OF OXEN

If used own oxen,

OPERATION NUMBER TOTAL COST ON MAINTENANCE[14]

....

....

....

[14]Maintenance includes dipping and other veterinary control measures.

If oxen was hired,

OPERATION	NUMBER	HIRE RATE	TOTAL PAYMENT

M:INVENTORY OF IMPLEMENT

TYPE OF IMPLEMENT	TOTAL EXPENDITURE	% USE ON SOYBEANS

APPENDIX 2.0 FARM DATA

Appendix 2.1 Efficiency values

#	Farm size (Hectares)	Total v.cost (kwacha)	Output (kgs)	Scenario I Aggregate capital	Scenario I Efficiency value	Scenario II Aggregate capital	Scenario II Efficiency value
1	0.25	2751.50	225.00	-3.06	0.30	-6.08	0.39
2	0.50	2869.00	270.00	-2.71	-0.10	-5.73	-0.08
3	0.81	4445.37	400.95	-2.71	0.02	-3.74	0.18
4	1.00	5349.89	585.00	-2.71	-0.45	-5.73	-0.84
5	1.00	5266.89	540.00	-2.71	-0.30	-5.73	-0.55
6	1.50	6397.97	945.00	-2.71	-1.12	-5.73	-2.11
7	2.00	12672.00	1080.00	-2.71	0.13	-5.73	0.11
8	2.00	10400.40	900.00	-2.71	0.17	-5.73	0.20
9	2.00	12171.50	990.00	-2.71	0.34	-5.73	-0.44
10	2.50	15661.00	1125.00	-2.71	0.27	-5.73	-0.11
11	2.50	14756.04	1350.00	-2.71	-0.16	-5.73	-0.55
12	2.50	16107.52	1237.50	-2.51	0.16	-5.53	-0.09
13	3.00	31914.38	2160.00	-3.03	0.30	-4.79	0.49
14	3.00	13802.10	1890.00	-3.17	-1.34	-4.96	-1.72
15	3.00	14396.60	1485.00	-3.10	-0.69	-4.87	-1.17
16	3.00	12251.96	1620.00	-1.95	-0.62	-4.73	-1.19
17	4.00	18918.34	3240.00	-2.71	-1.62	-5.73	-2.89
18	4.00	16809.03	2700.00	-2.51	-1.51	-5.53	-2.69
19	4.50	18828.35	2430.00	-2.36	-0.83	-5.38	-1.87
20	5.00	58685.50	4950.00	-2.36	0.03	-5.58	-0.53
21	6.00	49974.96	3780.00	-2.36	0.24	-5.38	-0.27
22	7.00	58947.00	3780.00	-2.51	0.40	-5.53	-0.35
23	8.00	61243.20	6480.00	-2.36	-0.68	-5.38	-2.53
24	10.00	72820.00	9000.00	-0.83	0.13	-0.83	0.08
25	10.00	63836.50	6300.00	-2.37	-0.11	-4.01	-0.19
26	12.00	97740.00	8640.00	-3.03	-0.03	-4.79	0.06
27	15.00	111690.00	14850.00	-2.77	-1.28	-4.49	-1.71
28	20.00	126609.00	25200.00	-2.86	-2.91	-4.59	-4.08
29	25.00	337315.00	31500.00	-0.29	0.41	-0.23	0.34
30	25.00	289048.00	38250.00	-0.42	-0.05	-0.26	-0.19
31	30.00	258998.00	54000.00	-0.21	-0.51	0.03	-0.44
32	30.00	344789.40	45900.00	-0.34	0.03	-0.32	-0.09
33	30.00	376950.09	48600.00	-0.28	0.07	-0.16	-0.04
34	35.00	494442.50	69300.00	-0.29	-0.16	-0.21	-0.25
35	40.00	610417.60	72000.00	-0.26	0.08	-0.23	-0.05
36	40.00	648308.40	61200.00	-0.11	0.32	0.02	0.19

Appendix 2.1 (Continued)

#	Farm size (Hectares)	Total v.cost (kwacha)	Output (kgs)	Scenario I Aggregate capital	Scenario I Efficiency value	Scenario II Aggregate capital	Scenario II Efficiency value
37	45.00	707044.26	60750.00	-0.24	0.41	-0.15	0.27
38	45.00	724936.86	72900.00	-0.11	0.31	0.02	0.17
39	50.00	701772.15	99000.00	0.02	-0.01	0.21	-0.09
40	50.00	753038.26	90000.00	0.01	0.15	0.20	0.04
41	50.00	800053.20	99000.00	-0.24	-0.02	-0.16	-0.16
42	55.00	1041181.53	103950.00	-0.23	0.20	-0.11	0.05
43	60.00	966897.66	113400.00	0.08	0.13	0.30	-0.01
44	80.00	1138115.96	129600.00	0.10	0.19	0.33	0.07
45	80.00	1396987.23	158400.00	-0.34	0.02	-0.26	-0.14
46	100.00	1434990.00	153000.00	-4.16	-1.24	-5.95	-1.26
47	100.00	1332965.80	144000.00	-0.08	0.16	0.13	0.07
48	100.00	1500566.63	153000.00	0.03	0.22	0.29	0.12
49	110.00	1621669.90	217800.00	-0.16	-0.12	-0.06	-0.22
50	120.00	1792881.54	226800.00	0.08	0.09	0.40	-0.01
51	120.00	1722342.60	205200.00	0.10	0.11	0.36	0.01
52	150.00	2435770.50	216000.00	-0.13	0.31	0.11	0.21
53	150.00	2074290.99	297000.00	0.10	-0.07	0.47	-0.01
54	185.00	2432670.95	283050.00	0.04	0.11	0.36	0.04
55	201.00	3243243.28	416070.00	0.00	0.00	0.17	-0.10

Appendix 2.2 Variable input costs (Kwacha)

			Seed				Labour				Chemicals			
#	Farm size	Fertilizer	Magoye	Hemone	Santa rosa	Lime	Family	Hired	Managerial	Inoculum	Herbicides	Pesticides	Bags	Fuel
1	0.25	0	1083	0	0	31	1617	0	0	0	0	0	20	0
2	0.50	0	2195	0	0	0	650	0	0	0	0	0	24	0
3	0.81	0	3510	0	0	0	900	0	0	0	0	0	36	0
4	1.00	0	4350	0	0	0	948	0	0	0	0	0	52	0
5	1.00	0	4333	0	0	0	886	0	0	0	0	0	48	0
6	1.50	0	0	4530	0	0	1784	0	0	0	0	0	84	0
7	2.00	0	8676	0	0	0	3900	0	0	0	0	0	96	0
8	2.00	0	0	6040	0	0	4280	0	0	0	0	0	80	0
9	2.00	0	0	6040	0	0	6044	0	0	0	0	0	88	0
10	2.50	0	10833	0	0	0	4729	0	0	0	0	0	100	0
11	2.50	0	10890	0	0	0	3746	0	0	0	0	0	120	0
12	2.50	0	10950	0	0	0	5048	0	0	0	0	0	110	0
13	3.00	0	13113	0	0	0	3279	0	0	0	0	0	192	15330
14	3.00	0	0	9657	0	720	3257	0	0	0	0	0	168	0
15	3.00	0	0	10551	0	0	3714	0	0	0	0	0	132	0
16	3.00	0	0	9750	0	0	2358	0	0	0	0	0	144	0
17	4.00	0	0	12500	0	0	3596	0	0	0	2534	0	288	0
18	4.00	0	0	12760	0	0	3809	0	0	0	0	0	240	0
19	4.50	0	0	14040	0	0	4572	0	0	0	0	0	216	0
20	5.00	8618	21790	0	0	6500	16878	0	0	0	4460	0	440	0
21	6.00	0	26190	0	0	0	18265	0	0	0	5184	0	336	0
22	7.00	0	30485	0	0	0	27983	0	0	144	0	0	336	0
23	8.00	0	0	25280	0	0	29440	0	0	0	5947	0	576	0
24	10.00	0	0	31450	0	0	0	12291	23859	0	4420	0	800	0
25	10.00	0	44000	0	0	0	0	7325	11952	0	0	0	560	0
26	12.00	20592	0	39780	0	0	0	18666	17934	0	0	0	768	0
27	15.00	35370	0	49500	0	0	0	9945	15555	0	0	0	1320	0
28	20.00	22680	0	0	58900	0	0	23808	14592	411	3978	0	2240	0
29	25.00	47213	0	0	74500	20250	0	38684	18204	0	0	17040	2800	118625
30	25.00	59500	0	0	71325	60000	0	8961	29999	503	44000	11360	3400	0
31	30.00	71820	0	0	89550	25560	0	3866	60574	312	0	2516	4800	0

Appendix 2.2 (Continued)

			Seed				Labour				Chemicals			
#	Farm size	Fertilizer	Magoye	Hemone	Santa rosa	Lime	Family	Hired	Managerial	Inoculum	Herbicides	Pesticides	Bags	Fuel
32	30.00	68580	0	0	86490	0	0	53460	68040	648	22352	41139	4080	0
33	30.00	39720	0	0	86040	0	0	19026	71574	0	6433	35957	4320	113880
34	35.00	63000	0	0	103250	0	0	65150	89968	770	0	40950	6160	125195
35	40.00	68040	0	0	119520	52800	0	45089	95814	0	32954	0	6400	189800
36	40.00	108000	0	135280	0	0	0	39977	126592	0	4638	23982	5440	204400
37	45.00	77625	0	0	128880	0	0	39738	149491	1125	21443	53393	5400	229950
38	45.00	112950	0	156915	0	34808	0	5684	107987	929	30906	38329	6480	229950
39	50.00	56950	0	112934.5	48400.5	0	0	46524	147326	0	26463	17124	8800	237250
40	50.00	125900	0	169000	0	9500	0	57618	100832	1021	42318	0	8000	237250
41	50.00	85050	0	0	147400	0	0	36877	180048	0	0	68128	8800	273750
42	55.00	187688	0	0	158125	106425	0	42273	180218	1220	17573	37296	9240	301125
43	60.00	141000	0	0	169200	0	0	13805	216278	1200	37133	71602	10080	306600
44	80.00	181440	0	277920	0	17600	0	87588	142908	1640	10652	27248	11520	379600
45	80.00	250400	0	0	228640	200000	0	52696	186832	1692	68447	0	14080	394200
46	100.00	460200	0	308000	0	14125	0	44794	179176	2255	54000	52240	13600	306600
47	100.00	226800	0	0	291800	12200	0	16664	191631	2110	0	67961	12800	511000
48	100.00	435600	0	0	298400	0	0	171212	73376	2240	0	68138	13600	438000
49	110.00	406560	0	0	317900	0	0	23069	186647	0	75558	70626	19360	521950
50	120.00	208260	0	0	346320	163200	0	16778	192952	0	48282	183730	20160	613200
51	120.00	191250	0	0	346200	0	0	91598	203878	0	52928	205049	18240	613200
52	150.00	500250	0	0	432000	0	0	88369	196691	3392	67500	361869	19200	766500
53	150.00	463125	0	0	432000	0	0	36134	221965	4500	127197	51220	26400	711750
54	185.00	524938	0	0	536130	0	0	30697	248367	4148	117882	0	25160	945350
55	201.00	572348	0	0	566820	99495	0	250495	213384	4539	157584	387850	36984	953745

Appendix 2.3 Capital Input

#	Farm size	Total Cost			Total Horsepowers		
		oxen	tractor	combine	oxen	tractor	combine
1	0.25	300	0	0	1	0	0
2	0.50	145	0	0	2	0	0
3	0.81	243	0	0	2	0	0
4	1.00	800	0	0	2	0	0
5	1.00	500	0	0	2	0	0
6	1.50	1425	0	0	2	0	0
7	2.00	1700	0	0	2	0	0
8	2.00	1200	0	0	2	0	0
9	2.00	1600	0	0	2	0	0
10	2.50	2125	0	0	2	0	0
11	2.50	2250	0	0	2	0	0
12	2.50	2375	0	0	3	0	0
13	3.00	0	1146	0	2	100	0
14	3.00	0	1530	0	2	80	0
15	3.00	0	1500	0	2	90	0
16	3.00	2400	0	0	3	50	0
17	4.00	6000	0	0	2	0	0
18	4.00	3000	0	0	3	0	0
19	4.50	3645	0	0	4	0	0
20	5.00	4250	0	0	4	0	0
21	6.00	900	0	0	4	0	0
22	7.00	4480	0	0	3	0	0
23	8.00	1000	0	0	4	0	0
24	10.00	200	40000	0	0	160	200
25	10.00	0	60000	0	0	280	0
26	12.00	0	57600	0	0	100	0
27	15.00	0	73800	0	0	150	0
28	20.00	0	96000	0	0	130	0
29	25.00	0	10000	87500	0	200	400
30	25.00	0	150000	100000	0	180	400
31	30.00	0	180000	105000	0	250	450
32	30.00	0	37500	90000	0	220	350
33	30.00	0	40440	102000	0	230	400
34	35.00	0	22484	102000	0	210	400
35	40.00	0	18384	134000	0	200	400
36	40.00	0	22000	160000	0	200	500

Appendix 2.3 (Continued)

#	Farm size	Total Cost			Total Horsepowers		
		oxen	tractor	combine	oxen	tractor	combine
37	45.00	0	17415	157500	0	260	400
38	45.00	0	17424	162000	0	200	500
39	50.00	0	22500	150000	0	190	600
40	50.00	0	19490	155000	0	250	550
41	50.00	0	28200	150000	0	240	400
42	55.00	0	29700	109000	0	270	400
43	60.00	0	24000	174000	0	250	600
44	80.00	0	31000	272000	0	280	600
45	80.00	0	62400	213120	0	180	400
46	100.00	0	105936	150000	0	250	0
47	100.00	0	77100	160000	0	270	500
48	100.00	0	115560	320000	0	250	600
49	110.00	0	126885	192500	0	280	400
50	120.00	0	137700	180000	0	320	600
51	120.00	0	91920	250000	0	300	600
52	150.00	0	114750	130000	0	250	500
53	150.00	0	171900	90000	0	350	600
54	185.00	0	213120	555000	0	300	600
55	201.00	0	230346	578880	0	300	500

Appendix 2.4 Farm Prices (K/Unit)

#	Output	Fertilizer	Seed			Lime	Labour			inoculum	Chemicals	
			Magoye	Hemone	Santa rosa		Family	Hired	Managerial		Herbicide	Pesticide
1	8.91	11.34	43.33			1.25	10.00			20.00	880.00	1135.00
2	8.91	11.34	43.90			1.20	10.73			20.00	880.00	1135.00
3	8.91	11.34	43.33			1.20	7.50			20.00	880.00	1135.00
4	8.91	11.34	43.50			1.20	10.70			20.00	880.00	1135.00
5	8.91	11.34	43.33			1.20	10.30			20.00	880.00	1135.00
6	8.91	11.34		30.20		1.20	10.23			20.00	880.00	1135.00
7	8.91	11.34	43.38			1.20	11.30			20.00	880.00	1135.00
8	8.91	11.34		30.20		1.20	12.30			20.00	880.00	1135.00
9	8.91	11.34		30.20		1.20	10.75			20.00	880.00	1135.00
10	10.91	11.34	43.33			1.20	11.30			20.00	880.00	1135.00
11	9.91	11.34	43.56			1.20	11.43			20.00	880.00	1135.00
12	10.91	11.34	43.80			1.20	12.45			20.00	880.00	1135.00
13	10.91	11.34	43.71			1.20	11.25			20.00	880.00	1135.00
14	9.99	11.34		32.19		1.20	10.50			20.00	880.00	1135.00
15	10.91	11.34		35.17		1.20	11.88			20.00	880.00	1135.00
16	8.95	11.34		32.50		1.20	11.65			20.00	880.00	1135.00
17	8.99	11.34		31.25		1.20	12.42			20.00	880.00	1135.00
18	9.91	11.34		31.90		1.20	12.15			20.00	880.00	1135.00
19	9.96	11.34		31.20		1.20	10.74			20.00	880.00	1135.00
20	10.91	11.49	43.58			1.30	12.40			20.00	892.00	1135.00
21	10.99	11.34	43.65			1.20	12.12			20.00	900.00	1135.00
22	12.99	11.34	43.55			1.20	12.50			20.50	880.00	1135.00
23	12.97	11.34		31.60		1.20	13.20			20.00	885.00	1135.00
24	10.97	11.34		31.45		1.20		22.50	2000.00	20.00	884.00	1135.00
25	11.18	11.34	44.00			1.20		18.90	1000.00	20.00	880.00	1135.00
26	10.63	11.44		33.15		1.20		31.00	1500.00	20.00	880.00	1135.00
27	10.65	11.79		33.00		1.20		24.00	1300.00	20.00	880.00	1135.00
28	11.99	11.34			29.45	1.20		30.00	1200.00	20.55	856.00	1135.00
29	10.45	12.56			29.80	1.35		25.50	1500.00	20.00	880.00	1136.00
30	11.78	11.90			28.53	1.60		25.60	2500.00	20.12	880.00	1136.00
31	12.50	11.97			29.85	1.42		20.00	5070.00	10.40	880.00	1130.00

Appendix 2.4 (Continued)

#	Output	Fertilizer	Seed: Magoye	Seed: Hemone	Seed: Santa rosa	Lime	Labour: Family	Labour: Hired	Labour: Managerial	inoculum	Chemicals: Herbicide	Chemicals: Pesticide
32	11.41	11.43			28.83	1.20		15.00	5700.00	21.60	887.00	1136.00
33	11.06	13.24			28.68	1.20		10.00	6000.00	20.00	893.45	1135.00
34	11.96	12.00			29.50	1.20		30.50	7500.00	22.00	880.00	1200.00
35	11.89	11.34			29.88	1.32		27.38	8000.00	20.00	915.40	1135.00
36	11.99	13.50		33.82		1.20		29.83	10500.00	20.00	682.00	1142.00
37	11.99	11.50			28.64	1.20		25.64	12500.00	25.00	882.41	1130.00
38	11.94	12.55		34.87		1.19		18.00	9000.00	20.65	880.52	1135.67
39	12.99	11.39		33.86	28.55	1.20		25.00	2300.00	20.00	882.10	1141.61
40	12.80	12.59		33.80		1.90		27.00	8500.00	20.41	881.62	1135.00
41	10.25	11.34			29.48	1.20		29.54	15000.00	20.00	880.00	1135.47
42	11.91	13.65			28.75	1.29		26.64	15000.00	22.19	887.50	1130.16
43	10.99	11.75			28.20	1.20		33.53	18000.00	20.00	884.12	1136.54
44	11.68	11.34		34.74		2.20		31.80	12000.00	20.50	887.96	1135.32
45	9.95	12.52			28.58	2.00		30.33	15500.00	21.15	891.24	1135.00
46	10.67	15.34		30.80		1.25		28.57	15000.00	22.55	900.00	1306.00
47	11.78	11.34			29.18	1.22		32.59	16000.00	21.10	880.00	1132.68
48	10.91	14.52			29.84	1.20		30.15	10500.00	22.40	880.00	1135.64
49	11.91	12.32			28.90	1.20		30.80	15500.00	20.00	891.27	1130.00
50	10.58	11.57			28.86	1.36		29.55	16000.00	20.00	894.12	1134.13
51	10.87	12.75			28.85	1.20		32.85	17000.00	20.00	882.13	1139.16
52	12.58	13.34			28.80	1.20		32.40	16500.00	22.61	900.00	1206.23
53	11.00	12.35			28.80	1.20		33.58	18570.00	30.00	883.31	1138.23
54	10.91	11.35			28.98	1.20		33.15	20700.00	22.42	885.00	1135.00
55	11.91	11.39			28.20	1.98		30.98	17900.00	22.58	980.00	1206.00

Appendix 2.5 Total Variable Inputs (Kgs)

#	Fertilizer	Seed: Magoye	Seed: Hemone	Seed: Santa rosa	Lime	Inoculum	# of Bags
1	0	25	0	0	25	0	3
2	0	50	0	0	0	0	3
3	0	81	0	0	0	0	4
4	0	100	0	0	0	0	7
5	0	100	0	0	0	0	6
6	0	0	150	0	0	0	11
7	0	200	0	0	0	0	12
8	0	0	200	0	0	0	10
9	0	0	200	0	0	0	11
10	0	250	0	0	0	0	13
11	0	250	0	0	0	0	15
12	0	250	0	0	0	0	14
13	0	300	0	0	0	0	24
14	0	0	300	0	600	0	21
15	0	0	300	0	0	0	17
16	0	0	300	0	0	0	18
17	0	0	400	0	0	0	36
18	0	0	400	0	0	0	30
19	0	0	450	0	0	0	27
20	750	500	0	0	5000	0	55
21	0	600	0	0	0	0	42
22	0	700	0	0	0	7	42
23	0	0	800	0	0	0	72
24	0	0	1000	0	0	0	100
25	0	1000	0	0	0	0	70
26	1800	0	1200	0	0	0	96
27	3000	0	1500	0	0	0	96
28	2000	0	0	2000	0	20	165
29	3759	0	0	2500	15000	0	280
30	5000	0	0	2500	37500	25	350

Appendix 2.5 (Continued)

#	Fertilizer	Seed			Lime	Inoculum	# of Bags
		Magoye	Hernone	Santa rosa			
31	6000	0	0	3000	18000	30	600
32	6000	0	0	3000	0	30	510
33	3000	0	0	3000	0	0	540
34	5250	0	0	3500	0	35	770
35	6000	0	0	4000	40000	0	800
36	8000	0	4000	0	0	0	680
37	6750	0	0	4500	0	45	675
38	9000	0	4500	0	29250	45	810
39	5000	0	3335	1695	0	0	1100
40	10000	0	5000	0	5000	50	1000
41	7500	0	0	5000	0	0	1100
42	13750	0	0	5500	88688	55	1155
43	12000	0	0	6000	0	60	1260
44	16000	0	8000	0	8000	80	1440
45	20000	0	0	8000	100000	80	1760
46	30000	0	10000	0	11300	100	1700
47	20000	0	0	10000	10000	100	1600
48	30000	0	0	10000	0	100	1700
49	32927	0	0	11000	0	0	2420
50	18000	0	0	12000	120000	0	2520
51	15000	0	0	12000	0	0	2280
52	37500	0	0	15000	0	150	2400
53	37500	0	0	15000	0	150	3300
54	46250	0	0	18500	0	125	3145
55	50250	0	0	20100	50250	147	4623

Appendix 2.6 Government announced producer & input prices in 1990/91 crop season

	Government	LintCo prices	Zamseed Prices
Produce price (K/Kg)	8.91		
Seed (K/Kg):			
i) Santa rosa			28.16
ii) Magoye		43.33	29.80
iii) Hernone		30.20	33.00
Fertilizer	11.34 K per kg		
Lime	1.20 K per kg		
Inoculum	20.00 K per pkt		
Herbicide	1135.00 k per lt		
Pesticide	880.00 k per lt		
Casual/Hired Labour	30.00 K per day		
Tractor hire	1500.00 K per hour		
Oxen hire	850.00 K per hectare		
Combine hire	3500.00 K per hectare		
Grain bags	8.00 K per bag		
Fuel	36.50 per lt		

Note: Private companies and farmers are allowed to negotiate for a price other than that announced by Government or parastatal companies.