Size Efficiency of Sugarcane Farms in KwaZulu-Natal[1]

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ABSTRACT

The analysis is based on survey data collected from small and large sugarcane farms during 1995 in the North Coast region of KwaZulu-Natal. A non-parametric research procedure to analyse farm efficiency was employed. Results indicate that farms smaller than eight hectares exhibit substantial economies of size; such economies tend to decline with size of enterprise; and farms larger than 10 hectares appear to have near constant returns to scale. This implies that efficiency of very small scale sugarcane farms can be enhanced by land consolidation while giving small scale farmers larger than 10 hectares access to the large scale commercial sector, may not lead to a loss in efficiency. Results are relevant as South Africa is embarking on settling small scale farmers on former large scale commercial farm land.

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1 INTRODUCTION

With government policies focusing on issues of equity and efficiency, the relationship between farm size and farm efficiency is of interest to South African (SA) agricultural policy makers (Van Zyl, 1994). Land reform has been accorded high priority by the national government and is expected to alter the distribution of farm sizes appreciably over a short period of time (Department of Land Affairs, 1996, pp. 4). As a vehicle to uplift living standards of people in rural areas in KwaZulu-Natal, the South African Cane Growers' Association (SACGA), is directing resources to develop small sugarcane growers (Chadwick and Sokhela, 1992). Sugarcane production is viewed as having the potential to support small-scale commercial agriculture, and the capacity to absorb a substantial amount of labour (Small Grower Financial Aid Fund-FAF, May 1992). This is compatible with recent policy shifts in South African agriculture where policy makers including the World Bank, believe small farmers can and should play a key role in developing rural areas in South Africa (SA). In the sugarcane industry, productivity differences are evident between small and large sugarcane farms, as average yield on small farms is 40 tons per hectare, compared to 55 tons per hectare on large scale farms (SACGA, 1994). There is a possible efficiency loss to the industry if emphasis is placed on small farm operations although some argue that efficiency of large scale farms results from policies which favour large farms over small-scale family type farms (Van Zyl, 1994; Binswanger, 1994).

In this study some information is provided on the trade-off between equity and efficiency if large sugarcane farms are subdivided into smaller units under the land redistribution programme. The critical question therefore discussed is the viability of very small farms, and what might be the effects on economic efficiency of the sugarcane industry if farm size structure were to change. Reasons for focusing on sugarcane farming include; the long history of small farms operating alongside large-scale farms, and the importance of the crop in the agricultural economy of KwaZulu-Natal, accounting for about 41 % gross value of agricultural products in the province (Erskine, 1982).

The main purpose of this paper is to examine how efficiency of resource use varies with size of a farm business, and implications which variations in performance might hold for the reallocation of resources between size-groups in pursuit of land redistribution. Efficiency differences in resource utilisation on farms were studied using data collected from a sample of 160 small and large sugarcane units in the North Coast region of the KwaZulu-Natal sugarcane belt. The presence of both small and large-scale farm units in the region enabled the collection of information showing resource use on a wide range of farm sizes, operating in relatively homogeneous agro-climatic conditions, and under a similar land tenure regime (private ownership).

Studies on farm size efficiency relationships in SA show mixed evidence for the existence of scale efficiencies (Van Zyl, 1995). Empirical studies showing inverse relationship between farm size and efficiency have a tendency to overlook the fact that the adoption and use of any technology involves fixed transaction and information costs (Lyne, 1996). Likewise many studies are based on information collected from "medium" and "large" commercial farms (Van Zyl, 1995), thereby drawing conclusions in isolation of information from the very small farms. In this study farms studied range from one to six hundred hectares, small farms are defined as farms of twenty hectares and below under sugarcane, as defined by the South African Cane Growers' Association (SACGA). The sample is stratified to maximize the variation of the farm size variable in order to study the effect of this variable on efficiency.

2 ANALYSIS OF FARM SIZE EFFICIENCY, OPTIONS AND CONSIDERATIONS

2.1 Meaning of efficiency

Conventional definitions of efficiency are in terms of the optimality conditions associated with the perfectly competitive norm, that is, "the marginal rates of substitution between any two commodities or factors must be the same in all their different uses" (Pasour, 1981). This implies a comparison of the observed situation with a defined efficiency norm. The 'perfect market' norm is often used in agriculture as agricultural producers are almost always price-takers. However, this norm has three important assumptions; (a) perfect communication, (b) instantaneous equilibrium, and (c) costless transactions. Decision makers are thus assumed to have perfect knowledge about all relevant variables, including future occurrences (Pasour, 1981).

Pasour (1981) argues that real world decision makers will always appear inefficient when measured against the perfect market norm which assumes away uncertainty and information costs. To be meaningful, efficiency measures must be based on the costs and returns which face the individual decision maker. Therefore many economists (Friedman, 1962; Pasour, 1981), contend that it is difficult to measure efficiency, because individual decision makers have different cost functions as they value opportunity costs differently and display different attitudes towards risk. Individual farmers therefore each have an optimum farm size and there is no single optimum farm size for all farmers.

The existence of specialized factors of production (Friedman, 1962, pp. 141) introduces an additional reason why firms should differ in size. In any industry where resources used cannot be regarded as unspecialized, there will tend to be firms of different sizes, hence one could speak of an "optimum distribution of firm size" rather than "optimum" size of a firm (Friedman, 1962, pp. 142). In a market economy an optimum distribution of farm size may occur, and a study of optimum size is thus superfluous. However in South Africa, where government is encouraging small farm development, the issue of efficiency and equity becomes relevant. In this study the term 'efficient farm' refers to a farm utilizing less resources than other farms to generate a given quantity of output. Alternatively, for a given quantity of resources they generate a greater output. This superior performance is manifested in higher efficiency ratios (output per unit of input), and a lower cost per unit of production. Therefore, agricultural efficiency is attained when the greatest possible product is achieved from a given stock of resources, or conversely, when a minimum input of resources is used to produce a given level of output.

2.2 Sources of efficiency (economics of size or scale)

Experience in agriculture as well as manufacturing industries has frequently confirmed that average costs per unit produced (or sold) decline as fixed costs are spread over a greater output, so that the small farm or firm with limited output and/as well as certain unavoidable costs finds itself at a disadvantage (Britton and Hill, 1975, pp. 7). Fixed costs such as management, supervision, information and machinery can be used over more units of output (Krause and Kyle, 1970), resulting in reductions in cost per unit of output (increasing returns to scale or size).

Lower operating costs per unit of capacity are often given as a major source of economies of size in the use of fixed capital (Britton and Hill, 1975, pp. 121). Tractors and harvest machines reach their lowest cost of operation per unit at a much larger area, so optimum operational family farm sizes will increase with mechanization (Hall and LeVeen, 1978; Binswanger *et al*, 1992, pp. 24). But Rao (in Binswanger and Elgin, 1988) argues that, economies of scale for machines do increase minimum efficient farm sizes but by less than expected, because of rental markets for machines. The renting of machinery involves fixed transaction costs which introduces size economies that favour large farm operations (Lyne, 1996). Rental markets for machines, can circumvent the economies of scale inherent in machines only partly, because rental markets often are feasible not for time-bound operations, such as seeding in dry climate or harvesting where climatic risks are high (Binswanger and Elgin, 1988; Binswanger *et al*, 1992, pp. 21).

Binswanger, *et al* (1992, pp. 21), argue that in plantation crops like sugarcane, economies of scale arise from processing or marketing stage rather than in farm operation. Economies of scale in processing are transmitted to the farm because processing must occur within hours from harvesting[2] (Binswanger and Elgin, 1988). Binswanger *et al* (1992, pp. 22), further explain that where little co-ordination between harvesting and processing is required, markets (local and national) are supplied by family farms even in economies dominated by plantations[3]. This explanation, however disregards fixed transaction and information costs incurred in the use of technology at farm level.

Deininger and Binswanger (1992) believe that there is considerable empirical evidence to indicate that large-scale *unmechanised* agriculture is less efficient than small-scale farming based on the effort of labour. Family labour is thought to cost less than hired labour as there are no search and hiring costs (i.e. transaction costs are zero), and transaction and supervision costs may indeed be lower for family labour. However, in a situation where an active and diversified off-farm labour market prevails, such as in KwaZulu-Natal (Lyne and Ortmann, 1996), people with different skills command different wages. The opportunity cost of a family member used on the farm is therefore likely to approximate his or her expected wage rate (adjusted by the probability of employment). In this study family labour *shadow* price is imputed by costing operations performed by family labour based on what is paid to similar factors of production in similar occupations as suggested by Britton and Hill (1975, pp. 50). Management costs were imputed considering what a farm operator could earn in his/her best paid alternative employment (opportunity cost).

The adoption and use of any technology involves fixed transaction and information costs (Lyne, 1996). Information costs are fixed and therefore introduce size economies (Huffman, 1974; Welch, 1978, pp. 259). Therefore average cost curves vary among managers. with better managers having lower cost curves, due to lower information costs (Huffman, 1974). In this study, information costs were computed based on mean annual cash costs of farm information from private sources compiled in a study by Bullock (1994, pp. 58) on small and large commercial vegetable farmers in KwaZulu-Natal. Using ranked scores accorded by a respondent to reflect the extent of use of each of the listed information source as weights, average information costs for each individual farmer were computed.

2.2.1 *Costs of borrowing*

Economies of size that stem from borrowing capital remain less documented (Britton and Hill, 1975, pp. 110). Variability of production and 'informational imperfections' restrict the amount of credit available to small farmers as lenders seldom have enough information to determine which of the small farms are relatively productive and low risk borrowers (Carter, 1988). The cost of information required to determine the credit-worthiness may exceed the benefits to be gained from the relatively small loan amount. Transaction costs associated with many small loans act as a disincentive for lenders and the cost of credit to small farmers is likely to increase (Carter, 1988). In the presence of fixed transaction costs, the cost of borrowing in the formal credit market is therefore a declining function of the amount of owned land (Binswanger *et al,* 1992, pp. 26).

Experiences from lending agencies in SA (e.g KwaZulu Finance Corporation-KFC and Small Cane Growers Financial Aid Fund-FAF) regarding small farmers, is that costs of lending to small farmers are substantially higher for small farmers than large farmers (Bates, 1996). In the South African sugarcane industry, the actual cost of small loans during the survey was 14.5 % which is highly subsidized. Interest rates (reflecting administration and transactions costs) on loans to small farmers are expected to range between 30 % to 48 % if there were no subsidy. Mortgage bond rates paid by large farmers ranged between 15 % to 18.5 % during the respective period, while small farmers were charged 12.5 % in 1993/94 season (Bates, 1996). In this study a shadow price of 30% on average, is used to cost funds lent to small borrowers.

3 CONCEPTUAL FRAMEWORK

3.1 The measurement of farm efficiency

The study of efficiency falls into two broad categories; parametric and non-parametric. The parametric approach relies on a parametric specification of the production function, cost function, or profit function (Forsund *et al,* 1980; Bauer, 1990). Alternatively, production efficiency analysis relies on nonparametric methods (Seiford and Thrall, 1990). The nonparametric procedure of analysing efficiency is adopted in this paper. This section relies substantially on Chavas and Aliber (1993) and contains a summary of description of efficiency. The analysis of farm efficiency has typically centred on the technical, allocative and scale efficiency of production decisions (Farrell, 1957; Färe *et al*, 1994; Chavas and Cox, 1996). In this paper more emphasis is placed on scale efficiency because of the importance of the farm size variable in the analytics of this study.

3.1.1 *Scale Efficiency*

A firm is producing optimally at a given output **y** has been analysed through the measurement of returns to scale S, expressed as S(y, x, T_v). According to Chavas and Aliber (1993), returns to scale can be characterised from the production function T_v, as well as the cost function C(r, y, T_v). Returns to scale can be expressed from the cost function in terms of the ray average cost (RAC):

$$RAC\,(k, r, y, T_v) = C(r, ky, T_v)/k, \tag{1}$$

where; r is an (M x 1) input price vector $r = (r_1, r_2, ..., r_M)' \varepsilon \Re^{M+}$ denoting prices for inputs x represented by an (M x 1) input vector $x = (x_1, x_2, ..., x_M)' \varepsilon \Re^{M+}$ in the production of an (N x 1) output vector $y = (y_1, y_2, ..., y_N)' \varepsilon \Re^{N+}$, and $y \neq 0$. $\Re^{N+}$ denotes n-dimensional space of a specified technology. The set of all technologically feasible production plans (firm's production possibilities set ***y***) is a subset of $\Re^{N+}$ (Varian, 1992, pp. 2). The underlying technology is characterised by the production possibilities set T_v, where $(y - x)\ \varepsilon\ T_v$ is a non-empty, closed, convex, and negative monotonic set that represents a general technology under variable return to scale (VRTS). $\boldsymbol{k}\ \varepsilon \Re^+$ and measures the proportion by which output changes given a change in inputs. Assuming differentiability, let the elasticity of the ray average cost function with respect to k (evaluated at k = 1) be denoted by e=∂ln(RAC)/∂ln(k). Then under competition, the function S(y,x,T_v) evaluated at the cost minimizing solution $\boldsymbol{x}^*$ (Baumol, *et al*, 1982:55) can be expressed as:

$$S\,(y, x^*, T_v) = 1/(1+e) \tag{2}$$

Given the above definition of returns to scale in terms of **S**, it follows that returns to scale at the point ***y*** are increasing, constant, or decreasing whenever the elasticity of ***e*** is negative, zero, or positive, respectively. This implies that, when returns to scale are increasing, then the ray average cost RAC(k,r,y,T_v) is a decreasing function of ***k*** (where a proportional increase in output leads to a less than proportional increase in cost). Similarly, when returns to scale are decreasing, then the ray average cost RAC(k, r, y, T_v) is an increasing function of ***k*** (where a proportional increase in output leads to a more than proportional increase in cost). In the case where the RAC function has a U-shape, then constant returns to scale are attained at the minimum of the RAC with respect to *k*. This suggests the following index of scale efficiency:

$$SE(r, y, T_v) = AC\,(r, y, T_v)/C(r, y, T_v), \tag{3a}$$

where

$$AC(r, y, T_v) = \inf_k \{\frac{C(r, ky, T_v)}{k} : k > 0\}$$

denotes the minimal ray average cost function with respect to k. Clearly, 0<SE≤1. Values of the vector $\boldsymbol{y}$ that satisfy SE(r, y, T_v) = 1 identify an efficient scale of operation corresponding to the smallest ray average cost. Alternatively, finding SE(r, y, T_v)< 1 implies that the value of the vector is not an efficient scale of operation. In this case (1-SE) can be interpreted as the maximal relative decrease in the ray average cost that can be achieved by proportionally rescaling all outputs toward an efficient scale of operation (where the output vector $\boldsymbol{y}$ exhibits locally constant return to scale). SE(r, y, T_v) rises (declines) with a proportional augmentation in $\boldsymbol{y}$ under increasing (decreasing) return to scale. According to Chavas and Aliber, (1993), AC(r,y,T_v) can alternatively be expressed as:

$$AC(r, y, T_v) = c(r, y, T_c).$$

Therefore scale efficiency index SE(r,y,T_v) can be alternatively written as

$$SE(r, y, T_v) = C(r, y, T_c)/C(r, y, T_v) \tag{3b}$$

3.3 The nonparametric approach

Consider a sample of *n* observations on firms in a given competitive industry. Let y^i and x^i be the output vector and input vector, respectively, chosen by the *i*th firm, I = 1, 2, . . ., *n*. Denote the production possibility set of each firm in the industry by $\underline{T}$, with (y^i, - x^i) ε $\underline{T}$, I = 1, . . ., *n*, where $\underline{T}$ is a non-empty, closed, convex, and negative monotonic set. The question then is: how to use the production data, (y^i, x^i) I = 1, . . ., *n*, to provide a representation of the set $\underline{T}$. Following (Afriat, 1972; Färe, *et al*, 1985), consider the following nonparametric representation of $\underline{T}$.

$$T_v = \{(y, -x) : y \leq \sum_{i=1}^{n} \lambda_i y^i, x \geq \sum_{i=1}^{n} \lambda_i X^i, \sum_{i=1}^{n} \lambda_i = 1, \lambda_i \in \Re, \forall i\} \tag{4}$$

The set T_v in (4) is closed, convex, and negative monotonic. Under variable returns to scale, it is the smallest convex set that satisfies the monotonicity property and includes all the observations (y^i, x^i), $i = 1, \ldots, n$. As such, it corresponds to the inner bound of the underlying production possibility set $\underline{T}$ (Banker and Maindiratta, 1988). Using $\underline{T}_v$ in (4) as a representation of technology, the measurement of the Farrell technical efficiency index *TE* for the *i*th firm is obtained form the following linear programming problem:

$$TE(y^i, x^i, T_v) = \min_{k,\lambda} \{k_i : y^i \leq \sum_{j=1}^{n} \lambda_j y^j, k_i x \geq \sum_{j=1}^{n} \lambda_j X^j, \sum_{j=1}^{n} \lambda_i = 1, \lambda_i \in \Re, \forall j\} \tag{5}$$

Where r is the price vector for x. Then, based on T_v, in (4), the measurement of the Farrell allocative efficiency index *AE* for the *i*th firm is obtained from the cost function $C(r, y^i, T_v)$ being calculated from the following linear programming problem:

$$C(r, y^i, T_v) = \min_{x,\lambda} \{r'x : y^i \leq \sum_{j=1}^{n} \lambda_j y^j, x \geq \sum_{j=1}^{n} \lambda_j X^j, \sum_{j=1}^{n} \lambda_i = 1, \lambda_i \in \Re^{\cdot}, \forall j\} \tag{6}$$

Alternatively, under constant return to scale (CRTS), consider the following nonparametric representation of $\underline{T}$:

$$T_c = \{(y, -x) : y \leq \sum_{i=1}^{n} \lambda_i y^i, x \geq \sum_{i=1}^{n} \lambda_i X^i, \lambda_i \varepsilon \Re, \forall i\} \tag{7}$$

Comparing (4) and (7), note that $T_c \subseteq T_v$, in (7) is closed, convex, negative monotonic and exhibits CRTS (Afriat, 1972; Färe, *et al*, (1985). It is the smallest cone that satisfies the monotonicity property and includes all the observations (y^i, x^i), $I = 1, \ldots, n$. As such, it corresponds to the CRTS inner bound of the underlying production possibility set *T*. Based on T_c in (7) as a representation of the CRTS technology, consider calculating $C(r, y^i, T_c)$ from the following linear programming problem:

$$C(r, y^i, T_c) = \min_{x,\lambda} \{ r'x : y^i \le \sum_{j=1}^{n} \lambda_j y^j, x \ge \sum_{j=1}^{n} \lambda_j X^j, \lambda_j \in \Re^+, \forall j \} \tag{8}$$

Then, the scale efficiency index *SE* for the *i*th firm can be obtained from (7b), where $C(r, y^i, T_v)$ and $C(r, y^i, T_c)$ are given in (6) and (8). This analysis of production efficiency is conducted using data from KwaZulu-Natal sugarcane farmers.

4 ANALYTICAL METHOD

4.1 Data sources

Farm input/output data used in the analysis were collected from a sample of 160 small and large scale sugarcane operations in the North-Coast region of the KwaZulu-Natal sugarcane belt during March/April 1995. Data were collected on costs and returns for farms in different size classes. Data include reported sugarcane output and inputs such as: (a) hired and family labour; (b) management; (c) fertilizers; (d) herbicides, seeds, and other chemicals; (e) operating and machinery maintenance costs; (f) miscellaneous (rent, supplies and utilities); (g) cost of borrowed capital; (h) information cost (I) machinery (intermediate-run assets); and (j) land and buildings (long-run assets).

The measurement of the effect of size on overall economic efficiency requires valuing all inputs so that the relative proximity of each farm to the cost frontier can be determined (Hall and LeVeen, 1978). All inputs were therefore valued at their opportunity cost. This included the imputed value of family and farm operator labour (management)[4], and the opportunity cost for land and capital. Quantity measurements are annual flow variables. A 6% interest rate was used to transform machinery and tools[5] (intermediate-run capital inputs) to service flows. The six percent per annum is the average interest on machinery investment in SA (Ortmann, 1985, pp. 72). After adjusting farm size for differences in land quality within regions by using land values to normalize area, a 5% interest rate on the value of land was used as a measure of the flow resource of land. The rental rate of return for land in SA agriculture is about five percent (Nieuwoudt, 1987).

4.2 Descriptive statistics

Tests of the difference in means on major factor costs, which could be sources of economies of size in sugarcane farming on the sample farms, are presented in Table 1. The data indicate significant differences in per ton average cost of labour, operator labour services and information costs on small and large farm units studied, with small farms recording higher costs than large farms.

Table 1: Mean differences in economic characteristics of sugarcane farms in Kwazulu-Natal, 1993/94 season

		Small	Large	t-value
Area under cane (ha)	*Mean*	8.3	197	6.81***
	SD	5.75	218	
	n	(95)	(62)	
Labour costs/ton (Rand)	*Mean*	78.7	33.3	-3.37***
	SD	121.6	21.6	
	n	(87)	(51)	
Management costs/ton (Rand)	*Mean*	250	22.8	-6.10***
	SD	359.6	24.2	
	n	(93)	(59)	
Information costs/ton (Rand)	*Mean*	2.20	1.07	-2.29**
	SD	4.10	1.42	
	n	(85)	(32)	
Interest on borrowed capital (%)	*Mean*	23	15	-13.22***
	SD	3	3	
	n	(85)	(32)	

Table 1 continued

		Small	Large	t-value
Input costs/ton (Rand)	*Mean*	32.9	20.6	-2.61***
	SD	38.6	16.9	
	n	(93)	(56)	
Sales/ha (Rand)	*Mean*	4761	5463	1.95*
	SD	2212	2010	
	n	(88)	(55)	
Yield (tons/ha)	*Mean*	48	55	1.91*
	SD	22	20	
	n	(88)	(55)	
Machinery Investment/ton (Rand)	*Mean*	166.9	41.4	-2.65***
	SD	350	49.4	
	n	(56)	(43)	

Significant at: *** 1 per cent, ** 5 per cent and * 10 per cent level. Figures in parentheses represent valid sample cases. All inputs presented in this table are valued at their opportunity cost.

The combined expenditure reported for fertilizers and herbicides shows that large farms have a significantly lower average costs for these items. This supports the contention by Hall and LeVeen (1978) that the combined factors of pecuniary economies of size may account for at least as much of the cost advantages of large units as do technical economies of size. However, it cannot be determined from the data collected if cost savings derive from lower input prices or from more efficient use of the inputs. Yields are higher for large farms, suggesting the possibility that resources are better utilized (as a result of better management on these farms). Per ton investment in machinery is about 303% greater on small farms than on large farms, while per ton investment of labour is 136% higher on small farms.

4.3 Economies of size

For each farm, the optimal objective function for (5), (6), and (8) (refer to section 3.1) was calculated from the linear programming problems using the GAMS computer program. The long-run (LR) estimate of the Farrell technical efficiency index **TE** is given by (5), where all inputs are rescaled toward the frontier isoquant[6]. The LR estimate of the Farrell allocative efficiency (**AE**) index is given by (2) and (6). Treating all inputs as variable, the scale efficiency (**SE**) indexes were obtained from (7b). The indexes; TE, AE and SE estimated for each farm range between zero and one, with 100% efficiency indicated by a score of one. A summary of the results is presented in Table 2.

The 0.71 mean technical efficiency **TE** within the small-scale farm group, and 0.81 for the large farms (Table 2) shows that, while the average technical efficiency score of the small farms is lower than the average score of large farms, gains from improving LR technical efficiency do prevail, but tend to be of limited magnitude for large farms compared to small farms. This is also reflected by the difference in percentages of technically efficient farms (with **TE**=1) between the small and large farms. The mean allocative efficiency of 0.52 and 0.60 for both small and large farms respectively, suggests that price or allocative inefficiency is more important than technical inefficiency in causing farms to fall short of achieving the LR economic efficiency (**TE AE**). The low percentage of price efficient farms (with AE=1) 2.4% among the small farms and the 9.4% for large farms, indicates that improving allocative efficiency can help to reduce production costs on both large and small farms.

The mean scale efficiency SE index of 0.46 and 0.88 for the small and large farms respectively, suggests that while there are inefficiencies (technical and allocative) for small scale farms, they are not as large as inefficiencies which are related to size. However, the percentage of scale efficient farms (with SE=1) tends to be low even among large scale farmers (see Table 2 and Figure 1).

Table 2: Long-run efficiency indexes of sample sugar cane farmers in KwaZulu-Natal

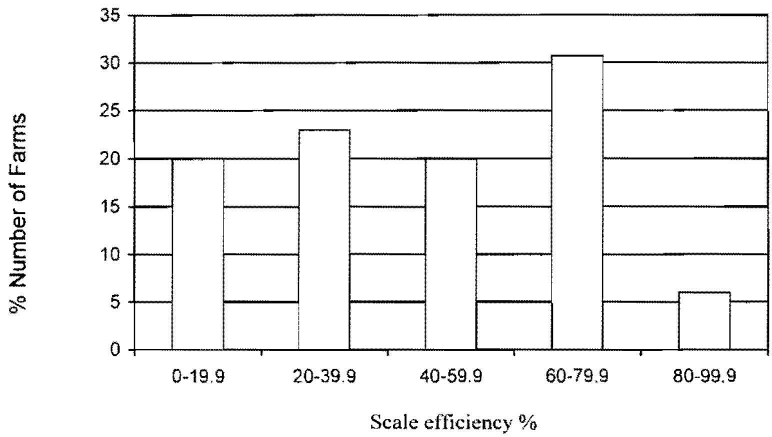
INDEX		SMALL-SCALE (n=85)	LARGE-SCALE (n=32)
Technical Efficiency (TE)	*Mean*	0.71	0.81
	SD	0.28	0.24
	% 1's	35.3	46.9
Allocative Efficiency (AE)	*Mean*	0.52	0.60
	SD	0.18	0.20
	% 1's	2.4	9.4
Economic Efficiency (TE AE)	*Mean*	0.37	0.49
	SD	0.21	0.24
	% 1's	1.2	9.4
Scale Efficiency (SE)	*Mean*	0.46	0.88
	SD	0.25	0.13
	% 1's	0	3.1

Note: Significant at *** 1 per cent,** 5 per cent and * 10 per cent level.

The inverse of scale efficiency index (**1/SE**) is plotted against output in Figure 2. Following the discussion in section 3.1.3, this inverse measure can be interpreted in a similar way to an average cost function (Chavas and Aliber, 1993). **1/SE** is a declining function of output/farm size under increasing returns to scale, and an increasing function of farm size under decreasing returns to scale.

Figure 1: Distribution of scale efficiency among sampled small and large sugarcane farms

1a Small Scale Farms



1b Large Scale Farms

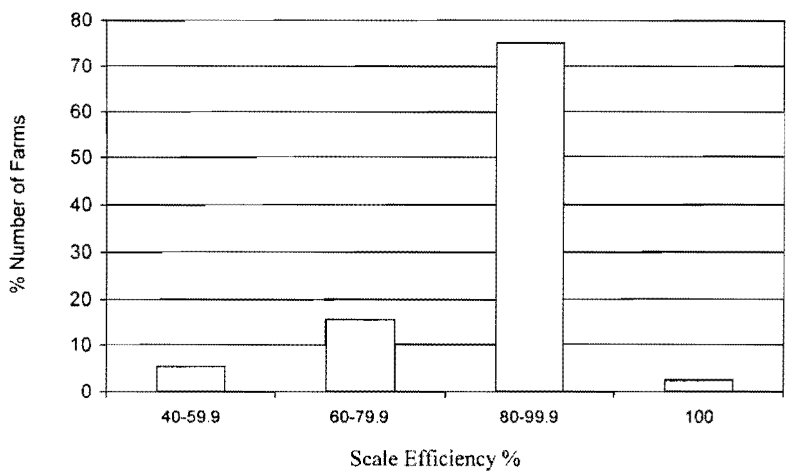
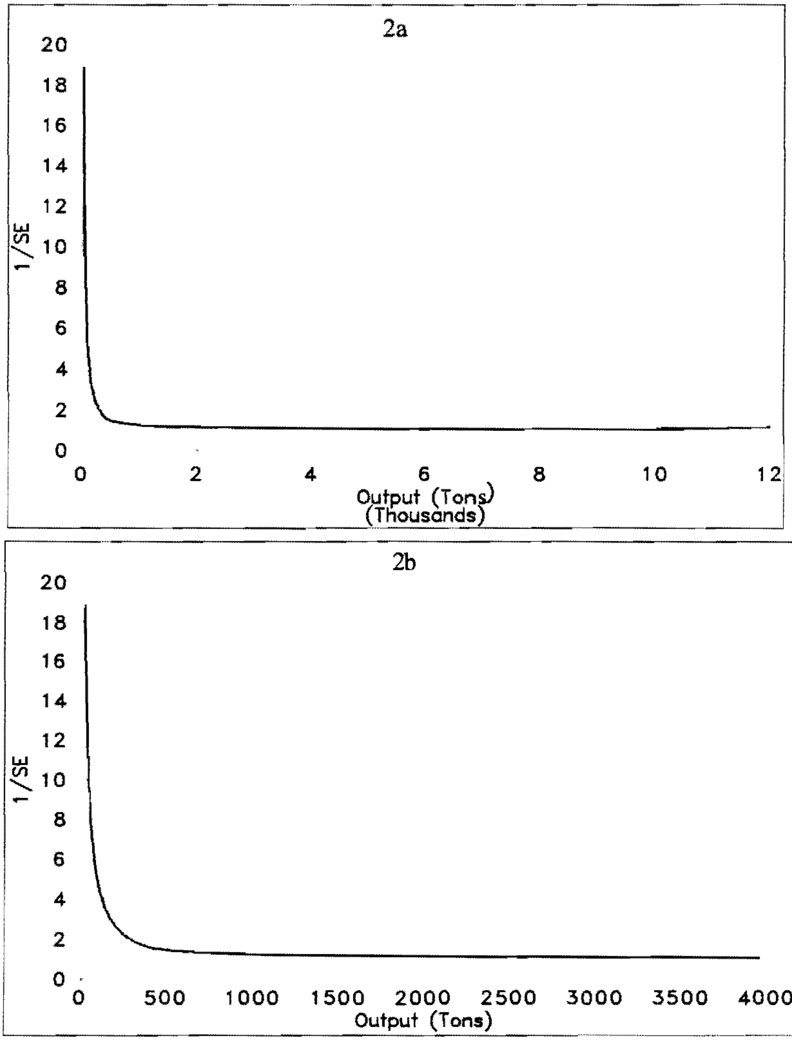


Figure 2: Economies of size in sugar cane production



Note: In Figure 2, graph (2b) gives details of graph (2a)

Figure 2, shows that the cost structure of sugarcane farms studied is "L"- shaped, indicating substantial economies of scale on very small scale farms. Diseconomies do not set in, thus the average cost remains relatively flat as typically found in previous research (Hall and LeVeen, 1978; Chavas and Aliber, 1993). Implications are that farms operating at the declining portion of the average cost curve (farms with gross income less than R 40 000) employ extra resources in the production process. In terms of area, these are farms of approximately 8 hectares and below. Farms larger than 10 hectares appear to have near constant returns to scale[7], which is in range with the 14 hectares estimated by Lyne and Ortmann (1996), as the size of a minimum sugarcane farm.

4.4 Further interpretations

Nonphysical inputs, for example; farming experience, information, and supervision tend to influence the ability of a producer to use the available technology efficiently (Parikh, *et al*, 1995). In this study, variation in scale efficiency recorded among farms prompted a further investigation of factors associated with differences in efficiency levels. Available data provided an opportunity to examine possible linkages between farm characteristics and farm efficiency by estimating an econometric model whereby scale efficiency indexes were regressed on a set of explanatory variables. With the largest possible value of SE indexes being 1, this generates the following Tobit model (McDonald and Moffitt, 1980; Chavas and Aliber, 1993; Gujarati, 1995, pp. 572).

$$SE_i \underset{1}{=} X_i B + e_i \qquad if \underset{otherwise.}{X_i B} + e_i < 1 \tag{9}$$

where SE_i is the scale efficiency index of *ith* farm, X_i is a vector of explanatory variables, β is a parameter to be estimated, and e_i is an error term $\sim N(0,\delta^2)$.

Explanatory variables in the tobit model were selected on the theoretical basis that; the level of education or farm operator improves efficiency performance of output as well as inputs in a production process (Kumbhakar and Bhattacharya, 1992). Likewise increased education and extension services improve allocative efficiency of farmers (Ram, 1980; Huffman, 1977; Parikh *et al*, 1995). However, age of household head has negative effects on efficiency (Parikh *et al,* 1995), because older farmers are constrained in resource utilization to attain scale efficiency. The explanatory variables in final estimated tobit model were; (a) an index (principal component) capturing farmers' formal education level and agricultural training, information use, and institutional extension supportive infrastructure (**PC_1**); (b) farm size in hectares (**FMSZE**); (c) age of farm operator (**AGE**); and a variable measuring farmer managerial proficiency (**ADOPT**)[7]. The results are presented in Table 3 below.

Table 3: Tobit Estimates

Explanatory Variable	Dependent Variable (SE)		
	Coefficient	Std. Error	t-Stat
Intercept	0.5921	0.0876	6.761***
PC_1	0.572	0.0275	2.076***
AGE	-0.0032	0.0013	-2.348***
ADOPT	0.1461	0.0013	2.544**
FMSZE	0.0004	0.0002	2.544**
n = 117			
Log-likelihood Function = 2.395			

Significant at: *** 1 percent and ** 5 percent

Tobit coefficients are estimated by the method of maximum likelihood (Breslaw, 1993, pp. 159). The value of a Tobit coefficient does not represent the expected change in the dependent variable given a one unit change in an explanatory variable (Norris and Batie, 1987). Rather, the Tobit model estimates a vector of normalized coefficients which can be transformed into the vector of first derivatives. Nonetheless, where such a decomposition is not relevant, beta coefficients are directly usable (McDonald and Moffitt, 1980) as in this study.

All coefficients of variables (PC_1, FMSZE, ADOPT, AGE) have *a priori* expected signs and are statistically significant. The positive relationship between SE and coefficients of variables PC_1, FMSZE, and ADOPT respectively, imply that high levels of knowledge attained by a farmer are associated with scale efficiency on a sugarcane farm. Large farms are more scale efficient, and farm operators demonstrating higher managerial abilities attain high level of scale efficiency on their farms. The negative sign on AGE implies that older farmers are constrained in resource utilization to attain scale efficiency. Human resource factors thus influence efficiency in farm resource use, supporting the results of Britton and Hill (1975, pp. 8).

5 CONCLUSIONS

A nonparametric approach of estimating technical, allocative and scale efficiencies was employed on a selected sample of 160 small and large sugarcane farms in the North Coast region of KwaZulu-Natal Sugar Belt. The method is flexible in the sense that it does not require imposing functional restrictions on technology as is typically done using a parametric approach. The procedure provides firm-specific information on sources, and magnitude of production efficiency by solving appropriately formulated linear programming models. Lack of statistical inferences associated with the estimates of the efficiency indexes is the major weakness of the method.

Farm-specific indexes for technical, allocative and scale efficiencies are estimated. Technical inefficiencies are rather limited among small and large sugarcane farms, with these farms attaining on average 71 % and 81 % level of technical efficiency, respectively. This indicates that economic losses are more generated by allocative inefficiencies, implying that most farms can find ways of reducing production costs. Small farms exhibited relatively high scale inefficiencies attaining on average 46% scale efficiency level, compared to 88% among large farms. Size of an operation therefore appears to affect the level of efficiency attainable in a sugarcane farm operation. Results show evidence of important economies of size in sugarcane production, with strong economies of size on farms less than eight hectares. This implies that smaller farms require relatively more resources to produce a rand's worth of output than large farms. If commercial farms are subdivided in the land resettlement programme, some significant efficiency loss may occur if resettled farms are less than eight hectares of planted sugarcane. Efficiency loss falls if resettled farms are larger than 10 hectares of cane.

An econometric analysis of efficiency indexes indicates significant linkages between scale efficiency and farmer characteristics, institutional factors and size of farm holdings. This suggests that the shape of the agricultural structure may not entirely be responsible for differences in efficiency but rather also a whole range of factors (for example, level of education, age and managerial proficiency) which are associated in different degrees with small and large farms. This implies that efficiency of very small scale sugarcane farms (less than 10 hectares) can be enhanced by land consolidation, farm operators' education, training and extension services for expansion and propagation of modern techniques of cane production, and by promoting the use of farm information. On the other hand, giving small scale farmers (farms larger than 10 hectares) access to the large scale commercial sector may not lead to a loss in efficiency, provided that land is individually owned. This require the repeal of Act 70 of 1970 which forbids the subdivision of agricultural land into 'non viable' farms.

ENDNOTES

1 The financial assistance of the Centre for Science Development (HSRC, South Africa) is hereby acknowledged. Opinions expressed and conclusions arrived at are those of the authors and are not necessarily attributable to the Centre for Science Development.

2 Sugarcane harvesting and processing must be well co-ordinated, for if cane is left unprocessed for more than 12 hours the sugar is lost to fermentation (Binswanger, *et al* 1992, pp. 22).

3 In Central America unrefined forms of sugar such as *muscovado*, where processing did not involve economies of scale, were produced by family farms (Binswanger, *et al* 1992, pp. 22).

4 The procedure is based on an assumption that the operators' main work activity even on the smallest farms is that of management and supervision.

5 Machinery and tools were valued at market prices to account for cost of depreciation.

6 Technology employed in sugarcane production on farms studies does not differ (i.e., both small and large farms are mechanised in most farm operations, sugarcane in the region studied is rain-fed, and both farm groups make considerable use of herbicides and fertilizers). Therefore the assumption of a single production frontier was made for both small and large in the analysis.

7 The conversion into hectares was done based on R 100 per ton of cane in crop season 1993/94, and average yield of 50 tons/ha recorded between small and large farms (see Table 1).

8 The variable ADOPT is computed as an average score recorded by a farmer on the implementation of appropriate farm practices (i.e., soil testing and use of certified seedcane)

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