Managerial Ability and its Influence on Size Economies in South African Dairy Production

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MANAGERIAL ABILITY AND ITS INFLUENCE ON SIZE ECONOMIES IN SOUTH AFRICAN DAIRY PRODUCTION.

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Abstract

Managerial ability, albeit an illusive concept, is related to analysis of size economies in South Africa's dairy production sector. Data from the 1997 production cost survey of 394 farms was used in econometric estimation of long run average cost (LAC) functions for different levels of (a proxy of) managerial ability. Results show that the LAC curves are U-shaped with greater economies than diseconomies of size. Also, better managers are shown to profitably produce any level of output at lower average cost per litre than other managers. In addition their optimum levels of output are between two and four times as large as firms with average or low levels of management. The better-managed enterprises are on average operating below their optimum levels, but low and average managed firms are producing output well in excess of their optima. Thus the hypothesised vertical and horizontal displacement of the LAC curve holds in the case of the South African dairy sector, as represented by the data set.

▪ INTRODUCTION

Deregulation in the South African agricultural sector led to the abolishment of the Dairy Marketing Board and the quota system. A number of new organisations developed to represent the interest of the diverse industry, particularly that of the broad range of milk producers. Low-volume producers (averaging less than 250 litres/day) constitute 18% of all dairy producers and deliver 9% of the total production. Eleven percent (11%) of raw milk deliveries to dairies is produced by farms that average more than 5 000 litres/day (1% of all milk producers). Figure 1shows the relative size and contribution of groups of milk producers.

The internationalisation of dairy markets seems to favour scale economies, yet the changes in food intake patterns and consumer expectations induce continuous changes in these international markets [Morrelson, 1998; Casala, 1998; Gillet, 1998; Hettinga, 1998]. Producers adjust the size of their operations accordingly to reap the benefits of the size economies.

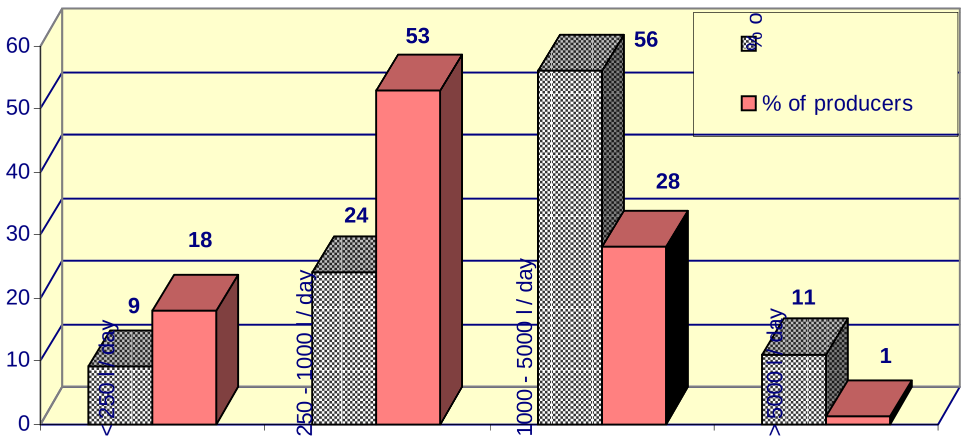

Figure 1: Comparing delivery per group to relative size of milk producer groups (1998).

Official figures of 1996 reported a total volume of 2 215 million litres of raw milk to the value of R 2,62 million produced with a cow stock of 562 000 cows in milk [IDF figures, 1996].

Data on the cost structures of 394 South African dairy farming operations was obtained from an annual production cost survey, conducted by SAMO[1] in 1997. This set of cross sectional data is used in the econometric estimation of long run average cost curves (LAC) for the dairy sector. From the LAC function, inferences are made regarding the prevailing economies of size. Despite the variability of nearly all inputs in the long run, management as a production input is assumed fixed. It represents the one input that co-

[1] South African Milk Organisation

ordinates the use of all other inputs, and frequently the management is in the hands of one person or a small number of people. Thus, an upper bound is placed on the firm' s long run expansion opportunities. However, management is rarely measurable and therefore a proxy of managerial ability, namely the efficiency in allocating the most substantial other input (feed), is employed [Dawson and Hubbard, 1987].

- **THEORY AND ASSUMPTIONS**

A typical problem in the collection of cost data is the absence of price and quantity information. Yet, with a cross-sectional study, in one year, the assumption can be made that farmers face the same market prices, and that observed differences can be ascribed to transaction cost (transportation cost or savings when buying inputs in bulk). These inter-farm differences are (assumed) negligible. The problem of lacking price and quantity information can be bridged through the application of duality theory, by which the indirect cost function can be estimated (for the evaluation of size economies).

In this analysis, the focus falls on the wider concept of economies of size, which encompasses economies of scale. However, size economies evaluates the unit cost variation associated with changes in some (one or more) or all inputs, as opposed to scale economies that measure the changes in production (output) due to a proportionate changes in all inputs. The former concept seems more realistic, since it is unlikely that proportionate changes will simultaneously occur in all inputs.

The LAC function, which shows the minimum production cost per unit, for every feasible level of output, is of interest in the analysis of size economies. Traditionally, the LAC-curve is assumed to be U-shaped due to the combination of average fixed- and average variable cost. Kaldor [1934] assumed that management, as a factor of production is fixed and that it fulfils a co-ordinating role between all other inputs. Dawson and Hubbard [1987] refer to studies in which L-shaped LAC-curves were inferred, based on the assumption that management and output is positively correlated, i.e. that larger farms also imply better management. Such an assumption ignores the impact of management, since better management should be associated with lower average production cost, at any level of output, not necessarily with large farms. Given this (fixed) level of managerial input, any firm's relative position to that of all other firms in the industry is represented on the LAC-curve.

The specific functional form of the LAC-curve depends on the researcher's assumptions regarding firms' economic behaviour and output. In this study, typical profit-maximising behaviour is assumed for all farms. Profit maximisation is achieved at the point of cost minimisation, for any given level of output [Varian, 1996; Chambers, 1991] and therefore the LAC-function should follow from a model in which output is given for each observation [Dawson and Hubbard, 1987].

A further assumption is that of a single, non-negative output (milk, measured in litres per year), denoted as Q. Output is produced through the combination of non-negative, homogenous and infinitely divisible flows of variable inputs, denoted as X_i (i = 1, ..., n), together with one strictly positive fixed input – management, denoted as X_M. A stochastic production function is assumed, in which the error term captures the effects of unpredictable variability (due to transaction cost, climatic differences, disease, etc.). The production function is also assumed to be twice differentiable, strictly quasi concave and the marginal products for each input is positive over the range of the function [Varian, 1996; Chambers, 1991].

The production function is defined as:

$$Q = f(X_1, X_2, ..., X_n, X_M) + \varepsilon$$

{Eq.1}

With profit maximisation as the firm' s goal, the objective is thus to minimise cost (C) for a given level of output, Q*. In mathematical terms the problem is:

$$\text{Minimise } C = \sum_{i=1}^{n} P_i X_i$$

{Eq.2}

Subject to:

$$Q^* = f(X_1, X_2, ..., X_n, X_M)$$

{Eq.3}

and invariant prices and noting that $\mathrm{E}[\varepsilon] = 0$

From the envelope theorem [Beattie and Taylor, 1993] the indirect cost function, $\tilde{C}$, is:

$$\tilde{C} = C^*(P_1, P_2, ..., P_n, Q^*, X_M)$$

{Eq.4}

C* is thus the minimum cost associated with the given or planned level of output, the fixed management input level and the given values of P_i (i=1,..., n). From {Eq.4} the minimum average cost (AC*) of producing Q*, is:

$$AC = \frac{TVC + TFC}{Q} = \frac{C^*(P_1, P_2, ..., P_n, Q^*, X_M)}{Q^*} = AC^*(P_1, P_2, ..., P_n, Q^*, X_M)$$

{Eq.5}

- **ESTIMATION PROCEDURES**

The Long run Average Cost curve provides a measure of the position of a firm relative to its competitors, and it is comprised of all feasible levels of output that a firm can realise on its expansion path [Dawson and Hubbard, 1987]. According to Johnston [1960], cross-sectional data is most suited to this type of analysis since the inter-temporal price variations are discounted (and captured in the error term) by the assumption that all farmers face the same prices at a given point in time.

The required "planned" levels of output (Q*) follows from the estimation of a production function, which is assumed to approximate the true production function. The specification of "managerial ability" poses a problem. In this study, an approach used by Dawson and Hubbard [1987] is followed. A proxy of managerial ability is taken as the “margin over feed cost per litre”, because feed cost constitutes on average 60% of all cost. A manager’ s ability to allocate this component on a day-to-day basis, in the process of profit maximisation, gives an indication of the manager’ s ability.

For the production function approximation, a translog functional form is chosen because it is a flexible second order approximation of some arbitrary form. It imposes a minimum of maintained hypotheses and restrictions on the form of economies of scale [Bairam, 1994]. Q* (measured in litres of milk per year) is estimated (in the translog form) as a function of feed cost (F), labour cost (L), capital cost (K) and management (M) as the inputs, X_i (i = F, L, K, M). Dawson and Hubbard [1987] explain how these estimated levels of output correspond with the required planned levels of output.

The assumed levels of minimum cost (C*) is divided by estimated levels of output (Q*) to obtain the AC* vector for each of the 394 observations. Estimated Q* is used as the independent variable (along with management) in the estimation of the LAC function. This approach has the underlying assumption that both the production and cost function are approximating the true functions, whereby the theory of duality is not violated [Dawson and Hubbard, 1987].

The production function is estimated in a log-linear form:

$$\ln Q^* = \alpha_0 + \sum_i \alpha_i \ln X_i + \alpha_M \ln X_M + \frac{1}{2}\sum_i \sum_j \alpha_{ij} \ln X_i \ln X_j + \sum_i \alpha_{iM} \ln X_i \ln X_M + \varepsilon$$

{Eq.6}

Then, the LAC function is estimated in log-linear translog format:

$$\ln AC^* = \beta_0 + \sum_i \gamma_i P_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \gamma_{iQ} \ln P_i \ln Q^* + \sum_i \gamma_{iM} \ln P_i \ln X_M + \beta_1 \ln Q^* + \beta_2 (\ln Q^*)^2 + \beta_3 \ln X_M + \beta_4 (\ln X_M)^2 + \beta_5 \ln Q^* \ln X_M + \upsilon$$

{Eq.7}

However, since prices are assumed equal and invariant, they do not enter the equation, and therefore the estimated equation takes on the form of:

$$\ln AC^* = \beta_0 + \beta_1 \ln Q^* + \beta_2 (\ln Q^*)^2 + \beta_3 \ln X_M + \beta_4 (\ln X_M)^2 + \beta_5 \ln Q^* \ln X_M + \upsilon$$

{Eq.8}

The random error term, v, is assumed to have the classical properties of zero expected value and constant variance [Pindyck and Rubinfeldt, 1991].

The translog functional form offers the advantage of a conventional U-shaped average cost curve, when drawn in an AC-Q space. It also requires the minimum of maintained hypothesis and restrictions concerning (dis-) economies of size and elasticities, i.e. the curve is *not* symmetric around the point of cost minimisation [Dawson and Hubbard, 1987]. Binswanger [1994] states several advantages of the use of the translog form for the cost function. Anderson, et al. [1996], discusses the wide use of the translog form, due to its flexibility.

Inclusion of management (a fixed asset) allows for evaluation of average cost at different levels of management along the complete expansion path. It is hypothesised that both a vertical displacement (higher or lower position of the LAC-curve) and a horizontal displacement (higher level of output at lower levels of average cost for firms with better management) will be evident when the LAC-curve is viewed in the AC-Q space.

The following section reports the estimation results and findings of the statistical tests.

▪ RESULTS[2]

When using cross-sectional data, the hypothesis of homoskedasticity[3] of the error term, and orthogonality[4] of the independent variables has to be tested. Tests (Goldfeld and Quandt) under alternative rankings of independent variables and the error term led to the rejection of the null hypothesis of homoskedastic errors. Yet, the exact cause and form of heteroskedasticity is not known. Therefore, Halbert White 's [1980] *heteroskedasticity-consistent covariance estimator* was used in the application of ordinary least squares (OLS) [White, K.J., 1987]. This *estimator* does not rely on knowledge of the source or functional form of heteroskedasticity and in the absence of heteroskedasticity the OLS variance-covariance matrix will be the same as that generated by the *estimator* [White, H., 1980]. Using this estimator will ensure that the standard errors from the OLS estimation will be unbiased and consistent, thus allowing reliable interpretation of the estimated parameters.
The calculated Farrar-Glauber test statistics are all significantly different from zero, thereby calling for a rejection of the null hypothesis (of orthogonality between the independent variables) [Koutsoyiannis, 1991]. However, it is felt that the presence of some degree of multicollinearity is not too harmful, since the main concern is not the parameter estimates of the production function, but rather the predicted values of planned output (Q*).

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[2] A 5%-level of significance is used throughout the analysis

[3] Homoskedasticity is the assumption that the variance of the random error term is constant for all observations on the independent variable(s) [Koutsoyiannis, 1991].

[4] Orthogonal variables are variables with zero covariance [Koutsoyiannis, 1991]. If the covariance between two explanatory variables is not zero, it is seen as a movement away from orthogonality, and termed multicollinearity.

In Table 1 the approximated production function results are given. At the point of approximation (where the logs of all variables are set equal to one) [Sadoulet and De Janvry, 1995] only the capital input (X_K) violates the increasing marginal returns assumption. The presence of multicollinearity obscures the interpretation of the adjusted R^2, which tends to be higher in the presence of multicollinearity. Yet, these results are used to calculate the expected output levels (Q*).

Table 1: Results from the OLS estimation of the translog production function in Eq.6

Variable	Parameter	Value	Std. Error	t-Statistic	Prob.
Constant	α_0	3.341	1.805	1.850	0.065
Ln (X_L)	α_L	-0.335	0.193	-1.737	0.083
Ln (X_F)	α_F	0.728	0.334	2.176	0.030
Ln (X_K)	α_K	-0.016	0.018	-0.908	0.365
Ln (X_M)	α_M	2.947	0.959	3.071	0.002
[*Ln* (X_L)] ^{2}	α_{LL}	0.005	0.003	3.598	0.000
[*Ln* (X_F)] ^{2}	α_{FF}	0.005	0.037	0.295	0.768
[*Ln* (X_K)] ^{2}	α_{KK}	0.001	0.001	2.283	0.023
[*Ln* (X_M)] ^{2}	α_{MM}	0.088	0.014	12.351	0.000
Ln (X_L)**Ln* (X_F)	α_{LF}	0.014	0.017	0.836	0.404
Ln (X_L)**Ln* (X_K)	α_{LK}	0.004	0.001	4.364	0.000
Ln (X_L)**Ln* (X_M)	α_{LM}	0.404	0.064	6.364	0.000
Ln (X_F)**Ln* (X_K)	α_{FK}	-0.002	0.002	-1.225	0.221
Ln (X_F)**Ln* (X_M)	α_{FM}	-0.508	0.095	-5.343	0.000
Ln (X_K)**Ln* (X_M)	α_{KM}	0.001	0.006	0.154	0.878
R^2	0.962		Mean dependent variable		12.325
R^2-adjusted	0.961		S.D. dependent variable		0.963
S.E. of regression	0.190		Akaike info criterion		-0.446
Log likelihood	102.876		Schwarz criterion		-0.295
F-statistic	694.416		Probability (F-statistic)		0.000

Figure 2 shows graphically how good the estimated production function fits the observed data.

Table 2 reports the results from regressing the Q* and management proxy (X_M) variables on the indirect average cost, AC* (from {Eq.8}). In the estimation of AC*, White 's [1980] *heteroskedasticity-consistent covariance estimator* was used. Figure 3 shows the actual and estimated values of average cost (in natural logarithms) as well as the regression residuals.

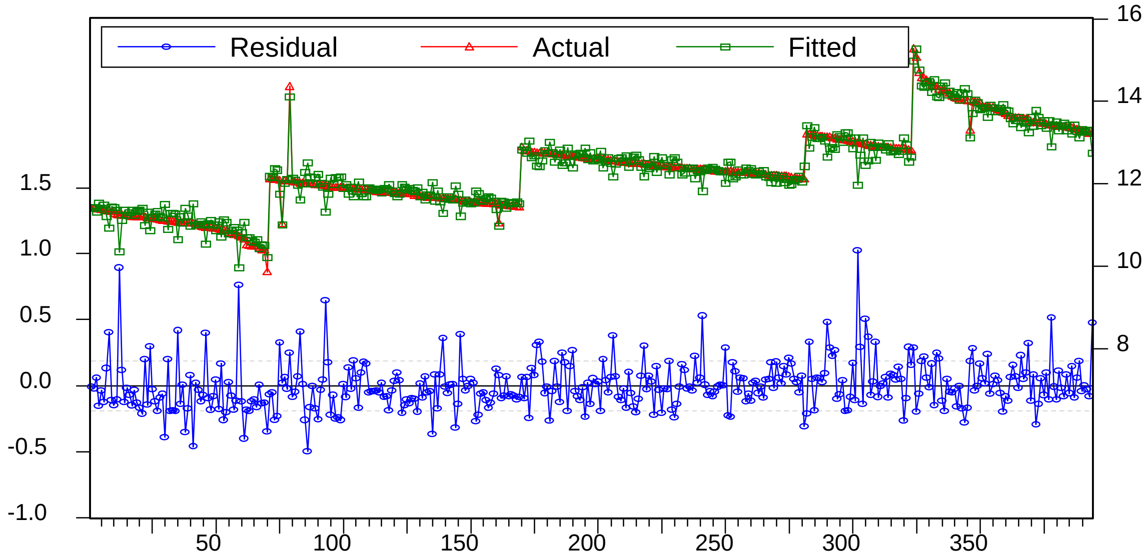

Figure 2: Estimated (Q*) versus actual (Q) litres of milk per year (in logarithms)

Table 2: OLS estimation of the translog long run average cost function in Eq.7

Variable	Parameter	Value	Std. Error	t-Statistic	Prob.
Constant	β_0	3.430	1.404	2.443	0.015
Ln (Q*)	β_1	-0.512	0.225	-2.273	0.024
Ln (M)	β_2	0.273	0.718	0.380	0.704
[*Ln* (Q*)] ²	β_3	0.022	0.009	2.392	0.017
[*Ln* (M)] ²	β_4	-0.063	0.005	-12.142	0.000
Ln (Q*)**Ln* (M)	β_5	-0.090	0.060	-1.484	0.139
R-squared	0.560		Mean dependent var		0.118
Adjusted R-squared	0.555		S.D. dependent var		0.344
S.E. of regression	0.230		Akaike info criterion		-0.090
Log likelihood	23.636		Schwarz criterion		-0.029
F-statistic	98.910		Prob (F-statistic)		0.000

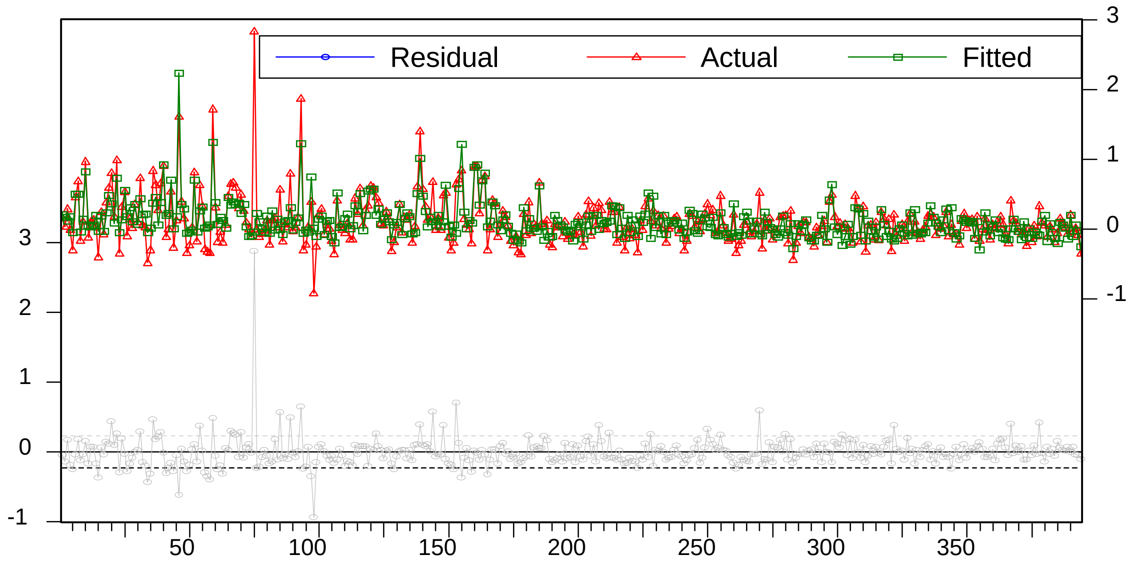

Figure 3: Estimated versus observed average cost per litre (in logarithms)

It is clear that the specification of the LAC function does not capture all the variation in the variable. The regression results are nevertheless used to evaluate the average cost per litre of milk, given different levels of management. Similarly, the optimum (cost minimising) and the break-even levels (where average cost equals marginal returns) of output are calculated, holding management fixed at specified levels.

Figure 4 depicts the LAC curve in an AC*-Q space with management fixed at the minimum (highest curve), average and maximum (lowest curve) levels of the management proxy variable.

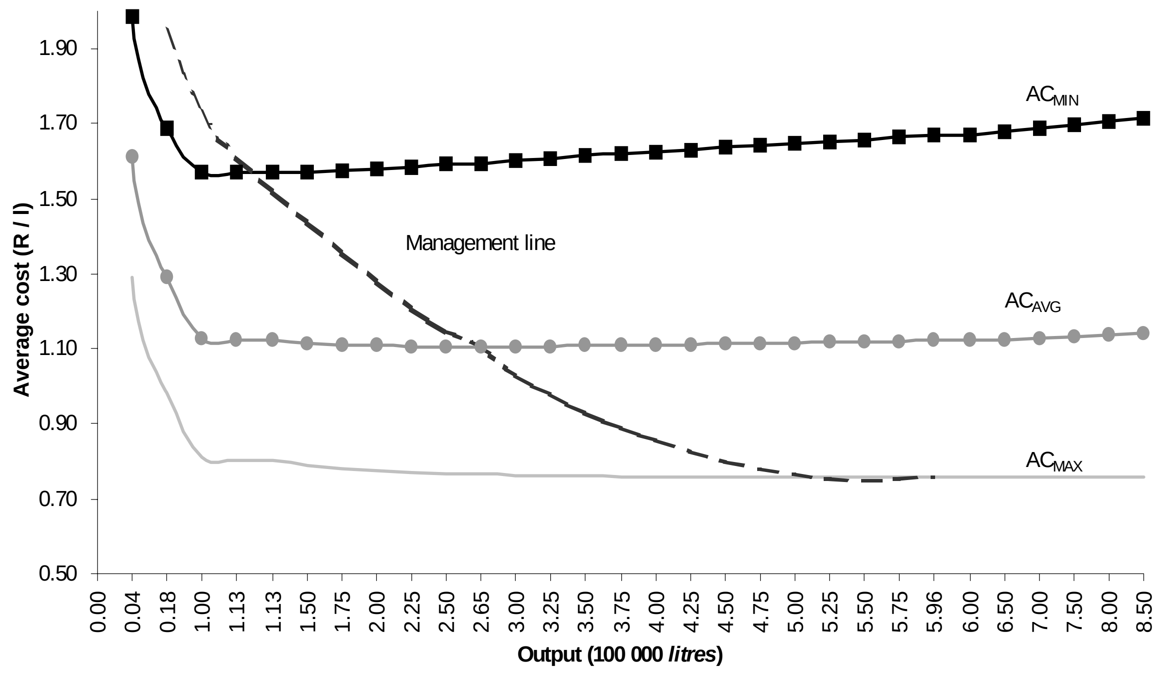

Figure 4: LAC curves at minimum, average and maximum levels of managerial ability

The lowest curve in Figure 4 (labelled AC_{MAX}) represents the long run average cost attainable by firms with the best level of managerial ability (defined as the maximum value of the management proxy in the sample). This curve can be seen as the stochastic cost frontier [Coelli, 1998] that represents the lower envelope of all the other average cost curves. The forms of the curves in Figure 4 only hint at the skewed U-shape that was inferred by Dawson and Hubbard [1987], but graphing over the whole sample range of Q also produces the typical U-shape curves, notably though with a loss of graphical detail.

It can thus be inferred from the curves that diseconomies of size are present at output levels beyond the optima (refer to Table 3) since average cost beyond these points rise as the size of operations expands. However, these diseconomies are overshadowed by the substantial gains in terms of decreased average cost as firms expand to reach the optima. In the case of firms with the best level of managerial ability, the curve is more L-shaped, indicating near constant returns to size beyond 300 000 litres of planned output.

Summarised in Table 3 are the implications of the estimated LAC functions. There is a direct positive relation between the level of management and the optimal level of planned output. As managerial ability improves, the level of optimal output increases: firms with a minimum level of managerial ability reach their optimal capacity at approximately 113 000 litres / year. Averagely managed enterprises can expand to more than double (266 000 litres / year) the size of low management firms, whilst the optimal size (596 000 litres / year) of firms with exceptional managerial ability is five times as large as low management firms.

Table 3: Optimum scale of operations depending on managerial levels

Level of management	Minimum	Mean	Maximum
Optimum Q* (litres)	113,138.01	265,752.59	596,149.83
Optimal herd size (cows in milk)	31.50	58.03	108.36
Opt AC* (Rand / litre)	1.57	1.11	0.76
Break even Q* (litres)	113137.996	18,688.83	4,278.13

The average milk price (at the farm gate) for the sample is R1.24 per litre (with a standard deviation of 13 cents). In comparison, the minimum average cost for low management firms is R1.57 per litre – that is a deficit over total cost of R0.33 per litre. Clearly, such firms have very bleak long-term profitability potential if management practices fail to change sufficiently in order to cover cost at all levels of output. In addition, the sample data shows that low management firms are operating well beyond the optima of 113 000 litres – the average annual output for the low management sub-sample is approximately 180 000 litres.

Conversely, average and high management firms produce milk at average cost levels that are well below the average milk return level (R0.13 and R0.48 surpluses over total cost, respectively). Compared to the optimum planned output, firms in the average management sub-sample also produce more milk than what is required for cost minimisation (compare average observed output of 360 000 litres to 266 000 litres per year). It is only the high management sub-sample that produces less than the optimum: an average of 511 000 litres per year as opposed to the optimum of 596 000 litres.

From Figure 4 the dashed line named "management line" shows the relationship between management, optimum output and average cost, as it traces the locus of minimum points on the LAC curves. Improved management would mean a movement down the management line, resulting in a lower average cost and a higher output level. As an example, a 10% improvement in the average management level would result in a 22% increase in the optimum output level and a corresponding 8% decrease in the minimum average cost level.

Amongst other things, management levels affect the optimal herd size that is required to produce the optimal output. Those farms in the three management groups with yields closest to the optima were used to determine the average yield per cow-in-milk per annum[5]. From these averages the optimal number of cows in milk was derived and is summarised in Table 3. The minimum and average management groups use 31% and 14% more cows-in-milk than the optimum number, whilst the best management group utilise 11% less than the optimum. In other words, only 34% of the sample farms operate within the optima.

Noteworthy is that no constraint has been placed on the long-term input use, since the LAC is constructed from successive short-run conditions. Certain variables, such as labour or capital input, may restrict expansion possibilities in the long run.

▪ CONCLUSIONS

In this article data for the 1997 production year was used to analyse the relationship between the scale of operations and the level of management, through estimated long run average cost functions (LAC). The theory developed by Dawson and Hubbard [1987] was applied to deal with situations of output uncertainty by minimising cost with respect to planned or expected output. The estimated LAC function has as its arguments planned output and managerial ability, but both are unobservable. Thus, proxies were constructed for each of the variables. In the case of management the margin above feed cost was used, while output was substituted with estimated planned output from a production function approach.

[5] The average yield per cow for the minimum, average and maximum levels of managerial input is 3592, 4580 and 5501 litres, respectively.

The results indicate that substantial economies of size exist in the South African dairy sector, and these outweigh the diseconomies of size, as is evident from the highly skewed u-shaped LAC curves (Figure 4). It was argued that the shape and position of the curve depends on the level of managerial ability and the results confirmed that better management was associated with lower average cost, higher levels of optimal output and larger optimal herd sizes (defined by cows in milk) over the whole range of farm sizes. For example, average management levels are associated with a break-even herd size of four (4) cows in milk and that can expand to 58 cows in milk before diseconomies come into play. Nevertheless, diseconomies are very small, allowing profit to be made over the whole range of farm sizes. This probably justifies the large number of firms that are operating beyond the optimum level of output. It does not hold for the low management level firms – they operate at average cost levels that are 24% higher than the average milk returns.

The lack of available time series data for the South African dairy sector makes it impossible to verify at this stage whether dairy farms are moving toward optimum levels of production or whether other forces than managerial ability dictates expansion decisions.

In another study of the sector, done with data for the 1998 year, compensated and uncompensated elasticities of input demand and output supply was calculated for a smaller sample of dairy enterprises [Beyers, 2000]. The results indicated that milk production is likely to contract over time and that milk price support measures would not induce expansion of the sector. Combined with the findings of the research presented in this article, it appears all the more essential to analyse the trends in the dairy production sector over homogenous farms, production regions and over time to determine which factors play the most marked role in shifting production, profitability and efficiency and what the extent of these changes are. If South African dairy producers truly strive to compete in the global market place, they too have to employ the benefits of similar analysis that has formed the basis of progress in the European and American markets.

- **DATA APPENDIX**

Table 4: Summary of the data

Variable	Minimum	Mean	Maximum	Std. Dev.
Q (litres)	19184	368817	4276056	464414
X_F	7200	264695	2669612	327508
X_L	-	45889	640493	56908
X_K	-	36291	1709500	109245
X_M	-	1.52	2.253482	0.36
Total Cost (1997 Rand)	26793	393321	4019913	458403
Cows in milk	8	70	560	67
Sample	394			

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