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Size economies on sugar cane farms in Queensland

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This paper contains an investigation into the existence and extent of size economies in the Queensland sugar cane growing industry. The paper includes a brief review of previous studies of size economies particularly in Australian agriculture, and of the various techniques employed in those studies.

Empirical analysis of the extent of scale economies in the Queensland sugar cane growing industry is undertaken using cross-sectional data. Returns to scale estimates derived from a Cobb-Douglas production function reveal no evidence of scale economies at either the state or regional level. Further, when a flexible translog production function was specified, the hypothesis that the traditional Cobb-Douglas production function is an adequate representation for the data was not rejected.

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Introduction

The existence of size and/or scale economies in a particular industry may have important implications in relation to industry performance and structural adjustment. The term 'economies of size' refers to the relationship between the costs of farm operation and farm size. Economies of size are said to exist if the unit cost of farm operation declines as farm size increases, where the change in unit cost can be associated with a change in some or all farm inputs. The term 'economies of scale' refers to the relationship between the proportional change in output in response to a proportional change in all inputs. The production process is said to have increasing, constant, or diminishing returns to scale depending on whether the change in output is more than, equal to, or less than the proportional change in inputs. Economies of scale can therefore be considered as a special, though restrictive, case of economies of size. If farms exhibit increasing returns to scale they will also exhibit economies of size. However, economies of size may also exist in the absence of increasing returns to scale. For example, unit costs may decrease as farm size increases if larger farms achieve a more efficient utilisation of particular inputs, such as physical capital (heavy machinery and equipment etc) or operator and family labour. The argument is based on the notion of limited divisibility and fixity of some inputs. That is, it is assumed that some inputs cannot be proportionately adjusted to the size of farm operation.

The question of capital indivisibility is more likely to be an issue where farmers are unable to take advantage of arrangements which increase the divisibility and flexibility of their physical capital inputs. Such arrangements include capital sharing with other farmers, contracting out specific activities (for example, harvesting), hiring, leasing or renting capital equipment, or engaging in sharefarming or joint management arrangements. Most or all of these arrangements are available to sugar cane growers.

In addition to economies of size and scale, larger farms may attain economies in the purchase of inputs or sale of outputs, usually referred to as pecuniary economies. For example, large farms may be able to reduce their input costs by receiving discounts on the prices they pay for inputs through bulk purchasing or through their capacity to engage in longer term contracts with input suppliers.

Review of previous studies

There have been a number of theoretical and empirical studies on the existence and extent of scale and size economies in Australian agriculture. Early on, Anderson and Powell (1973) presented a review of the Australian literature on size economies of some 31 studies, all of which were based on the specification of the Cobb-Douglas production function. They observed that the overall empirical evidence on Australian agriculture indicated constant returns to scale. Specifically, the evidence for the wheat, sheep, dairy, cotton and egg industries suggested significant size economies for small to medium farms. No clear evidence on size economies was observed for the beef industry or most of the fruit industries.

McKay (1974) investigated the existence of size economies using data from the Australian sheep industry survey for the years 1967-68 to 1969-70. He considered a number of specifications including log-log, semilog and linear cost functions in his analysis. He found that there were significant size economies in the pastoral, wheat–sheep and high rainfall zones for small to medium size farms. Furthermore, the results indicated no diseconomies of size associated with the increase in size from medium to large sizes.

The existence of size economies for apple and pear specialist farms in southern Victoria and Tasmania was studied by Stoeckel (1974). Based on the analysis of a rectangular hyperbola fitted to averaged data for the years 1965-66 to 1968-69, he found that significant size economies existed for smaller farms, with the economies rapidly diminishing with increases in farm size, especially for Victorian farms.

Ryan (1976) undertook an economies of size study by considering time series and cross-sectional data for eighteen years on New South Wales wheat–sheep farms. He found that the economies of size realised by farms that changed in size over time were in general more than two to three times as large as indicated by analysing cross-sectional data of the same farms. However, it is important to note that part of the disparity in size economies obtained from the time series data compared with the cross-sectional data is likely to be explained by changes in technology and other factors.

Later, Vlastuin, Lawrence and Quiggin (1982) examined the extent of size economies for the New South Wales wheat–sheep zone using data for the years 1966-67, 1975-76 and 1976-77. A flexible translog production function was used and it was found that, when the relatively fixed inputs of operator and farm labour were excluded, the results indicated constant returns to scale. However, when operator and family labour were included, there were size economies for smaller farms and no apparent diseconomies with increases in sizes.

Given the importance of 'family farms' as the principal form of economic unit engaged in most agricultural industries (including sugar cane growing), the question of how to measure or account for operator and family labour input is very important when examining the issue of overall farm efficiency and economies of size. For example, measuring the input of operator and family labour by the number of weeks worked (or equivalent) does not account for either the intensity or the quality of the labour. As a result, quantitative studies of size or scale economies which use imputed labour input data may give misleading results.

For a more detailed discussion of the theoretical, conceptual and estimation issues involved in studies of scale and size economies, as well as empirical results for Australian agriculture, see Anderson and Powell (1973), Vlastuin, Lawrence and Quiggin (1982) and Samuel and Shaw (1983). For a more recent and general review on scale and size economies, see Hallam (1991) and the references therein.

Analysis of scale economies using production functions

There are a number of alternative techniques that can be employed to study scale and size economies. A summary and detailed discussion of the techniques employed is presented in Anderson and Powell (1973). The various techniques are generally classified into four broad categories:

- synthetic firm approach;
- direct analysis of cost–output observations;
- indirect analysis based on the estimated production functions;
- indirect analysis based on survivor and growth of firms of different sizes.

While the choice of any of these techniques in a particular research project depends on the objectives of the analysis and availability of resources, the majority of studies on size economies in Australian agriculture have used the indirect approach based on the estimation of production functions, specifically, the Cobb-Douglas production function.

The study presented below is based on the estimation and analysis of production functions. As will be apparent, two different forms of production function (the Cobb-Douglas and Translog models) are considered and the results evaluated using standard statistical techniques. The results from the preferred model are used to test whether Australian sugar cane farms exhibit increasing, constant or decreasing returns to scale.

The data used in the analysis were collected by ABARE in a sample survey of sugar cane growers in Queensland conducted on behalf of the Sugar Industry Review Working Party. A comprehensive range of physical and financial performance measures were collected from 195 sugar cane farms throughout the state, covering the 1994-95 financial year.

Assume that the production function can be described by:

$$\text{(1)}\ \log(output)_i = \beta_0 + \beta_1 \log(land)_i + \beta_2 \log(capital)_i + \beta_3 \log(labour)_i + \beta_4 \log(other)_i + u_i$$

where the subscript i ($i = 1, 2, ..., N$) refers to farm i in the sample; *output* is measured by total gross farm returns (including returns from non-sugar activities), *land* represents the total cane cut area in hectares; *capital* represents the closing value of plant, machinery, equipment plus cost of farm structures; *labour* denotes the value of the total farm labour which includes the operator's on-farm labour, other family labour, partner or sharefarmer's labour and total hired labour; and *other* denotes the total value of fertiliser, chemicals, seed and other expenses including fuel, oil and grease, electricity, and administrative costs. u is a random disturbance term representing factors such as measurement errors.

The logarithmic form of the Cobb-Douglas production function as specified in model (1) is widely used in applied research because it is simple to estimate and mathematically manipulate. However, it imposes restrictive properties to the production structure, such as a fixed return to scale and an elasticity of substitution equal to unity. Alternatively, one can use more flexible models, such as the translog production function, which do not impose these restrictions (see Christensen, Jorgensen and Lau 1973).

The translog production function is of the form:

$$\text{(2)}\quad \log(output)_i = \beta_0 + \beta_1 \log(land)_i + \beta_2 \log(capital)_i + \beta_3 \log(labour)_i + \beta_4 \log(fother)_i + \beta_5 \log(land)^2_i + \beta_6 \log(capital)^2_i + \beta_7 \log(labour)^2_i + \beta_8 \log(other)^2_i + \beta_9 \log(land)\log(capital)_i + \beta_{10} \log(land)\log(labour)_i + \beta_{11} \log(land)\log(other)_i + \beta_{12} \log(capital)\log(labour)_i + \beta_{13} \log(capital)\log(other)_i + \beta_{14} \log(labour)\log(other)_i + u_i$$

where the variables are as defined in model (1) above.

The translog production function, although flexible in functional form, can be mathematically cumbersome to estimate as the number of explanatory variables increase.

For instance, as shown above, one needs to estimate fifteen parameters in model (2) as compared with only five parameters in model (1). The model can also suffer seriously from statistical problems such as multicollinearity.

It is important to note that model (1) is a special case of model (2), where $\beta_5 = \beta_6 = ... = \beta_{14} = 0$. Thus the adequacy of model (1) relative to model (2) can be examined by testing the null hypothesis that $H_0 = \beta_5 = \beta_6 = ... = \beta_{14} = 0$ using an F-test or the log-likelihood ratio test. Rejecting this hypothesis implies that the Cobb-Douglas production function does not adequately represent the data, relative to the translog model.

Given the above alternative specifications, and assuming that the random term, u, is independently and identically distributed with mean zero and constant variance, the parameters of the model can be estimated using the method of least squares. The 1994-95 survey data on sugar farms from ABARE is used in the analysis of the models. The survey consists of a sample of 195 sugar farms in four regions in Queensland.

Empirical results

The least squares estimates of model (1) are given in table 1. The estimates of the parameters (elasticities) of the model are all statistically significant and have signs as would be expected. The adequacy of the model is also evidenced by the high value of the coefficient of correlation (R-square = 0.90), which implies that more than 90 per cent of the variation in the dependent variable is explained by the explanatory variables in the model. On the other hand, most of the estimates of the parameters in model (2) were not statistically significant. Furthermore, many coefficients in the model had signs which are contrary to our expectations. This is not surprising given that many of the explanatory variables in the model are highly correlated. In other words, it is difficult to identify the effects of individual variables in model (2) because of multicollinearity. Moreover, the hypothesis that model (1)

Table 1: Estimated results for model (1)

Variable	Estimated coefficient	Standard error	t-value
Intercept	5.385	0.366	14.69
Log(*land*)	0.656	0.053	12.31
Log(*capital*)	0.084	0.027	3.10
Log(*labour*)	0.076	0.038	2.01
Log(*other*)	0.229	0.044	5.25

R-square = 0.9065; R-square adjusted = 0.9046.

is an adequate representation of the data relative to model (2) (that is, $H_0 = \beta_5 = \beta_6 = ... = \beta_{14} = 0$) generated an F-value of 1.18 with 10 and 180 degrees of freedom. Thus the hypothesis cannot be rejected at the 5 per cent level. In short, there was enough evidence which made model (2) suspect and therefore inadequate for further consideration.

Given model (1), the returns to scale parameter is given by the sum of the elasticities, that is, $RTS = \beta_1 + \beta_2 + \beta_3 + \beta_4 = 1.04$. The test is whether or not *RTS* is statistically different from one. This test has an F-value of 2.76 with 1 and 190 degrees of freedom, which is not significant at 5 per cent level. Thus the hypothesis of constant returns to scale is not rejected at the 5 per cent level.

The analysis was extended to include irrigation and regional factors. To do this model (1) was re-estimated by including a series of dummy variables to represent irrigation and region. Let *Irrigation* be a variable which takes a value of one if a farm irrigates and zero otherwise. Similarly, the variables *Region*1, *Region*2 and *Region*3 are defined to represent, respectively, Northern, Burdekin and Central regions in Queensland. Coefficients for the Southern Queensland region can be derived by setting the coefficients on the three regional dummy variables to zero. The variables were analysed in the model by including all four dummy variables simultaneously. The results of the model are presented in table 2. The results indicate significant variations among regions. It is also evident that irrigated farms are likely to yield higher outputs for given inputs.

However, while the differences in output caused by irrigation and regional effects are statistically significant, the hypothesis of constant returns to scale is not rejected at the

Table 2: Results for model (1) with irrigation and regional variables

Variable	Estimated coefficient	Standard error	t-value
Intercept	5.999	0.323	18.56
Log*(land)*	0.718	0.046	15.68
Log*(capital)*	0.069	0.023	3.01
Log*(labour)*	0.070	0.033	2.13
Log*(other)*	0.164	0.038	4.33
Irrigation	0.079	0.037	2.21
*Region*1	–0.082	0.042	–2.01
*Region*2	0.266	0.053	5.12
*Region*3	0.119	0.0407	2.96

R-squared = 0.9357; R-squared adjusted = 0.9329.

5 per cent level. Furthermore, separate models were estimated for each of the four regions and the existence of economies of scale examined. Again, in all cases, the constant returns to scale hypothesis was not rejected at the 5 per cent level.

Assessing cost–size relationships on sugar cane farms

Although the preceding analysis indicated that returns to scale in the sugar cane growing industry were constant, the survey data have also been used to examine size econon. by considering how costs of production vary across different sized farms. To do this, production costs on a per tonne of cane basis have been calculated for each sample farm. The relationship between costs of production and farm size is illustrated in table 3, which is a distribution of average unit costs of production and farm size.

Costs of production include payments made by the farm business for materials and services, hired labour and rent, lease payments on capital, and payments to sharefarmers. Costs also include an allowance for depreciation of farm improvements, plant and equipment. The value of labour inputs by farm operators and their families were measured by the number of weeks worked and a value imputed at the relevant Federal Pastoral Industry Award rates. Household expenditures are excluded. Total costs are divided by cane production to give average unit costs of production. As noted above, however, imputing the value of family labour inputs might not accurately reflect actual labour inputs, and care is needed in interpreting the results of the following analysis.

There is substantial variation in average unit costs of production across all size categories (table 3). In the smallest category (farms harvesting less than 34 hectares), there are proportionately more farms in the highest cost group than the lowest cost group. In the large farm category (those harvesting more than 94 hectares of cane), there are propor-

Table 3: Distribution of unit costs of production, by area of cane harvested
Proportion of farms in each group

	Cane area harvested (hectares)				
	Less than 34	**34 to 45**	**46 to 65**	**66 to 94**	**More than 94**
Unit costs ($/tonne)	%	%	%	%	%
Less than 23.0	2.7	4.9	2.6	5.0	4.9
23.0 to 26.5	3.0	4.4	3.3	5.3	4.0
26.6 to 30.0	4.5	4.9	4.9	2.3	4.0
30.1 to 35.2	4.0	1.9	5.1	3.5	5.0
More than 35.2	6.0	3.6	3.9	4.0	2.6

tionately more farms in the lowest cost group then the highest cost group. Nevertheless, in general there are significant numbers of small to medium sized farms with relatively low unit costs alongside medium to large sized farms with relatively high unit costs. Overall, the survey data reveal that while many larger farms have lower than average unit costs of production, many smaller farms have low unit costs as well.

For the group of small farms with relatively high costs of production, it may be possible for profitability to be increased by using existing resources more efficiently. However, it may be that farms in this group have higher costs because they are inherently less productive, in which case it is unlikely that they could make major efficiency and productivity gains simply by becoming bigger.

Summary and conclusions

Economies of size exist if large scale farm operation leads to savings in average unit costs of production as a result of changes in the volume of output of the farm. This could happen for several reasons. Larger farms may be able to achieve significant cost savings through more efficient utilisation of their physical capital (heavy machinery and equipment etc) and their operator and family labour. The argument is based on the notion of the 'lumpiness' or indivisibility of some capital inputs. That is, it is assumed that some capital inputs cannot be proportionately adjusted to the size of farm operation. In addition to economies of size and scale, larger farms may also be able to reduce their input costs by receiving discounts on the prices they pay for inputs through bulk purchasing or through their capacity to engage in longer term contracts with input suppliers.

Earlier studies of Australian agriculture often found evidence of size economies between small and medium sized farms, but did not often find size economies on larger farms. It is worth noting that many of these studies used farm survey data from the 1960s and 1970s, and that since then the average farm size in Australia has risen considerably (around 50 per cent over the past 25 years). In some of the earlier studies cited, size economies were related to the indivisibility of operator labour input. Given that most sugar cane growing occurs in relatively densely populated areas, cane farmers may have greater opportunity to divide their labour into off-farm work or work on other farms, allowing them to optimise their farm labour input.

The results of the analysis undertaken in this study do not support the existence of size economies in the overall context of the sugar cane growing industry. Empirical estimates using the Cobb-Douglas production function approach indicated constant returns to scale, while an examination of the relationship between unit costs of production and farm size did not provide any evidence of size economies.

The lack of evidence of size economies is not that surprising given that canegrowers, like farmers in most agricultural industries, have the opportunity to adjust their labour and physical capital according to their overall farm size. Growers can optimise their capital and labour resources through such arrangements as capital sharing with other farmers, contracting out specific activities (for example, harvesting), hiring, leasing or renting capital equipment, or engaging in sharefarming or joint management arrangements.

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