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Relative Economic Efficiency in the Australian Grazing Industry

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The Lau and Yotopoulos restricted profit function methodology for testing for differences in economic efficiency and its components of allocative and technical efficiency is applied to data from grazing properties in the High Rainfall Zone of New South Wales. Tests are made on the basis of property size and operator's age. Larger farms are found to be significantly more economically efficient than smaller farms. The range of data considered in this study is found to exhibit constant returns to scale. Operator's age is found to have no effect on economic, allocative or technical efficiency and both younger and older operators are found to allocate variable inputs optimally. Finally, the usefulness of the methodology for examining issues related to economic efficiency in the Australian agricultural sector is assesed.

Introduction

Grazing industry producers, like all entrepreneurs, are under continuing pressure to adjust their operations to changing economic conditions. The grazing industry in Australia has been put under considerable pressure to adjust in the face of a long-term trend decline in the ratio of prices received to prices paid by graziers (Lawrence and McKay 1980). This long-term trend decline in graziers' terms of trade has accentuated the importance of improving the level of economic efficiency of grazing operations as one means of ameliorating these pressures by improving the overall profitability of grazing properties. Furthermore, knowledge of the levels and sources of differences in economic efficiency between groups of farms with different characteristics will be of importance for policy purposes and in determining the most efficient form of grazing industry organisation.

Economic efficiency consists of two components:— technical efficiency and allocative or price efficiency. Technical efficiency refers to the relationship between physical outputs and inputs. One firm is more technically efficient than another if it consistently produces more output from a given amount of measurable inputs. Allocative efficiency refers to the extent to which firms maximise profits for a given level of technical efficiency. A firm which maximises profits will simultaneously equate the value of marginal product of each variable input to its respective price. That is, a firm moves along the expansion path until the returns from applying an additional unit of input are equated with the cost of the additional unit. Clearly, if one firm is more economically efficient than another then it may be either more technically efficient or more allocatively efficient or both.

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Empirical evidence of differences in technical and allocative efficiency between groups of farms with different characteristics will be of considerable importance in the formulation of a wide range of government policies concerning such matters as adjustment assistance, pricing and supply of agricultural inputs, marketing, and the provision of credit, extension and training facilities. For instance, examining differences in economic efficiency between smaller and larger farms in conjunction with a related test for constant returns to scale will indicate if overall industry efficiency can best be increased by encouraging smaller farms to increase their scales of operation or by encouraging them to make more efficient use of resources already at their disposal or by some combination of these two initiatives. If the two groups are equally technically efficient but one group is more allocatively efficient than the other, then policies which improve the quantity and quality of market information available to the relatively inefficient group may improve their allocation of resources. Similarly, an examination of differences in allocative and technical efficiency between younger and older operators will present a partial guide for the development of farm-level extension policies and the likely usefulness of young farmer training schemes.

Farrell (1957) was one of the first to develop a framework for measuring the technical and allocative efficiency of different firms using linear programming techniques to derive an efficient unit isosurface. A firm's technical efficiency was measured in ratio form by its closeness to the frontier while its allocative efficiency was measured by its closeness to the point of tangency of the frontier with the isocost surface. This approach suffers from the same limitations as all linear programming studies in regard to sensitivity of the frontier to outliers and the lack of standard statistical measures of significance and goodness of fit. Furthermore, the "frontier" runs parallel to the respective input axes past the extreme efficient observations. This may cause biased results for a relatively large proportion of the observations. O'Connor and Hammonds (1975) outline the limitations of the Farrell approach in detail. Lau and Yotopoulos (1971, 1972) and Yotopoulos and Lau (1973) developed a framework for testing for differences in economic efficiency using the dual profit function which overcame some of the limitations of the Farrell approach. Whereas the Lau and Yotopoulos methodology has been applied, to date, to peasant or dual agricultural sectors, the usefulness of this alternate approach for addressing the above issues in Australian agriculture is examined in this paper.

The actual profit functions of groups of farms at given output and variable input prices and quantities of fixed inputs are compared, using the Bureau of Agricultural Economics' Australian Grazing Industry Survey data for the High Rainfall Zone of New South Wales for the year 1975–6. The framework for statistical tests on profit functions and input demand equations is used to examine whether differences exist between the relative economic efficiency of smaller and larger grazing industry properties and younger and older grazing industry producers. The methodology used is outlined in the following section while the data employed in the study are described in the third section. The results of the tests carried out on the basis of property size and operator's age are presented in the fourth and fifth sections, respectively. Finally, conclusions are drawn and the usefulness of the approach with respect to the Australian agricultural sector is assessed in the sixth section.

Methodology

The profit function framework developed by Lau and Yotopoulos is purported to have certain advantages over the traditional production function approach. Shephard's (1953) Lemma states that the input demand and output supply functions may be derived from the first-order derivatives of an arbitrary profit function which is decreasing and convex in the prices of variable inputs and increasing in the quantities of fixed inputs. Duality theory also states that the system of input demand and output supply equations derived from a profit function provide a complete description of the technology of the firm with a production function which is concave in variable inputs with given fixed inputs in a competitive market. Furthermore, these profit, supply and input demand functions are explicit functions of variables exogenous to the individual firm. This framework for examining differences in economic efficiency allows for firms to operate at different input and output price levels and to succeed to different degrees in maximizing profits. It also takes into account that, for a given amount of measurable inputs, firms may produce different levels of output. Clearly, these attributes make the use of the dual profit function specification theoretically attractive.

The Lau–Yotopoulos model may be represented as follows. Consider the n production functions.

$$(1)\quad V^i = A^i F(X^i; Z^i),\ i = 1, \ldots, n,$$

where superscripts refer to firms, V is output, A is a firm specific technical efficiency parameter, X is a vector of variable inputs and Z is a vector of fixed inputs.[1] The corresponding marginal conditions are:

$$(2)\quad \frac{\partial A^i F(X^i; Z^i)}{\partial X^i_j} = k^i_j c^i_j;\quad k^i_j \geq 0;\ i=1,\ldots,n;\ j = 1,\ldots,m$$

where c^i_j is the opportunity cost of a unit of variable input j normalised by the price of output, and k^i_j is a firm and input specific variable representing allocative behaviour. There are m variable inputs. Lau and Yotopoulos (1971, p. 99) point out that the decision rule for the firm consisting of "equating the marginal product to a constant times the normalized price of each input may be rationalized as follows: (i) Consistent over- or under-valuation of the opportunity costs of the resources by the firm: (ii) Satisficing behaviour; (iii) Divergence of expected and actual normalised prices; (iv) Divergence of the subjective probability distribution of the normalized prices from the objective distribution of normalized prices; (v) The elements of k^i may be interpreted as the first-order coefficients of a Taylor's series expansion of arbitrary decision rules. . ." A firm

1. The technical efficiency parameter A^i allows for neutral differences in the production functions of individual firms. The parameter A^i represents differences in non-measurable inputs such as management ability and environmental factors. Equal technical efficiency for two firms is achieved when $A^1 = A^2$.

is successful in maximizing profits if $k_j^i = 1$ for all j and, similarly, two firms are equally allocatively efficient if $k_j^1 = k_j^2$ for all j.

The right-hand sides of (2) can be viewed as the "behavioural" prices facing the firm. Profit maximization subject to these behavioural prices can be represented by the following behavioural normalised profit function.

$$(3)\ \pi_b^i = A^i G\,(k_1^i c_1^i/A^i, \ldots, k_m^i\, c_m^i/A^i;\ Z^i),\ i = 1, \ldots, n,$$

where π^i is profit (total revenue less total variable costs) normalized by the price of output.[2]

Input demand functions are then derived by differentiating the behavioural profit function with respect to the behavioural prices as follows:

$$(4)\quad x_j^i = -A^i \frac{\partial G(k^i c^i/A^i;\ Z^i)}{\partial k_j^i c_j^i}$$

$$= -\frac{A^i}{k_j^i} \frac{\partial G(k^i c^i/A^i;\ Z^i)}{\partial c_j^i}$$

The corresponding supply equations are given by:

$$(5)\ V^i = A^i\, G(k^i c^i/A^i;\ Z^i) - A^i \sum_{j=1}^{m} k_j^i c_j^i \frac{\partial G(k^i c^i/A^i;\ Z^i)}{\partial k_j^i c_j^i}$$

Since X_j^i and V^i are the actually observed quantities of variable inputs and output supplied, respectively, the actual normalized profit function can be derived as follows:

$$(6)\ \pi^i = V^i - \sum_{j=1}^{m} c_j^i X_j^i$$

$$= A^i\, G(k^i c^i/A^i;\ Z^i) + A^i \sum_{j=1}^{m} \frac{(1 - k_j^i)\, c_j^i}{k_j^i} \frac{\partial G(k^i c^i/A^i;\ Z^i)}{\partial c_j^i}$$

$i = 1, \ldots, n.$

By specifying a specific functional form for G, statistical tests on relative efficiency can be made. Here the Cobb-Douglas specification is used giving rise to the following normalised profit function and input demand functions:

2. Normalization of the profit and variable input price variables by the price of output leads to a neater exposition of the methodology.

(7) $\pi^i = B^i \prod_{j=1}^{m} (c_j^i)^{a_j} \prod_{j=1}^{f} (Z_j^i)^{b_j}$, $i = 1, \ldots, n$,

(8) $$\frac{-c_j^i X_j^i}{\pi^i} = a_j^i,\ i=1,\ldots,n\ ,\ j=1,\ldots,m,$$

where a_j and b_j are variable input price and fixed input quantity parameters, respectively, and a_j^i is a constant.

The properties of the actual profit function and input demand equations are such that: (i) profit always increases with the level of technical efficiency, given the quantity of fixed inputs and value of k_j^i; (ii) profit is decreasing in the normalized prices of variable inputs and increasing in the quantities of fixed factors; (iii) a firm is a profit maximizer if $k_j^i=1$ for all $j=1,\ldots,m$; (iv) the actual profit functions of two firms coincide if and only if $A^1=A^2$ and $k_j^1=k_j^2$ for all $j=1,\ldots,m$.

These properties allow testable hypotheses concerning relative economic, allocative and technical efficiency to be formulated. Firstly, equal relative economic efficiency can be investigated by testing whether $B^1 = B^2$ (or $ln(B^1/B^2)=0$), since B^i contains only the two types of efficiency parameters and a production elasticity which is constant across all firms (Lau Yotopoulos 1971). Clearly, two firms can be equally economically efficient without necessarily being both equally technically and allocatively efficient.

In addition, if two firms are equally technically and equally allocatively efficient, then $B^1 = B^2$ and $a_j^1 = a_j^2$, for all j. Both profit functions and both sets of input demand functions are then identical. Therefore, jointly testing whether $B^1 = B^2$ and $a_j^1 = a_j^2$, for all j, provides a test for equal relative technical efficiency combined with equal relative allocative efficiency.

Equal relative allocative efficiency may also be tested. If and only if the allocative efficiency parameters are equal, then $a_j^1 = a_j^2$ for all j. Furthermore, we can test for absolute allocative efficiency of firm i by testing whether $a_j = a_j^i$ for all j. Absolute allocative efficiency occurs when $k_j^i = 1$, for all j, *i.e.* when the firm maximizes profits with respect to the use of variable inputs.

By dividing a group of observations into two subgroups based on possession of a particular characteristic, it is possible to carry out the above hypothesis tests statistically between the two groups. In this case, two separate sets of tests were carried out; the first with a sample divided on the basis of property size and the second with a sample divided on the basis of the operator's age. In both cases a model with one variable input (labour) and three fixed inputs (livestock, capital and land) was estimated.

The methodology is presented in more detail in Lau and Yotopoulos (1971, 1972) and Yotopoulos and Lau (1973). Other examples of the application of this methodology are Sidhu (1974), O'Connor and Hammonds (1975), Yotopoulos, Lau and Lin (1976), Trosper (1978), Khan and Maki (1979) and Sidhu and Baanante (1979). All these studies, with the exception of that by O'Connor and Hammonds which examines meat retailing in the USA, have concentrated on peasant or dual agricultural sectors. Atkinson and Halvorsen (1980) have extended the methodology to examine relative price efficiency using the flexible translog functional form. The authors believe the Lau-Yotopoulos methodology has not previously been applied to data for Australian agriculture.

Data and Estimation

The date used in this study were taken from the BAE's Australian Grazing Industry Survey sample for the High Rainfall Zone of New South Wales for the year 1975-6. To be eligible for inclusion in the survey, properties must be carrying at least 200 sheep and/or 50 head of cattle. The sample for tests based on property size consisted of 70 observations split into the subgroups of smaller and larger farms based on the number of stock equivalents[3] carried. The sample for tests based on operator's age consisted of 66 observations (operator's age was not available for all sample farms).

The estimating equations were the following profit function and input demand function:

$$(9)\quad \ln \pi = \ln B_o + d_1 D_1 + a_L \ln c_L + b_V \ln V + b_K \ln K + b_N \ln N$$

$$(10)\quad -\frac{c_L L}{\pi} = a^o_L D_o + a^1_L D_1,$$

where the variables are defined as follows[4]:

π, profit, is total farm returns less total labour costs[5];

3. Stock equivalents are defined as the number of sheep carried plus eight times the number of beef cattle carried plus twelve times the number of dairy cattle carried plus twelve times the number of hectares of crop harvested and are designed to facilitate a comparison of physical production between farms with different enterprise combinations (BAE 1976).

4. Materials and services were not included in the estimated model as the profit function formulation requires a price for each variable input for each farm. Since it is not possible to arrive at an aggregate quantity (and, hence, a price) for variable inputs as diverse in composition as materials and services, these inputs were assumed to be used in fixed proportions to output. It is difficult to predict what effect relaxation of this assumption would have on the results.

5. The profit and variable input price variables are normally divided by the price of output facing each individual firm in the Lau and Yotopoulos methodology. In this case it seemed most tractable to assume that all firms faced the same output price for a standardised unit of output once quality differences have been eliminated.

B_0 is the intercept term for farms in group O;

D_1 is a dummy variable whose value equals 1 if the observation is in group 1 and zero otherwise, and whose coefficient, $d_1 = ln(B_1/B_0)$;

c_L is the price of labour where the price of labour is derived from the opportunity cost of labour used divided by total operator man-week equivalents worked on farm by the operator, partners, hired labour and family labour. Labour inputs are valued at their opportunity cost off the farm, *i.e.,* at the return they would obtain from employment in the next most profitable alternative off farm, and are measured in standardized units of quantity, thus eliminating quality difference[6];

V is the quantity of service flow from livestock inputs which is represented by the cost of the livestock service flow, assuming that all firms face the same price for a standardised unit free of quality differences. The service flow from durable inputs consists of three components: depreciation, maintenance and opportunity cost. In the case of livestock, depreciation is assumed to be zero on the average unit but this requires maintenance in the form of purchases and the absolute value of decreases in total livestock held between the beginning and end of each year. Sales and increases in livestock inventory appear as outputs. Implicit interest charges on the opening value of livestock are included as a measure of opportunity cost. A more detailed discussion of service flows can be found in Lawrence and McKay (1980);

K is the quantity of service flow from capital inputs which is represented by the value of depreciation, opportunity cost and repairs on total capital excluding land;

N is the quantity of service flow from land inputs which is represented by the opening value of land as a proxy for opportunity cost (depreciation is assumed to be zero and maintenance is included in other categories);

L is the quantity of labour input in man-weeks;

and D_0 is a dummy variable whose value equals 1 if the observation is in group 0 and zero otherwise.

Given the assumptions of the model, the decision variables for each farm are the quantities of output and the variable input labour. Variable input prices, output price and fixed input quantities are all predetermined and cannot be changed by the action of individual firms. Therefore, output and variable input quantities

6. This enables the components to be aggregated into inputs with equal productivity on farm but where the various components of the input may face differing opportunity costs off farm. This leads to farms facing different effective prices for the same homogeneous input. The operator faces a higher opportunity cost off farm because of his entreprenurial ability and is consequently given a wage of four-thirds the award rate (*i.e.,* \$145.50 per week), approximating the average rate paid to station managers, while family labour which faces a lower opportunity cost off farm is given a wage of two-thirds the award rate (*i.e.,* \$67.75 per week). While these opportunity cost rates may be somewhat arbitrary, we feel that they are likely to be a reasonable approximation, on average, to the actual opportunity costs faced. It is acknowledged that some older operators may face a lower opportunity cost while other operators will face a higher opportunity cost. Hired labour faces an opportunity cost equal to the award rate of \$101.62 per week.

or, alternatively, output quantity and the expenditure on the variable input are jointly dependent variables. Hence, the variables on the left-hand sides of equations (9) and (10) are jointly dependent while those on the right-hand sides are predetermined.

Additive errors with zero expectation and finite variance were assumed for each of the estimating equations, (9) and (10). Non-zero covariances for the errors of the two equations for the same farm were permitted but the errors of any two equations corresponding to different farms were assumed to have zero covariance. Under these assumptions, Byron's (1970) estimator for seemingly unrelated equations with linear restrictions imposed was employed.

The hypotheses outlined in the preceding section may be tested by imposing the relevant linear restriction implied by the null hypotheses on the model and then testing the validity of this restriction. The test statistic for the validity of a restriction on the system is $-2\ ln\ R$ where R is the ratio of the likelihood of the restricted system to the likelihood of the unrestricted system. Asymptotically the likelihood ratio test statistic has a chi-square distribution with degrees of freedom equal to the number of restrictions being tested.

The mean values of selected key variables for the farm size and operator's age subgroups are presented in Tables 1 and 2, respectively. From the data presented in Table 1 it can be seen that the two farm size subgroups exhibited similar enterprise combinations. Similarly, from Table 2 it can be seen that on average there was no marked difference in the size and structure of farms in the two operator's age subgroups.

Table 1: Means of Key Variables Based on Farm Size

Variable	Unit	Larger farms	Smaller farms
Number of observations	no.	53	17
Total farm returns	$	64 750	15 624
Land	ha	2 630	398
Plant and structural improvements	$	64 631	32 458
Average cattle	no.	831	121
Average sheep	no.	4 206	1 050
Crops	ha	14	13
Total stock equivalents	no.	10 744	2 061
Man-weeks worked on farm	no.	142	57
Operator's age	years	46	48

Table 2: Means of Key Variables Based on Operator's Age

Variable	Unit	Older operators	Younger operators
Number of observations	no.	48	18
Total farm returns	$	51 098	53 329
Land	ha	1 651	1 506
Plant and structural improvements	$	50 179	62 414
Average cattle	no.	481	539
Average sheep	no.	3 637	3 406
Crops	ha	14	15
Total stock equivalents	no.	7 415	7 706
Man-weeks worked on farm	no.	118	107
Operator's age	years	55	34

An alternative procedure is to test for two characteristics simultaneously as done by O'Connor and Hammonds (1975). This requires the inclusion of a multiplicative dummy term to avoid linear dependence and involves testing four groups. In this case there would be large farms with young and old operators and small farms with young and old operators. The results for the age and size characteristics could not be recovered separately. It was considered to be of more interest to test for the size and age characteristics separately in this study. This procedure is valid provided there is no link between the characteristic being tested and other characteristics, *i.e.* if the two subgroups are homogeneous. From Tables 1 and 2 it can be seen that the size and age groups are homogeneous with the two size subgroups having similar average operator ages and the two age subgroups having similar average farm sizes.

Results — Property Size

The sample of 70 observations for the regressions based on property size was divided into two subgroups. The first of these contained 53 observations of properties with greater than 3 000 stock equivalents, while the second contained 17 observations of properties with at most 3 000 stock equivalents. Equations (9) and (10) were estimated from the total sample of 70 observations incorporating the dummy variables D_S and D_G which take the value of one for smaller and larger farms, respectively, and zero otherwise. The two dummy variables were required for the input demand equation.

Table 3: Joint Estimation of the Coefficients of the Normalized Profit Function and Input Share Equations — Property Size (a)

Normalized profit function	Parameter	Estimated coefficients							
		Single equation OLS	Zellner's method with restrictions (b)						
			Unrestricted	Restriction (1)	Restriction (2)	Restriction (3)	Restriction (4)	Restriction (5)	Restriction (6)
Constant	$ln\,B_S$	1.955 (0.64)	4.323 (2.04)	4.208 (1.98)	4.635 (2.18)	4.511 (2.13)	5.845 (5.84)	3.016 (3.33)	3.807 (2.19)
Size dummy	d_G	0.391 (1.81)	0.579 (3.06)	0	0.168 (1.11)	0	0.540 (2.96)	0.581 (3.07)	0.550 (3.13)
Labour price	a_L	−0.697 (−1.32)	−0.770 (−2.09)	−0.856 (−2.33)	−0.770 (−2.09)	−0.809 (−2.20)	−1.050 (−8.09)	−0.524 (−6.83)	−0.734 (−2.04)
Livestock quantity	b_V	0.327 (2.53)	0.279 (3.09)	0.374 (4.40)	0.279 (3.09)	0.322 (3.95)	0.284 (3.15)	0.275 (3.05)	0.287 (3.25)
Capital quantity	b_K	0.846 (5.22)	0.655 (5.79)	0.671 (5.94)	0.655 (5.79)	0.662 (5.86)	0.637 (5.74)	0.671 (6.06)	0.685 (7.83)
Land quantity	b_N	0.022 (0.61)	0.026 (1.01)	0.022 (0.84)	0.026 (1.01)	0.024 (0.94)	0.023 (0.89)	0.029 (1.15)	0.028 (1.08)
Input share functions Labour	a_L^G	−0.513 (−6.44)	−0.513 (−6.53)	−0.584 (−7.79)	−0.653 (−9.56)	−0.653 (−9.56)	−0.513 (−6.53)	−0.524 (−6.83)	−0.513 (−6.53)
	a_L^S	−1.090 (−7.75)	−1.090 (−7.86)	−0.868 (−7.34)	−0.653 (−9.56)	−0.653 (−9.56)	−1.050 (−8.09)	−1.090 (−7.86)	−1.090 (−7.86)

(a) The variables are defined in the text following equation (10). The letters S and G refer to smaller and larger properties, respectively. Figures in parentheses are t-statistics.
(b) The restrictions are specified in the text and Table 4 under the same number.

The results of the regressions based on property size are presented in Table 3. The results in the first column of this table are those obtained from single equation ordinary least squares (OLS) estimation of the three equations. These estimates are presented merely for comparison purposes, while the seemingly unrelated equations estimates appear in the second and subsequent columns.[7] The equations estimated with linear restrictions imposed were used to test the hypotheses in regard to relative efficiency outlined in the preceding section. The estimated profit function is decreasing in the variable labour price. The profit function is increasing in the quantities of the fixed inputs, livestock, capital and land, and the coefficient of the dummy variable for large farms is also positive and significant, except where it is restricted to equal zero.

Table 4: Tests of Hypotheses — Property Size (a)

Tested hypotheses	Chi-square tests		
	Computed value	Critical values	
		5 per cent	1 per cent
(1) $d_G = o$	9.39	3.84	6.63
(2) $a^S_L = a^G_L$	13.11	3.84	6.63
(3) $d_G = o$, $a^S_L = a^G_L$	14.34	5.99	9.21
(4) $a^S_L = a_L$	0.66	3.84	6.63
(5) $a^G_L = a_L$	0.46	3.84	6.63
(6) $b_V+b_K+b_N = 1$	0.18	3.84	6.63

(a) The parameters and hypotheses are described in the second and third sections of the text. The letters S and G are used to denote coefficients for smaller and larger properties, respectively. The test statistics are $-2\ ln\ R$ where R is the ratio of the likelihood of the restricted system to the likelihood of the unrestricted system.

The results of the hypothesis tests carried out on the basis of property size[8] are presented in Table 4. The 5 per cent level of significance was used for the tests of the hypotheses reported. Unlike Yotopoulos and Lau (1973) hypotheses which have been accepted have not been imposed as maintained hypotheses in subsequent tests. Not imposing maintained hypotheses improves the statistical efficiency of the tests. The following hypotheses were tested:

7. Given the potential for misinterpretation of goodness-of-fit statistics in jointly estimated equations, no goodness-of-fit statistics are reported in Table 3. However, the OLS R^2 value for the profit function was 0.71.

8. The hypothesis tests were also carried out on the sample with both 2 000 and 5 000 stock equivalents as the cut-off values between the smaller and larger property groups. The results were insensitive to the number of stock equivalents used as the division between the two groups.

1. Equal Relative Economic Efficiency, $H_O : d_G = 0$ *(i.e.* $ln\,(B_G/B_S) = 0$*)*

This null hypothesis states that the profit functions for the two groups are identical and, hence, the two groups are equally economically efficient. The restriction implied by this null hypothesis[9] was not found to be valid and so the null hypothesis of equal relative economic efficiency between smaller and larger farms must be rejected. The positive value of the coefficient on the dummy variable for larger farms indicates that larger farms are more economically efficient than smaller farms.

2. Equal Relative Allocative Efficiency Between Smaller and Larger Farms, $H_O : a^S_L = a^G_L$

Again, the null hypothesis that smaller and larger farms are equally relatively allocatively efficient with respect to labour inputs must be rejected at the 5 per cent level of significance.

3. Equal Relative Technical and Allocative Efficiency, $H_O : d_G = 0$ and $a^S_L = a^G_L$

The null hypothesis of equal relative economic and equal relative allocative efficiency combined and, hence, of equal relative technical efficiency and equal relative allocative efficiency combined was rejected. Given that the two groups have differences in both relative economic and relative allocative efficiency, it is not possible, using this methodology, to test whether the two groups have equal relative technical efficiency.

4. Absolute Allocative Efficiency of Smaller Farms, $H_O : a^S_L = a_L$

The null hypothesis of absolute labour allocative efficiency of smaller farms cannot be rejected, implying that smaller farms are successful in equating the value of marginal product of the variable input with its purchase price.

5. Absolute Allocative Efficiency of Larger Farms, $H_O : a^G_L = a_L$

The null hypothesis of absolute allocative efficiency of larger farms also cannot be rejected. This means that, taken as a group, larger farms have succeeded in equating the value of marginal product of the variable input to its price.

6. Constant Returns to Scale, $H_O : b_V + b_K + b_N = 1$

The null hypothesis of constant returns to scale cannot be rejected. This result implies that constant returns to scale were exhibited over the range of production levels considered in this study.

The conclusion drawn from the tests of these hypotheses was that larger farms were significantly more economically efficient than smaller farms.

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9. The likelihood ratio test on an imposed restriction is conceptually equivalent to a simple t test in the unrestricted system where only one coefficient in one equation is being tested.

However, in the statistical testing framework used in this study it was not possible to identify the source of this difference in efficiency. As the hypotheses of equal relative economic efficiency and equal relative allocative efficiency were both rejected, it was not possible to isolate relative technical efficiency. Further, although the hypothesis of equal relative allocative efficiency was rejected, from subsequent tests it was not possible to reject absolute allocative efficiency of both larger and smaller farms.[10] This result appears to have arisen because although the "k" values of the two groups are statistically different from each other, neither is statistically different from one. This is consistent with the two "k" values lying on either side of one. The null hypothesis of constant returns to scale was accepted.

Results — Operator's Age

The sample of 66 observations for the regressions based on the operator's age was divided into two subgroups. The first of these contained 48 observations where the age of the property's operator was greater than or equal to 40 years. The second contained 18 observations where the operator's age was less than 40 years. The dummy variables D_E and D_Y were formed and take the value of one when the operator is a member of the older and younger groups, respectively, and zero otherwise.

Table 5: Joint Estimation of the Coefficients of the Normalized Profit Function and Input Share Equations — Operator's age (a)

Normalized profit function	Parameter	Estimated coefficients						
		Single equation OLS	Zellner's method with restrictions (b)					
			Unrestricted	Restriction (1)	Restriction (2)	Restriction (3)	Restriction (4)	Restriction (5)
Constant	$\ln B_Y$	−0.131 (−0.04)	2.515 (1.10)	2.851 (1.26)	2.474 (1.09)	3.072 (1.36)	1.806 (1.65)	2.262 (2.29)
Age dummy	d_E	0.236 (1.39)	0.198 (1.23)	0	0.254 (2.04)	0	0.211 (1.35)	0.197 (1.22)
Labour price	a_L	−0.744 (−1.41)	−0.739 (−1.91)	−0.761 (−1.97)	−0.739 (−1.91)	−0.787 (−2.04)	−0.611 (−4.36)	−0.692 (−7.73)
Livestock quantity	b_V	0.432 (3.66)	0.341 (3.93)	0.344 (3.97)	0.341 (3.93)	0.348 (4.02)	0.340 (3.92)	0.341 (3.93)
Capital quantity	b_K	1.010 (5.97)	0.810 (6.52)	0.795 (6.43)	0.810 (6.52)	0.779 (6.31)	0.819 (6.75)	0.813 (6.72)
Land quantity	b_N	0.019 (0.51)	0.022 (0.81)	0.023 (0.87)	0.022 (0.81)	0.025 (0.94)	0.023 (0.89)	0.022 (0.85)
Input share functions								
Labour	a_L^E	−0.690 (−7.38)	−0.690 (−7.49)	−0.727 (−8.37)	−0.663 (−8.44)	−0.663 (−8.44)	−0.690 (−7.49)	−0.692 (−7.73)
	a_L^Y	−0.592 (−3.87)	−0.592 (−3.94)	−0.492 (−3.89)	−0.663 (−8.44)	−0.663 (−8.44)	−0.611 (−4.36)	−0.592 (−3.94)

(a) The variables are defined in the text following equation (10). The Y and E refer to younger and older operators, respectively. Figures in parentheses are t-statistics.
(b) The restrictions are defined in the text and Table 6 under the same number.

10. It should be noted that the operator's labour is not in infinitely elastic supply and, hence, the optimum quantity of operator's labour and the optimum marginal composition of labour may not be attainable.

The results of the regressions are presented in Table 5. Single equation ordinary least squares (OLS) estimates are presented in the first column.[11] The subsequent seemingly unrelated equations estimates incorporate the various restrictions required to test the hypotheses on relative economic efficiency. The profit function is decreasing in the price of labour in all cases and is increasing in livestock, capital and land quantities with these coefficients being significant in all cases.

Table 6: Tests of Hypotheses — Operator's Age (a)

Tested hypotheses	Chi-square tests		
	Computed value	Critical values	
		5 per cent	1 per cent
(1) $d_E = 0$	1.50	3.84	6.63
(2) $a^Y_L = a^E_L$	0.31	3.84	6.63
(3) $d_E = 0$	4.46	5.99	9.21
$a^Y_L = a^E_L$			
(4) $a^Y_L = a_L$	0.13	3.84	6.63
(5) $a^E_L = a_L$	0.02	3.84	6.63

(a) The parameters and hypotheses are outlined in the second and fourth sections of the text. The letters Y and E are used to denote coefficients for younger and older operators, respectively. The test statistics are $-2\ ln\ R$ where R is the ratio of the likelihood of the restricted system to the likelihood of the unrestricted system.

The results of the hypothesis tests for operator's age[12] are presented in Table 6. Once again, the following hypotheses were tested:

1. Equal Relative Economic Efficiency, $H_o : d_E = 0$ *(i.e.* $ln(B_E/B_Y) = 0$)

The restriction implied by this null hypothesis was found to be valid and, hence, the null hypothesis of equal relative economic efficiency of properties with younger and older operators cannot be rejected.

2. Equal Relative Allocative Efficiency, $H_o : a^Y_L = a^E_L$

The null hypothesis of equal relative allocative efficiency with respect to labour inputs between younger and older operators also cannot be rejected.

11. The OLS R^2 value for the profit function incorporating the age dummy was 0.73.

12. The hypothesis tests were also carried out on the sample using both 35 and 50 years as the age values for division between the younger and older groups. The results were insensitive to the age used as the division between the two groups. A lower cut-off value than 35 years could not be used due to a lack of observations with operators younger than 35.

3. Equal Relative Technical and Allocative Efficiency, $H_o : d_E = 0$ and $a^Y_L = a^E_L$

The restrictions implied by the null hypothesis of equal relative economic and equal relative allocative efficiency (and, hence, of equal relative technical efficiency and equal relative allocative efficiency) were found to be valid and the null hypothesis cannot be rejected. This could be anticipated from the failure to reject the preceding null hypotheses.

4. Absolute Allocative Efficiency of Younger Operators, $H_o : a^Y_L = a_L$

The null hypothesis of absolute labour allocative efficiency of younger operators cannot be rejected indicating that younger operators were successful in maximizing profits.

5. Absolute Allocative Efficiency of Older Operators, $H_o : a^E_L = a_L$

This null hypothesis cannot be rejected indicating that older operators were also successful in maximising profits.

The results of these hypotheses tests indicate that the operator's age has no effect on the efficiency of grazing properties. This applies to all facets of efficiency: technical, allocative and, hence, economic efficiency.

Conclusions, Implications and Limitations

Application of the Lau and Yotopoulos normalized profit function methodology for testing for differences in economic efficiency between groups of farms has shown that, within our range of observations, property size does have a significant effect on relative efficiency, with larger farms being more economically efficient than smaller grazing industry properties in the New South Wales High Rainfall Zone. Furthermore, larger and smaller farms were not equally relatively allocatively efficient with respect to the variable input. Paradoxically, absolute allocative efficiency could not be rejected for either small or larger farms. Both larger farms and smaller farms were found to be absolutely allocatively efficient, *i.e.*, they equate the value of marginal product of the labour input to its price. Given that the two groups were not equally economically efficient and that the two groups have differences in relative allocative efficieny, it was not possible to test whether the two groups are equally technically efficient using this methodology. However, the result of the test on returns to scale suggested that constant returns to scale prevailed over the range of data considered.

Further application of the Lau and Yotopoulos methodology has shown that the age of the property's operator has no effect on relative economic efficiency. Similarly, there were no significant differences in relative allocative efficiency or relative technical efficiency between properties with younger and older operators. Furthermore, both younger and older operaors were absolutely allocatively efficient with respect to the variable input.

While an evaluation of alternative policy options was not undertaken in this study, the results do have some implications for government policies aimed at improving farm-level efficiency. Although the results show that larger farms are more economically efficient than smaller farms they do not necessarily lend support to government policies aimed at increasing the size of small farms. The evidence of constant returns to scale presented in this study indicates that there are no size cost economies present over the range of the data. Furthermore, since efficiency is closely related to management ability government encouragement to expand farm size may result in existing relatively inefficient managers being confronted by more complex decisions.

While the results of the tests on the two age groups are based on an age of 40 years as the cut-off between younger and older groups, they suggest that there appears to be no reason from an efficiency point of view why policies such as the provision of extension services, credit facilities and adjustment assistance should favour operators in any particular age group. It should also be remembered that these results are not consistent with the hypothesis that operators become relatively less efficient as they age.

In assessing these results it is essential that the limitations of the profit function approach in measuring economic, technical, and allocative efficiency are fully considered. The value of the above results for policy prescription purposes is limited by the nature of the underlying methodology used in this study. For example, the analysis in this paper, and all earlier applications of this model, has been based on cross-sectional data. This has important implications for the specification of the model as, at any point in time, all farmers in a region of Australia are confronted by essentially the same price levels for standardised units of most of their variable inputs. Inputs such as materials and services, which together accounted for around 20 per cent of all costs in 1975–6, fall into this category (McKay, Lawrence and Vlastuin 1980). As it is not possible to derive a variable price for these inputs they are omitted from the estimating equations. If these inputs are used in fixed proportions to output across all farms the relationships in the profit function will not be biased but drawing implications on overall allocative efficiency from only a sub-group of variable inputs can be misleading. A farmer is only allocatively efficient in its most commonly used sense, if he succeeds in simultaneously equating the value marginal product of all inputs with their respective prices. Clearly, from the one variable input analysis presented in this paper we can conclude that both older and younger operators are absolutely allocatively efficient only if we assume that both groups are also simultaneously equating the value marginal product with marginal cost for all the unspecified variable inputs.

The cross-sectional orientation of the model may also affect the overall interpretation that can be placed on the results. Farming, and in particular grazing, is an economic activity in which producers are faced with extended lags between the commitment of resources to production and the receipt of output. Similarly, producers often have longer term development plans or objectives which may take some years to come to fruition. Both of these factors have implications for the appropriateness of evaluating efficiency in Australian agriculture over a relatively short period of time, *i.e.*, 12 months. A study based on 12 months data may lead to biased conclusions with respect to economic efficiency if farmers are actually operating on a significantly longer production horizon.

The selection of the period on which the analysis is based may also have implications for the results. Adverse climatic condition, changes in market conditions, or changes in government policies may lead to the results of the study having limited relevance for other periods.

In addition the usefulness of the results is also limited by the apparent inconsistencies which may be exhibited in the results obtained from the statistical framework underlying the profit function approach. In our analysis of larger and smaller farms we rejected the hypothesis of equal allocative efficiency yet could not reject the related separate hypothesis of absolute price efficiency of larger and smaller farms. This paradox arises because, at the 5 per cent level of significance, the "k" values of the two groups are statistically different from each other but are not statistically different from 1. In addition, the test for absolute price efficiency is biased in favour of acceptance of the null hypothesis because the standard errors of the coefficients in the input share equations are very small while the standard error of the price coefficient in the profit function is quite large.

Just as the methodology does not always identify the direction of allocative efficiency differences between groups of farms it provides a measure of relative technical efficiency only if certain conditions are satisfied. Relative technical efficiency between two groups of farms can be identified only if the two groups are found to be equally allocatively efficient. Failure to establish this equality rules out the possibility of drawing any conclusions with respect to technical efficiency.

The reservations expressed above relate, in the main, to conceptual problems in dissecting economic efficiency into its two component parts (technical and allocative efficiency). These problems are accentuated in Australian agriculture as compared with agriculture in less developed countries due to a relative lack of cross-sectional price variation for some variable inputs and generally longer planning horizons.

Notwithstanding these reservations, the profit function approach does provide a useful framework for evaluating differences in overall economic efficiency. In this regard the methodology has general applicability to a number of issues relevant to Australian agriculture apart from the issues of farm size and farmer age. A comparison of the overall economic efficiency of adoptors and non-adoptors of new technology is an example of one such issue. However, the model does require further development before its full value can be realized in the analysis of Australian agriculture. The methodology has recently been extended by the introduction of functional forms that are more flexible than the traditional Cobb-Douglas form (Atkinson and Halvorsen 1980). Further refinement of the methodology in the area of broadening the model beyond its present cross-section base to incorporate time-series, or time-series/cross-section data may enhance the confidence which can be placed on the results concerning allocative efficiency.

References

Atkinson, S. E. and Halvorsen, R. (1980), "A test of relative and absolute price efficiency in regulated utilities", *Review of Economics and Statistics* 62 (1), 81-8.

BAE (1976), *The Australian Grazing Industry Survey 1973-4,* AGPS, Canberra.

Byron, R. P. (1970), "The restricted Aitken estimation of sets of demand relations", *Econometrica* 38(6), 816-30.

Farrell, M. J. (1957), "The measurement of productive efficiency", *Journal of the Royal Statistical Society* 120 (3), 253-82.

Khan, M. H. and Maki, D. R. (1979), "Effects of farm size on economic efficiency : the case of Pakistan", *American Journal of Agricultural Economics* 61(1), 64-9.

Lau, L. J. and Yotopoulos, P. A. (1971), "A test for relative efficiency and application to Indian agriculture", *American Economic Review* 61(1), 94-109.

____________________ (1972), "Profit, supply, and factor demand functions", *American Journal of Agricultural Economics* 54(1), 11-8.

Lawrence, D. and McKay, L. (1980), "Inputs, outputs and productivity change in the Australian sheep industry", *Australian Journal of Agricultural Economics* 24(1), 46-59.

McKay, L., Lawrence, D. and Vlastuin, C. (1980), "Input demand and substitution in the Australian sheep industry", this *Review* 48(2), 57-70.

O'Connor, C. W. and Hammonds, T. M. (1975), "Measurement of the economic efficiency of central-fabrication versus carcass-meat-handling systems", *American Journal of Agricultural Economics* 57(4), 665-75.

Shephard, R. W. (1953), *Cost and Production Functions,* Princeton University Press.

Sidhu, S. S. (1974), "Relative efficiency in wheat production in the Indian Punjab", *American Economic Review* 64(4), 742-51.

________________ and Baanante, C. A. (1979), "Farm-level fertiliser demand for Mexican wheat varieties in the Indian Punjab", *American Journal of Agricultural Economics* 61(3), 455-62.

Trosper, R. L. (1978), "American Indian relative ranching efficiency", *American Economic Review* 68(4), 503-16.

Yotopoulos, P. A. and Lau, L. J. (1973), "A test for relative economic efficiency : some further results", *American Economic Review* 63(1), 214-23.

________________, ________________ and Lin, W. (1976), "Microeconomic output supply and factor demand functions in the agriculture of the province of Taiwan", *American Journal of Agricultural Economics* 58(2), 333-40.