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GROWTH AND SIZE ECONOMIES OVER SPACE AND TIME: WHEAT-SHEEP FARMS IN NEW SOUTH WALES

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Time series and cross-sectional data for 18 years on 26 N.S.W. wheat-sheep properties are combined to test whether farms that grew in size over time reaped the postulated size economies derived from the cross-sectional statistical cost functions. Realized economies of farms that remained in the industry and changed in size during the 18-year period were found to be significantly greater than measured potential economies from 'static' cost functions would have suggested. The 'dynamic economies of growth' differed significantly amongst farms indicating there was no single economy of size curve along which farms moved.

A substantial part of the conventional wisdom on rural adjustment in Australia and other developed countries is that relatively small farms must be amalgamated into larger units. This is to assist their survival against the pressures of technological change and the cost-price squeeze.[1] A move towards larger farms enables farmers to appropriate the postulated benefits of economies of size according to this line of reasoning.[2] Along with these internal resource adjustments the pace of resource movement out of agriculture must be quickened. Unless this occurs, as Harris [11, 12] and others argue, surplus production, lower product prices and reduced farm incomes will result.

Some empirical studies which have been conducted in Australia recently have mostly found L-shaped average cost (*AC*) curves using cross-sectional data. The most notable are the studies by Longworth and McLeland [19], Powell [25] and Tuck [32]. Anderson and Powell, [1] in their review of the empirical evidence for farm size economies in Australian agriculture, conclude that L-shaped average cost (*AC*) curves can be identified in the wheat, sheep, dairy, cotton and egg industries. Madden [20] in his review of the American literature also concludes that L-shaped *AC* curves predominate.

One implicit ingredient in the above discussion has always been the belief that the L-shaped or U-shaped average cost (*AC*) curves, mostly

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[1] For example see Anderson and Powell [1], Bureau of Agricultural Economics [5, pp. 19-28], Harris [12, p. 11], Cassidy *et al.* [6, p. 179], Davidson [8, pp. 147-150] and several authors in Ball and Heady [2].

[2] Size economies are defined here as reductions in average unit costs of production of physical output as a result of changes in the volume of that ouput. I recognize that this definition tends to blur the distinction between movements along short-run versus long-run cost functions. However, in the majority of statistical cost analyses which have been conducted in the past using cross-sectional data and regression techniques, this distinction has not been made.

derived from cross-sectional farm data, imply that small farms can move along these 'planning curves' and achieve significant cost economies. As Penrose [24, pp. 2, 100], Raup [26], Renborg [27, p. 56], and Ryan [28] have all noted, a serious defect in studies of economies of size has been their static nature. Statistical cost curves derived from cross-sectional analyses should be used with care in making statements about potential size economies and growth prospects. The whole question of the relationship between firm growth and economies of size depends on whether L- or U-shaped cost curves just mean that efficient firms grow big rather than that large firms *always* realize cost economies. It *may not* mean that small firms in an industry can grow to become the low-cost firms. Often, growth to a larger and more efficient size is more difficult than starting at the beginning with a large enterprise.[3]

Furthermore, as Stigler [31, p. 161] points out, a disadvantage of statistical cost functions derived by relating *AC* to output for a sample of firms, is the possibility of confronting the 'regression fallacy'. This occurs when individual firms with similar fixed resources operate at different output levels because of limitations on other resources, risk, uncertainty, and random fluctuations. A regression equation fitted to a scatter of average cost observations passes through these points and can give a curve which is above the true envelope curve, and which may not have the same slope. Needless to say, the vast majority of statistical cost function studies have failed to take explicit account of this limitation. Notable exceptions are Barker [3] and Hopkin [13].

Anderson and Powell [1] have fitted cost functions to data from wheat farms in New South Wales at different points in time but with *a different sample of farms* in each survey. However, it would appear there have been no studies which have attempted to empirically test whether firms that grow in fact reap postulated size economies *over time*. This is an important policy question and the aim in this paper is to conduct some empirical tests on the performance of a sample of 26 surviving wheat-sheep farms in New South Wales using annual data on them over the period 1952/53 to 1969/70 to determine if measured size economies at a point in time across farms are reflected in the cost experience of the same farms over time.

Models and Hypotheses

If firms grow because the *AC* curve is L- or U-shaped, then there should be a relationship between growth in size (g) and the subsequent reduction in firms' *AC*.[4] For the ith firm let the output difference be:

(1) $g_{i,t+n} = Q_{i,t+n} - Q_{i,t}$ in absolute terms, or

(1a) $g'_{i,t+n} = (Q_{i,t+n} - Q_{i,t})/Q_{i,t}$ in proportionate terms,

[3] Recently, Bassett [4] nd McElroy [22] have demonstrated the difficulties involved in making inferences about scale economies from comparisons of average costs at widely separated (i.e. non-marginal) outputs or sizes.

[4] Almost without exception empirically derived AC curves are designated 'planning curves'. Hence, if they are, we should observe the specified relationship. The discussion generally fails to mention precisely how firms who decide to increase their output should achieve it, i.e. whether by increased fixed capital investments, more labour applied to existing plant, more working capital, etc.? For example, see Longworth and McLeland [19], and Davidson [8]. More will be said about this later in the paper.

where $Q =$ size of firm output

$i = 1, 2, \ldots, m$, or the number of firms in the industry, and

$n = 1, 2, 3, \ldots, p$, or the number of years of observations on the m firms.

To test if there are *genuine* economies of size *within* firms (i.e. when a firm increases size its AC declines), as opposed to *apparent* economies of size *across* firms in cross-sectionally derived AC curves, the following (null) relationship should hold, *ceteris paribus*:

$$(2) \quad E_{i,t+n} = AC_{i,t+n} - AC_{i,t} = f(g_{i,t+n}, d_{i,t+n}, W_{i,t+n}).$$

That is, the change in a firm's AC between two periods (E) is a function of its output growth between the two periods, the degree of diversification in its production (d) and the change in weather (W). The inclusion of a diversity index (d) is to allow for the possibility that economies of joint production may cause AC changes rather than size, *per se*.[5] In an agricultural context weather has an important bearing on a firm's cost structure and is a logical inclusion in (2). The effect of inflation on AC's can be taken account of by deflating costs by the appropriate index.

In relation to (2) the hypotheses to be tested are that:

$$(3) \quad \partial E/\partial g < 0$$
$$(4) \quad \partial^2 E/\partial g^2 > 0$$
$$(5) \quad \partial E/\partial d > 0$$
$$(6) \quad \partial E/\partial W < 0$$

where W is positive when the weather changes from 'bad' in period t to 'good' in period $(t + n)$, and negative when the reverse occurs. If (3) and (4) are not rejected in empirical tests then the existence of L- or U-shaped AC curves which can be used as guides in dynamic planning is not rejected.

An alternative formulation of the above model is related to Gibrat's law of proportionate effect. This law states that the probability of a firm growing by x per cent is the same for small and large firms. Mansfield [21] has shown that the law does not hold up very well empirically in the U.S. steel, petroleum refining, and rubber tyre industries. A similar finding was made by Jarrett [16] for farms in the BAE's Australian Sheep Industry Survey from 1952-53 to 1962-63, and also by Hymer and Pashigian [14]. These studies concluded that small firms mostly tended to grow faster than larger firms and that the variance of growth rates within size groups was also negatively related to the size class. To refine this type of test it would seem to be more meaningful to include potential economies of size instead of present size as the proxy for growth incentive. Potential size economies would be represented for farm i at time t as $AC'_{i,t}$, where:

$$(7) \quad AC'_{i,t} = AC_{i,t} - AC_t^*.$$

Here AC_t^* represents the estimated minimum AC level from a cross-sectional statistical cost analysis conducted on data during time period t. We would expect firms with larger potential economies to grow faster.

[5] See Mitchell [23, p. 97]. Here d is set up so that it increases as production becomes more diversified.

The model of the determinants of growth of the agricultural firm would be:

(8) $$g_{i,t+n} = h(AC'_{i,t}, L_{i,t}, P_t^*, W_{i,t+n}).$$

$L_{i,t}$ is a variable representing 'high' and 'low' cost firms in year t. One may reasonably expect differential growth rates and AC changes for 'efficient' versus 'inefficient' firms of similar size. This variable could be set up as $L_{i,t} = 0$ for 'inefficient' firms whose actual $AC_{i,t}$ are greater than the predicted $\hat{AC}_{i,t}$ from a fitted cross-sectional statistical cost function, and as $L_{i,t} = 1$ for 'efficient' firms with $AC_{i,t} < \hat{AC}_{i,t}$. Alternatively, the algebraic differences between $AC_{i,t}$ and $\hat{AC}_{i,t}$ could be used directly to form the $L_{i,t}$ efficiency variable. In the absence of any better measure of 'management' these options seem acceptable and the latter was in fact chosen for the empirical analysis. P_t^* represents expected product prices in year t and is included to test Stigler's [29, p. 319] hypothesis that market conditions (prices) affect choices of firm size. According to this hypothesis if the marginal revenue curve of the firm falls then equilibrium output levels will also fall, and firms will move left along their marginal and average cost curves. In this formulation the minimum point on the *ex ante* AC curve has no particular relevance for planning. Desired size is determined by intersection of marginal revenue and marginal cost curves, and the corresponding AC point is the outcome of this process. It is these AC's which one observes in cross-sectional data and they are the *result*, and not the basic *cause*, of size decisions.[6]

The hypotheses to be tested in (8) are therefore:

(9) $$\partial g/\partial AC' > 0,$$
(10) $$\partial^2 g/\partial AC'^2 < 0,$$
(11) $$\partial g/\partial L < 0,$$
(12) $$\partial g/\partial P^* > 0,$$
(13) $$\partial^2 g/\partial P^{*2} < 0,$$
(14) $$\partial g/\partial W > 0.$$

A third type of model which can be used involves a direct test of the comparability of AC curves derived cross-sectionally, versus AC curves derived over time within farms. To do this involves the construction of an analysis of covariance incorporating firm and time dummies with interactions between them and farm output (Q) of the form:

(15) $$AC_{i,t} = 1(F_i, T_t, Q_{i,t})$$

where

$$F_i \begin{cases} = 1 \text{ for an observation on farm } i \ (i = 1, 2, 3, \ldots, m) \\ = 0 \text{ otherwise} \end{cases}$$

and

$$T_t \begin{cases} = 1 \text{ for an observation in year } t \ (t = 1, 2, 3, \ldots, p) \\ = 0 \text{ otherwise.} \end{cases}$$

[6] Ijiri and Simon [15] contend that current firm growth is dependent upon both the extent of past growth and how recently the growth occurred. Firms that grew more recently grow more in the current period than similar sized firms whose growth occurred earlier. As we are attempting to explain why growth occurs it was decided to exclude lagged growth rate as an explanatory variable.

Equation (15) allows both the AC curve intercepts and slopes to vary from farm-to-farm and from year-to-year. An F-test can be used to test the hypothesis that the vector of slope coefficients relating AC's to size of firms over time is not significantly different to the vector of slope coefficients relating AC's to size across firms within years. This is outlined by Johnston [18, pp. 192-207].

In the following sections empirical tests of the models outlined in equations (2), (8) and (15) are performed on 18 years of continuous data on 26 farms in the wheat-sheep zone of New South Wales, Australia.

Empirical Analyses

The numerator of AC is total cost and was measured by first summing all annual operating expenses on the farms (seeds, fertilizers, pesticides, insecticides, hired labour, family labour at award rates, etc.) and adding depreciation and interest charges on capital. Depreciation on buildings was charged at $1\frac{1}{2}$ to 3 per cent depending on the type, fences at 3 per cent, water supplies and irrigation at 2 to 10 per cent depending on the type, shearing equipment at $7\frac{1}{2}$ per cent, vehicles at 15 per cent, and 10 per cent on all other items. Interest on all capital was charged at 6 per cent on the opening value. Capital included all land at constant 1966-67 unit values as determined by qualified valuers, whether freehold or leasehold (excepting short-term leases), plus improvements, plant, and livestock. All changes in land ownership or leaseholdings during the 18 years were included at the appropriate period but at constant 1966-67 per acre values. These values were calculated separately for each farm. Financial assets and off-farm assets were not included in capital. Rent paid was not included in costs as the capital figure included the value of all freehold and leasehold land.

The total costs arrived at by the above procedure were deflated each year by the BAE's Prices Paid Index. To arrive at AC the deflated costs were divided by the output of the farm (Q). Output was measured as annual gross income ($) deflated by the BAE's Prices Received Indices, with 1952-53 as a base.[7] Growth was measured in absolute and proportionate terms using both Q and total capital employed on the farms each year (K) to determine which form had the best explanatory power. The diversity index (d) was calculated as the numer of enterprises on the farm (in excess of one) which contributed more than 15 per cent to total gross income. The weather variable (W) was constructed from unpublished rainfall data obtained from the Commonwealth Bureau of Meteorology in Melbourne using annual rainfall in deciles. Previous empirical work by Freebairn [9] suggested a weighting scheme which places more weight on low rainfall years. Weather in any year was specified as:

$$(16)\quad W' \begin{cases} 1 \text{ for decile ranges 9 and 10 (high rainfall)} \\ 0 \text{ for decile ranges 4 through 8} \\ -1 \text{ for decile range 3} \\ -2 \text{ for decile range 2} \\ -3 \text{ for decile range 1 (very low rainfall)} \end{cases}$$

[7] Gross income was first separated into income from wool, wheat, cattle, sheep, and other, and the appropriate commodity price indices used to deflate each item. In this way an attempt is made to obtain a proxy physical measure of output which moves independently of the prices received.

In all formulations W was set up as the change in weather between periods, being positive when weather changes for the good and vice versa.

P^*, the expected price of wheat-sheep farm products, was constructed from the BAE's All Farm Products Prices Received Index (P) using a lagged structure of the form:

$$(17) \qquad P_t^* = 0{\cdot}50P_{t-1} + 0{\cdot}33P_{t-2} + 0{\cdot}17P_{t-3}.$$

This has proved a suitable weighting structure in previous work by Freebairn [9].

Determinants of Average Cost Changes Over Time

Table 1 contains the results of the empirical analyses relating changes in average costs of production for farms over time to changes in output, enterprise diversity and weather changes. The four equations represent those preferred from amongst 24 which were fitted. First of all three different time periods were used to calculate E and growth (from t to $t + 3$) to account for the possibility of lags in adjustment. In addition both absolute and proportionate growth rates using output and then capital as size measures were fitted. All these were then fitted using quadratic and linear functions for the growth variables. The four equations in Table 1 were chosen from among these variants on the basis of the correctness of signs and significance of the coefficients. The equations where capital (K) was used as the size measure in place of output (Q) gave very poor R^2 values and generally lacked significance in the coefficients.[8]

The one-year lag models were superior to the others and equations I(a) and I(b) show the hypothesis that farms' average costs over time are significantly influenced by absolute growth in farm output (in dollars) is not rejected. As farm output grows, so average costs decline, although not at a diminishing rate as hypothesized. The largest positive change in output between $(t + 1)$ and t in the data was \$100,500 in deflated 1952-53 terms. The smallest was a reduction in output of \$70,130. The one year mean absolute growth was \$869, with a standard deviation of \$13,960. The coefficients in equation I(b) of Table 1 suggest that if output increased by \$100,500 in one year then total real costs would decline by 2·432 dollars per dollar of output, *ceteris paribus*. If output increased by \$869 then total costs would decline by 0·02 dollars per dollar of output. The mean level of AC in the data was 1·185, with a range of 0·342 to 6·356. Hence, for a farm growing in absolute terms at the mean level observed on the farms and having an AC also at the mean level, its AC could be expected to decline by 1·7 per cent per year.

Enterprise diversity did not appear to offer any significant economies of joint production amongst these farms, contrary to expectations. However, this may be due to the lack of variability in the data for this

[8] Onko Kingma (pers. comm.) suggests one reason why changes in capital failed to provide any significant explanation of AC changes in any of the equations could be that unused capacity in one or more elements of the firm's resource vector in the short-run is the main determinant of growth in size, in line with Penrose's hypothesis [24]. Capital may change due to lumpy investments which are reflected more rapidly in costs than in output, thus leading to a poor relationship between ΔAC and K. The fact is that in theory there is no *a priori* reason to expect a relationship between these two variables unless we hold all other inputs constant.

TABLE 1

Effect of Farm Growth, Enterprise Diversity, and Weather on Average Costs for New South Wales Wheat-Sheep Farms[a]

Equation	Dependent Variable	Explanatory Variables[b]: Constant	Absolute Growth of Output $(t+1)-t$	$\left(\text{Absolute Growth of Output } (t+1)-t\right)^2$	Rate of Growth of Output $(t+1)-t$	$\left(\text{Rate of Growth of Output } (t+1)-t\right)^2$	Enterprise Diversity Index	Δ Weather $(t+1)-t$	R^2
I(a)	Δ Average Cost $(t+1)-t$	—0·0922 (0·31)[c]	$-0{\cdot}2400\times10^{-4}$** (12·17)	$-0{\cdot}1195\times10^{-10}$ (0·32)	—	—	0·0384 (0·35)	—0·0334* (2·21)	0·33
I(b)	„	—0·0927 (0·31)	$-0{\cdot}2420\times10^{-4}$** (12·48)	—	—	—	0·0369 (0·34)	—0·0335* (2·22)	0·33
I(c)	„	0·0174 (0·09)	—	—	—0·9824** (22·99)	0·0943** (8·58)	0·0469 (0·65)	0·0038 (0·38)	0·71
I(d)	„	—0·0183 (0·09)	—	—	—0·6782** (26·21)	—	0·0886 (1·14)	—0·0089 (0·82)	0·65

[a] The four equations were fitted with 25 dummy variables representing farms. None of these were significant at the one per cent level.
[b] * and ** represent significance at the five and one per cent levels, respectively, using a one-tail t-test. See the text for the units used for each variable.
[c] Numbers in parentheses are t-values.

variable which was observed in the sample of farms. In all equations in Table 1 the sign of the coefficient on the diversity index was positive, which was according to expectations. Weather, as hypothesized, had the effect of significantly reducing average costs when it changed from 'bad' to 'good' between two periods, and vice versa.

The three variables chosen in equation I(a) and I(b) plus the 25 farm dummies only accounted for one-third of the variation in average cost changes over time on these farms. Other factors which we have not been able to represent have been far more influential. This suggests factors like technology and management may have large roles. However, in single period lag models of the type used here, it is doubtful if technological change could be expected to affect average costs significantly. The management factor is explicitly examined in the next section as a determinant of farm growth.

A much improved explanatory power was achieved in equations I(c) and I(d) of Table 1 where the rate of growth of output was used instead of absolute growth, as used in I(a) and I(b). More than two-thirds of the change in average costs over time is explained by rate of growth, and there is evidence that the relationship is of a curvilinear U-shape. Hence the size from which a given increment in output occurs is important in achieving cost economies. The larger the output of the farm the less is the effect of a given increment in output over time on average costs of production up to a certain level of output. This supports the hypotheses represented by equations (3) and (4). The output of the average farm grew at a rate of about 19 per cent per year in real terms during the period studied, with a standard deviation of 76 per cent. Equation I(c) shows that, up to a one-period growth rate of 521 per cent, AC would still decline. After that AC would begin to rise again. The maximum growth rate in the data was 576 per cent. Hence, for virtually all farms in this study, the relationship between changes in AC and output growth rates was monotonically negative as hypothesized.

Determinants of Farm Growth

Table 2 contains results of the regression equations fitted to determine whether potential size economies, expected product prices, farmer efficiency and weather changes affect the absolute growth of farms over time. These three equations were selected from a total of 12 which were fitted. The 12 variations represented three different lag structures for growth and weather, and four different methods of computing efficiency (L) and potential size economies (AC_t'). The first method of computing potential size economies involved fitting quadratic AC curves for four consecutive groups of years, calculating the minimum AC_t^* point on each and subtracting this from each firm's actual AC to obtain AC_1'.[9] The second (AC_2') involved fitting a quadratic AC curve to each of the 18 years of data separately, calculating the minimum AC_t^* point on each and then calculating AC_2'. The third form (AC_3') was the same as AC_1' except a logarithmic function was used to derive the AC curves. Similarly, AC_4' was the logarithmic equivalent of AC_2'.[10] The efficiency

[9] Year dummies were included in this and the other three AC variants used to derive AC'.

[10] In most instances the minimum AC points on the logarithmic functions were close to zero so the minimum observed value of AC in the data was employed to calculate AC'_3 and AC'_4.

TABLE 2

Effect of Potential Size Economies, Expected Product Prices, Efficiency and Weather on Farm Growth for New South Wales Wheat-Sheep Farms[a]

Equation	Dependent Variable	Explanatory Variables[b]									R^2
		Constant Term	Potential Size Economies at t	$\left(\text{Potential Size Economies at } t\right)^2$	Expected Produet Prices at t	$\left(\text{Expected Product Prices at } t\right)^2$	Efficiency Index at t	Δ Weather $(t+1)-t$	Δ Weather $(t+2)-t$	Δ Weather $(t+3)-t$	
II(a)	Absolute Growth of Output $(t+1)-t$	409,474* (1·96)[c]	16,792** (6·10)	−2,885** (4·56)	−762,654* (1·96)	349,534* (1·94)	1,961 (0·54)	2,157** (6·29)	—	—	0·26
II(b)	Absolute Growth of Output $(t+2)-t$	107,768 (0·48)	9,274** (2·75)	−2,116** (2·97)	−191,162 (0·45)	86,378 (0·44)	1,782 (0·47)	—	1,351** (3·38)	—	0·15
II(c)	Absolute Growth of Output $(t+3)-t$	270,426 (1·00)	19,750** (5·60)	−2,608** (2·86)	−475,295 (0·95)	207,506 (0·90)	−3,118 (0·71)	—	—	1,421** (2·84)	0·24

[a] The three equations were fitted with 25 dummy variables representing farms. None were significant at the one per cent level.
[b] * and ** represent significance at the five and one per cent levels, respectively, using a one-tail t-test. See the text for the units used for each variable.
[c] Numbers in parentheses are t-values.

variable L was constructed by subtracting each farm's estimated $\hat{AC}$ (derived from fitting AC curves cross-sectionally to the data by the four different methods just described) from its actual AC each year. The three equations in Table 2 were selected on the basis of correctness of signs and significance levels of coefficients. Equations II(a) and II(b) used the third method of calculating potential size economies and efficiency, whereas equation II(c) used the first method.

Equation II(a) had somewhat better explanatory power and significance levels than either II(b) or II(c), which used respectivly two- and three-year lags for growth and weather. This was perhaps unexpected if growth decisions are believed to take some time to effect. In all three equations the hypothesis that absolute output increases are positively influenced by the extent of measured potential size economies is accepted. As also hypothesized, the influence of these potential economies on output growth diminishes the larger the potential economies are. For every increase of one dollar in potential cost economies per dollar of output at the mean levels of other variables in equation II(a) in year t, absolute output increases by some \$13,200 in the next year $(t + 1)$. In the following year $(t + 2)$ equation II(b) shows the output of the firm is less than in $t + 1$. This is because the one dollar increase in potential economy in year t only causes output to increase by \$6,700 in $t + 2$ compared to t, or by —\$6,500 compared to $t + 1$. In $t + 3$ output increases by \$18,000 compared to t, which is an increase of \$11,000 on $t + 2$.

The point of maximum absolute one year growth at the arithmetic mean levels of the other variables occurs at a potential cost economy of 2·91 dollars per dollar of output. At this point the optimum growth is well beyond the maximum range of the data of \$100,500. Hence we can conclude that, for all feasible ranges of the data, positive absolute output growth will always occur in response to potential cost economies that exist at points in time. The average potential size economy from the data was 0·619 dollars per dollar of output. The range was from —0·323 to 5·691.

Expected product prices significantly affected growth over single time periods, as shown in equation II(a) in Table 2. Over two and three year growth phases [equations II(b) and II(c)] expected prices had no significant effect on growth. The partial derivative of growth with respect to expected product prices (P^*) in equation II(a) has the expected positive sign only if $P^* > 1{\cdot}09$. The mean value of P^* from the data was 1·07, and the range was 0·99 to 1·19, with the largest values occurring in the early 1950s (coinciding with the wool boom) and then trending downwards to 1970. Hence in the early 1950s when there were large downward changes in P^*, it is possible to gain support for Stigler's hypothesis of a positive relationship between expected prices and size. However, in later periods when P^* fell below 1·09 and did not vary as much, we do not detect such a relationship. The probable reason is that technological change was more rapid in the latter period and clouds the effect of P^*. If an independent measure of technological change was included this may not have occurred.

There is no evidence from any of the equations in Table 2 that, *ceteris paribus*, more efficient farms grow any faster than less efficient farms. To the extent this variable is a proxy for managerial capacity, the results do not support Penrose's contention [24, pp. 2, 98, 262-263] that managerial capacity primarily determines a firm's growth rate. There may be more appropriate measures of managerial capacity than the one used here, but the literature did not help a great deal in identifying one which could be used with the data available in the present study.

An alternative way of looking at the efficiency variable L is as a proxy for unused capacity in the Penrose context [24]. At a given output level, those farms with AC above $\hat{AC}$ (i.e. $L > 0$) might be looked upon as having unused capacity compared to those with AC below $\hat{AC}$ (i.e. $L < 0$). One would then hypothesize that $\partial g/\partial L > 0$, as Kingma points out. This is contrary to equation (11) which is based on L as a measure of efficiency. As Table 2 shows, the coefficients on L were never significant and had a mixture of signs in the various formulations. Hence, to the extent L is a measure of unused capacity, there is no support for the Penrose hypothesis that unused capacity accelerated growth on these wheat-sheep farms. However, it is recognized that one requires refined empirical measures of 'efficiency' and 'unused capacity' to make conclusive statements on these hypotheses. Unfortunately, obtaining such measures remains an elusive task.

In all equations weather showed up as having a significant effect on the growth of farm output. When rainfall in one year is at drought levels and in the next year it is 'normal' (a change in weather of +3), equation II(a) shows that output would grow by about \$6,500.

Comparability of Cost Functions Over Space and Time

Table 3 summarizes the results of fitting both quadratic and logarithmic average cost functions to the data using year and farm dummies in analyses of covariance. Only functions using output as the size measure are shown as the equations with capital used as the size measure mostly gave coefficients that were not of the expected sign and/or were not significant.

F-tests are used to determine whether the slope of cost functions fitted at points in time to cross-sectional farm data are similar to those derived for farms using time-series data. Using either functional form we do not reject the hypothesis that measured size economies in real terms are the same in each of the 18 years in which they were fitted.[11] This means that in cases where only one year of data are available on a cross-section of farms the slope parameters of the fitted function may fairly well represent those which would be derived if additional data for other years were incorporated. At an output of \$10,000 the average slope across years of the cross-sectional quadratic AC curves was $-0{\cdot}2647 \times 10^{-4}$. If output doubled then AC would fall by 0·2647 dollars per dollar of output according to a 'static' cost analysis.

An important result in Table 3 is that we reject the hypothesis that slope parameters of cost functions derived for different farms using time-series data are homogeneous.[12] When farmers decide to expand in size

[11] These tests are performed using mean square errors from equations III(a) and III(d) for the quadratic case, and IV(a) and IV(d) for the logarithmic in F-tests described by Johnston [18, pp. 192-207].

[12] Equations III(b) and III(e) for the quadratic case and IV(b) and IV(e) for the logarithmic are used for these tests.

Measured Size Economies Over Space and Time for New South Wales Wheat-Sheep Farms

Equation	Description[a]	Average Value of Slope of AC Curve: Using Time-Series Data[b]	Average Value of Slope of AC Curve: Using Cross-Section Data[b]	R^2	Hypothesis tested	Result	F-Value	Critical $F_{0.99}$
	Quadratic Models							
III(a)	$AC = f(Q, T)$	-0.1522×10^{-4}		0·35				
III(b)	$AC = f(Q, F)$	-0.4603×10^{-4}		0·45				
III(c)	$AC = f(Q, T, F)$	-0.3305×10^{-4}		0·54				
III(d)	$AC = f(QT, T)$		-0.2647×10^{-4}	0·42	Coefficients on size and (size)^2 are homogeneous among years	Not Rejected	1·49	1·64
III(e)	$AC = f(QF, F)$	-0.5948×10^{-4}		0·70	Coefficients on size and (size)^2 are homogeneous among farms	Rejected	6·55	1·53
III(f)	$AC = f(QT, T, F)$		-0.6012×10^{-4}	0·65	Intercept coefficients on farms are not different to those on years	Rejected	10·46	1·79
III(g)	$AC = f(QT, QF, T, F)$	-1.1387×10^{-4}	-0.7114×10^{-4}	0·78	Coefficients on size and (size)^2 are homogeneous among years and farms	Rejected	4·06	1·53
	Logarithmic Models							
IV(a)	$AC = 1\ (Q, T)$	-0.2001		0·47				
IV(b)	$AC = 1\ (Q, F)$	-0.6185		0·69				
IV(c)	$AC = 1\ (Q, T, F)$	-0.4771		0·75				
IV(d)	$AC = 1\ (QT, T)$		-0.1805	0·48	Coefficients on ln (size) are homogeneous among years	Not Rejected	0·56	1·96
IV(e)	$AC = 1\ (QF, F)$	-0.6685		0·81	Coefficients on ln (size) are homogeneous among farms	Rejected	10·45	1·79
IV(f)	$AC = 1\ (QT, T, F)$		-0.5050	0·77	Intercept coefficients on farms are not different to those on years	Rejected	21·51	1·79
IV(g)	$AC = 1\ (QT, QF, T, F)$	-0.5990	-0.7330	0·85	Coefficients on ln (size) are homogeneous among years and farms	Rejected	8·26	1·79

[a] Q is a vector of size variables, T a vector of year variables in dummy form and F is a vector of farm variables in dummy form. QT and QF represent interactions between size and years and size and farms, respectively.

[b] These are the algebraic sums of the partial derivatives of each equation with respect to size Q. Quadratic slopes were calculated at an output of \$10,000. This is about half of the mean size over all farms over all years.

the results indicate that the slopes of their resultant ('dynamic') real cost functions are significantly different from one another. Of perhaps even more relevance for policy purposes is that the slope parameters of such 'dynamic' real cost functions fitted for each farm are significantly different from the (homogeneous) slope parameters of 'static' cost functions fitted for each year across farms.[13] The average absolute slopes of the quadratic 'dynamic' functions in equation III(e) of $-0{\cdot}5948 \times 10^{-4}$ are more than twice those of the 'static' functions in equation III(d). The logarithmic 'dynamic' functions in equation IV(e) have an average absolute slope of 0·6685, which is almost four times that of the 'static' logarithmic functions in equation IV(d).

The latter result implies that when these 26 farms grew (reduced) in size over these 18 years they experienced significantly greater economies (diseconomies) than one would have expected on the basis of 'static' cost function analysis of the conventional type conducted at any point of time during this period. Hence, *at least for these 26 farms that remained in the industry throughout the 18-year period* (and stayed in the survey!) their realized size economies were significantly greater than measured potential economies from 'static' cost functions would have suggested. A large part of the explanation for this no doubt lies in the effect of technological change on average costs over time. The net reduction in average real costs over the 18-year period studies was $0·822, or an average annual compound reduction of 4·3 per cent. This is an approximate measure of the rate of technological change in these farms and was calculated as the annual downward shift in the cross-sectional *AC* curves at a fixed output. This finding does not conflict with the earlier finding of homogeneous cross-sectional slope parameters across years, as here we are dealing with the heights of the *AC* curves, not their slopes. Unfortunately, the downward shifts in *AC* curves are not independent measures of technological change and hence it is not possible to separate the effects of this and size *per se* on *AC's*.

I rationalize the *apparent* contradiction between L-shaped empirical *AC* curves and neoclassical firm theory which predicts that firms will operate on the ⌟ part of *AC* curves in terms of Figure 1. What we observe in the cross-section data are points like *A*, *B* and *C* which reflect the *AC* of different firms at time *t* as determined from the output where their marginal cost functions (*MC*) intersect their marginal revenue functions (*MR*).[14] In time-series data technological change shifts cost curves downwards as illustrated by $SAC_{i,t+1}$, $SAC_{i,t+2}$, and their corresponding marginal cost curves $MC_{i,t+1}$ and $MC_{i,t+2}$ for firm *i*. As *MR* curves shift downwards (which has been the trend in Australian agriculture over the period examined) so the points of intersection of *MC* and *MR* curves generate *AC* observations of *A*, *D* and *E* for firm *i*. *This explains the steeper slopes of time-series AC curves and the fact that even though firms may be maximizing profits (MR = MC) we can still observe L-shaped empirical AC curves.* In fact, as illustrated in Figure 1, observed data on firm sizes and their *AC*s are not independent of the behaviour of marginal revenue functions that face them, as was found in the early 1950s for these farms (Table 2).

[13] Equations III(f) and III(g) are used in the quadratic test and IV(f) and IV(g) in the logarithmic test.

[14] *SAC* are short-run average cost curves and *LAC* is the envelope average cost curve.

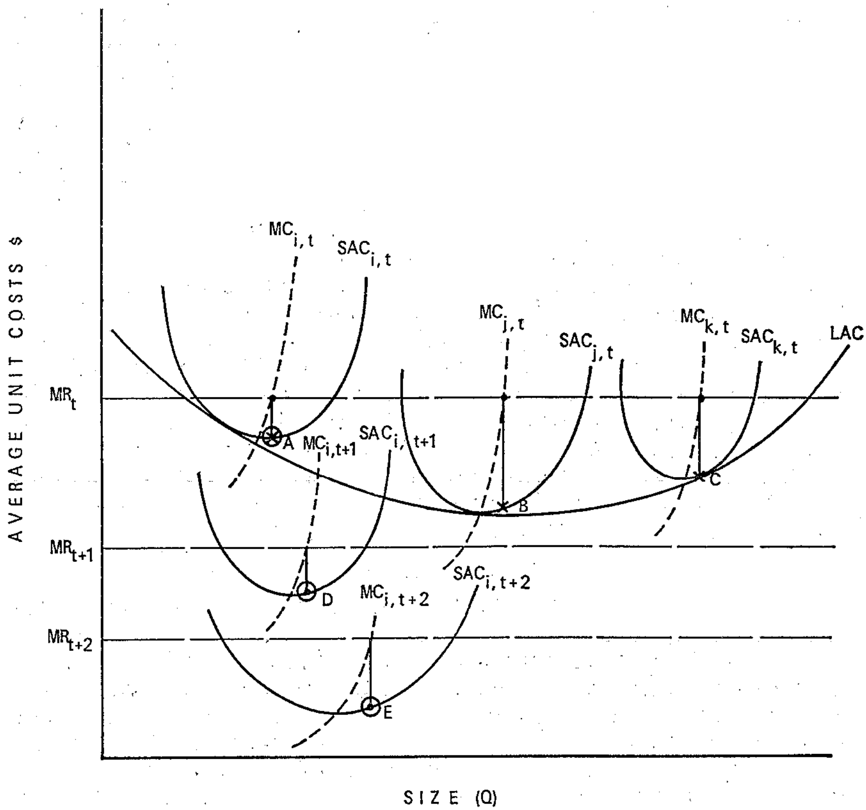

FIGURE 1

Explanation for Steeper 'Dynamic' Cost Functions Compared to 'Static' Functions.

We do not know what the cost experience was of those wheat-sheep farmers who went out of business during the period studied, or what the reasons for their exit were. By the very nature of the data used here we observe only the performance of the survivors, who presumably were best able to withstand the pressures of the cost-price squeeze and technological change. It may therefore be expected that measured size economies of these survivors over time would be superior to those derived from a cross-section. However, in this study, cross-section data are generated from the same set of farms as the time-series, so this argument is weakened, although it is still relevant. What is required, as Daly *et al.* [7, pp. 316-317] point out, are data on movements of farms into and out of different size classes and the industry together with their cost performances.

Another implication from Table 3 is that there may be a tendency when 'static' cost functions are fitted to overestimate the farm sizes at which:

(i) minimum average costs are achieved in the case of quadratic or U-shaped cost functions, and

(ii) achievement of most of the size economies are exhausted in the case of logarithmic or L-shaped cost functions.

This is due to the relative flatness of 'static' functions compared to their 'dynamic' counterparts. Some examples of this from the present data are shown in Figures 2 and 3. Almost all other graphs, whether from time-series or cross-section data, show similar patterns, with the former all tending to have an asymptote at an AC of \$0·40. The 'dynamic' cost functions also have much higher R^2 values than the 'static' functions. Policy-makers should be cautioned against setting unnecessarily large size minima based on 'static' cost functions as there is a danger that they could in the process cause some farmers to move past the desirable size and into the region where diseconomies of size set in. However, if L-shaped cost functions rather than U-shaped ones are as pervasive as the work of Anderson and Powell [1], Johnston [17], Longworth and McLeland [19], Powell [25], Tuck [30] and others suggest, diseconomies may not be as serious an issue. The question of the minimum efficient size required to achieve most size economies remains and, at least in Australia, is still a live issue as illustrated recently by Gibbon [10]. In this respect Figures 2 and 3 suggest that envelope curves joining the points of minimum AC in cross-sectional data may more closely approximate the real economies of size which growing firms experience than do 'static' statistical cost functions.

Conclusion

This study has shown that for 26 of the wheat-sheep properties continuously surveyed for 18 years in New South Wales, the economies of size realized by individual farms that changed in size over time were in general more than two to three times as large as a 'static' cost curve analysis using cross-section data from the same farms would have suggested. These 'dynamic economies of growth' were also significantly different among farms, indicating that there is no single economy-of-size curve along which farms can move. Policy-makers should be cautious in drawing inferences from 'static' economies-of-size curves as they may (i) over-estimate the minimum farm sizes required to achieve most of the postulated size economies and (ii) not reflect the economies individual farmers will experience.

Potential size economies measured from 'static' cost functions were found to have a significant positive influence on subsequent farm growth. Hence, to the extent smaller farmers have larger potential economies, they grow faster than larger farms. This is further evidence against Gibrat's law of proportionate effect. However, potential size economies and other variables explained only one quarter of the variability in growth observed on these farms. Identifying and measuring the determinants of growth remains an area where more research can profitably concentrate.

There was no evidence that more efficient farms grow at different rates to less efficient farms. However, observations did not include the growth and cost performance of farmers who left or joined the industry (and/or the survey) during the period examined. Future research in this area could profitably examine dropouts from the industry to see if the reasons for their demise might not lie in an upward sloping 'dynamic' cost function, contrary to the downward sloping function of the surviving farms examined in this paper. If this were found to be the case it would lend support to Stigler's [30] 'survivorship' hypothesis. Its fundamental

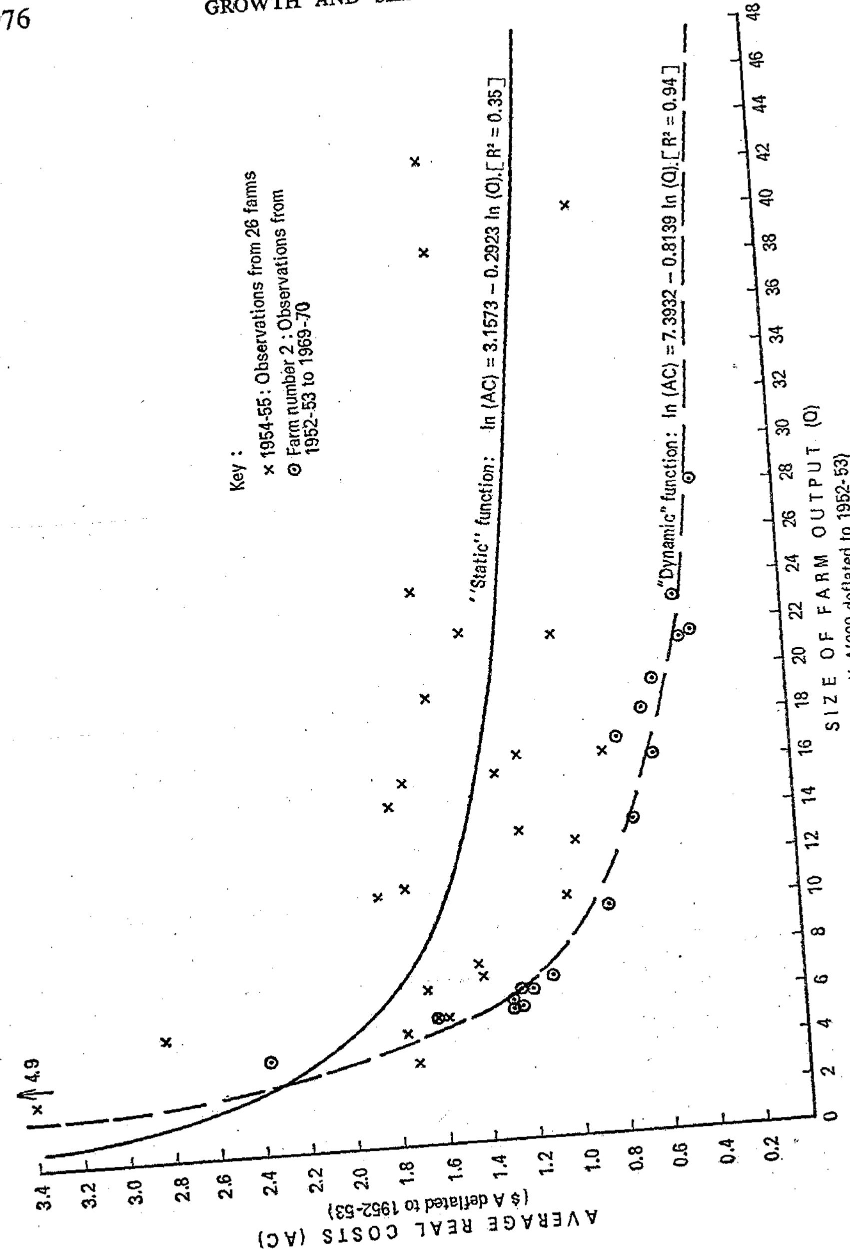

FIGURE 2.
Comparison of AC Curves derived using cross section and time-series data—Example 1.

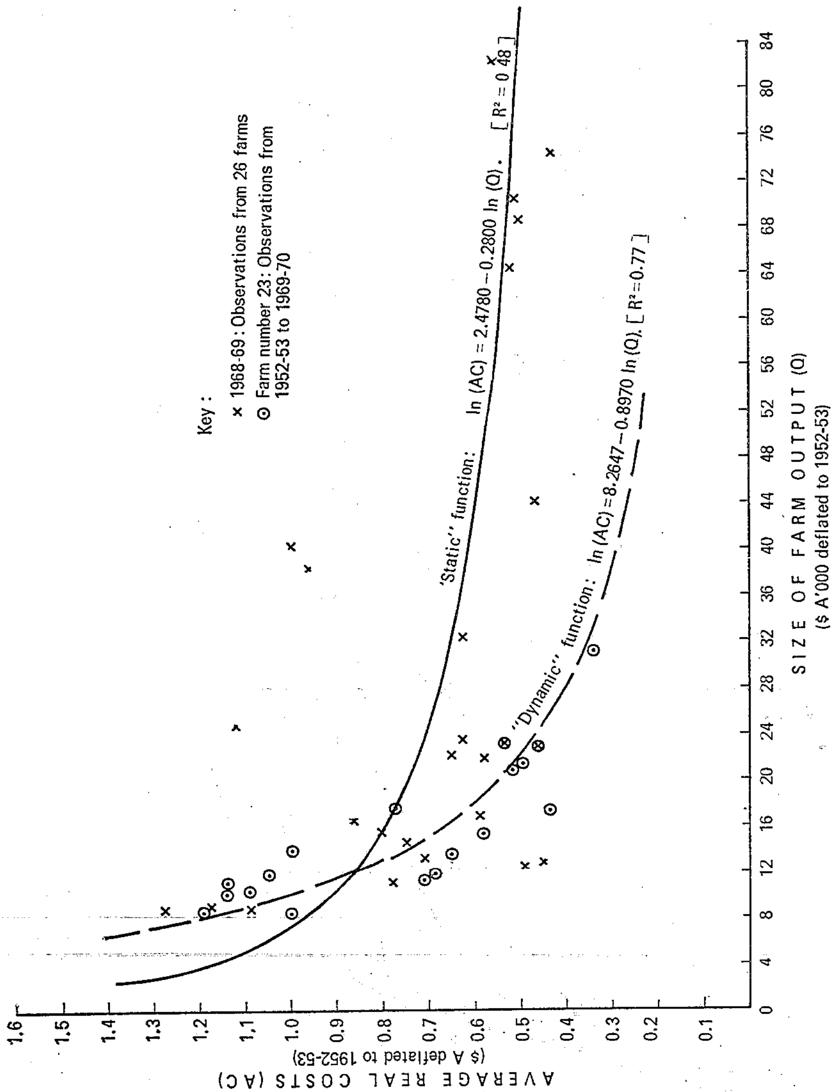

FIGURE 3.
Comparison of AC Curves derived using cross section and time-series data—Example 2.

postulate is that the competition of different sizes of firms sifts out the more efficient enterprises. A desirable refinement in future research on these questions might be inclusion of an explanatory variable which measures 'plant' size in models which aim to explain firm AC changes over time and AC differences among firms in a given period. This might allow separation of short from long-run changes in AC, which can be clouded by using only output as the size measure. The experience in this research when total capital was used as an explanatory variable suggests that it might not be a good proxy for 'plant' size in the traditional sense. However, it is yet to be used in conjunction with output in such models.

There is much scope for further work in the whole area of combining time-series and cross-sectional analysis to exploit the large body of accumulated data from various farm surveys conducted over both space and time on the same sample in Australia and elsewhere. The data utilized here were only a small portion of this and analysis of other data is required to confirm or deny the results found. The econometric techniques and computer capabilities are now available to allow much more of this type of research.

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