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Size Economies in Australian Agriculture

Chris Vlastuin, Denis Lawrence and John Quiggin*

Theoretical, conceptual and estimational issues relevant to economies of size studies are discussed in this paper. Some of the issues discussed are the effects of technological change on the position and shape of the average cost curve over time, the relationship between farm size and relative economic efficiency and frontier versus average estimation techniques. There is also a brief review of various measurement and specification problems.

In addition, empirical estimates of the extent of size economies were derived from a flexible translog production function using ASIS data for the New South Wales Wheat/Sheep Zone for the years 1966–67, 1975–76 and 1976–77. Estimation of the production function revealed that, when the relatively fixed inputs of operator and family labour were excluded, the sample exhibited constant returns to scale. On the other hand, when operator and family labour were included, the cost curve exhibited the familiar L shape found in earlier agricultural studies.

1. Introduction

Much of the government response to pressures for rural adjustment in Australia has been in the form of initiatives and encouragement for small-farm amalgamation and build-up. This process has also been occurring autonomously, as part of the continuing structural adjustment of Australian agriculture to the declining trend in farmers' terms of trade (Lawrence and McKay 1980). Technological change, particularly with regard to cropping, also appears to have been biased in favour of larger farms in recent times.

The promotion or implementation of reconstruction schemes, with the aim of increasing the size of small farms, has been prompted partly by the belief that economies of size will be achieved (Threlfall 1977, p. 185). Economies of size are defined as reductions in average total costs per unit of output resulting from changes in the size of the firm's operations, assuming a constant rate of capacity utilization. Consequently, there is a need for accurate information on the nature and extent of size economies in Australian agriculture and how size economies change over varying levels of output. This would allow assessment of the likely usefulness of reconstruction policies, from an efficiency point of view. Knowledge of changes in the least cost size and the nature of size economies over time resulting from technological change are also of importance in determining the continuing relevance of farm build-up policies and the need for structural adjustment. In addition, information about size economies will

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be important in any analysis of off-farm employment. The possibility of off-farm employment as a means of maintaining the viability of small farms has become increasingly topical in recent years (Riethmuller and Spillman 1978; Robinson and McMahon 1981).

Furthermore, since the position and shape of the long-run average cost curve is changing over time with technological progress, up-to-date studies are required to monitor the current situation with regard to scale economies and the structure of agriculture resulting from the continuous process of structural adjustment. For instance, knowledge of changes in the shape of the cost curve over time will enable an evaluation to be made of whether or not technical change has been biased in favour of larger scale production. A number of important conceptual distinctions, such as that between long-run and short-run average cost curves, must be drawn clearly if studies of this kind are to yield accurate results.

After reviewing briefly the Australian literature on economies of size in Section 2, some theoretical and conceptual issues relating to economies of size are discussed in Section 3. Problems in estimation are discussed in Section 4. An empirical analysis of size economies in the New South Wales Wheat/Sheep Zone is then presented in Sections 5 and 6, while some conclusions are given in Section 7 of the paper.

2. Previous Australian Studies

Anderson and Powell (1973) presented an overview of the Australian literature on economies of size up to 1972 and provided a brief summary of the alternative techniques available for measuring economies of size. These techniques were broadly classified as:

- the synthetic firm approach;
- the direct analysis of cost output observations;
- indirect analysis based on estimated production functions; and
- the survivor technique.

The choice of technique largely depends upon the objectives of the analysis and the funds available. Most of the earlier Australian studies on economies of size used the Cobb-Douglas production function. This functional form has numerous limitations such as expansion paths which are scale lines and derived average cost curves which cannot take the classical U shape. An examination by Anderson and Powell of some 31 Australian studies which used this specification revealed that, for Australian agriculture, overall estimated total production elasticities were generally close to unity, indicating constant returns to scale.

In particular, the evidence for the sheep, wheat, dairy, cotton and egg industries suggested that significant economies of size existed for small-to-medium sized farms but, thereafter, the average cost curves became relatively flat. Furthermore, for the beef and most of the fruit industries there was no clear evidence of any significant economies of size. Anderson and Powell, however, pointed to the failure of researchers to account for differences in the quality of factors, such as labour, leading to a probable downward bias in the estimated extent of size economies and the subsequent need for caution in the interpretation of these results.

Some further Australian economies of size studies have been published since the Anderson and Powell review article. McKay (1974) fitted simple log-log, semi-log and linear cost functions to data from the Australian Sheep Industry Survey for the period 1967–68 to 1969–70. Significant economies of size were found to exist in the Pastoral, Wheat/Sheep and High Rainfall Zones for small-to-medium sized farms, with no significant diseconomies associated with increasing size in the medium-to-large range. Some of the problems of obtaining a universally accepted definition of size, where there is a heterogeneous production mix are also discussed. In such cases, the use of the gross value of production appears to be the best measure of size.

Stoeckel (1974) undertook an economies of size study for apple and pear specialist producers in southern Victoria and Tasmania. A rectangular hyperbola was fitted to actual observations of gross output and average costs. Averages of four years data (1965–66 to 1968–69) were used to reduce the influence of seasonal variation on the measure of farm size. Significant economies were available for smaller farms. However, these economies diminished rapidly with increasing size, particularly for producers in southern Victoria.

Gibbon (1974) further extended the work on economies of size by developing a criterion for identifying the minimum structural farm size. The concept of minimum efficient firm size has been more widely studied with respect to secondary industries, but in agriculture it is of relevance to certain aspects of the Rural Reconstruction Scheme, in particular the farm build-up provisions. Gibbon postulated a model with unit costs as a function of size, soil quality, level of utilization and an additional variable which represented all other factors which influence unit costs. Unimproved land value was used to measure size in an attempt to approximate production potential of land, rather than characteristics that reflect, for example, management policy. A rectangular hyperbola was fitted to data for 19 farms from the Riverina area of the Wheat/Sheep Zone for the three years 1968–69 to 1970–71. The use of different gradient criteria yielded three-yearly minimum structural sizes of from \$58,000 to \$75,000 unimproved land value. The minimum structural size obtained varied somewhat from year to year. The minimum structural farm size concept may, therefore, help form a bench-mark against which adjustment assistance initiatives can be assessed.

Finally, Ryan (1976) examined economies of size for individual farms over time, as opposed to apparent economies of size derived from cross-sectional average cost curves. He found that the economies of size realized by individual farms which increased in size over time were generally more than two-to-three times as large as those indicated by static cost curve analysis using cross-sectional data. Technological change is likely to be an important factor in explaining part of this apparent disparity between measured cross-sectional economies of size and realized economies over time.

In summary, most Australian studies of economies of size have used a simple Cobb-Douglas or quadratic function fitted to cross-sectional data. Significant size economies were usually found up to the "medium sized" farm, beyond which the long-run average cost curve tended to flatten out, with no significant diseconomies becoming apparent.

3. Conceptual and Theoretical Issues

Economies of scale is a special case of economies of size. In the case of economies of scale, all inputs are increased by equi-proportionate amounts; if unit costs decrease (increase) in response to an increase in output resulting from an equi-proportionate increase in all inputs, economies (diseconomies) of scale are operating. Since firms are unlikely to increase all their inputs by equal proportions, the economies of scale measure is a relatively restrictive one. Economies of size, on the other hand, measure the change in unit costs associated with a change in some or all of the firm's inputs.

Economies of size studies usually involve a close examination of the shape and position of the long-run average cost curve. Both the short-run and the long-run average cost curves are based on the assumptions of constant input prices and given technology. The short-run is that period of time in which some, but not all, of the firm's input levels can be changed. Hence, short-run average cost curves indicate those costs which will occur at various levels of output in the period of time in which some inputs are still relatively fixed. On the other hand, the long-run average cost curve shows the costs which would occur at various levels of output if all inputs were allowed to be freely adjusted. The long-run average cost curve is the envelope of all the short-run average cost curves and a firm which is at the point of tangency of the long-run average cost curve with the short-run average cost curve is in long-run equilibrium even though, special cases excepted, the firm may not be minimizing "short-run" costs.

If diseconomies of size operate, after a period of economies of size and then constant returns to size, the classical U-shaped long-run average cost curve will emerge. If, on the other hand, unit costs are relatively constant over a wide range of output, following an initial region in which economies of size occur, an L-shaped cost curve will be representative of the industry's cost structure. Changes in the position and shape of the long-run average cost curve over time are determined mainly by technological change. Some studies which have examined the effect of technological change over time have found that the long-run average cost curve shifts downwards and to the right (Christensen and Greene 1976). The nature and direction of this shift is dependent on whether technical change is scale invariant. If technical innovations are biased in favour of large-scale production, then the long-run average cost curves, at different points in time, will tend to diverge with increasing levels of farm output. Also, given adjustment costs, it will not be optimal for the farm-firm to pursue continually the least cost size as it shifts to the right because of technical change. Therefore, not only do we require information on the likely economies achieved from an increase in farm size, but we also require information on the costs of structural adjustment to be able to provide useful policy recommendations.

As the long-run average cost curve shifts over time, so the minimum efficient farm size will also be changing. If the cost curve is moving downwards and to the right, the minimum efficient farm size will be increasing over time due to increases in labour productivity and other dynamic realizations. However, since the long-run average cost curve typically "flattens out" asymptotically, the point at which no further useful size economies can be achieved, *i.e.*, the minimum efficient farm size, may be difficult to determine. Although a point may exist beyond which no further statistically significant size economies can be detected, it may still be worthwhile for profit-maximizing firms to achieve small size economies beyond this point.

The relationship between farm efficiency and farm size is also of importance in economies of size studies. A firm's distance from the long-run average cost curve will be determined largely by its economic efficiency (Lund and Hill 1979). The size of the band of average cost-output observations may vary with farm size. If large farms, for example, are more economically efficient than small farms, then scale elasticities, estimated by ordinary regression techniques, will be biased upwards. An examination of differences in economic efficiency between different size groups of farms is, therefore, an integral part of economies of size studies. Furthermore, as Lund and Hill point out, increases in farm size are likely to lead to decreases in relative efficiency at least in the short run, not only from the usual impediments to short-run adjustment, such as input fixity, but also from management deficiencies. The efficiency level at which the new, larger farm will operate will be determined largely by the ability of the small farmer to cope with the management requirements of the larger farm.

Account must also be taken of the fact that agricultural industries differ in a number of ways from the other industries, which have typically been the subject of economies of size studies (*e.g.*, electricity generation). Perhaps the most important is the pattern of firm organization. Whereas most other industries are characterized by corporate forms of organization, the family firm remains dominant in many agricultural industries. Moreover, farm-firms differ from other family and entrepreneurial firms in a number of ways. The latter are generally concentrated in service industries, have relatively low capital requirements and are frequently associated with corporate entities through franchising or subcontracting arrangements. This enables such firms to take advantage of size economies in areas such as purchasing.

An even more distinctive feature of farm firms is the requirement that the farm operator live on farm, frequently at a significant distance from alternative sources of employment. While off-farm employment and its converse the "hobby-farm" are growing, there is no doubt that farm operators have considerably less flexibility in dividing their time between their own business and outside employment than do other entrepreneurs. Indeed for many, though by no means all, farm operators, the only effective alternative to on-farm work is increased leisure.

This creates immediate problems for the treatment of operator labour in any study of economies of size. Depending on farmers' tastes with respect to work and leisure, the opportunity cost of operator labour may be quite low. As the most usual measure of this input, number of weeks worked on farm, contains no significant information on the work-leisure trade-off, any approach which treats operator labour as a variable input involves severe conceptual difficulties.

The most usual course in production function studies has been to aggregate operator and hired labour (possibly with a weighting to account for differences in intensity of labour). This approach involves major difficulties. First, it takes no account of the distinct entrepreneurial role of the farm operator. Second, and more seriously, it is based on the implicit assumption that the intensity of operator labour does not vary with farm size. This is a severe problem, since one of the most frequently noted problems of excessively small farms is that operators are under-employed for significant parts of the year. Treating (measured) operator labour as a variable rather than a fixed input is thus likely to lead to the spurious conclusion that small farms use excessive inputs of labour.

The suggestion that farm operators are "under-employed" is not meant to imply that they are allocating their resources inefficiently, or that they would be better off leaving the farm. Rather, it means that, having made a utility-maximizing choice to operate their farm, they are constrained in the amount of work they can do. More precisely, if more work became available and yielded a net return at least as high as the wage of hired labour, they would probably choose to take it.

Family labour involves some of the same difficulties, especially those relating to data availability. While its treatment as a variable input is more reasonable than in the case of operator labour, it is hard to obtain reasonable measures of opportunity cost, labour quality or labour intensity.

Another problem arising from the difficulty of measuring the quantity and quality of operator and family labour input is that arising from collinearity of these variables with other inputs. It has frequently been suggested, for example, that management ability and capital intensity are correlated. If so, the omission of management ability will lead to specification error, namely a biased coefficient on capital. Some attempts have been made to solve the problem (Hoch 1976) but none appears to be very satisfactory.

At this point, it is worth making an observation on the "survivor technique". As Anderson and Powell point out, this technique has not been used much in studies of farm-size economy. Nevertheless, the continued robustness of the family farm is striking. It suggests the hypothesis that the most important economies of size in agriculture arise from the fixity of operator and, to a lesser extent, family labour. Thus, the minimum efficient farm size is dictated by the need to employ these resources fully.

In view of the discussion above, any conclusions derived from economies of size studies need to be interpreted with caution. In the remainder of this paper, two aspects discussed in the previous section will be examined in detail. These are the effect of technical change on cost curves over time and the treatment of operator and family labour.

4. Estimation Procedures

As outlined in Section 2, there are a number of alternative techniques which can be employed to study economies of size. The statistical analysis of observed data using either a production or cost function is emphasized in this discussion. The analysis of observed data may be undertaken with either of two statistical approaches. These are the estimation of the "average" function by ordinary least squares regression techniques and the estimation of the "frontier" function by linear programming or maximum likelihood techniques. Proponents of the latter approach argue that, theoretically, the production function should reflect the maximum output attainable from given inputs and technology and, similarly, the long-run average cost curve should reflect the minimum cost of production achievable for a given level of output, given available technology. Furthermore, econometricians in favour of the frontier approach argue that the position and shape of the average function may bear no relationship to that of the frontier function. For instance, consider the observations on unit costs and farm size shown in Figure 1.

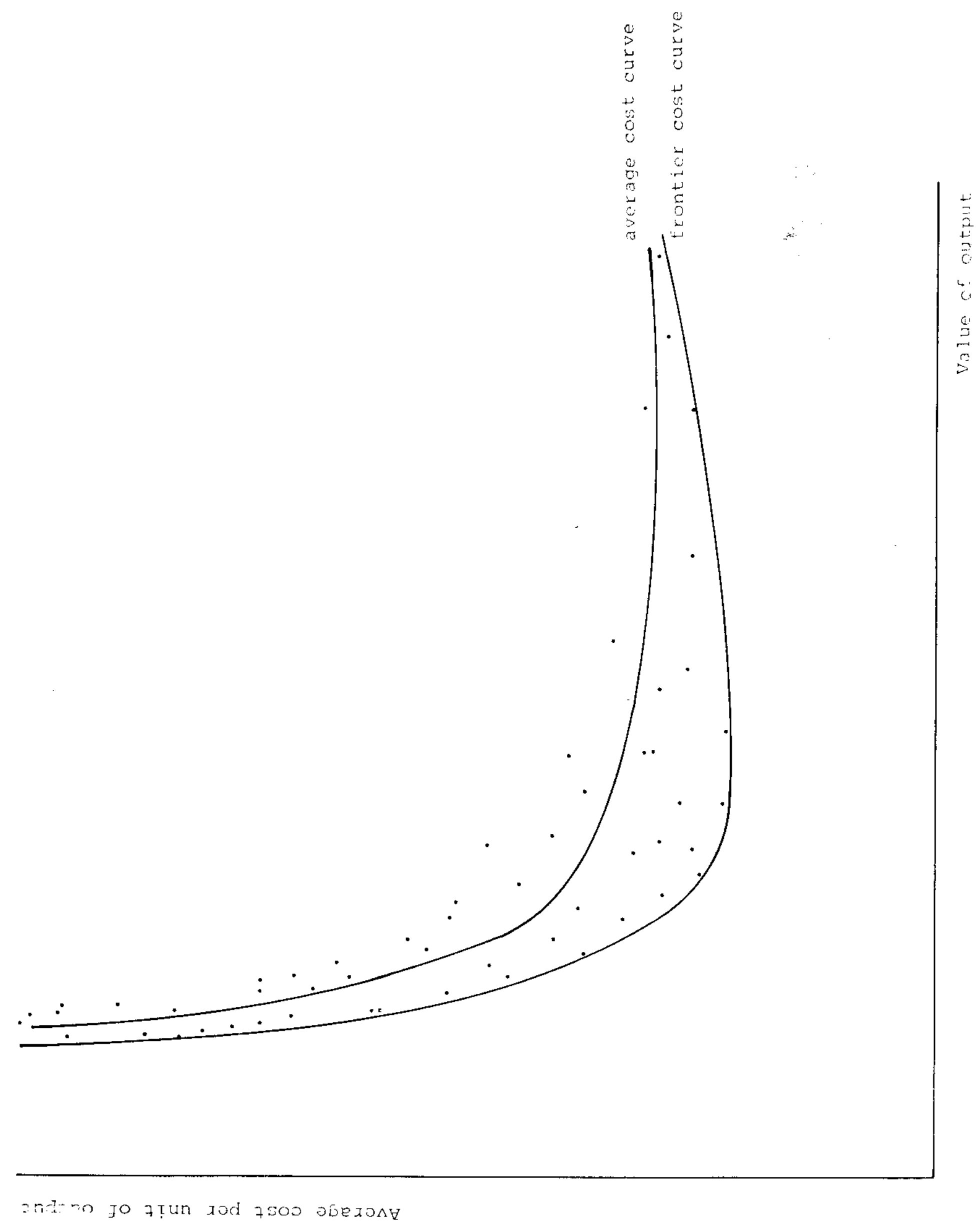

Figure 1—Illustration of Frontier and Average Cost Curves

Clearly, a different impression of the extent of economies of size, the least-cost size and the existence of diseconomies is gained, depending upon whether the frontier function or the average function is estimated. In this case a much smaller least-cost size is obtained with the frontier function than the average function and the frontier function indicates that diseconomies do exist. The relationship between the estimated average and frontier functions will be determined largely by differences in the range of observed efficiency levels as farm size varies. Note that if the number of farms in a particular size group is small, the estimated cost frontier is likely to be biased upwards. This is likely to lead to spurious conclusions that the cost curve is U-shaped, if most firms observed are of medium size.

Proponents of the average approach argue that the frontier function is highly sensitive to errors in measurement, since the shape and the position of the curve is determined by a handful of observations which appear to lie on it. Furthermore, the possibility that the observations which appear to lie on the frontier curve achieve their low average cost levels due to superior resource endowments not available to other farms vitiates the usefulness of this curve for policy analysis. Moreover, in cross-sectional studies a major source of variation in farm performance will be differences in climatic experience. The frontier function will thus measure production under ideal weather conditions and the relevance of this measure is doubtful.

A number of the problems associated with the frontier approach may be overcome using a stochastic specification in which the error term is divided into two components. One component is the usual, normally distributed term, reflecting climatic effects, while the other is a one-sided component capturing the effects of inefficiency relative to the stochastic frontier. However, in this case OLS provides an unbiased and consistent estimator of all coefficients except the intercept (Olsen, Schmidt and Waldman 1980). Thus, the estimated cost and production function will be similar in shape whichever approach is used.

Stollsteimer, Bressler and Boles (1961) pointed out the problems of using simple functional forms in statistical cost analyses to examine economies of size issues. They found that different simple functional forms of the cost function, each of which included a capacity variable, yielded quite different results, even though the models fitted the data well with high $\bar{R}^2$ values and significant coefficients. Stollsteimer *et al.* (1961, p. 83) state that ". . . it would be difficult to devise a more heterogeneous set of relationships, either with respect to the indicated levels of average costs or the rates at which average costs change with increases in scale". However, their small sample size of only 29 observations may have contributed to the wide range of results. These problems can be reduced by using a larger sample size and adopting one of the flexible functional forms now available. The transcendental logarithmic function is an example of the family of flexible functional forms which are capable of giving a second-order approximation to an arbitrary function (Christensen, Jorgenson and Lau 1973). Most of the simple functional forms used by Stollsteimer *et al.* are special cases of the general translog form.

The replacement of Cobb-Douglas production functions by flexible functional forms is relatively straightforward. Problems may arise, however, in the interpretation of individual coefficients as a result of multicollinearity. This may be partially remedied by the use of extra information, such as that contained in cost share equations. Furthermore, the major applications of the results do not depend on individual coefficients but on linear combinations of coefficients, thus obviating a great many of the difficulties which multicollinearity would otherwise raise.

An alternative approach is to estimate a cost function with prices and output as the independent variables (Christensen and Greene 1976). This approach runs into two major difficulties when it is applied to cross-sectional data. First, there is frequently little variation in the prices faced by different farms and, second, the measured differences in prices are frequently the result of quality differences or simple reporting error and this can lead to substantial biases.

Another problem with the statistical analysis of cost data commonly referred to is the so-called "regression fallacy" first outlined by Stigler (1952). This fallacy is illustrated by the example of three firms, identical in every respect, but subject to purely random influences which affect the level of output. If each farm has a given level of fixed costs and variable costs associated with each unit of output and if in the particular period being observed, one firm is subject to random influences leading to above-average output, one has average output and the other has below-average output, the different spreadings of fixed costs will lead to apparent economies of size. These observed economies, however, will be illusory, since the three firms are, in fact, identical. In agriculture, the main random influence which is likely to cause this sort of effect is weather. The random influence of weather will not alter measured inputs significantly, but will affect measured output. This means that regression fallacy will be less of a problem if a production function approach or, more generally, an approach using output as the dependent variable, is used. If, however, cost is used as the dependent variable, regression fallacy will be a significant problem, unless the study is undertaken for a region which is sufficiently small to have uniform weather effects in the period of observation.

Finally, the measure of firm size used in economies of size studies, is of particular importance in agriculture, given the heterogeneous nature of production. Measuring farm size by total value of farm output could lead to a bias in the economies of size measures, if the production mix varies between farms of different sizes. If certain size groups tend to specialize in different enterprises, the unit costs of production for which differ significantly at any point in time, then a distortion in the measured scale elasticity may be introduced.

The use of land value, as a measure of farm size, may be misleading, since the value of the land is determined not only by its productive potential, but also by its geographical location and other non-agricultural attributes. This problem may be accentuated by the fact that smaller farms tend to be located near towns and hence their land value is determined more by non-agricultural influences. However, this problem will only arise if farming is not the most productive use of land in the long run, *i.e.*, on farms which are either allocatively inefficient or "living on borrowed time".

A further possibility is the use of total stock equivalents run as a measure of size. Problems may arise here, however, since there may not be a uniform relationship between the amount of resources employed on the farm and the rate of turnoff or level of output. Similarly, many problems may be encountered in the measurement of inputs, particularly durable inputs. For example, the opportunity cost of capital is likely to vary considerably between farms, due to differences in their asset levels and their entrepreneurial skills.

These problems of measurement and the more fundamental conceptual and theoretical issues outlined in Section 3 require careful consideration prior to the commencement of an economies of size study. In view of the problems associated with the direct estimation of cost functions discussed above, the indirect approach, based on the estimation of an "average" flexible production function, was considered to raise the least severe problems for an empirical application. Consequently, this approach is adopted in the empirical analysis reported in the following sections.

5. Methodology

The following translog production function was estimated for cross-sectional, Australian Sheep Industry Survey (ASIS) data for the New South Wales Wheat/Sheep Zone, for the years 1976–77, and 1966–67:

$$(1)\quad \ln Y = \alpha_o + \Sigma_i \alpha_i \ln X_i + \tfrac{1}{2}\Sigma_i \Sigma_j \gamma_{ij} \ln X_i \ln X_j; \quad i, j = 1, \ldots, 5,$$

where the X_i are inputs and Y is output. Note that this formulation implies the restriction $\gamma_{ij} = \gamma_{ji}$.

For inputs which are variable in the short-run, the cost share in output of the i'th input for a competitive profit-maximizing firm is:

$$(2)\quad P_i X_i / P_y Y = \alpha_i + \Sigma_j \gamma_{ij} \ln X_j$$

where P_i is the price of the i'th input and P_y is the output price. This enables extra information on the coefficients α_i and γ_{ij} to be obtained. The hypothesis that a given input is being fully adjusted in the short-run may be tested by testing for equality of the coefficients in (1) and (2), if the system of equations is estimated using Zellner's (1962) estimator for seemingly unrelated regressions.

The measure of scale economies, the elasticity of scale, may be interpreted as either the increase in output resulting from an equi-proportionate increase in all inputs on a ray through the origin or as the increase in output relative to costs for variations along the expansion path, given constant input prices and cost minimization for all levels of output (Hanoch 1975). Hanoch points out that in the absence of homotheticity, only measures of the elasticity of scale along the expansion path will give the shape of the average-cost curve.

The translog functional form is very flexible and involves a minimum of maintained hypotheses. It imposes no specific form on economies of size and is, therefore, an appropriate tool for examining them. The elasticity of scale may be obtained by summing the partial elasticities of the various inputs. The partial elasticity of a particular input is given by:

(3) $(\partial Y/\partial X_i)\,(X_i/Y) = \alpha_i + \Sigma_j\,\gamma_{ij} \ln X_j$

Total scale elasticity (θ) is, therefore, given by

(4) $\theta = \Sigma_i\,\alpha_i + \Sigma_i\Sigma_j\,\gamma_{ij} \ln X_j$

This measure of the elasticity of scale is equal to that obtained by setting $Y = f(sX)$ and evaluating $\partial Y/\partial s$ at $s = 1$.

The following five input categories were employed in this study: labour, capital, land, materials, and livestock. Details of variable specification are given in the Appendix. Land and capital were assumed to be fixed in the short run, while labour, livestock, and materials were assumed to be variable. In view of the discussion of the role of operator and family labour given in the theoretical and conceptual issues section, two specifications of the labour variable were used. Model I included operator and family labour, along with hired labour and contracts as the variable labour input. Different weightings of the respective components were also tried in an attempt to account for differences in intensity. For example, operator labour was valued at four-thirds of the hired rate and family labour at two-thirds of the hired rate in order to try and pick up the additional managerial input of the operator and the lesser physical input of family members. As the use of weightings made no significant difference to the estimated function, these results have not been reported. In Model II, hired labour and contracts were used as the sole components of the variable labour input. Operator and family labour were assumed to be fixed and constant in this model and were excluded during estimation. Model II performed substantially better and was used in subsequent estimation.

6. Results

A four-equation seemingly unrelated regressions system comprising the production function and the share equations for the three variable inputs, labour, livestock, and materials, was estimated and likelihood ratio tests were applied for the hypotheses that each of the variable inputs was being fully adjusted in the short run. This is equivalent to testing for equality of the relevant coefficients in the production function and the share equation for the variable input in question. Since there are six independent restrictions, the likelihood ratio is distributed asymptotically χ^2_6. Results of these tests for both labour specifications for 1976–77 and for 1966–67 Model II estimates are given in Table 1. For 1976–77 Model II estimates, the labour and livestock equality restrictions could not be rejected, while that for materials was rejected.

Consequently, the restrictions for equality of the corresponding coefficients in the production function and the labour and livestock share equations were imposed in subsequent estimation. As expected from discussion in the earlier section, the hypothesis that the total labour variable including operator and family labour (Model I) was being fully adjusted in the short run was rejected. In conjunction with the acceptance of the hypothesis that hired and contract (Model II) labour was being adjusted fully in the short term, this lends support to the contention that operator and family labour inputs are relatively fixed.

Table 1: *Test Statistics for Equality between Production and Share Equation Coefficients*[a]

	Equality restrictions		
	Labour	Materials	Livestock
Critical χ^2_6 (1 per cent)	16.81	16.81	16.81
χ^2 1976–77 I	21.96	24.62	4.50
χ^2 1976–77 II	7.64	21.14	10.10
χ^2 1966–67 II	10.64	27.14	18.68

[a] Model I includes operator and family labour in addition to hired labour and contracts, while Model II excludes operator and family labour.

The resulting estimated production functions for the years 1976–77, 1975–76 and 1966–67 are given in Table 2. The estimates for 1975–76 were obtained to check the stability of the 1976–77 estimates. The estimates for these two years are very similar, indicating that the model is relatively stable. Because of the size of the data set, it was impossible to obtain combined estimates for the two periods for use in a Chow test. The mid-points of the two sets of estimated coefficients were used as the basis for a likelihood ratio test of the hypothesis that all coefficients except the intercept were stable. This hypothesis could not be rejected at the 5 per cent level of significance. The OLS R^2 value for the production function for 1976–77 was 0.77. (Due to difficulties in calculating goodness-of-fit statistics for systems of equations, no such statistics are presented.) A plot of the residuals, based on increasing land value, indicated that the error term was homoskedastic, implying that the parameter estimates are efficient.

Table 2: *Model II Translog Production Parameter Estimates*[a, b]

Parameters[c]	1976–77	1975–76	1966–67
α_O	5.05 (2.18)	7.60 (2.53)	2.63 (1.92)
α_L	0.56 (4.04)	0.49 (3.29)	0.29 (4.56)
α_K	−0.77 (−1.38)	−1.43 (−1.53)	0.41 (1.27)

Table 2—continued

Parameters[c]	1976–77	1975–76	1966–67
α_N	0.84 (2.11)	0.23 (0.40)	−0.63 (−2.67)
α_M	−0.03 (−0.11)	0.76 (1.93)	0.85 (6.27)
α_V	0.12 (4.05)	0.10 (1.72)	0.08 (5.66)
γ_{LL}	0.08 (10.41)	0.09 (11.21)	0.06 (13.87)
γ_{LK}	−0.09 (−4.75)	−0.09 (−4.04)	−0.03 (−4.02)
γ_{LN}	0.04 (2.67)	0.03 (1.92)	−0.01 (−0.86)
γ_{LM}	−0.02 (−2.48)	−0.01 (−1.27)	−0.003 (−0.59)
γ_{LV}	−0.002 (−1.59)	−0.009 (−3.21)	−0.001 (−1.22)
γ_{KK}	0.29 (2.86)	0.43 (2.84)	0.16 (2.71)
γ_{KN}	−0.09 (−1.12)	−0.06 (−0.98)	0.07 (1.70)
γ_{KM}	−0.01 (−0.24)	−0.09 (−1.48)	−0.23 (−8.77)
γ_{KV}	−0.03 (−6.48)	−0.03 (−3.73)	−0.02 (−7.90)
γ_{NN}	0.05 (0.86)	0.02 (0.24)	0.06 (1.32)
γ_{NM}	−0.07 (−1.81)	−0.004 (−0.15)	−0.04 (−1.23)
γ_{NV}	0.001 (0.24)	0.006 (1.06)	−0.004 (−2.23)
γ_{MM}	0.12 (7.97)	0.04 (1.30)	0.22 (11.54)
γ_{MV}	−0.005 (−2.44)	−0.009 (−2.41)	−0.003 (−2.98)
γ_{VV}	0.03 (14.05)	0.04 (9.76)	0.03 (18.49)

[a] Model II includes hired and contract labour but excludes operator and family labour.

[b] The production functions were jointly estimated with labour, livestock, and materials share equations. Equality restrictions were imposed between the parameters of the production function and the labour and livestock share equations.

[c] The letters L, K, N, M, and V refer to labour, capital, land, materials, and livestock, respectively. Figures in parentheses are *t*-statistics.

A number of restrictions on the translog function may readily be tested. Those examined in this study were homotheticity, linear homogeneity and the imposition of the Cobb-Douglas production structure. A homothetic production structure is one in which the iso-production frontiers have the same shape and in the case of the translog form implies the following restriction:

$$(5) \quad \sum_{j=1}^{5} \gamma_{ij} = 0, \; i = 1, \ldots, 5.$$

This restriction could not be rejected for Model II, since the 1976–77 observed likelihood ratio test statistic of 7.22 was below the 5 per cent critical value of 11.07, for a χ^2 distribution with 5 degrees of freedom.

The test for linear homogeneity, or constant returns to scale, in the translog production function involves the homotheticity restriction (equation 5) plus the following:

$$(6) \quad \sum_{i=1}^{5} \alpha_i = 1, \; i = 1, \ldots, 5.$$

This restriction was also accepted for the model without operator and family labour (Model II), with the observed 1976–77 test statistic of 8.96 being below the 5 per cent critical value of 12.59 for a χ^2 distribution with 6 degrees of freedom, indicating that constant returns to scale cannot be rejected for this model. The hypothesis of constant returns to scale was, however, rejected for the model including operator and family labour (Model I) at the 5 per cent level. The hypothesis that the production structure was not significantly different from that of Cobb-Douglas (*i.e.*, all $\gamma_{ij} = 0$) was soundly rejected, with the observed test statistic of 186.97 being above the 5 per cent critical value of 24.99 for a χ^2 distribution with 15 degrees of freedom.

In order to examine economies of size further, the sample was divided into five size groups, based on total output in 1976–77 dollars. Scale elasticities and marginal products were calculated at the mean input vector for each group. This procedure is open to the objection that the mean input vectors may not be cost minimizing, but the difficulties arising from this approximation do not appear to be great. The scale elasticities and marginal products for the five size groups for 1976–77 and 1966–67 are presented in Table 3. Slight (not statistically significant) economies of size are apparent for 1976–77, while the scale elasticities for 1966–67 are all close to one. All partial elasticities are of reasonable magnitude and all except two are positive. It should be noted that the statistical test for homotheticity, which could not be rejected for the overall sample, implies constant cost shares and partial elasticities. The results in Table 3 are largely consistent with this finding. Similarly, the test for linear homogeneity, which could not be rejected for Model II in the overall sample, implies that the overall scale elasticity was not significantly different from one.

Table 3: Estimated Scale Elasticities and Partial Elasticities

	Size group[a]				
	1	2	3	4	5
Mean output in 1976–77 dollars	18,308	40,829	57,705	89,423	223,070
	Model II 1976–77				
Scale elasticity	1.03	1.08	1.07	1.09	1.13
Partial elasticities[b]—					
PE_L	0.08	0.09	0.12	0.11	0.15
PE_K	0.64	0.69	0.65	0.70	0.71
PE_N	0.07	0.03	0.03	−0.01	−0.03
PE_M	0.19	0.23	0.23	0.26	0.27
PE_V	0.05	0.04	0.04	0.03	0.03
	Model II 1966–67				
Scale elasticity	1.00	0.98	0.99	0.97	0.99
Partial elasticities[b]—					
PE_L	0.05	0.06	0.09	0.09	0.12
PE_K	0.53	0.47	0.42	0.38	0.34
PE_N	0.19	0.22	0.23	0.25	0.30
PE_M	0.18	0.19	0.20	0.21	0.19
PE_V	0.05	0.04	0.05	0.04	0.04

[a] Scale elasticities and partial elasticities for both years were estimated at the mean input vectors for the five size groups derived from the 1976–77 sample.

[b] The letters L, K, N, M, and V refer to labour, capital, land, materials, and livestock, respectively.

Finally, cost curves were obtained. Since the translog function is too intractable to permit the analytic derivation of the dual cost function, the following procedure was adopted. Cost curves were derived from a plot of average cost per unit of predicted output against predicted output. Using predicted output reduces the danger of regression fallacy due to climatic effects, which may be the case if actual output is used. Figures 2A and 3A show the scatter of points obtained using average Model II cost (*i.e.*, excluding operator and family labour costs) for 1976–77 and 1966–67, respectively. As expected from Table 3, both sets of points indicate a flat cost curve exhibiting constant returns to scale. The points for 1976–77 lie well below those for 1966–67.

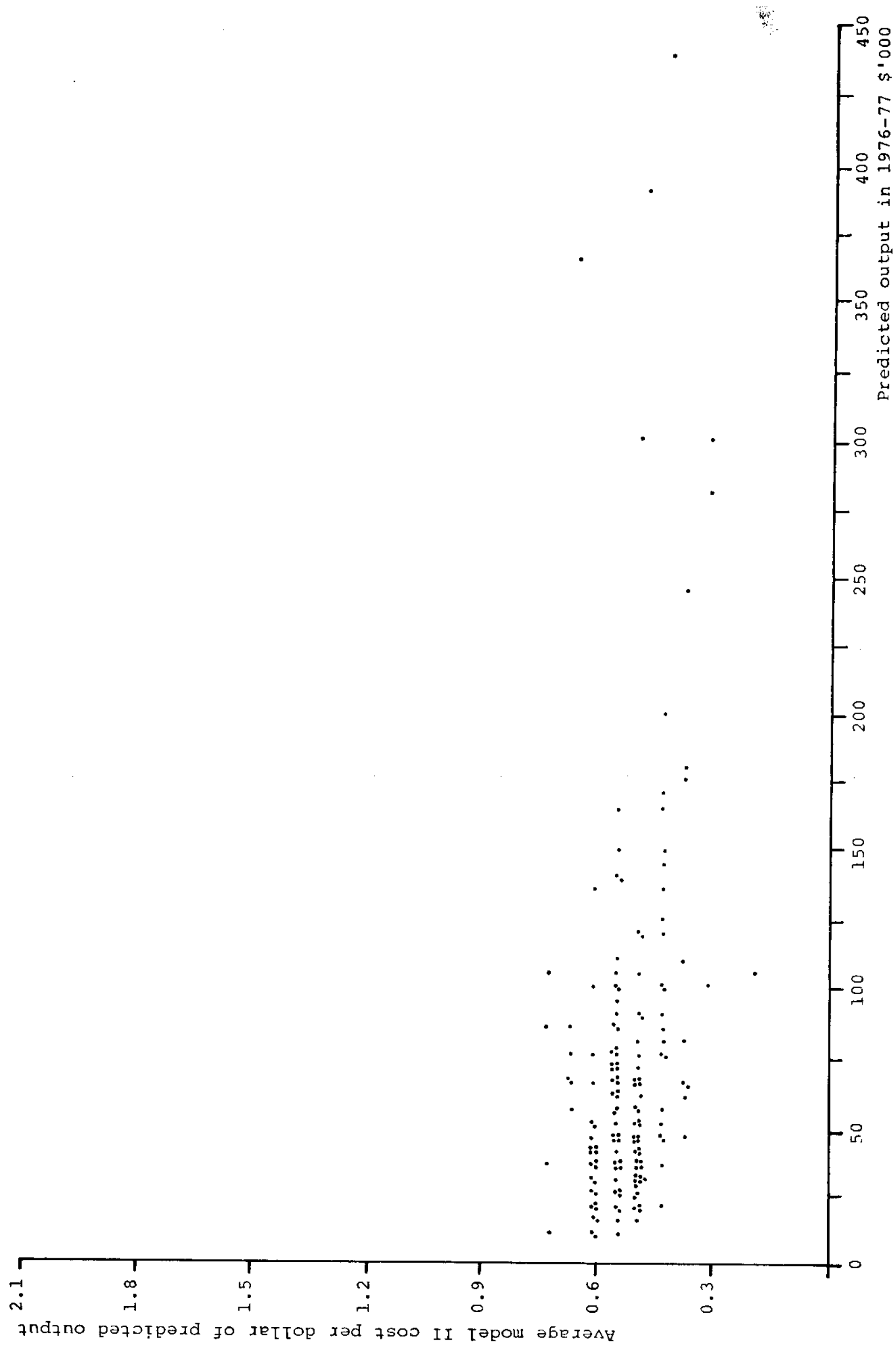

Figure 2A—Average cost per unit of predicted output (excluding family and operator labour costs): 1976–77

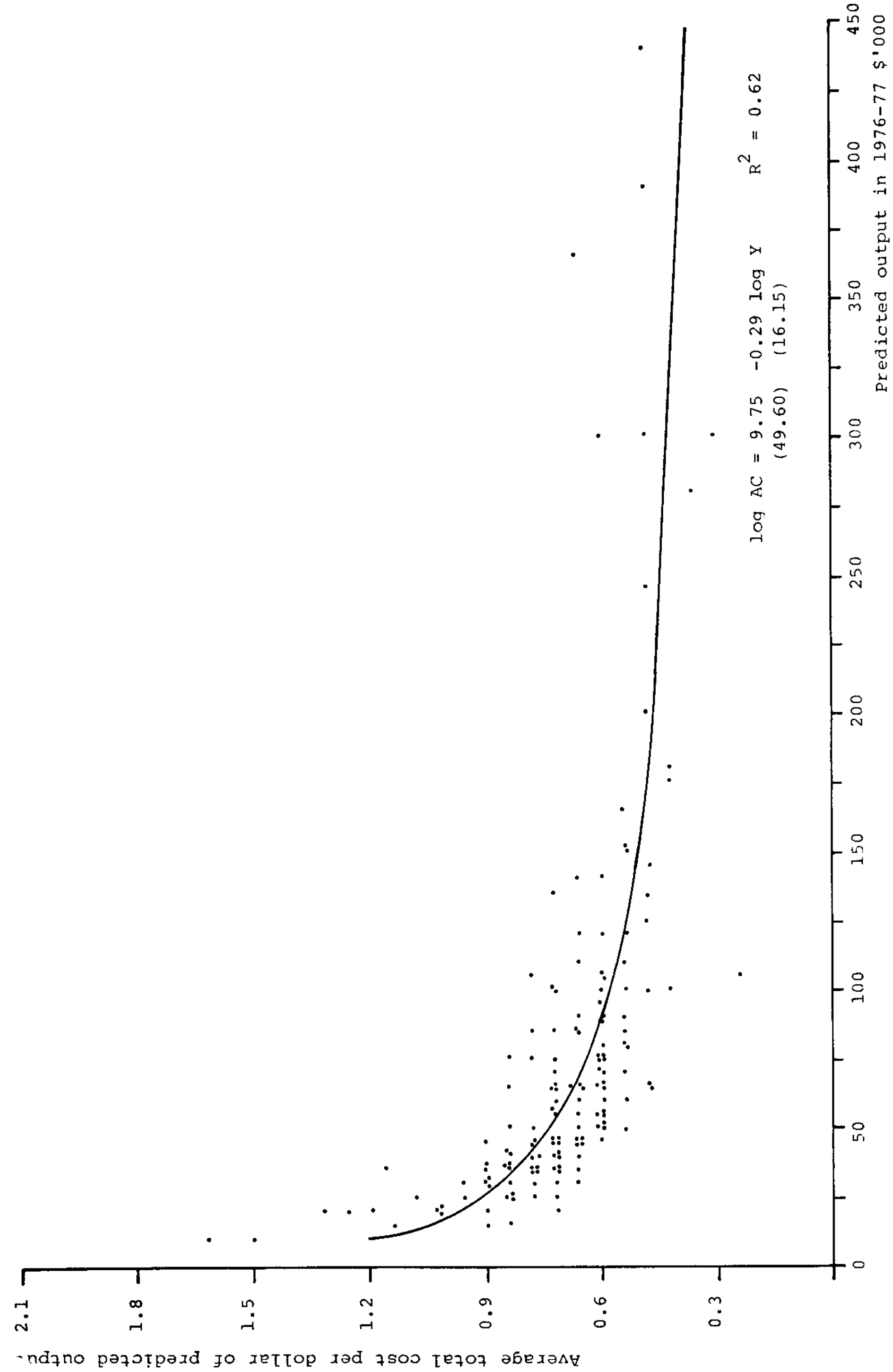

Figure 2B—Average total cost per unit of predicted output (including family and operator labour costs): 1976–77

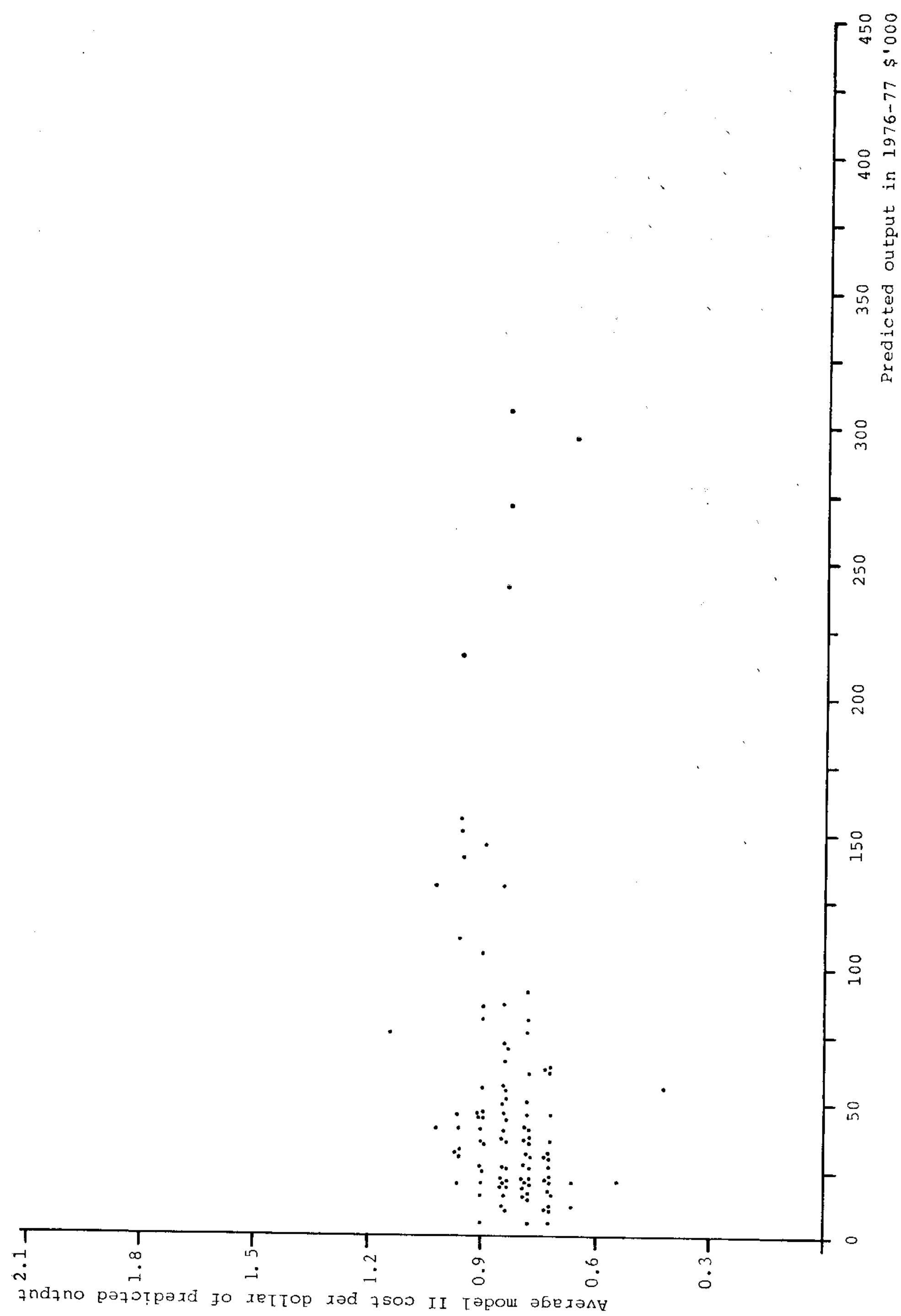

Figure 3A—Average cost per unit of predicted output (excluding family and operator labour cost): 1966–67

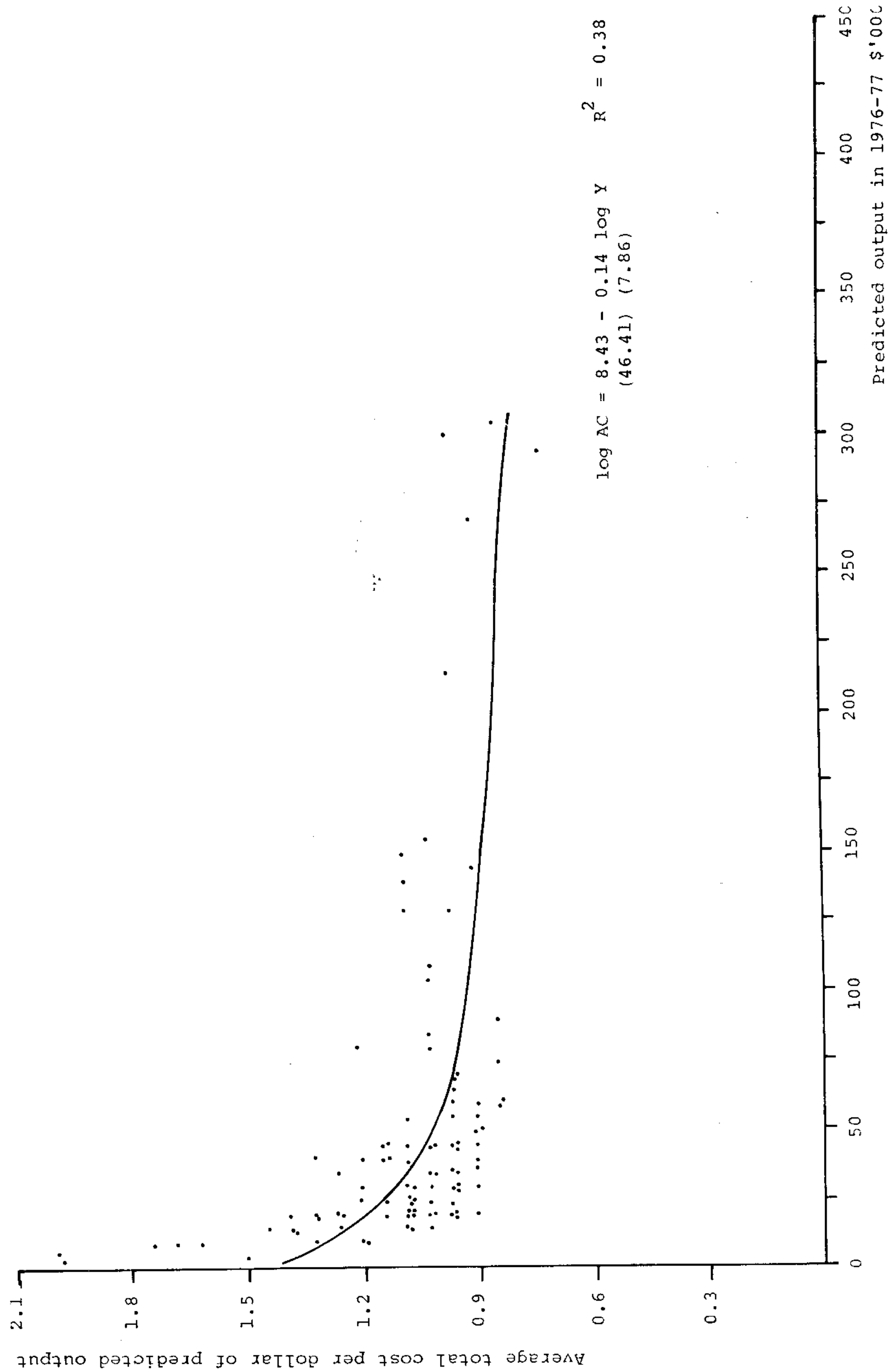

Figure 3B—Average total cost per unit of predicted output (including family and operator labour costs): 1966-67

In order to examine the situation where all costs are taken into account, average total cost (including imputed operator and family labour costs valued at award rates) per unit of predicted (Model II) output was plotted against predicted output. The resulting scatters of points for 1976–77 and 1966–67 are presented in Figures 2B and 3B, respectively. Power curves have been fitted for expositional convenience. These curves should in no way be interpreted as long-run average cost curves and should not be used for policy analysis. A few observations of very large farms of over \$500,000 output were dropped for 1976–77, so as not to exert undue influence on the shape of the power curve. In both cases, the scatters of average cost exhibit the usual "L" shape obtained in other agricultural studies (Anderson and Powell 1973).

Since average Model II costs per unit of output indicated a flat cost curve, while average total costs per unit of output indicated an "L" shaped cost curve, this tends to verify the premise that size economies in agriculture are principally derived from making full use of the "fixed" input of operator and family labour. As stated earlier, this is further supported by the test for constant returns to scale being accepted at the 5 per cent level for Model II, while being rejected for Model I. Thus, the minimum efficient farm size is dictated by the need to employ these fixed inputs of operator and family labour fully. It should, however, be noted that the aim of increased efficiency of resource allocation within agricultural industries might be achieved by policies which are designed to increase the availability of, and disposition of, operators of small farms towards off-farm employment. This could enable them to improve the efficiency of their operations by working on farm only up to the point where their opportunity cost was equal to their marginal value product on farm. Although it is recognized that it may not be feasible to provide other employment for farm operators and their families in all cases, such a policy would be an alternative approach to the attempts of most existing schemes to aid rural adjustments by means of farm build-up and amalgamation assistance.

It would appear that both of these avenues of adjustment are being adopted by farm operators. As has been pointed out above, both average farm size and the extent of off-farm employment have displayed a long-term upward trend. Thus, the object of adjustment assistance schemes should be to attempt to remove sources of market failure such as institutional obstacles to these processes.

Both power curves are plotted in Figure 4. The cost curve for 1976–77 is lower and slightly to the right of that for 1966–67. All values were expressed in terms of 1976–77 dollars. While the process of technological change has reduced costs, in real terms, over this period, the positions of the curves tend to indicate that technological change has been somewhat biased in favour of larger scale production.

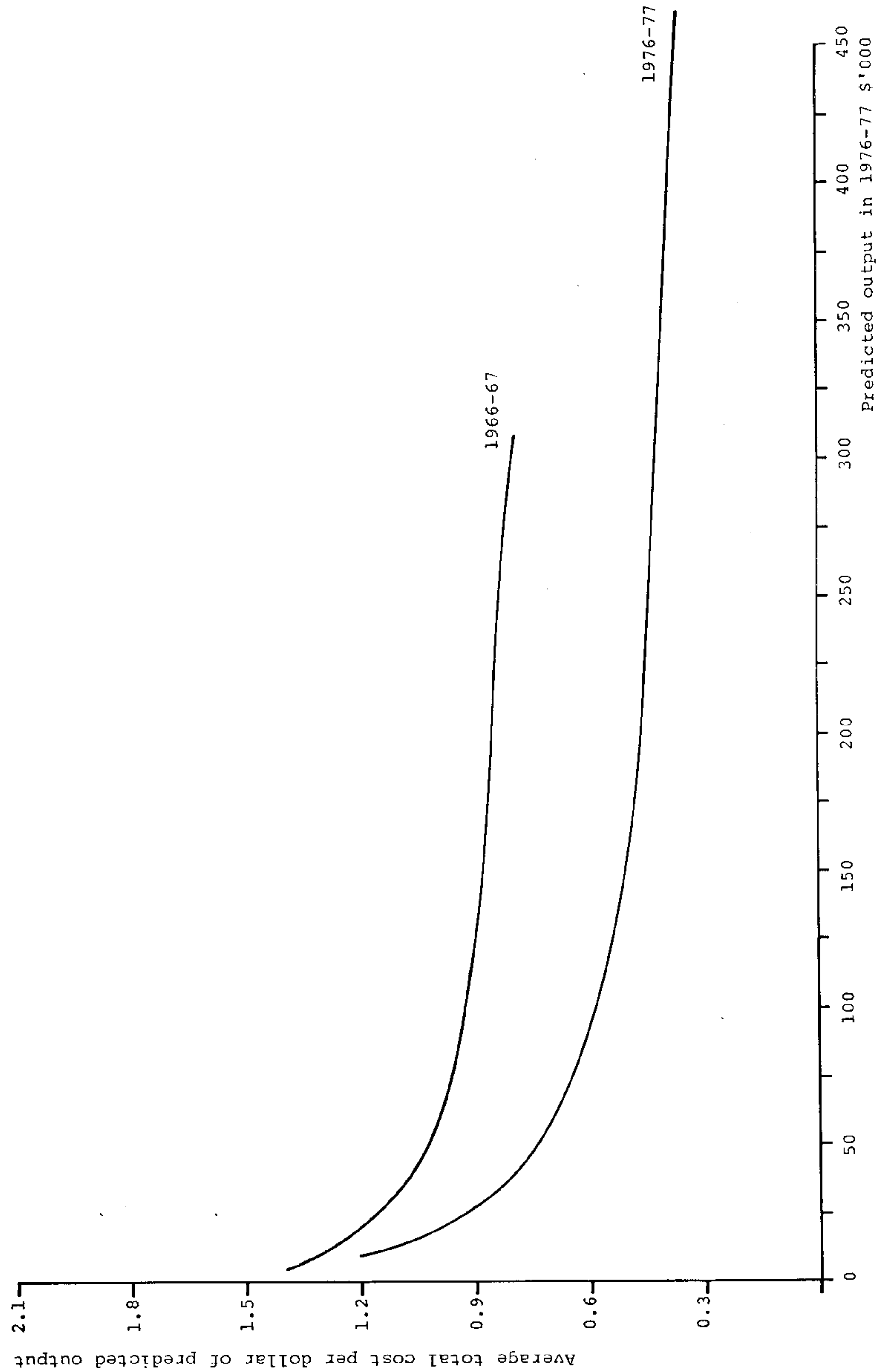

Figure 4—Average total cost curves: 1966–67 *and* 1976–77 *(derived from Figures 2B and 3B)*

7. Conclusions

Given the continued need for structural adjustment in agriculture, as in other sectors of the economy, and the continuing interest of governments in policies aiding rural adjustment, the study of economies of size remains an important research topic. It is essential that further research be undertaken to keep information on size economies in Australian agriculture up to date and to help gain a better understanding of the forces contributing to structural adjustment and technical change.

To this end, after discussing some of the conceptual and estimational issues involved in economies of size studies, an empirical analysis was undertaken using ASIS data from the New South Wales Wheat/Sheep Zone. Estimation of a flexible translog production function revealed that, when the relatively fixed inputs of operator and family labour were excluded, the sample exhibited constant returns to scale with a flat average cost curve. However, when operator and family labour were included, the cost curve was found to exhibit the familiar "L" shape found in earlier agricultural studies. This result is consistent with the existing policies aimed at facilitating rural adjustment, by means of farm build-up and amalgamation, to employ operator and family labour more fully and hence achieve the minimum efficient farm size. It also indicates that the provision of off-farm employment opportunities for operators of small farms and their families may be an alternative means of improving resource allocation in agriculture. This would enable them to work on-farm up to the point where their opportunity cost is equated to their on-farm value of marginal product and then seek off-farm employment for the remainder of their time.

The analysis in this paper has been essentially static, although movements in the cost curve over time have been described. The hypothesis of fixity of operator labour has important implications which have not been explored here. In particular, the steady increase in average farm size could be related to an increase in labour productivity. Such an increase, in a situation of labour fixity, would tend to increase the minimum efficient scale of operation over time. If problems of this kind are to be analysed a dynamic approach must be adopted.

Despite this, a great many of the conceptual problems which have been discussed here will arise in a dynamic framework as well. Thus, the static analysis presented here could make a contribution to future dynamic studies as well as providing an insight into the cross-sectional dimensions of the problem of size economies.

Appendix

Data Specification

Cross-sectional ASIS data for the New South Wales Wheat/Sheep Zone for the years 1976–77, 1975–76 and 1966–67 were employed in this analysis. The number of farms in the sample for the three years 1976–77, 1975–76 and 1966–67 were 160, 105 and 106, respectively. All values were expressed in terms of 1976–77 dollars. The value of total farm returns, less certain miscellaneous services such as insurance, bank and legal fees, subscriptions, rates and taxes, was used as the measure of farm output and farm size. The following five input categories were used: labour, capital, land, materials, and livestock.

The labour input included permanent and casual hired labour, shearing and crutching costs, farm operation contracts, stores and rations and payments to sharefarmers but excluded operator and family labour costs. The number of man weeks was derived by dividing the total value of labour by the minimum award rate. The minimum operator labour recorded in the sample was 40 weeks and the maximum 52 weeks. In view of the data difficulties with this input and with family labour, it was decided to treat them both as constant.

The items included in the materials input category were pesticides and sprays, fertilizer, seed, fodder, water and irrigation charges, and agistment costs.

An attempt was made to measure the service flow from the three durable input categories (capital, land, and livestock). The service flow from durable inputs consists of maintenance and operating costs, depreciation and opportunity costs. The value of the capital input was obtained by multiplying the opening stock value of plant, water structures, building, fencing and yards by their appropriate opportunity cost and depreciation rates. Plant maintenance and improvements maintenance were also included in the capital group and were treated as durable inputs. Other maintenance and operating costs included in the capital group were fuel, grease, oil, electricity, plant hire and motor vehicle expenses.

The value of land was obtained by multiplying the opening land value by the opportunity-cost rate. Land was assumed to have zero depreciation. Any maintenance costs associated with this input are picked up in the materials and labour input group.

The value of livestock inputs was obtained by multiplying the midpoint stock values of sheep and cattle by the opportunity cost rate. Also included in the livestock input group were veterinary and drench expenses.

For all durable inputs, a real opportunity-cost rate of 3 per cent per year was used. Although the choice of a rate of return to reflect the real return to alternative forms of investment is somewhat arbitrary, this should not affect the results markedly, since, in the case of land and livestock, a constant proportion of the stock value is being taken and, in the case of capital, the effect would be on the relative weight given to the opportunity-cost and depreciation components. The depreciation rates used for the capital input components were the same as those used by Lawrence and McKay (1980).

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