MANAGEMENT ADVICE, PRODUCTION FUNCTIONS AND SMALL FARM GROUPS *

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This article gives some results of production function studies carried out on small groups of farms. The results indicate that such studies can produce useful suggestions for farm reorganization even when only 20 farms constitute the sample. Since service centres are being set up in Australia to help advise farmer groups or samples of this size, production function studies on the material provided may be unexpectedly rewarding.

In Australia, at the present time, an increasing amount of farm survey data is being analysed by Departments of Agriculture and Universities for the benefit of individual farmers as well as for the farming community at large. Moreover, certain organizations are already processing large quantities of data from small farm groups. For example, the University of New England Farm Management Service Centre[1] provides analyses for consultants' clients who may desire them. In addition the Queensland Department of Primary Industries Farm Management Accounting Groups Scheme[2] has been developed towards the same end. To date, the analyses carried out have provided information of a descriptive nature and this has allowed farmers in the scheme to compare their results one with another.

While comparative analyses can be very useful in alerting farmers to possible weaknesses in their businesses, it is desirable that farmers be advised in more positive terms as to the likely advantages of altering their farm organization in a given way. A production function or input-output relationship provides one basis for doing this. One of the aims of the University of New England Farm Management Service Centre is to establish such relationships for advisory purposes.[3]

It seems to have been generally accepted in the past that to establish significant relationships by production function analysis, a substantial number of farms is needed in a survey. Time series regression analyses, however, are often made with fewer than 20 observations. Cozens[4] suggested that small surveys analysed by regression analysis might be helpful to advisers by providing more precise estimates of input-output

* Thanks are due to R. Jardine for guidance in the statistical analysis, and for a host of illuminating suggestions during the preparation of this paper. John L. Dillon was also of great assistance in commenting on an earlier draft, as has R. Officer on a later draft.

[1] University of New England. *Farm Management Service Centre Annual Report 1964/65*. U.N.E., Armidale, 1965, mimeo.

[2] Moorhouse, W., and O'Neil, A. L. *Farm Management Accounting Group Report No. 2*. Queensland Department of Primary Industries, Brisbane, Sept. 1965.

[3] University of New England, *op. cit.*, p. 2.

[4] Cozens, L. E. Production Economics, Averages and Standards in Research and Extension. *Aust. J. Agric. Econ.*, Vol. 9, No. 2, Dec. 1965, p. 127.

relationships than would be possible using simpler techniques. Advisers already intuitively guess and act upon relationships which they think they see displayed by farms amongst which they work and the problem is, therefore, how best to help them interpret as accurately and usefully as possible such information as is available. Accordingly, several small surveys, already carried out by various officers of the Victorian Department of Agriculture, have been subjected to regression analysis. One of these surveys[5] originally contained 118 farms, but for the purpose of this work four small samples of 20 or less farms were drawn.

Description of the Survey Samples

At the head of Table 1 some information is given about the survey samples. Dairy farms which use concentrates tend to be different from those which do not, and where possible the two types of farms were analysed separately. Thus two samples were drawn from the Undulating area of Woorayl Shire in South Gippsland, one group using concentrates and the other not.

Three areas of Woorayl Shire are shown. The two 20 farm samples from the Undulating area were drawn from the 68 farms in this area in the original study.[6] The sample of 20 farms for the Hills area came from an original 25 farms.

The results from these smaller analyses are very similar to those obtained in the original study. The Undulating area is near Leongatha where the annual rainfall is about 40 inches. It is probably the best dry land dairying area in Australia and is gently undulating. The Hills area has similar soils and climate, is geographically contiguous, but is hilly. The Plains area lies to the south of the other two, and while having a similar rainfall, the soils in this region are sandy and have trace element deficiencies. Compared to the two areas to the north of it the Plains area is relatively undeveloped. The sample farms from the Undulating and Hills areas were remarkably homogeneous, but those from the Plains area were much less so.

The farms in the Upper Yarra Valley survey[7] come from an area some 20 miles east of Melbourne. Though physically rather homogeneous it would be idle to pretend that management practices on these farms were even "fairly" homogeneous. Rainfall in the area is about 30 inches yearly and all farms but one were situated not far from the river Yarra, between Lilydale and Healesville. About 80 per cent of the milk produced was sold at whole milk contract rates and the average contract per cow was close to one gallon.

The Heywood dairy survey[8] area lies in a 30 inch rainfall region between Portland and Hamilton in the south-west corner of Victoria. The soils vary from farm to farm and management practices, although far from homogeneous, were more uniform than in the Upper Yarra Valley.

[5] Cozens, L. E., and White, H. A. *A Survey of Dairy and Pig Farms in Woorayl Shire, South Gippsland, Victoria*. Dept. of Agric., Melbourne, 1959.

[6] *Ibid.*, p. 54.

[7] Cozens, L. E. *A Survey of Contract Milk Farms, Upper Yarra Valley, Victoria, 1962/63*. Dept. of Agric., Melbourne, 1964.

[8] Gilmour, W. I. D. *Economic and Management Survey, 1962/63*. Dept. of Agric., Melbourne, 1964.

The Heywood sheep survey[9] took place in the same area as the previous study. Each of the 19 farms in this study had some beef cattle, but inputs and outputs relating to these cattle were excluded from the analysis.

None of the survey material was ideal for production function analysis, having regard to the assumptions involved. However, each survey area was about as physically homogeneous as most advisory officers outside irrigation areas are likely to meet. The uniformity of farm management practices was not very great except in the Undulating and Hills areas of Woorayl Shire. Despite this, there was unanimity of the results in certain respects.

Description of the Variables

The term "milking cows" refers to the number of cows milked, but it also includes the supporting stock necessary to maintain the milking herd. The ratio of supporting stock to milking herd was similar in all surveys. In the Woorayl Shire surveys for instance, there was an average of one yearling heifer for each four milking cows, one rising two year old heifer for each five milking cows, and one bull for each 25 milking cows.[10] "Concentrates" varied from farm to farm and included bran, pollard, brewers' grains, and crushed oats. "Hay equivalents" consisted of both hay and silage, the latter converted to hay equivalents. In all cases, however, the amount of hay used far outweighed the silage fed. "Per acre" means per acre of improved grassland. Where land other than improved pasture was grazed it was converted to improved pasture equivalents.[11]

"Dry sheep equivalents" was estimated by calculating the average number of three classes of sheep on the farm over the year, assigning each class a dry sheep equivalent value, and adding the total dry sheep equivalents in each class together. The values assigned to the three classes were as follows: wethers, 1·5 dry sheep equivalents; weaners, 2·0 dry sheep equivalents; ewes with lambs, 2·5 dry sheep equivalents. A "forage crop" was a crop specially grown to be grazed in either summer or winter. The main forage crops were rape, turnips, millet and oats.

Variables which were not common to every farm in the sample (e.g. concentrates) were assigned a very small figure when none of the variable was used so as to enable use of the Cobb-Douglas form of production function. Inputs which did not relate to the output being measured were excluded from the analysis. Thus inputs and outputs relating to beef and pig production, which were minor enterprises on many farms, were excluded.

Method of Analysis

Cobb-Douglas production functions were fitted to the survey data for well-accepted reasons elaborated elsewhere.[12] One variable, land,

[9] Unpublished data.

[10] Cozens and White, *op. cit.*, p. 3.

[11] *Ibid.*, p. 2.

[12] Parish, R. M., and Dillon, J. L. Recent Applications of the Production Function Approach in Farm Management Research. *Rev. Mktng. Agric. Econ.*, Vol. 23, No. 4, 1955, pp. 219-221.

was included in the regression model on a whole farm basis, but all others were included on a per 100 acre basis. The production function fitted was therefore of the form:

$$(1) \qquad \left(\frac{100P}{A}\right) = K\,A^{a} \left(\frac{100B}{A}\right)^{b} \left(\frac{100C}{A}\right)^{c} \left(\frac{100D}{A}\right)^{p}$$

where P is production, A is acres, B, C, D, etc. are other inputs, all on a whole farm basis; a, b, c, d are the corresponding coefficients (elasticities), and K is the production function constant.

The above production function can, after estimation, be converted to an equivalent whole farm equation,

$$(2) \qquad P = K'\,A^{a'}\,B^{b}\,C^{c}\,D^{d}$$

where P, A, B, C, D, b, c, d are as before, K' is a new constant, and a' is a new coefficient for acreage such that $a' = (1 + a - b - c - d)$. Thus, when the equation is fitted in the form (1) above, the coefficient a directly indicates the presence or absence of increasing or decreasing returns to scale. Furthermore, the sum of coefficients $(b + c + d)$ indicates whether increasing or decreasing returns will follow from a general increase in intensity of use of the corresponding inputs.

The original analysis of the Woorayl Shire survey used whole farm data[13] (area, animals, fertilizer, etc.), to which only minor adjustments were made. However, there is some disadvantage in treating the data in this way, in that there tends to be a higher correlation between variables than there would be if all farms were the same size. For example, large farms generally both conserve more hay and have more stock than smaller farms, and this may lead to a higher correlation between hay and stock numbers than would otherwise be the case. To minimize the effect of such high correlations the analyses were carried out on a per 100 acre basis. A comparison with five of the surveys, previously analysed on a whole farm basis, confirmed that the inter-correlations between the variables were in fact reduced.

All variables were retained in the final equation whether statistically significant or not. The degree of precision of the estimates of the input coefficients was measured by the ratio of the coefficients to the standard error. This is the reciprocal of a coefficient of variation: that is, it is a signal-to-noise ratio. The point of view adopted here is that all variables probably had some (even if only small) effect on production and should, therefore, be included in the model. The exclusion of non-significant variables from the final equation implies that the regression analysis is capable of determining a theoretical issue; namely, whether a particular variable does, in fact, have any effect on production. Since regression analysis cannot do this there is a case for leaving all variables in the final equation regardless of their statistical significance. The magnitudes of the signal-to-noise ratios indicate the degree to which the data are capable of establishing the effects of variables and this approach permits a more flexible interpretation than when significance tests are used.

Thus when the signal-to-noise ratios of coefficients are in the vicinity of 1·5, 2·0 and more than 3·0 then the estimates can be regarded as fairly well determined, well determined and very well determined, respectively. A graduation of this kind gives an adviser some latitude in

[13] Cozens and White, *op. cit.*, p. 20a.

interpretation of the results without disguising the fact that the effects of some variables are ill-defined. The practical application of production function analyses is to provide "clues and hints" for future action rather than a precise quantitative recipe. If all variables appear in the final equation, the effect of each variable and the accuracy of its estimation can be seen and action taken accordingly.

Discussion of the Results

The problems of obtaining satisfactory input-output relationships from production function analyses of farm survey data are legion. The results and conclusions of this paper should therefore be read with these problems in mind.[14]

The object of a production function analysis of farm survey data is to indicate likely profitable directions of change. The discussion of results therefore largely centres around marginal value products and marginal costs (opportunity costs) as shown in Table 2. Not all inputs, however, have well determined marginal value products. Hence, only those inputs which have a signal-to-noise ratio (S-N ratio) of about 1·5 or above are considered well determined and the discussion is confined to these inputs. Furthermore, only general discussion is possible here, since the specific recommendations which could arise from these analyses, are as numerous as the number of real farm situations. Accordingly, the discussion is associated with the geometric mean farm.

Table 1 shows that the elasticities of land for all of the survey areas, except the Hills area of Woorayl Shire, were so small as to be only poorly determined by these data (S-N ratios < 1). Consequently, it may be assumed that, except for the Hills area, the size of the farm has little influence on production per 100 acres. In the Hills area, however, it appears that larger farms do tend to have higher production per 100 acres than smaller farms. The explanation may be that larger farms incorporate a greater proportion of relatively easily managed land (i.e. flat land), an advantage resulting in higher production per 100 acres.

A prominent feature of the seven analyses was that there were increasing returns to intensification for four of them. Thus, for the two Undulating area samples, the Hills area, and the Heywood sheep survey, the sums of the elasticities of the inputs other than land exceed unity. Increasing returns to intensification means that a one per cent increase in all the inputs applied to a given area of land yields a greater than one per cent increase in production. Though this state of affairs seems, on the face of it, unlikely, there is occasional technical evidence[15] that an increase of stocking rates on understocked farms can lead to increased production per animal. It therefore seems quite possible that there are considerable gains to be made, on the average, from farming more intensively in four of the survey areas, provided of course that present production is profitable.

In the Woorayl Shire areas, stocking rate (milking cows) and concentrates were the inputs having a well determined effect on production. Table 2 shows that the marginal value product per $1 of opportunity

[14] Parish and Dillon, *op. cit.*, pp. 221-230.

[15] Green, J. E. Case Study Farms. *Dairyfarming Digest*, Vol. 13, No. 3, May-June, 1966 (Dept. of Agric., Melbourne), pp. 3-10.

TABLE 1

Descriptive Results of Small Sample Production Function Studies: Victoria

Characteristic	Butterfat production					Contract Milk Production	Sheep Production
	Woorayl Shire Areas						
	Undulating	Undulating	Hills	Plains	Heywood	Upper Yarra Valley	Heywood
Number of Farms	20	20	20	17	20	18	19
Concentrate use	All farms	No farms	Some farms	Some farms	Some farms	All farms	
Year	1957/58	1957/58	1957/58	1957/58	1962/63	1962/63	1962/63
Production elasticities and signal-to-noise ratios							
Land	0.086 (0.91)	0.135 (0.45)	0.307 (3.17)	—0.069 (0.51)	—0.095 (0.37)	0.003 (0.04)	—0.036 (0.74)
Milking cows	0.982 (4.09)	1.433 (2.58)	1.146 (5.34)	0.635 (3.37)	0.687 (3.10)	0.773 (5.56)	
Concentrates	0.083 (2.53)		0.028 (2.34)	—0.002 (0.11)	0.035 (1.41)	0.150 (2.25)	
Hay equivalents	—0.063 (0.63)	0.056 (0.34)	—0.053 (0.75)	0.076 (1.51)	0.030 (0.63)	—0.001 (0.02)	—0.042 (3.06)
Labour	0.135 (0.99)	—0.224 (0.68)	0.138 (0.68)	0.061 (0.48)	0.057 (0.18)	0.079 (0.80)	
Superphosphate	0.158 (1.50)	0.126 (0.51)	0.128 (1.62)			0.206 (2.43)	0.040 (0.24)
Dry sheep equivalents							1.015 (7.03)
Forage crop							0.026 (1.57)
Ewes in flock							—0.102 (1.09)
Returns to scale (*a*)	1.086	1.135	1.307	0.931	0.905	1.003	0.964
Returns to intensification (*b*)	1.295	1.391	1.387	0.770	0.809	1.207	0.937
Production function constant	1.631	1.314	1.046	2.752	2.821	1.116	0.835
R^2	0.87	0.74	0.82	0.69	0.82	0.92	0.84
Sample geometric means							
Output per 100 ac. (lb. butterfat)	11,614	9,897	9,334	8,000	8,253		
(gal. milk)						21,091	
($ sheep returns)							2,616
Land (acres)	133.81	121.73	161.99	166.31	117.52	177.66	418.79
Milking cows per 100 ac. (no.)	43.48	43.40	37.60	38.90	36.80	35.10	
Concentrates per 100 ac. ($)	271.40		22.90	17.80	10.90	717.00	
Hay equivalents per 100 ac. ('00 lb.)	946.00	880.50	649.10	336.40	569.00	694.00	29.40
Labour per 100 ac. (a.m.w.e.'s)	69.80	71.00	60.30	54.50	49.50	49.20	
Superphosphate per 100 ac. ($)	248.10	261.00	243.90			151.40	
Superphosphate per 100 ac. (tons)							6.44
Dry sheep equiv. per 100 ac. (no.)							663.00
Forage crop per 100 ac. (acres).							2.89
Ewes in flock (per cent) (*c*)							48.60

(*a*) 1 + elasticity for land.

(*b*) The sum of all elasticities except land.

(*c*) Ewes as a percentage of total adult stock.

cost invested in an additional cow at the geometric mean was $3 or above in all the samples. Furthermore, the production function equations support the conclusion that, on the average, stocking rates could profitably be increased by at least fifty per cent (other factors remaining at the geometric mean) without marginal value product falling below $2·7 per $1 of cost. In all except the Plains area it would be above $4. It was profitable to increase the use of concentrates at the geometric mean level in all but the Plains area. However, marginal value product per $1 of cost from additional milking cows was so comparatively high in every case that concentrate feeding above approximately $2 per head would represent a misallocation of funds where higher stocking was possible.

In these areas, the elasticities of the hay input were quite small and, except in the Plains area, poorly determined (Plains: S-N ratio, 1.51). Thus, there is, in general, little evidence that hay feeding is important to production. The Plains area is much less well developed than the other two areas, but since the stocking rate is much the same, there tends to be a higher grazing pressure. There is thus some evidence that because of the higher grazing pressure in the Plains area, hay feeding may be profitable on the average, provided it is available and can be fed for less than 80 cents per 100 lb. Superphosphate use per acre showed a fairly well determined relationship with production in the Undulating area farms using concentrates, and in the Hills area farm sample (S-N ratios of about 1·5). The marginal value product per $1 of cost from additional superphosphate at the geometric mean was more than $2 in both cases. This information indicates the possibility that additional superphosphate may be profitable.

The Heywood dairy survey showed a very well determined relationship between stocking rate and production. The production function equation indicates that even at double the present average stocking rate the marginal value product per $1 of cost would still be over $2·5. Only six farms used concentrates, and it is not surprising that a well determined S-N ratio failed to materialize. Nevertheless, the S-N ratio of 1·41 is high enough to justify further investigation, particularly since the marginal value product of an extra $1 of concentrates was $11·9. Hay feeding showed a very poorly determined association with production though all farms in the study used some hay.

The Upper Yarra Valley contract milk survey produced a rather surprising result in that three well determined variables emerged from an 18-farm sample (Table 1). An extra milking cow, at the geometric mean, added $3·1 per $1 of cost (Table 2). The evidence again suggests that on the average, stocking rates could be profitably almost doubled without marginal value product falling below $2·5 per $1 of cost. Table 2 also shows that increased superphosphate application at the geometric mean level of $151·4 per 100 acres (1·75 cwt. per acre) was highly profitable. At this level, marginal value product per $1 of cost was $6·5, but even at 3 cwt. per acre ($260 per 100 acres), it was still over $4. Thus, taking the figures in Table 2 literally, it would pay to increase superphosphate to 3 cwt. per acre before increasing stocking rate on the average farm in the survey, provided all other factors were near the geometric mean.

The geometric mean value of concentrates used in the Upper Yarra

TABLE 2

Marginal Productivities and Opportunity Costs—Small Sample Production Function Studies: Victoria

Measure	Butterfat production					Contract Milk Production	Sheep Production
	Woorayl Shire areas						
	Undulating	Undulating	Hills	Plains	Heywood	Upper Yarra Valley	Heywood
Marginal products (a)							
Milking cows (lb. b'fat per cow)	262.0	327.0	284.0	131.0	154.0		
Milking cows (gal. milk per cow)						464.0	
Concentrates (lb. b'fat per $)	3.6		11.4	—0.9	26.5		
Concentrates (gal. milk per $)						4.4	
Hay equivalents (lb. b'fat per '00 lb.)	—0.8	0.6	—0.8	1.8	0.4		
Hay equivalents (gal. milk per '00 lb.)						—0.03	
Labour (lb. b'fat per a.m.w.e.)	23.0	—31.2	21.4	8.9	9.5		
Labour (gal. milk per a.m.w.e.)						33.7	
Superphosphate (lb. b'fat per $)	7.4	4.8	4.9				
Superphosphate (gal. milk per $)						28.7	
Marginal value products (a) (b)							
Milking cows ($ per cow)	118.0	147.0	128.0	59.0	69.0	104.4	
Concentrates ($ per $)	1.6		5.1	—0.4	11.9	1.0	
Hay equivalents ($ per '00 lb.)	—0.4	0.3	—0.4	0.8	0.2	—0.01	—3.7
Labour ($ per a.m.w.e.)	10.4	—14.0	9.6	4.0	4.3	7.6	
Superphosphate ($ per $)	3.3	2.2	2.2			6.5	
($ per ton)							16.2
Dry sheep equiv. ($ per d.s.e.)							4.0
Forage crop ($ per acre)							23.5
Ewes in flock ($ per percent)							5.5
Opportunity costs (c)							
Milking cows ($ per cow)	20.0	20.0	20.0	20.0	20.0	34.0	
Concentrates ($)	1.0	1.0	1.0	1.0	1.0	1.0	
Hay equivalents ($ per '00 lb.)	0.42	0.42	0.42	0.42	0.45	0.45	0.45
Labour ($ per a.m.w.e.)	33.6	33.6	33.6	33.6	34.2	34.2	
Superphosphate ($) (d)	1.0	1.0	1.0			1.0	
Superphosphate ($ per ton)							22.0
Dry sheep equiv. ($ per d.s.e.)							1.0
Marginal value product (a) per $1 of opportunity cost							
Milking cows ($)	5.9	7.4	6.4	3.0	3.5	3.1	
Concentrates ($)	1.6		5.1	—0.4	11.9	1.0	
Hay equivalents ($)	—1.0	0.7	—1.0	1.9	0.4	—0.02	—8.2
Labour ($)	0.3	—0.4	0.3	0.1	0.1	0.2	
Superphosphate ($)	3.3	2.2	2.2			6.5	0.7
Dry sheep equivalents ($)							4.0

(*a*) Estimated at the geometric mean.

(*b*) For the butterfat producing farms. butterfat is priced at 45 cents per lb. For the milk producing farms, additional milk is given a butterfat price of 45 cents per two gallons, which, with a 5 per cent test, is equivalent to 45 cents per lb. of butterfat. For the sheep properties, additional production is measured in $'s.

(*c*) The opportunity cost of additional labour is not included.

Valley was about $20 per cow and at this level Table 2 shows that the return from additional concentrate just covered the extra cost. Where the alternative resource use is either to apply more superphosphate or increase stocking rate, it is only profitable to use concentrates at much lower levels. For instance, if superphosphate is used at 1·75 cwt. per acre (with all other factors at the geometric mean), concentrate feeding would only be profitable at $2 per cow or less. Where the stocking rate is below 68 cows per 100 acres (with other factors at the geometric mean) concentrate feeding would only be profitable in the range of $4 to $6 per cow.

The Heywood sheep survey showed that there was a very well determined relationship between the number of dry sheep equivalents per acre and production. Table 2 indicates that, at the geometric mean of all factors, the marginal value product per $1 of opportunity cost from an added dry sheep equivalent was $4. The upper limit of stocking rates in the sample was 982 dry sheep equivalents per 100 acres. It can therefore be concluded that, on the average, stocking rates in the area can be profitably raised to a point a little below this level. The second well determined input was hay, but it was negatively, not positively, correlated with production. The equation thus suggests that, as more hay is fed, production per animal falls. Although some sheep and wool experts agree that this is not impossible, it seems a rather surprising result to say the least, and would not be expected to apply to special purpose feeding. It may, however, be a significant result in more than the statistical sense, and further surveys will endeavour to examine the situation in greater detail by obtaining more accurate data. The conclusion about hay feeding from this survey, however, must be that less hay need be fed than is at present used. The analysis suggests, and it may even be, that no hay need be fed at present stocking rates, in many seasons. There was, in addition to the two inputs mentioned, a fairly well determined relationship between forage crops and production. It is difficult to assess the significance of this result since several kinds of forage crops were grown and the opportunity cost of these crops is not readily determined.

Conclusions

Small surveys with about 20 farms in the sample are capable of producing well determined relationships between inputs and outputs when analysed statistically. In this case, four inputs—stocking rate, concentrates, hay and fertilizer—were established as having a well determined effect on production. It appears that information from well designed surveys can create a little more certainty than there was before if analysed statistically. Thus the present trend towards analysing farm records on a group basis may be unexpectedly rewarding.

The importance of stocking rate is apparent in each of the surveys attempted. This suggests that the intensity of stocking has a very important bearing on the profitability of farming over a wide area in Victoria.

Production function analyses of this kind often need to be followed by further work to clarify or confirm what appear to be unexpected results. Thus a finding that there is a significant negative relationship between hay feeding and returns from sheep needs further investigation before advisers could be expected to accept this as the basis for guidance to farmers.