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RESOURCE PRODUCTIVITY AND OPTIMUM RESOURCE ALLOCATION ON A SAMPLE OF QUEENSLAND SUGARCANE FARMS*

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GENERAL

In Queensland (Australia), sugarcane is grown both under irrigation and under dry land farming conditions. In view of the fact that no estimates of resource productivity on either type of farms have ever been published, it was decided to choose two groups of farms, one having dry land cane and the other irrigated cane, for this study.

The study described in this article is about the derivation of average production functions for two groups of sample sugarcane farms from Ayr and Mackay districts of Queensland State. For the Ayr sample whole farm production functions have been estimated, based on farm survey data, for the three financial years 1957-58 to 1959-60, and for Mackay sample for the four financial years 1957-58 to 1960-61.

To be eligible for selection, farms had to have a net assigned area[1] of between 40-80 acres. The imposition of a lower limit on the sample meant that sidelines or part-time cane farmers are eliminated. (If farms under 40 acres net assignment are disregarded, 77 per cent of Queensland full time commercial cane farms fall within 40-80 acre range, the average net assigned area in Queensland being 59.7 acres).

Rather than include a management variable (with its associated difficulties of formulation and measurement) it was decided to try and minimise variations due to differing levels of management. Farms were, therefore, eliminated from the mill population on three further counts.

(*i*) If a farm was above 80 acres net assignment.

Large cane farms generally have a higher return on capital than small farms.[2] Part of the difference could possibly be attributed to the level of managerial ability.

(*ii*) If the owner had been less than five years on the farm.

This eliminated farms in the early stage of development or managers with limited experience in the district.

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* This paper is a summary of a thesis submitted in 1963 for the degree of Doctor of Philosophy, University of Queensland (Australia).

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1. Because, historically, export markets for sugar have been limited, restrictions have been placed on production. Prior to 1931, cane accepted by a mill had to be grown on a particular area known as the gross assigned area. From 1931 onwards, cane was only accepted from the net assigned area, which is three-fourth of the gross.

2. W. O. McCarthy: The Australian Sugar Industry, Econ. Soc. Australia and New Zealand, Queensland Branch, Monograph No. 8, 1962.

(*iii*) If the owner had been more than 15 years on the property.

This attempts to account for farmers who are not of the "new" generation and who might have attitudes and expectations markedly different from the consensus.

SAMPLING

The sample farms were then selected at random from the remaining suppliers to each mill in Ayr and Mackay districts.[3] Thirty-five farms were chosen in each group, keeping ten alternatives.

Table I includes data comparing assigned areas of the sample group with areas of all farms supplying the respective mills.

TABLE I—DETAILS OF THE TWO SAMPLES

S. No.	Description	Mackay Sample (acres)	Ayr Sample (acres)
1.	Total number of farms supplying the mill ..	241	247
2.	Total gross assigned area	26,486	20,684
3.	Total net assigned area	19,915	15,554
4.	Average gross per farm	110	84
5.	Average net per farm	83	63
6.	Number of farms in the survey	35	35
7.	Total gross area of survey farms	2,970	3,299
8.	Total net area of survey farms	2,232	2,468
9.	Average gross assigned area of survey farms	85	84
10.	Average net assigned area of survey farms ..	64	71

CHOICE OF MODEL AND PROBLEMS ASSOCIATED WITH IT

The model used for this investigation was a power function of the Cobb Douglas form :

$$Y = a \prod_{i=1}^{n} (X_i)^{b_i}$$

where Y is the gross income, X_1, X_2,.....X_n the inputs.

Although there are advantages and disadvantages of the Cobb-Douglas function for analysis of farm management data, yet its wide usage in studies of this kind is due to its conformance to economic theory and the ease of statistical computation.[4] Parish and Dillon,[5] and Jarrett[6] have commented on the problems associated in the use of farm data, particularly with regard to economic and statistical specification. Soper[7] maintained that an average production

3. Of four mills in Ayr district the Inkermen mill was chosen at random, and of five mills in Mackay area, the Racecourse mill was chosen at random.

4. E.O. Heady, "Use and Estimation of Input-Output Relationships or Productivity Coefficients," *Journal of Farm Economics*, Vol. 34, 1952, pp. 775-786.

5. R. M. Parish and J. L. Dillon, "Recent Applications of the Production Function in Farm Management Research," *Review of Marketing and Agricultural Economics*, Vol. 23, 1955, pp. 215-236.

6. F. G. Jarrett, "Resource Productivities and Production Functions," *Review of Marketing and Agricultural Economics*, Vol. 25, 1957, pp. 67-78.

7. C. S. Soper, "Production Functions and Cross-Section Surveys," *Economic Record*, Vol. 33,1958. pp. 111-118.

function could not be derived from cross-sectional survey data using least squares because the data would consist of only one point on each of a number of different production functions. Konijn,[8] however, refuted this argument and concluded that a production function which includes all inputs and which is fitted by least squares will as a rule be approximately unbiased. Further, he suggested that even if the data available were likely to lead to biased results, they could be adjusted so that a usable approximation to an average production function resulted. Plaxico[9] and Antill[10] have suggested that if farms were using essentially similar production techniques and producing much the same combination of products, and if selected from a "single well defined revenue type," then the function can provide a legitimate basis for farm planning.

CHOICE OF VARIABLES

The final choice of the input combinations to use in the analysis was made after fitting thirteen functions to each of the nine sets of data (Ayr 1958, 1959, 1960 and 1958-60; Mackay 1958, 1959, 1960, 1961 and 1958-61), using correlation matrices, R^2 and t-values of individual coefficients as criteria for choice.

Although the literature on farm survey studies suggests that the problem of selection of the optimum combination of inputs is at least a tedious trial and error approach, this did not prove to be so in the present study. Of the 117 functions fitted, the values of R^2 was less than .5 in four cases, less than .6 in five cases and less than .7 in eight cases. The crux of the matter probably is that sugarcane farming is a single enterprise type of farming without sideline enterprises, and, therefore, the choice of input combinations to represent land, labour and capital is relatively straight-forward and non-controversial.

The function eventually chosen and used in the analysis is :

$$Y = a\, X_1^{b_1}\, X_2^{b_2}\, X_3^{b_3}\, X_4^{b_4}$$

where,

Y = gross income (£)
X_1 = fertilizer (£)
X_2 = labour (man-weeks)
X_3 = plant and machinery (£)
X_4 = land (farm peak tons cane)

Description of Variables

(*a*) Dependent variable

Y is the gross income received by the farmers from the mill for the sale of sugarcane and does not include any other receipts, such as sale of cane plants or bonus receipts by the Mackay farmers for the mill which is co-operatively owned.

8. H. S. Konijn, "Estimation of an Average Production Function from Surveys," *Economic Record*, Vol. 35, 1959, pp. 118-125.
9. J. S. Plaxico, "Problems of Factor-Product Aggregation in Cobb-Douglas Value Productivity Analysis, *Journal of Farm Economics*, Vol. 37, 1955, pp. 664-675.
10. A. G. Antill, "Towards a Production Function for Dairy Farms," *The Farm Economist*, Vol. 8, 1955, pp. 1-11.

(*b*) Independent variables

(*i*) Fertilizer (X_1)

Very few previous production function studies include fertilizer as a separate input. Of the total running expenses in each of the years observed, Ayr farmers spent up to 20.92 per cent on fertilizer, and Mackay farmers up to 46.17 per cent.[11] Hence fertilizer, measured as total cash outlay, is included as a separate variable.

(*ii*) Labour (X_2)

All sugarcane farms in the two samples were owner-operated. In assessing the labour input, as far as the owner-operated is concerned, the unit used was labour available (in man-weeks) rather than the work hours actually spent, because comprehensive records were not available for the latter. On many farms the owner-employed family labour, permanent labour or casual labour, on a part-time or full time basis. In all cases records were available of the actual man-weeks worked.

(*iii*) Plant and machinery (X_3)

The value of plant and machinery has been chosen to represent the capital input. Heady[12] had a capital input called machinery and equipment, measured as the dollar value of the beginning inventory and including the value of machinery, repairs, fuel and lubricants. This study tested similar aggregation. Following Jarretts[13] example, a capital input, including depreciation of plant and equipment and operating expenses, was also tried. However, the function chosen included as the capital input, plant and machinery measured as the sum of the depreciated values of individual items.

(*iv*) Land (farm peak tons cane) (X_4)

Farm peak,[14] that is tonnage of cane accepted by the mill, was chosen as the independent variable measuring the land input, because it is the most precise measure of the area of land actually used in producing the required quantity of cane. Gross and net assigned areas were not used to measure land input, because of the additional restriction imposed by farm peaks which ensure that the mill does not usually accept all cane grown on net assigned areas. Farm peak, it is realised, is not the ideal measure of the land input, since in certain years when overseas demand is buoyant, the mill may accept a percentage of cane above farm peak.

PRODUCTION FUNCTIONS AND MARGINAL PRODUCTIVITIES

Table II lists the regression coefficients (which are also elasticities of production of individual inputs) for the function which was chosen as best representing

11. Sugarcane requires heavy fertilizer dressings and non-fertilization is unknown.
12. E. O. Heady, "Production Functions from a Random Sample of Farms," *Journal of Farm Economics*, Vol. 28, 1946, pp. 989-1004.
13. F. G. Jarrett. "Estimation of Resource Productivities as Illustrated by a Survey of the Lower-Murray Valley Dairying Area," *Australian Jour. Stat.*, Vol. 1, 1959, pp. 3-11.
14. This was a further restriction on production introduced in 1940 to those mentioned in footnote 1 on p. 21.

the relationship between input and output quantities. The 30 farms included in the Mackay sample are the same for each of the four years, while the size of the Ayr sample differed from year to year due to the fact that complete financial data were not available for all farms for the three years.

TABLE II—ELASTICITIES OF PRODUCTION

Year	Sample size	Fertilizer X_1	Labour X_2	Plant and Machinery X_3	Land (farm peak) X_4	Sum of elasticities b_i
Mackay sample						
1958	30	·036853	·196947	·223029	·829734**	1·286563
1959	30	·084748	·012394	·104912	·718153**	0·920206
1960	30	·222250*	·029370	·298530*	·479215*	1·029365
1961	30	·098702*	—·046004	·005090	·963160†	1·020948
1958-61	120	·113588*	·036216	·135165*	·768619†	1·053588
Ayr sample						
1958	25	·198378*	·120789	·119494	·797452†	1·236113
1959	30	·050680	—·050751	·038433	·980556†	·1·018918
1960	32	·024631	·178113*	—·004507	·759774†	0·958008
1958-60	120	·065988*	·086508	·032727	·868651†	1·053877

* Significant at 5 per cent level.
** Significant at 1 per cent level.
† Significant at 0·1 per cent level.

(a) *Elasticities*

The coefficients included in Table II estimate elasticities of production with respect to each particular input. *Ceteris paribus*, these elasticities indicate the average per cent change in total product associated with a 1 per cent change in the factor concerned. In no case is the individual coefficient greater than unity, so that diminishing marginal returns to individual factors of production are indicated.

Negative elasticities observed for labour and plant and machinery implies a decrease in total product when the factors concerned are increased. While this might be possible in some cases and hence explain negative coefficients (*e.g.*, fertilizer at heavy levels of application), no ready explanation in terms of production theory can be offered for the particular coefficients under consideration.

As regards the wide variations in elasticities of individual inputs among years, it may be that these variations are no more than could be expected in view of the uncertain future and variable environment in which decisions are made and production carried out.

(b) *Statistical Significance*

(*i*) *Multiple correlation coefficients:* Table III gives multiple correlation coefficients for each of the functions in Table II.

TABLE III—MULTIPLE CORRELATION COEFFICIENTS

Year	Adjusted Values* of		F-Value
	Coefficient of multiple determination R^2	Multiple correlation coefficient R	
Mackay sample			
1958	·7952	·8917	29·16†
1959	·7288	·8537	20·53†
1960	·7979	·8933	29·63†
1961	·9470	·9736	132·90†
1958-61	·8143	·9024	131·44†
Ayr sample			
1958	·8943	·9457	51·77†
1959	·9709	·9853	242·00†
1960	·8428	·9180	42·53†
1958-60	·8944	·9457	183·17†

* Values based on unbiased variances.
† Significant at less than ·5 per cent level.

On the basis of the F-test, all the values of R^2 were found to be significant at less than .5 per cent level. Appendix A lists the analyses of variance on which the F-tests were based.

The adjusted coefficients of multiple determination indicate the percentage of variance in total product accounted for by fitting the function. In general a high degree of variation has been explained. The function fitted the Ayr data somewhat better than the Mackay data.

(*ii*) *Returns to Scales:* The presence of constant, increasing or decreasing returns to scale is of interest both from an efficiency and policy point of view. Thus if increasing returns to scale can be demonstrated, it is possible that either farm size is small or that there is misallocation of resources.

If it is assumed that no inputs have been excluded from the function, the sum of elasticities of the four inputs (shown in the last column of Table II) is a measure of returns to scale. Except in two cases (Mackay 1959 and Ayr 1960) the sum was greater than one. The sums were tested statistically using the method outlined by Tintner[15] to determine whether they differ significantly from unity. Appendix B includes the analyses of variance associated with the test.

15. G. Tintner, "A Note on the Derivation of Production Functions from Farm Records," *Econometrica*, Vol. 12, 1944, pp. 26-34.

The only function for which the sum of the elasticities was significantly different from unity at the 2.5 per cent level, was that of Ayr for 1958. The 1958 Mackay function was found to be significant at the 5 per cent level. All the functions were non-significant at the conventional probability levels. Hence the hypothesis of constant returns to scale is not rejected in these cases. The presence of increasing returns to scale in two cases is not an unexpected finding in the light of the decision by the Queensland Sugar Board in the year 1957-58 season to acquire sugar in excess of mill peaks due to the high prices that prevailed for world free market sugar at that time.

(c) *Marginal Productivities*

Marginal productivities estimated for each of the nine functions are presented in Tables IV and V.

TABLE IV—MEAN QUANTITIES OF INPUTS AND OUTPUT, AND MEAN MARGINAL PRODUCTIVITIES—MACKAY SAMPLE

		Unit of measurement	Year				
			1958	1959	1960	1961	1958-61
(i)	Geometric means of inputs						
	Fertilizer (X_1)	£s	659	376	477	541	503
	Labour (X_2)	Man-weeks	76	76	76	76	76
	Plant and machinery (X_3)	£s	3,530	3,208	3,095	2,577	3,083
	Land-farm peak (X_4)	Tons of cane	936	936	936	936	936
(ii)	Geometric means of output	£s	5,943	4,881	4,832	5,183	5,192
(iii)	Mean marginal productivities						
	X_1 (£s per 1£ spent)		0.033	1.100	2.251	0.946	1.173
	X_2 (£s per man-week)		15.401	0.796	1.867	—3.137	2.474
	X_3 (£s per 1 £ spent)		0.376	0.160	0.466	0.010	0.228
	X_4 (£s per ton of cane)		5.268	3.745	2.474	5.333	4.264

TABLE V—MEAN QUANTITIES OF INPUTS AND OUTPUT, AND MEAN MARGINAL PRODUCTIVITIES—AYR SAMPLE

		Unit of measurement	Year			
			1958	1959	1960	1958-60
(i)	Geometric means of inputs					
	Fertilizer (X_1)	£s	663	410	528	517
	Labour (X_2)	Man-weeks	87	91	92	90
	Plant and machinery (X_3)	£s	4,432	4,253	3,793	4,127
	Land-farm peak (X_4)	Tons of cane	1,834	1,968	1,995	1,938
(ii)	Geometric means of output	£s	9,412	10,380	10,230	10,040
(iii)	Mean marginal productivities					
	X_1 (£s per £1 spent)		2·812	1·283	0·477	1·282
	X_2 (£s per man-week)		13·067	—5·789	19·805	9·650
	X_3 (£s per £1 spent)		0·254	0·094	0·012	0·080
	X_4 (£s per ton of cane)		4·093	5·172	3·896	4·500

The marginal productivities were derived from the elasticities of production using the geometric means[16] of inputs and output. Marginal products indicate the expected increase in total output resulting on an average from the use of one additional unit of a particular input.

In general marginal returns to fertilizer were higher than marginal costs. The irrigated Ayr farms had relatively higher marginal returns than the dry land Mackay group. For Mackay in 1958 the very low marginal return to fertilizer was associated with the heaviest fertilizer use for any of the four years, while the high marginal returns in 1960 was associated with lower than average fertilizer use and heavy per acre yields of cane. The explanation for the comparatively low 1960 and high 1958 marginal returns to fertilizer in Ayr appeared to lie not so much with usage of fertilizer, but with yields per acre compounded with cane prices.

Labour productivity was lower than prevailing wage rates[17] in all years except in Mackay in 1958 and in Ayr in 1960. Labour productivity in the Mackay sample was consistently low compared with the Ayr group. Possible contributing factors are:

(*i*) Mackay farms on an average employed more full time family labour (.59 full time adult family labour equivalents per farm compared with .23 units per farm in the Ayr sample). As sugarcane farming has heavy seasonal labour requirements (peaks at planting, early cultivation and harvesting), managerial and family labour is under-employed for long periods.

(*ii*) Ayr farms being irrigated use labour more evenly throughout the year. (The number of irrigations per year in the Ayr sample averages 9 and each irrigation is followed by a cultivation).

(*iii*) In Ayr the average farm peak per full time labour unit is 1,632 tons compared with 610 tons for Mackay.

Marginal returns for plant and machinery were also low for both the groups. On an average, the farms investigated may have excess plant and machinery. But a more correct explanation is that there are heavy demands on machinery for short periods throughout the year. Another possible reason for high plant and machinery inventories is that cane farmers are relatively prosperous and may tend to buy machines with larger capacities than required and renew machinery prematurely. A point which should be made relative to the apparent low productivity of plant and machinery is that movement towards an optimum is restricted because of acreage assignments. It is not suggested that machinery is not approaching capacity at some times of the year, but that the relatively small acreages involved result in "lumpiness" of machinery inputs, which could only be overcome by increasing acreage.

16. Geometric means are commonly used for agricultural data partly because the distribution of inputs and outputs is usually positively skewed. Hence the geometric mean being closer to the mode is a more appropriate measure of the central tendency than the arithmetic mean.

17. Wage rates for labour employed on cane farms averaged £15 per week for the period under consideration.

Land has been measured in terms of farm peak because the area of land used to produce farm peak is the best estimate of the land input. For both the groups, for all years, the marginal value product is considerably greater than annual cost. In general, variations in value products between years are due to differences in market prices for cane and quantities of cane accepted in excess of farm peak. It appears that on an average as far as the land input is concerned, farms are producing on the downward slope portion of the average cost curve. However, no increase in the land input is possible because land available for production is fixed by the system of farm peaks.

SUMMARY AND CONCLUSIONS

This study was undertaken with the object of estimating resource productivity and investigating resource allocation on two samples of sugarcane farms in Queensland (Australia). It is not suggested that the findings from the samples studied apply to the sugar industry generally. Rather it was intended to demonstrate the methodology and to indicate the applicability and usefulness of economic analysis to farms in the industry.

Despite the limitations of the Cobb-Douglas type functions which have been discussed fairly well in recent literature because of the fact the function has some advantages and lacks some disadvantages of various possible forms, it has been used in the present analysis. The estimated production functions for the two samples studied provide an approximate rather than very precise estimates of the input-output relationships from which the following conclusions can be drawn regarding the two groups of farms from Mackay and Ayr districts.

(*i*) In general, marginal returns to fertilizer were greater than marginal costs. The irrigated Ayr farms had relatively higher marginal returns than the dry land Mackay group.

(*ii*) Labour productivity was below ruling wage rates in almost all functions, which may be explained as resulting from the seasonal nature of sugarcane farming, wherein labour needs are at a peak at planting, cultivation and harvesting, but are under-employed for the remainder of the year. Labour productivity in the Mackay sample was consistently low compared with the Ayr group possibly because the former are dry land farms while the latter are irrigated.

(*iii*) Marginal returns to plant and machinery were low for both the groups. Again this is probably related to heavy seasonal requirements, as well as to the existing tendency on the part of the relatively prosperous cane farmers to buy more machinery than required, thus leaving excess capacity.

(*iv*) Marginal productivity for the land input was high. In theory, this would suggest that land inputs should be increased. However in practice, this cannot be done because of farm peak restrictions.

APPENDIX A
ANALYSIS OF VARIANCE
TABLE I—MACKAY SAMPLE

Year	Variation due to	d.f.	S.S.	M.S.S.	V.R.
1958	Regression	4	1·229945	0·307486	
	Deviations	25	0·263623	0·010545	29·159†
	Total	29	1·493568		
1959	Regression	4	0·689034	0·172259	
	Deviations	25	0·210232	0·008409	20·485†
	Total	29	0·899266		
1960	Regression	4	0·771176	0·192794	
	Deviations	25	0·162668	0·006507	29·629†
	Total	29	0·933844		
1961	Regression	4	0·899470	0·224868	
	Deviations	25	0·042298	0·001692	132·901†
	Total	29	0·941768		
1958-61	Regression	4	3·502362	0·875591	
	Deviations	115	0·766080	0·006662	131·431†
	Total	119	4·268442		

ANALYSIS OF VARIANCE
TABLE II—AYR SAMPLE

Year	Variation due to	d.f.	S.S.	M.S.S.	V.R.
1958	Regression	4	0·743113	0·185778	
	Deviations	20	0·071767	0·003588	51·778†
	Total	24	0·814880		
1959	Regression	4	0·881856	0·220464	
	Deviations	25	0·022780	0·000911	242·002†
	Total	29	0·904636		
1960	Regression	4	0·654178	0·163544	
	Deviations	27	0·103803	0·003845	42·534†
	Total	31	0·757981		
1958-60	Regression	4	2·228105	0·557026	
	Deviations	82	0·249393	0·003041	183·172†
	Total	86	2·477498		

† Significance level less than 0·5 per cent.

APPENDIX B

RETURNS TO SCALE TEST — ANALYSIS OF VARIANCE

MACKAY SAMPLE

Year	Variations due to	d.f	S.S.	M.S.S.	V.R.
1958	Q_1	25	0·263623	0·010545	
	Q_2	1	0·050888	0·050888	4·8258*
1959	Q_1	25	0·210232	0·008409	
	Q_2	1	0·004020	0·004020	0·4781N.S.
1960	Q_1	25	0·162668	0·006527	
	Q_2	1	0·000501	0·000501	0·0768N.S.
1961	Q_1	25	0·042298	0·001692	
	Q_2	1	0·000239	0·000239	0·1413N.S.
1958-61	Q_1	115	0·766080	0·006662	
	Q_2	1	0·007028	0·007028	1·0559N.S.

AYR SAMPLE

1958	Q_1	20	0·071767	0·003588	
	Q_2	1	0·024287	0·024287	6·7690**
1959	Q_1	25	0·022780	0·000911	
	Q_2	1	0·000256	0·000256	0·2810N.S.
1960	Q_1	27	0·103803	0·003845	
	Q_2	1	0·001204	0·001204	0·3141N.S.
1958-60	Q_1	82	0·249393	0·003041	
	Q_2	1	0·005421	0·005421	1·7826N.S.

Q_1 = Fit of regression equation without restriction.

Q_2 = Difference between the results of the fits with and without restriction.

* Significant at 5 per cent level.

** Significant at 2·5 per cent level.

N.S. = Not significant.