RESOURCE PRODUCTIVITIES FROM A SAMPLE OF LIGHT PLAINS FARMS, CANTERBURY, NEW ZEALAND*

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The study described in this article is concerned with the derivation of an average production function for 50 sheep farms on an area of light land in the Malvern County, Canterbury Plains, New Zealand.

It is based on farm survey data for the 1955/6 season. The locality of the survey was chosen chiefly because it contained 51,000 acres of essentially similar soils, the Lismore series, and an adequate number of farms exhibiting a fairly high degree of homogeneity in their management.

Although there are variations in farm management in the area, the predominant pattern consists of the maintenance of half bred, three-quarter bred, or Romney-cross ewe flocks for the production of Down-cross fat lambs. Most of the replacements for ewe flocks are purchased from other areas but some of the larger properties breed their own.

The average winter carrying capacity of the sheep farms in the area was 1.7 ewe equivalents per acre for 1956.

The system of farming is practically confined to a pastoral one due to the desiccating effect of the north west Föhn type winds which prevail during the summer. These conditions, combined with a shallow shingly soil, result in unreliable yields of cash crops and small seeds.

A summary of the land utilisation of the survey farms for the 1955/6 season showed only 5.4 per cent of the area in cash crops and small seeds while 5.6 per cent of the area was devoted to summer fattening crops of rape and 12.2 per cent to winter fodder crops, mainly turnips and greenfeed oats.

A system of fat lamb production is adjusted very well to the regular occurrence of dry summer conditions as food requirements can be kept to a minimum at this time. Most of the season's lamb crop can be drafted off fat before the dry spell and the remainder may be finished off on a rape crop, while the ewe flock requires only maintenance rations.

The main pasture production period is during the spring, and autumn rains produce valuable late autumn and early winter feed. Winter requirements are supplemented with crop and hay.

Choice of Model and Problems Associated with the Use of Farm Data

The model used for this study was 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.

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The common choice of this function in studies of this kind is due to its conformance to economic theory and ease of computation.[1] Greater accuracy can be expected from the use of more complex functions where modern computing machines become available for this purpose.

Parish and Dillon, and Jarrett have made comprehensive statements of the problems encountered in the use of farm data, particularly of economic and statistical specification.[2]

With regard to the statistical problem of multicollinearity, this was checked in the present study by examination of the simple correlation matrix and also by the use of confluence analysis. Having determined a linear relationship between variables the solution used was simply to exclude the appropriate variable.

Konijn has pointed out that the omission of inputs will lead to biassed results, and it is now evident that results obtained with variables omitted should be adjusted along the lines suggested in his paper.[3]

The Farm Data

It has already been mentioned that the survey area was chosen because it presented a compact area of similar soils on which a group of similarly managed sheep properties were located. The larger area of light lands, of which the survey is representative, comprises 800,000 acres, a significant portion of the Canterbury Plains and one which has of recent years aroused considerable interest and speculation, regarding its present and potential productivity.

Sampling

When the farms not conforming to the typical pattern of farm management in the area were excluded it was found that the 58 remaining properties presented a manageable number for survey purposes and sampling was not necessary, or expedient. Of these, full data was collected from 50 properties, which formed the basis of the survey. Thus, information concerning 39,700 acres was obtained from a possible 44,200 acres, while atypical farms accounted for about 7,000 acres making a total of 51,000 acres for the soil group as a whole.

Problems Encountered in the Use of the Farm Data

One of the first tasks was to assemble the data into meaningful categories of inputs for purposes of analysis. There is a limit to the number of inputs which it is desirable to include in an estimation of a production function and the problem becomes one of including all variables which

1. See E. O. Heady, " Use and Estimation of Input-Output Coefficients " *Journal of Farm Economics*, Vol. 34, No. 5 (December, 1952), pp. 775-777.

2. 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, No. 4 (December, 1955), pp. 215-236.
F. G. Jarrett, " Resource Productivities and Production Functions ", *Review of Marketing and Agricultural Economics*, Vol. 25, Nos. 1 and 2 (March-June, 1957), pp. 67-78.

3. H. S. Konijn, " Estimation of Average Production Function From Surveys ", *The Economic Record*, Vol. 35, No. 70 (April, 1959), pp. 118-125.

are significant in the production relationship, thus entailing a certain amount of aggregation, while at the same time maintaining the desirable identification of some of the variables, the effects on production of which it is desired to examine independently.

The categories chosen for analysis together with the problems encountered comprise the remainder of this section.

Output

In order to combine the products of each farm into one output category the common basis of monetary value was used and this was expressed as Gross Income (Y). While such an aggregation may be unsatisfactory when farm incomes are comprised of widely differing combinations of products, under such circumstances that productivity estimates may be partly reflecting the skill of product combination, the composition of incomes of the fat lamb properties under discussion was sufficiently uniform to validate this procedure.[4]

The definition of Gross Income adopted for the present study was :

Gross Income = total receipts for produce plus livestock profits.

" Livestock profits " is the surplus of livestock sales over purchases plus the excess of closing livestock inventories over opening livestock inventories.

The allowance for stock purchases in Gross Income has the merit that incomes which include proceeds from the sale of store stock purchased for fattening are then more comparable with incomes from properties where this is not the practice.

Data for assessing Gross Income was taken from the 1955/6 financial accounts, but livestock inventories were re-assessed so that similar classes of stock were given the same valuation throughout the survey.

Inputs

The following is a description of the inputs considered for use in the regression equations (1) to (3) of the next section. The notation X_i ($i = 1$ to 8) refers also to that used in the regression analysis.

Land (X_1)

This was simply the total farm area in acres. There were no large areas of waste land on the properties to make any adjustment necessary. The validity of including land in terms of area depends on the homogeneity of the soils involved.

Total Farm Capital (X_2)

Total farm capital is defined as the value of improvements to land, plus the value of farm plant and machinery, plus the value of livestock. The " unimproved " value of land was considered to be covered by the input land (X_1). The value of improvements to land were taken from

4. For discussion on this point see J. S. Plaxico, " Problems of Factor—Product Aggregation in Cobb-Douglas Value Productivity Analysis ", *Journal of Farm Economics*, Vol. 37, No. 4 (November, 1955), pp. 664-675.

the Valuation Department assessments. Plant and Machinery were estimated at resale value and standard values were applied to livestock.

Plant and Machinery (X_3)

The resale value of plant and machinery.

Labour (X_5)

This was calculated as follows :

Payments for wages for the year
+ 40 % of contract expenditure (the estimated labour content of contract charges)
+ Allowance for owner's labour
— Payments for shearing.

The allowance for owner's labour was assessed at the ruling rate of £624 per annum where the owner was engaged full time on his property and correspondingly less where he was not. The purpose of excluding shearing payments was to avoid false " production " relationships with output. Shearing payments are determined by output rather than representing genuine inputs, and the inclusion of such " inputs " having a high degree of correlation with output, gives a spuriously high " marginal productivity ".[5]

Portion of contract is included because in some cases where dependence on contract work was heavy, e.g., for cultivation, there was a genuine labour content which would otherwise be ignored.

It may be mentioned here in explanation of the apparently low " wage " for the owner that this represents only the *labour* input and is not meant to include the *management* input.

Superphosphate (X_7)

The total number of cwts. of phosphate applied on each property for the 1955/6 season.

Lime (X_8)

The total number of tons of lime applied on each property for the 1955/6 season.

In the case of these last two inputs there is undoubtedly a lagged effect on output which is difficult to express in the regression equation. Apart from the fact that the initial impact on fertility and production is manifested in the same season as application, the *relative* usage of lime and superphosphate as between farms for any one year is likely to be representative of the general pattern of fertiliser use for previous years. Therefore, the lagged effect may be of only minor importance in regression analysis.

It may be mentioned here that the diversity of the various categories adopted by different accountants in presenting farm accounts, makes the task of identifying farm inputs correspondingly more difficult. If farm accounts were presented in standardised form, the work involved in productivity estimates such as those adopted in this study, would be greatly facilitated.

5. R. M. Parish and J. L. Dillon, *op. cit.*, p. 226.

The following variables,*

- Y Gross Income
- X_1 Land (acres)
- X_2 Total Farm Capital
- X_7 Superphosphate (cwt.)
- X_8 Lime (tons)
- X_5 Labour
- X_3 Plant and Machinery

described in the previous section, were considered for inclusion in the regression equation.

There was strong evidence that the inclusion of variable X_2, Total Farm Capital, introduced multicollinearity. This is shown by the high simple correlations of X_2 with X_1, X_7 and X_5 (Table 1) and also from the results of confluence analysis (Appendix 1).

TABLE I

Simple Correlation Matrix

Regression Equation (1)

	Y	X_1	X_2	X_7	X_8	X_5	X_3
Y	1.00	0.77	0.93	0.65	0.48	0.74	0.71
X_1	0.77	1.00	0.81	0.39	0.27	0.78	0.51
X_2	0.93	0.81	1.00	0.61	0.43	0.81	—
X_7	0.65	0.39	0.61	1.00	0.53	0.47	0.46
X_8	0.48	0.27	0.43	0.53	1.00	0.24	0.26
X_5	0.74	0.78	0.81	0.47	0.24	1.00	0.58
X_3	0.71	0.51	—	0.46	0.26	0.58	1.00

Note also the high correlation between X_2, Total Farm Capital, and Y, Gross Income (Table 1) which indicates that the two variates are almost " synonymous ". On these grounds X_2 was discarded as a variable.

Consideration was then given to including some of the capital items left out when X_2 was excluded.

The components of " Total Farm Capital " which were largely responsible for the high correlation with gross income were the capital values of improvements to land, and also those of livestock. In the case of improvements to land, it seems likely that as well as the dependent relationship of income to this input, the level of improvements, and expenditure

*A larger number of input categories was originally considered, hence gaps in the notation.

on these, will also bear some relationship to the level of previous and current level of income, i.e., there is also a reverse relationship connecting these two with improvements to land as a function of gross income. Such relationships invalidate the ordinary linear multiple regression technique. Also, as regards livestock capital, this input was highly correlated with gross income because the latter contained a high proportion of sheep products.

At the same time it was considered necessary to include some capital items where they were appropriate. It was found possible, and statistically significant to include " Plant and Machinery " X_3 as a variable. This gave regression equation (1) which " explained " 82 per cent of the variance in Gross Income (Table II).

Regression equation (1)

$$\log Y = 0.4889 + 0.4204 \log X_1 + 0.2232 \log X_7 + 0.0562 \log X_8 + 0.1539 \log X_5 + 0.2642 \log X_3$$

Standard errors : $b_1 = 0.11, b_7 = 0.08, b_8 = 0.03, b_5 = 0.16, b_3 = 0.08$

$R^2 = .8185$ $N = 50$

TABLE II

Analysis of Variance for Gross Income

Regression (1)

Source	S.S.	d.f.	M.S.	F	Result
Regression	2.0499	5	.4100	40	* *
Residual	.4550	44	.0103		
TOTAL	2.5049	49			

* * Significant at the 1% level.

The productivities derived from regression equation (1) are shown in Table III.

TABLE III

Elasticities, Geometric Means and Marginal Productivities of Inputs.

Regression (1)

Input	Elasticity	Geometric Mean	Marginal Product[6] £ Gross Income per : Unit of Input	£1 of Input[7]
X_1 Land	0.4204	698 ac.	£3.1 per acre	£2.5
X_7 Superphosphate	0.2232	433 cwt.	£2.7 per cwt.	£3.9
X_8 Lime	0.0562	113 tons	£2.6 per ton	£1.2
X_5 Labour	0.1539	£939	£0.85	£0.85
X_3 Plant & Machinery	0.2642	£1,974	£0.7	£2.3

Sum of Elasticities = 1.1179

Geometric Mean of Gross Income = £5,205

Comments on the Results

The marginal productivities derived for superphosphate and lime are in agreement with findings regarding nutrient responses on the Lismore group of soils. From fertiliser trials and practical results on farms, the returns from superphosphate usage are known to be substantial. In the case of lime, however, recent investigations by the Department of Agriculture indicate that in some individual cases more lime is being used than is necessary to maintain optimum plant growth. The rates of lime usage recorded for the survey farms are relatively high (22% of the total farm area received an average application of 1 ton/ac. for the 1955/6 season) and the fact that there are only moderate returns to lime usage substantiates the contention that in relation to the present level of other inputs, lime is possibly being used at a level not very much short of optimum for the area as a whole.

6. Marginal products were calculated at the geometric means of the inputs from the equation :

$$\text{Marginal Product of X, } \frac{\Delta Y}{\Delta X} = Ep_X \cdot \frac{Y}{X}$$

where Ep = Elasticity of production.

7. For purposes of estimating the marginal product in terms of £1 gross income per £1 expenditure on each input, complementary costs associated with the use of some of the inputs have been included. The basis of costing each input is as follows :

LAND

The " cost " of land is estimated at £1.25 per acre. The representative price paid for land in this area for the 1955/56 season was £25 per acre. The annual cost of this land was therefore considered to be the interest charge of 5% on the money required for purchase,

$$£25 \times \frac{5}{100} = £1.25$$

Therefore the marginal product (£ gross income per £1 expenditure on input).

$$\frac{£3.1}{1.25} = £2.5$$

SUPERPHOSPHATE

Cost of superphosphate assessed at 14/- per cwt. " on the paddock ".

$$\frac{£2.7}{.7} = £3.9$$

LIME

Cost of lime £2.25 per ton applied,

$$\frac{£2.6}{2.25} = £1.2$$

PLANT & MACHINERY

The costs associated with the use of each £1 capital value of plant and machinery are estimated to be :

	£
Interest at 5% ...	0.05
Depreciation 10% ...	0.10
Repairs 5% ...	0.05
Annual running expenses 10% ...	0.10
	0.30

$$\frac{£0.7}{£0.3} = £2.3$$

The estimate of the productivity of land is a relatively high figure. Unusually high prices have been paid for land in this area recently and it may be that earlier values (both current sales and Government valuation) of which the 1955/6 is typical, were somewhat lower than the economic returns from the land merited.

An earlier survey of the area provided evidence that the larger properties earned a higher return per unit of capital invested.[8] The present study indicates that there are increasing returns to scale (sum of elasticities = 1.12).

Conclusions

Subject to the limitations of the Cobb-Douglas technique, which have been fairly thoroughly covered in recent literature, the estimated production function for the area under study provides approximate rather than precise estimates of quantitative production relationships from which the following conclusions may be drawn regarding the group of 50 farms :[9]

(a) High productivities are recorded for the inputs of land, superphosphate and plant and machinery. This would justify the recent high prices paid for land in the area, encourage the continued use of superphosphate and suggest a more profitable use of plant and machinery.

(b) It would appear that increasing returns to scale operates and that the smaller farms are in a position to make greater profits from an overall expansion in the level of outputs.

(c) The estimated productivity for lime usage indicated that for the area as a whole lime was being used at levels not very short of optimum, having regard to the particular combination of other inputs being used. It appears likely that in some individual cases more lime is being used than is necessary to provide maximum economic returns for the existing system of farming.

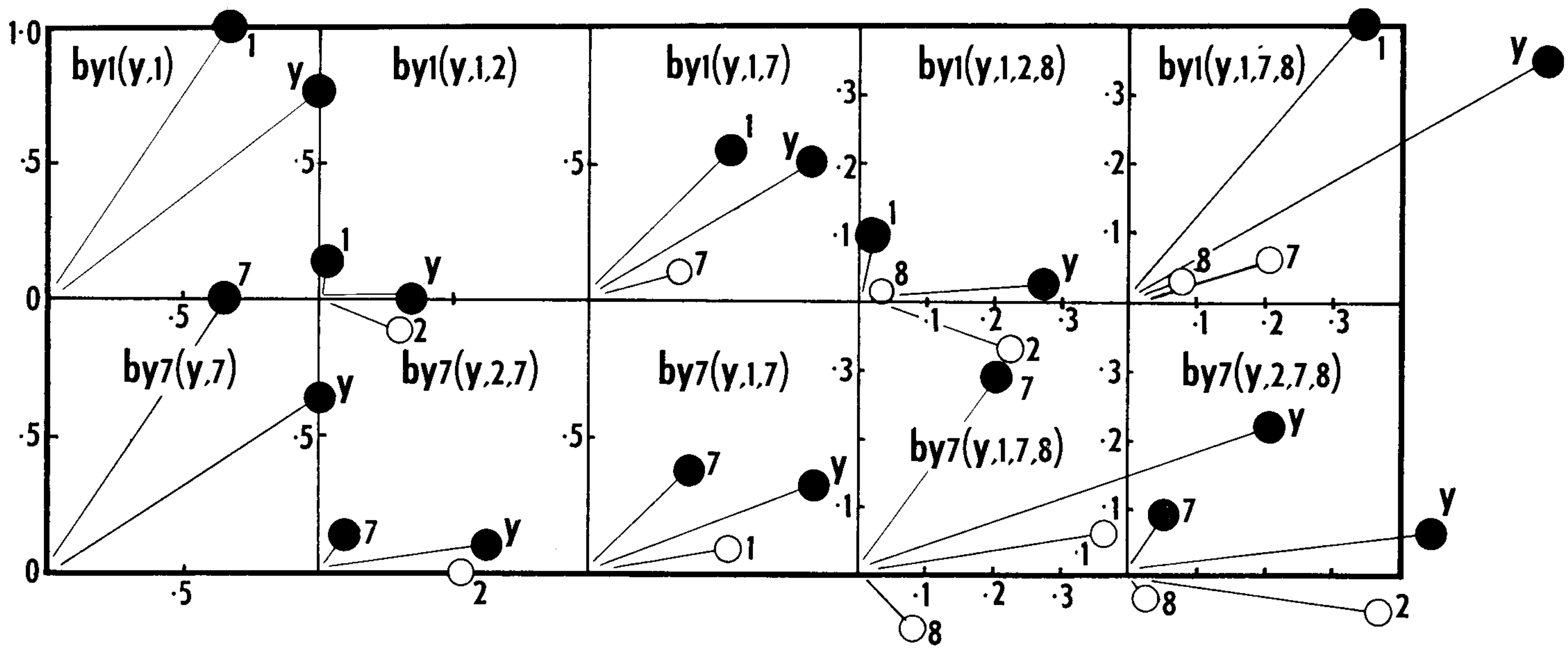
While it is obvious that the present methods of estimating production functions are subject to some serious practical and theoretical limitations, it is also true that many of these limitations may be overcome or their effects minimised by appropriate statistical and other means.

The writer agrees with the views of Parish and Dillon that " the practical consequences of some of the imperfections in the (production function) technique may be small in relation to the usually accepted standards of accuracy in economic investigations."[10]

8. See R. C. Stuart and H. H. Tocker, " Farm Management on Light Lands of Malvern County ", *New Zealand Journal of Agriculture*, Vol. 84, No. 12 (February, 1952), pp. 127-134.

9. For discussion of the limitations of the Cobb-Douglas technique see Parish and Dillon, *op. cit.*; Jarrett, *op. cit.*; C. S. Soper, " Production Functions and Cross-Section Surveys ", *Economic Record*, Vol. 34, No. 67 (April, 1958), pp. 111-117 and " Production Functions : A Reply to Dr. Konijn ", *Economic Record*, Vol. 35, No. 72 (December, 1959), pp. 434-435 ; H. S. Konijn, " Estimation of an Average Production Function from Surveys ", *Economic Record*, Vol. 35, No. 70 (April, 1959), pp. 118-125.

10. Parish and Dillon, *op. cit.*, p. 231.



APPENDIX—CONFLUENCE ANALYSIS

Multicollinear Effects Produced by Including Total Farm Capital (X_2) *in Regression Equation* (1)

As an example the above bunch maps show the effect on the coefficients b_{y1} and b_{y7} of including X_2 in three and four variate subsets.

Considering first b_{y1} and starting from the two variate set (y, 1) the addition of X_7 tightens the bunch slightly, whereas the addition of X_2 shortens the leading beams and greatly increases the angle between them.

Still considering b_{y1} the same conditions are seen to prevail in the 4 variate subsets (y, 1, 2, 8) and (y, 1, 7, 8). The inclusion of X_2 is definitely detrimental in this case, while when it is replaced by X_7 tightness is restored.

Similar, though less marked effects appear when the coefficient b_{y7} is considered and X_2 is included in subsets.