ANALYSIS OF SOME FACTORS AFFECTING SMALLHOLDER RUBBER PRODUCTION

G. B. WHITLAM*

ABSTRACT

The application of multiple regression analysis to sample cross-section farm resource data resulted in the explanation of a statistically significant percentage of rubber production variance. The inclusion of a proxy variable representing management ability improved the fit of the Cobb-Douglas function. Significant and substantial resource productivity differences were found between management groups. Extension-induced technical change to increase farm output is likely to widen this gap and accelerate the degree of relative performance. Any improvement programme must, therefore, take cognizance of this fact particularly in the selection of farmers for smallholder settlement schemes, allocation of credit and the design of extension strategies.

INTRODUCTION

It has been suggested (Yotopoulos 1968) that one approach to the analysis of economic development is through the micro-economic theory of production. In any production process, output depends on the flow of inputs and the proportions in which they are combined. The inputs involved are the productive factors conventionally defined as land, labour, capital and management. The economic development problem has to do, among other things, with increasing output per unit of input, i.e. resource productivity.

The purpose of this paper is to employ production function analysis (Heady and Dillon 1961) to show that a statistically significant percentage of interfarm variation in smallholder rubber production can be explained in terms of differences in farm resource structures and resource productivities. Such information can contribute to the definition of changes in the farm situation which may result in a more productive use of resources being attractive to individual farmers.

DESCRIPTION OF THE SURVEY AREA†

The data for the analysis were obtained from a sample of 32 of the 33 farmers producing rubber at the Murua Settlement Scheme (Gulf Province) during the year 1971. This work was the first in a programme of annual surveys designed to study resource productivity changes over time.

The settlement area lies on the southern bank of the Murua River (a tributary of the Matupi) approximately six miles from Kerema, the provincial capital. The topography and soils fall into two major groups. Bordering the river is a narrow flood plain with alluvial soils mainly of sandy loam. This area is flanked by a line of low hills where soils developed *in situ* are generally well-structured clay loams. The land was originally under coastal forest with limited areas of garden regrowth along the river and sago palm swamp in depressions between the low hills which form the dominant relief in the area.

In 1962, 36 blocks were allocated to settlers drawn, with the exception of one Kamea, from the coastal areas of the Gulf District. Block sizes of 8 to 25 ha provided a minimum of approximately 8 to 10 ha of cultivatable land. Development programmes for each block were planned on the basis of a DASF smallholder budget (Charles, unpublished) containing planting projections and cash flow analysis. The budget was adopted by the Native Loans Board as a basis for lending for personal needs and development expenditure of settlers. The minimum area of rubber per block, as determined by arbitrary labour input analysis, was 2.43 ha for a family supplying 1.5 units of labour for a total of 375 man days per year. The balance of the development on each block was not programmed. The blockholders were to be self-supporting and sufficient area was provided to allow for a permanent traditional garden with bush fallow cycle to be established.

Budgeted planting and income levels have not been achieved by the majority of the

*Formerly Economist, DPI. Present address: 2 MacGregor St, Deakin, ACT 2600, Australia.

†Hartley 1972 and Irwin 1968.

growers. For example, only 16 of the 33 rubber producers had fulfilled the planting covenant and approximately the same number had not begun loan repayments by mid 1971. As there were no indications of agronomic difficulties, budget labour supply and productivity estimates appear to have been, on average, too high.

The following table shows Scheme rubber production and sales figures up to and including the period being studied. In 1971, 30 per cent of the producers sold 50 per cent of total output.

Table 1.—Rubber production and income

Year	Production kg	Sales K	Average Price K/kg
1968-69	10 218	3 553	0.348
1969-70	24 545	10 928	0.445
1970-71	32 642	9 384	0.287
1971-72	33 274	7 885	0.237

Source: Marketing Branch, DPI, Konedobu

In all cases rubber was stated as the major source of cash income.

However, some money was earned from the sale of fresh vegetables to Kerema. The unreliability of data defining the vegetable activity restricts the following analysis to rubber enterprise input-output relations. It was found that the enterprises were not competing for resources. Cross-section farm information was collected on rubber output, land, labour, fixed capital and settler personal characteristic variables.

DESCRIPTION OF THE VARIABLES

The significance and content of any production function derived from empirical data depends on the way in which factors entering into the production relationship are defined. Problems of specification and of variability of individual farm situations are particularly acute.

Rubber output is measured in physical units—kilograms of rubber sold in 1971. There was little difference among farms in crop quality as reflected by the average price per block, so there was justification for treating the dependent variable as homogeneous. Average farm output was 955 kg with a coefficient of variation equal to 50 per cent.

Land is represented by the number of rubber trees that had been tapped as at the end of June, 1971. Average tapped trees per block was 542 (C.V. = 37 per cent). However, because tapped trees comprised only 70 per cent of the number of mature trees on the average farm and 54 per cent of total trees stocks, it could have been argued that rubber trees were not limiting and that the productivity of land is really the product of labour used in exploitation.

Labour was provided by members of the farm family. Because labour proved to be a constraint, particularly with respect to the tapping activity, the labour variable is included in the analysis by the number of "full-time" tappers on each block. Weights were allocated on the basis of the extent of participation by family members in the operation. The average farm had 2.6 tappers (C.V. = 38 per cent). Coagulation capacity could provide a daily constraint to output. Therefore the capital variable was represented by the number of coagulating pan equivalents owned by each blockholder. The average number equalled 22.6 (C.V. = 27 per cent).

The physical independent variables defined above have particular limitations. Specification errors relating to the use of stock concepts for inputs instead of service flows consumed by the production process, among other things, tend to limit the usefulness of the analysis. Nevertheless, the derived relationships are considered not as a quantitative definition of possible optimum input levels but rather as providing an indication of important variable inter-relationships and directions of change.

The remaining variable to be discussed is management ability. A comprehensive review of the literature on the importance of the human factor in the production process has been reported elsewhere (Muggen 1969). The conceptual and measurement problems of including management as an explicit variable in conventional economic models are considerable and only crude attempts seem possible (Minnesota Agric. Exp. Stn 1968). However, for a review of production function studies incorporating proxy variables for management in similar semi-traditional rural situations refer to Upton (1970). Theoretically, by incorporating management in the production function an estimate is made of its influence on farm output. Its inclusion should decrease specification bias in the estimated marginal productivities of physical factor inputs. The classification of farmers into relatively homogeneous groups is attempted in this study.

The Nielson (1962) management model was adopted as the conceptual framework for the "measurement" of management ability. The following figure (*Figure* 1) presents the essential elements of this model.

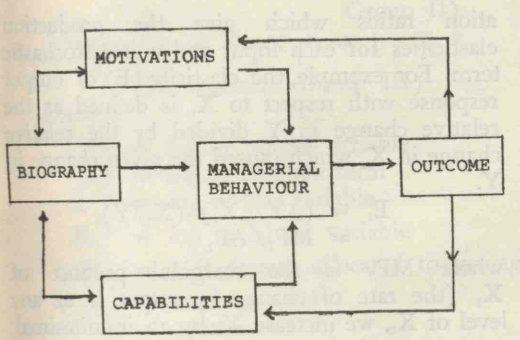

Figure 1.—Nielson Management Model

The manager is viewed as a goal-oriented system seeking to produce a desirable outcome. The manager possesses a biography of past experiences, motivations and capabilities which produce management behaviour and in turn generate an outcome. The model is completed by appropriate feedback from the outcome to the attributes where results may be used to influence future decisions. No allowance was made for reciprocal causation and the two-stage interaction between the behavioural antecedents (biography, capabilities and motivation) and management behaviour and managerial performance, in this application. In addition it is *assumed* that social structure variables as they relate to individual management ability remain constant over the sample, and that the four elements, as specified (refer Appendix 1) relate to the performance outcome—rubber production. It was considered that the rubber enterprise, although existing simultaneously with competing activities, and differing with respect to economic aims and social significance, was the relatively more modern activity and its outcome may be measured in physical units. The criterion problem remains: to what extent are the "measurements" of managerial ability inferences from performance?

A proxy management ability index is constructed from information given in response to personal characteristic questions relating to each of the four elements (variates) of the Nielson model. A dichotomous scoring system was adopted to obtain variate scores for each smallholder. Ranks were allocated on the basis of these results. The four variate ranks were summed to arrive at the total score for each farmer. These scores allowed the final ranking of farmers on the basis of managerial ability. The aim of the above procedure was to reduce the number of variables involved and to provide a ranking of farmers approximately according to the first principal component of the variates of the model, that is, the single factor which explains most variance generated by the data. Kendall (1965) states that such a method maximizes the average Spearman correlation between the final ranking and the ranking according to the four variates.

Because ordinal data may not be directly used in regression analysis without giving it a higher measurement status, cutting points were set to enable the allocation of farmers to three mutually exclusive management ability groups. The effect of the three management groups in the explanation of production variance was obtained by employing a dummy variable model (Massell 1967). The essence of the technique is that a dummy variable has the value one if the individual belongs to that management group and zero otherwise.

Table 2

Management Group	Dummy Variable		
	M_1	M_2	M_3
I	1	0	0
II	0	1	0
III	0	0	1

The two variables M_1 and M_2 are included in the production function analysis, but M_3 is excluded to prevent singularity of the moments matrix (Tomek and Ben-David 1965).

Table 3.—Average input and output per unit input for farms by management groups

Management Group		Output (kg)	Inputs			Output/Input		
			Trees	Tappers	Pans	Output per tree	Output per tapper	Output per pan
I	(11)	1294	654	2.7	25.4	2.0	511.8	58.4
II	(10)	1104	560	3.1	23.8	2.1	326.9	47.8
III	(11)	480	414	1.9	18.6	1.2	264.2	27.7
SAMPLE	(32)	955	542	2.55	22.56	1.76	268.9	44.5

Table 3 presents calculated summary data for the average farm in each management group.

It appears that both output and input are related to managerial ability; better managers tending both to use larger inputs and to obtain a larger output from a given set of inputs. A more recent survey (unpublished) of 23 of the 1971 rubber producers has supplied data to enable the construction of a scale of individual modernity (Appendix 2). Better managers tend to be more modern in their outlook. Seventy-five per cent of the relatively high management ability group (cutting point at the median) exhibited a high modernity outlook compared with 27 per cent of the low management group, giving a percentage difference of 48 per cent.

METHOD OF ANALYSIS

The most commonly used form of aggregate function employed to analyse production relationships is the Cobb-Douglas function. The general form of this model is

$$Y = a X_1^{b_1} X_2^{b_2} \ldots\ldots\ldots X_n^{b_n} . u$$

which, if transformed into logarthms, reduces to the simple linear equation:

$$\log Y = \log a + b_1 \log X_1 + \cdots\cdots + b_n \log X_n + \log u$$

where Y is the dependent variable (output), $X_1, X_2, \ldots\ldots X_n$ are the independent variables (inputs), a is a constant term, the exponents $b_1, b_2, \ldots . b_n$ are the transformation ratios which give the production elasticities for each input and u is a stochastic term. For example, the elasticity (E) of output response with respect to X_1 is defined as the relative change in Y divided by the relative change in X, which caused the given change in Y.

$$E_1 = (\Delta Y/\Delta X_1)\ (X_1/Y)$$
$$= MP_1/AP_1$$

where MP_1 is the marginal product of X_1 (the rate of change in output if at any level of X_1, we increase X_1 by an infinitesimal amount) and AP_1 is the average product of X_1. The widespread use of the Cobb-Douglas function can be attributed to the relative ease in determining factor elasticities, marginal values and to its simple computational requirements. In the following analysis, it was found to give the best fit to the data relative to the linear model. In particular, the effect of management was proportional rather than additive. The log transformation assists to establish both additivity of effect and equality of variance between groups.

Given the Cobb-Douglas framework, the effect of management ability in the production process was conceptualized by two different specifications of the dummy variable model, as follows.

1. It is assumed that management directly affects factor elasticities. In particular, management is assumed to affect the elasticity of the labour input variable. Labour is selected given the problem of separating management and labour on a family farm. Data in *Table* 2 suggest that this is the appropriate specification. Further, the statistical advantage of pooling a limited number of observations through employing the dummy variable technique is

greatest if changes are permitted in one selected coefficient and *prima facie*, the labour variable seems the obvious choice. This regression model can be formulated:

$$Y^* = a^* + b_1 X_1 + b_2 X_2^* + c_1 X_2^* M_1 + c_2 X_2^* M_2$$

Thus,

$$Y^* = a^* + b_1 X_1^* + (b_2 + c_1) X_2^* \text{ (Management Group I)}$$

$$Y^* = a^* + b_1 X_1^* + (b_2 + c_2) X_2^* \text{ (Management Group II)}$$

$$Y^* = a^* + b_1 X_1^* + b_2 X_2^* \text{ (Management Group III)}$$

where

Y^* = log of output variable
a^* = log of constant term
X_1^* = log of tree variable
X_2^* = log of labour variable
M_1 = 1 if farmer allocated to management group I
= 0 otherwise
M_2 = 1 if farmer allocated to management group II
= 0 otherwise

2. It is assumed that management directly affects the elasticity of the labour variable and in addition is responsible for a vertical shift in the production function. This regression model can be written:

$$Y^* = a^* + b_1 X_1^* + b_2 X_2^* + c_1 X_2^* M_1 + c_2 X_2^* M_2 + d_1 M_1 + d_2 M_2$$

In this case we have:

$$Y^* = (a^* + d_1) + b_1 X_1^* + (b_2 + c_1) X_2^* \text{ (Management Group I)}$$

$$Y^* = (a^* + d_2) + b_1 X_1^* + (b_2 + c_2) X_2^* \text{ (Management Group II)}$$

$$Y^* = a^* + b_1 X_1^* + b_2 X_2^* \text{ (Management Group III)}$$

RESULTS AND DISCUSSION OF THE ANALYSIS

The results of the multiple regression analysis are reported in *Table* 4. Regression equations 1, 2 and 3 include only physical variables. Regression equation 4 includes management specified as a slope changing agent with respect to labour input (model one). Equation 5 represents the result of employing model two. All the regressions are significant at least at the 1 per cent level.

Table 5 shows analysis of variance results contributing to the exclusion of the capital regressor. Given the low level of rubber yields, it appears that production is limited not by daily coagulating capacity but rather by tapping frequency. The capital variable is not retained as the statistical results confirm a strong prior belief.

***Table* 5.—Analysis of variance**

Source of variation	Sum of squares	d.f.	Mean square	F	Prob. value for H_0
X_1 and X_2	1.327	2			
Add X_3	0.054	1	0.054	1.93	$p > 0.05$
	1.381	3			
Residual	0.800	28	0.028		
TOTAL	2.181	31			

The inclusion of the management factor in the production function leads to a significant increase (at least at the 1 per cent level) in explanation of rubber output variance—the coefficient of multiple determination increases from 63 to 75 per cent. Analysis of covariance results in *Table* 6 indicate the statistical superiority of model one in the specification of the management effect.

Timmer's (1970) suggestion that the impact of management in a production function would likely be through changes in factor elasticities rather than neutral shifts in the entire function is consistent with this analysis. Regression equation 4 is selected as the basis for the calculation of factor marginal value products. A Cobb-Douglas function does not give a single estimate of factor marginal productivities, for this varies according to the input level. *Table* 7 shows the estimated marginal productivities calculated for the geometric mean quantities of total sample input and output.

Conventional analysis emphasizes statements on the relative efficiency/inefficiency of resource allocation on the representative farm. This is determined on the basis of a comparison of marginal value productivities of inputs with

Table **4.—Estimated production elasticities and related function statistics**

Regression equation No.	Regression coefficient								R^2 %	F	d.f.
	Const a	Land b_1	Labour b_2	Capital b_3	Management						
					c_1	c_2	d_1	d_2			
1	0.143	1.129	—	—	—	—	—	—	48	27.29	1/30
2	0.227	0.907	0.608	—	—	—	—	—	61	22.55	2/29
3	0.289	0.735	0.552	0.322	—	—	—	—	63	16.10	3/28
4 (model one)	1.363	0.512	0.138	—	0.841	0.692	—	—	75	20.26	4/27
5 (model one)	1.518	0.435	0.098	—	0.51	0.48	0.107	0.042	76	12.75	6/25

Table 6.—Analysis of covariance

Source of variation	Sum of squares	d.f.	Mean square	F	Prob. value for H_0
Residual	0.423	23	0.018		
Add M_1 and M_2 (differential slope vectors)	0.309	4	0.077	4.28	$p<0.01$
Residual	0.732	27	0.027		
Add M_1 and M_2 (differential intercepts)	0.122	2	0.061	2.25	$p>0.05$
TOTAL	0.854	29			

Table 7.—Estimated factor marginal products by management groups

Variable	Management group	Elasticity (b_1)	Average physical product (kg/unit)	Marginal physical product (kg/unit)	Marginal value product (K/unit)*
Land (trees)	I, II, III	0.512	1.6	0.82	0.22
Labour (tappers)	I	0.979	342.8	335.60	88.60
	II	0.830	342.8	284.52	75.11
	III	0.138	342.8	47.31	12.49

*Average rubber price received was equal to K0.264 per kilogram

Table 8.—Estimated factor marginal products by management groups

Variable	Management group	Elasticity (b_1)	Average physical product (kg/unit)	Marginal physical product (kg/unit)	Marginal value product (K/unit)
Land	I	0.512	1.90	0.97	0.26
	II	0.512	1.96	1.00	0.26
	III	0.512	1.12	0.57	0.15
Labour	I	0.979	492.2	481.8	127.19
	II	0.830	353.5	293.4	77.46
	III	0.138	233.5	32.2	8.50

their respective prices or opportunity costs. The absence of reliable opportunity cost data precludes such analysis. In the "transitional" type farm environment which we are investigating, the conceptual and measurement complexities of evaluating "returns" received from competing activities are considerable. Mellor (1969) argues that in the case of labour, the major input, its cost may be largely determined not by the rural minimum wage but by the subjective judgement of farmers concerning the utility they derive from purchased goods and services relative to the satisfaction generated by the range of competing activities, including leisure. Current capital expenditure is likewise provided from internal sources and its cost is determined by a subjective compromise between present and future consumption.

All that can be concluded is that the "return" to land and labour from competing activities is in fact higher than their estimated marginal value products. However, a comparison is possible between resource productivities for the three management categories. As well as substantial differences in resource structure, interfarm rubber output variation is influenced by variation in resource productivity between management groups. *Table* 8 shows marginal value product estimates relative to the mean input and output levels for each management category.

Estimated marginal resource productivities are substantially higher for management groups I and II compared with group III. Except for the case of the land (trees) input, management group I productivities exceed group II. For all groups, marginal values are less than their respective average equivalents, therefore marginal products must be falling. Given the production potential of the trees, a relatively low rate of tapping intensity and a production process characteristic of high resource divisibility, this phenomenon seems strange, unless specification errors have been made in the measurement of factor input. This seems likely, as no allowance was made for the age distribution of tree stocks in tapping, and the problem of assigning efficient weights for the aggregation of labour units over age groups differing markedly in their effective participation in the production process is most apparent.

Recent analysis (unpublished) has shown that the average Murua farmer exhibits a relatively high short-run price elasticity of supply. In this type of situation an increase in rubber output will be encouraged by an increase in resource marginal productivities. However, the critical question is not whether added labour would increase output, but whether the incremental increase in the value of output to the farmer is greater than the marginal opportunity cost of labour.

In the short term there are limited technically acceptable means by which resource productivities can be increased relative to their marginal physical cost. Pilot recommendations would include:

(1) Increase tapping intensity to between 60 and 70 per cent by adopting a full spiral tapping system particularly on tree panels C and D. A full spiral cut sixth or seventh daily system would increase both return per hectare and per man-day in spite of increased percentage of scrap rubber and possibly lower task size. The use of full spiral tapping on the virgin bark panels of A and B must be associated with a continuous check of dry tree incidence. Unfortunately, seedling planting material is most unreliable in its response to longer cut tapping systems.

(2) Initiate a programme of selective tapping. Eventual thinning of 30 per cent of lower producing trees (a decrease in tree density from 445 trees/hectare to 312) would increase average yield per tree and therefore per tapper by 20 to 25 per cent (Edgar 1958).

(3) Remove any daily output constraint provided by coagulating capacity by making available significantly cheaper coagulating containers. Such a product is currently being researched by A.C.I. (New Guinea) Pty Ltd.

In the long term the supply of high-yielding budgrafted clonal rubber planting material compatible with low labour input tapping systems would ensure a significant increase in resource productivities. Some of the budgrafted clones now being planted in Malaysia have shown that they can produce 2 000 to 3 000 kg per hectare. Yields of more than 6 000 kg/ha have been achieved in small-scale experimental plantings, and theoretical estimates indicate that the summit yield is much higher.

The maximum yield expected from the clonal seedling material planted at Murua would be in the vicinity of 1 300 kg per hectare.

It should be emphasized that changing the "technical" situation works only to the extent that farmers have a response structure appropriate to the perception, evaluation and action on the changed incentives (Nadkarni 1970). The marginal return to the above innovations must be sufficiently large to offset the non-material costs of adoption.

These costs will tend to be large where technical change is infrequent or when traditional values are strongly held, or both. Therefore, it is suggested that the response pattern may broadly reflect management group membership. The better managers (groups I and II) tending to increase resource productivity and output relative to group III. Extension induced technical change will, therefore, widen the gaps between the groups (Ashcroft 1973). Blanket advice can never "fit" the actual situation on every farm and in a wide range of circumstances, real improvement can only be made by modifying and tailoring the technique or practice to meet the individual circumstances. However, a substantial opportunity has been shown to exist to increase factor productivity and output by concentration of extension effort on the development of the smallholders' management resources.

CONCLUSIONS

The production function analysis indicates that a significant percentage of interfarm variation in rubber production can be explained in terms of differences in physical farm resource structures and productivities. The inclusion of a proxy variable set representing management ability was successful in improving the fit of the Cobb-Douglas function to the cross-section data and in reducing bias in the estimation of marginal productivities.

The adoption of technical innovations to increase resource marginal value products will more than likely parallel management group membership. Relatively better managers tending to be more modern in their outlook and possessing higher transactions demand for cash may be induced to increase factor supplies.

Extension programmes aimed to increase Scheme production should be explicitly designed to take into account variation in the management ability of farmers. Research should be initiated into the behavioural components of the management factor and the responsiveness of such components to different extension strategies. The potential implications of such research are substantial since more accurate measurement and prediction of the management factor would add a greatly needed element in economic analysis. There are obvious practical applications in the screening of applicants for smallholder blocks on capital intensive settlement schemes and rural credit.

APPENDIX 1

Personal characteristic question themes used as a basis for measuring management model component variates (*Muggen* 1969)

(1) *Biography* (6 *items*)
- (a) Age
- (b) Work experience
  - (i) location (urban/non urban)
  - (ii) type (skilled/unskilled)
- (c) Job mobility
- (d) Community responsibility
- (e) Education

(2) *Capabilities* (8 *items*)
- (a) Knowledge of crop
- (b) Knowledge of economic principles
- (c) Opinionatedness

(3) *Drives and motivation* (3 *items*)
- (a) Relative income aspiration
- (b) Attitude towards credit
- (c) Attitude to price changes

(4) *Management process* (5 *items*)
- (a) Planning and organizational practices
- (b) Plans for future
- (c) Use of information sources

APPENDIX 2

(A) *Minimum scale of individual modernity*: *Short form* 6 (Smith and Incheles 1966).

This scale provides a summary index of overall modernity—defined as a set of personal qualities which reliably cohere as a syndrome and which identify a type of man who may validly be described as fitting a reasonable conception of the modern man. Personal qualities central to this syndrome are:

(1) Openness to new experience;

(2) Assertion of increasing independence from the authority of traditional figures;

(3) Belief in the efficacy of science and medicine and a general abandonment of passivity and fatalism in the face of life's difficulties;

(4) Ambition for one's self and one's children to achieve high occupational and educational goals;

(5) Appreciation of punctuality and forward planning;

(6) Activity in community affairs; and

(7) Interest in national and international news.

(B) *Results*

Management ability	Modernity: Low	Modernity: High	TOTAL
High	3	9	12
Low	8	3	11
	11	12	23 = N

$$P\ (3.5 \Sigma X^2 < oo) = 6.5\%$$

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