J. Trop. Agric. and Fd. Sc. 25(1) (1997): 115–123

Technical efficiency and resource use in the production of cocoa in West Malaysia

(Kecekapan teknikal dan penggunaan sumber dalam pengeluaran koko di Malaysia Barat)

O. Nasuddin*

Key words: technical (in)efficiency, production frontier, efficiency index, farm inputs, intensity, potential yield, profitability

Abstrak

Kajian ini meneliti kecekapan teknikal dan tahap penggunaan sumber dalam pengeluaran koko pada peringkat pekebun kecil di kawasan Hilir Perak. Hasil daripada kajian menunjukkan bahawa kebanyakan pekebun kecil tidak cekap dalam pengeluaran koko. Sebilangan besar pekebun kecil mempunyai tahap output di bawah potensi. Kajian ini juga menunjukkan adanya perbezaan dalam penggunaan sumber antara kumpulan pekebun. Mereka yang cekap menggunakan tanah yang lebih luas dan jumlah tenaga pekerja yang lebih kecil daripada kumpulan yang tidak cekap. Terdapat hubungan yang positif antara kecekapan teknikal dan keuntungan. Pekebun yang paling cekap memperoleh output setiap tenaga pekerja yang berganda berbanding dengan yang diperoleh oleh mereka yang paling tidak cekap.

Hasil daripada kajian memberi implikasi bahawa masih ada skop untuk merapatkan jurang dengan mengenal pasti mereka yang kurang cekap dan mengkaji dengan lebih lanjut sebab-sebab prestasi mereka rendah.

Abstract

This study examines the technical efficiency and the intensity of resource use in cocoa production at the smallholders' level in the region of Hilir Perak. The results indicated that the majority of farmers were technically inefficient in cocoa production. A large proportion of the farmers were found to have output levels below their potential. The outcomes of the study also showed that there were variations in the use of farm resources among the various groups of farmers. The efficient farmers used more land and less labour than the least efficient group. The study also discovered that there existed a positive relationship between technical efficiency and profitability. The most efficient farmers have double output per man over the amount received by the least efficient group.

The findings from this study imply that there is scope to narrow the gap by identifying the less efficient farmers and to further investigate the reasons for their poor performance.

*School of Applied Sciences, Mara Institute of Technology, 40450 Shah Alam, Selangor, Malaysia
Author's full name: Nasuddin Othman

Introduction

Cocoa as the third major export crop plays a substantial part in the economic development of the country mainly through its contribution to the foreign exchange earnings and employment. For instance in 1994, the export earnings from cocoa was RM721 million based on the export of 290 000 t of processed and unprocessed cocoa (Anon. 1995). However, in spite of its significant role, this particular production sector is still plagued with the problem of low agricultural productivity at the smallholders' level. At the farm level, production per hectare is relatively low. For example in 1991, the average yield was about 500 kg/ha compared with 1 000–2 500 kg/ha obtained by the plantation sector (Mohaini and Abd. Malik 1991).

One of the reasons that may account for this phenomenon is the presence of technical inefficiency which forms the subject of this study. This study aims to estimate the level of technical efficiency of the individual cocoa producers and to examine the intensity of the farm resources used in the production of this crop. The information that emerged will assist the relevant authority to take the appropriate policy actions to remedy the situation.

Materials and methods

Theoretical concepts

In theory, the production function represents the boundary of the range of possible output from a given set of inputs so that all observations should lie on or below it. This indicates that there is a frontier which sets a limit to the maximum possible output which could be produced. Thus, a farm producing less than the maximum possible output may lie below the production frontier and is regarded as a technically inefficient farm. In fact, this interest in the measurement of inefficiency has been the main idea behind the study of the frontiers.

Farrell (1957) proposed that efficiency measurements should be made in relative sense and not in the absolute term. It is relative since the measurement is made based on the deviation from the best performance in a representative peer group.

Following Farrell, a considerable amount of theoretical and applied research on the measurement of efficiency using the concept of the frontier production function has been undertaken by many researchers. Forsund et al. (1980), Schidmt (1986), Bauer (1990) and Battese (1992) provide extensive reviews of this literature.

From the reviews, there seems to be a consensus among the researchers that there are three frontier production models which have been widely used in empirical studies, namely the deterministic production frontier estimated by linear programming techniques (Aigner and Chu 1968; Timmer 1970), the statistical production frontier which is estimated either by using the corrected least squares (Richmond 1974; Greene 1980), and the stochastic production frontier with a composed error structure that is estimated by using the maximum-likelihood technique (Aigner et al. 1977; Battese and Corra1977; Meeusen and van den Broeck 1977; Battese et al. 1989).

Assumptions

In this study, attention was focused on the deterministic production frontier developed by Timmer (1970) since this is the methodology that is employed in the analysis that follows. In the deterministic model, all the deviations from the frontier are attributed to technical inefficiency. The main reason for choosing this approach is that it can be applied for the measurement of technical inefficiency for each observation in the sample. In addition, this method also provides the ease of comparing the frontier estimates with that of the traditional or average production estimates computed.

An important assumption in the use of this approach is that technical efficiency is subsumed within the disturbance term of the chosen function. Therefore, the linear programming objective function is the sum of the disturbances. It is further assumed that all the disturbances are of the same sign so that all observed points in the production space lie on or below the frontier. The specification errors and the errors of measurement in all variables are assumed to be negligible. Consider the Cobb-Douglas production function

$$lnY_j = \sum_{i=0}^{m} \alpha_i \ ln \ X_{ij} + \in_j$$

where

Y_j = output of farm j

X_{ij} = level of input i used by farm j

m = the number of inputs

α_i = parameters

$\in_j$ = logarithm of the random error term

To make this a frontier function, all the error terms are constrained to one side of the production surface such that it satisfies:

$$\sum_{i=0}^{m} \alpha i ln \ X_{ij} = ln \ \hat{Y}_j \geq lnY_j$$

where

$\hat{Y}_j$ = potential output

Y_j = actual output

The frontier function can be estimated by minimising the linear sum of the residuals assuming all $\in_j$ are non-negative. This estimation according to Timmer (1970) is equivalent to solving the linear programming problem:

Minimise $\alpha_0\bar{X}_0 + \alpha_1\bar{X}_1 + ... + \alpha_m\bar{X}_m$

Subject to $\alpha_0 X_{01} + \alpha_1 X_{11} + ... + \alpha_m X_{m1} \geq Y_1$

" " " "

" " " "

$\alpha_0 X_{0n} + {}_1X_{1n} + ... + \alpha_m X_{mn} \geq Y_n$

$\alpha i \geq 0$

where

$\bar{X}_i$ = mean of X_{ij} (j = 1, ..., n)

$X_0 = 1$

The technical efficiency of the jth farm can be estimated from the linear programming solution by computing an index of technical efficiency given by the ratio $Y_j/\hat{Y}_j$. Farms are considered 100% technically efficient if $y_j = \hat{y}_j$.

There are four points of departure from the standard linear programming model, i.e. (a) the objective function minimises the mean resource levels used for the production of a given output level, (b) the matrix of constraints is given by individual farm observation of inputs in contrast to the input-output coefficients of the standard linear programming, (c) the level of constraints, i.e. the right side values are represented by individual farm output levels, and (d) the activities in the matrix will be the coefficients.

Selection and measurement of farm inputs

In this study, the effects of six conventional inputs comprising land, farm tools, chemicals, fertilizers, labour and living capital on the production of cocoa were analysed.

The issue of measuring the inputs used in the production process and the output produced should deserve considerable attention. Ideally, both inputs and the output should be measured in physical units of homogeneous nature since the production function stresses a physical relationship between inputs and output produced. However, in farm management studies, it is impossible to measure all the factors in physical terms. As there are many different types of inputs used and output involved, aggregation has to be made to some extent. This is especially in the case of the capital goods, farm tools, pesticides and the different kinds of output produced.

In this study, capital is categorized into two main categories, namely the cocoa and the coconut trees as well as farm tools. The latter includes knapsack sprayers, harvesting tools, weeding implement, baskets and the wooden boxes used for fermenting the cocoa beans.

In production theory, it is the quantity of capital services which is entered in the production process. In this study, in the case of the farm tools, only the depreciation costs were computed to reflect the actual service flow. No discount rate was used in the computation mainly because most of the equipment, except for knapsack sprayers, have short life expectancies. The maintenance, operating and repair costs were also not added. Based on the nature of the equipment used, such type of cost, if it exists, is very negligible indeed.

As for living capital, this service flow is a function of the age of the trees; it increases at the early stage and decreases when the trees become older. Chew (1984) used the expected yield concept as a proxy for the capital service flow in fitting the production function for rubber smallholders. By this method, a graphical yield profile of the trees was first constructed from sources other than the sampled farmers. This represents the yield potential of the planting materials under more idealized conditions than that of the smallholdings. By assuming proportionality between these two conditions, then given the age of the trees of a particular smallholder, the expected yield which is estimated from the yield profile, will represent a perfect substitute for the capital service flow per unit area of land. This method proved to be simple and effective and was adopted in this study.

Land was measured in physical units of area (in acres). Fertilizers and chemicals which comprise weedicides, insecticides and fungicides, were all measured in Malaysian Ringgit. Labour was measured as the total man-days used in the maintenance and harvesting operations. The services from farm tools and living capital comprising cocoa and coconut were also computed in Malaysian Ringgit. The measurement of the dependent variables was based on the expected income from cocoa and coconut (in Malaysian Ringgit).

Characteristics of the sample survey and data

This study uses cross-sectional data which were collected from 260 cocoa smallholders from the district of Hilir Perak which is one of the largest cocoa growing areas in the country. The data were gathered from the four main areas in the district, i.e. Bagan Datoh, Rungkup, Teluk Baru and Hutan Melintang. Personal interviews were conducted using questionnaires designed for the study and the data collected were confined to the calendar year 1988.

In the surveyed areas, all the farmers planted cocoa intercropped with coconut. The age of the farmers ranged from less than 30 years to more than 71 years. The level of education attained was very low. Nearly half of the sample had primary education, 11.6% with no schooling, 32.6% had adult education and only 1.9% managed to reach upper secondary level.

The farming experience acquired ranged from less than 5 years to more than 26 years, with an overall average of 12.7 years. Almost all the farmers (99%) owned the farms they lived in. The land size used for cocoa cultivation averaged 3.5 acres and ranged from less than an acre to more than 11 acres.

The age of the cocoa plants varied from less than 5 years to 25 years, giving an overall mean of 13.5 years for the whole district.

All the farmers realized the importance of fertilizer for crop production. Nevertheless, the use of this input is closely associated with their financial standing and the ease involved in obtaining it. The majority of the farmers used compound fertilizers CCM 66 and CCM 77 to fertilize their plants. However, the quantity of these fertilizers used was considered very little, amounting to 12.5 and 22.5 kg/acre respectively. Besides, they also used urea and lime for their cocoa plants. Again, the quantum applied was extremely low averaging around 7.7 kg/acre.

The use of chemicals that comprised weedicides, insecticides and fungicides was very minimal. On the whole, the farmers spent approximately between RM10 and more than RM45 an acre annually for the purchase of these inputs.

Labour consumption per acre was relatively low in this study area. This was attributed mainly to the minimal usage of complementary inputs and less maintenance work that was being undertaken. The use of labour for the maintenance and harvesting activities ranged from less than 10 man-days to more than 40 man-days an acre.

The response of the farmers towards credit facilities provided by the credit institutions was rather poor during the study period since only a small percentage (i.e. 1.5%) of the sample took advantage of the facilities provided.

The amount of extension contact was very minimal. Approximately 86.2% of the sample had contact less than five times a year with the extension agents. As a result, the diffusion of appropriate new technology which is vital to the development of the smallholders, is restricted.

Results and discussion

Results of fitting the linear form of the Cobb-Douglas function using both the average and the frontier approaches are presented in *Table 1*.

All the estimated coefficients have *a priori* expected sign. The coefficients of farm tools, chemicals and fertilizers are small. As with most production function estimates, multicollinearity may be the cause. However, it would be inappropriate to drop the variables from the equation because of their relevance in the production of cocoa. Gujerati (1978) pointed out that if the purpose of the regression analysis is prediction, then multicollinearity is not a serious problem. His rationale is that the greater the fit, the better the prediction. However, the writer is convinced that although the collinear influences are present in the estimation process, they will not excessively plague the results.

A comparison of the deterministic frontier (LP 100) and the average production function results indicated the major difference between the two to be the larger coefficient for labour for the frontier function. When a closer examination of the

Table 1. Regression coefficients using average and frontier production functions

Variable	Av. production function (*n* = 260)	LP (100) (*n* = 260)	LP (98) (*n* = 255)
Intercept	4.4684*** (0.4443)	4.6224	4.8628
Land	0.5702*** (0.0756)	0.5679	0.5691
Farm tools	0.0091** (0.0047)	0.0082	0.0087
Chemicals	0.0070** (0.0031)	0.0040	0.0057
Fertilizers	0.0181*** (0.0029)	0.0298	0.0168
Labour	0.1197** (0.0520)	0.2429	0.1324
Living capital	0.2310*** (0.0571)	0.2385	0.2296
R^2	0.8624		
F-statistic	271.49***		

Values in brackets are the standard error
***significant at 1% level
**significant at 5% level
The column labeled LP (100) is the result from fitting the deterministic frontier function; while the label LP (98) is the result obtained after removing 2% of the extreme observations from the sample.

magnitude of the frontier intercept was made, it was discovered that its value was actually within the 95% confidence interval of the average production estimates. This, therefore, implied that there was no significant difference in its value between the two methods used. The large labour coefficient was rather puzzling. The plausible explanation is that the efficient farmers might have used less labour input than the less efficient farmers in this study area. This has the consequence of increasing the marginal productivity of this input. The magnitude of the frontier coefficient indicated that the increase in the use of this input would increase total output by a larger amount for the farmers on the frontier than it would be for the farmers on the average. For instance, while a 10% increase in labour would result in a 2.4% increase in output for farmers on the frontier, the corresponding increase for farmers on the average is 1.2%.

When 2% of the observations were removed, the estimated coefficients looked remarkably like those estimated with the ordinary least squares. All the coefficients were very similar to those of the analogous average function. The intercept and the magnitude of the labour coefficient of the deterministic function were also within the 95% confidence interval of the average estimates. The rest of the inputs have similar output elasticities because the amount used increased proportionately, or approximately so, with output.

With the exception of high labour elasticity of output with respect to the deterministic frontier function, the overall results of this analysis clearly seemed to indicate that the frontier production function has shifted neutrally outward from the average production function.

To estimate the performance of the individual producer, Timmer's (1970) technical efficiency indices were computed. From the analysis as shown in *Table 2,* it was found that the sample has a mean efficiency level of 0.82 with a standard deviation of 0.07. The mean technical efficiency level of 82% recorded implies that if the average farmer were to improve his management expertise or improve his efficiency in the use of his farm inputs so as to operate on the production frontier, he would obtain 18% more output. It was also observed that the least efficient operator had an index of 0.66. For this particular producer, output would increase by 34% if similar actions were taken.

Considering the frequency distributions as illustrated in *Table 2*, it is clear that the range of efficiency in all the sample groups was quite large. For the whole survey area, the range was 0.66–1.00, with approximately 86% of all the farmers having an index of 0.75 or more.

Theoretically, given the levels of input and technology, a farmer's actual output should be equal to his potential if he operates on the frontier production function. However, the efficiency indices distribution *(Table 2)* indicated that only a small proportion of the farmers were on the efficient frontier. This implies that the majority of them have output levels below their potential.

In agriculture, it is argued that good and efficient farmers often use their inputs

Table 2. Frequency distribution of technical efficiency indices

Technical efficiency index	Pooled data (n = 255)
≥ 0.50 < 0.55	–
≥ 0.55 < 0.60	–
≥ 0.60 < 0.65	–
≥ 0.65 < 0.70	19 (7.45)
≥ 0.70 < 0.75	17 (6.67)
≥ 0.75 < 0.80	49 (19.22)
≥ 0.80 < 0.85	84 (32.94)
≥ 0.85 < 0.90	53 (20.78)
≥ 0.90 < 0.95	28 (10.98)
≥ 0.95 ≤ 1.00	5 (1.96)
Mean efficiency level	0.82
Standard deviation	0.07
Minimum efficiency level	0.66
Maximum efficiency level	1.00

Values in brackets are percentages

in large quantities and in the right combination to achieve larger output. In this study, the extent to which the levels of resource use differ for different technical efficiency classes is examined.

The mean levels of various factors of production applied per unit of land area by technical efficiency class are presented in *Table 3.* For the whole region, it was observed that land size tends to be positively related to efficiency. Those with technical efficiency scores of 0.95–1.00 used more land than the least efficient farmers. As for fertilizer and labour, although there were significant differences in the level of usage among the various technical efficiency classes, the relationship with efficiency was not monotonic. For other inputs comprising chemicals and farm tools, no significant differences were noted in the levels of resource use among the various technical efficiency classes.

The relationship between computed technical efficiency indices and the two commonly used farm management measures, i.e. output per man and gross margin per acre, is examined. From *Table 4,* it is evident that there were significant differences between output per man for the different efficiency classes. For the least technically efficient farmers, output per man was RM20.80 compared with the top performer of RM48.84. In other words, the most efficient farmers have double output per man over the amount received by the least efficient group.

It was noted that in almost all the sample groups, gross margin tends to increase as the technical efficiency scores increase. For the whole region, while the gross margin was RM228.06 for the least technically efficient farmers, the top performers, however, managed to obtain almost twice the amount received by the least efficient group.

Based on the values of both the potential and actual output, the magnitude of losses due to technical inefficiency could be ascertained. This is done by expressing the difference between the two values as a percentage of the actual output value.

Table 3. Resource use in cocoa cultivation by technical efficiency class (based on sample without outliers)

Technical efficiency class@	Land size (acres)	Fertilizer (RM/acre)	Chemical (RM/acre)	Farm tool (RM/acre)	Labour (man-days/ acre)	Living capital (RM/acre)
1 (19)	1.12	6.89	5.84	9.86	22.93	1 142.51
2 (17)	1.74	21.95	13.14	9.59	22.67	1 204.52
3 (49)	2.26	4.83	10.82	8.77	24.43	1 328.49
4 (84)	3.04	25.24	15.53	8.15	26.40	1 259.20
5 (53)	4.43	32.32	12.35	8.54	24.62	1 213.72
6 (28)	6.12	58.82	14.49	7.43	25.82	1 269.45
7 (5)	13.20	25.60	10.66	3.17	17.66	1 259.89
F-statistics	5.15***	4.78***	1.52	1.09	2.08**	1.50

@ Technical efficiency class	Technical efficiency index
1	= ≥ 0.65 < 0.70
2	= ≥ 0.70 < 0.75
3	= ≥ 0.75 < 0.80
4	= ≥ 0.80 < 0.85
5	= ≥ 0.85 < 0.90
6	= ≥ 0.90 < 0.95
7	= ≥ 0.95 ≤ 1.00

Values in brackets are no. of farmers in each class
***significant at 1% level
**significant at 5% level

Table 4. Relationship between technical efficiency, output per man equivalent and gross margin

Technical efficiency class	Technical efficiency index	Output per man equivalent (RM)	Gross margin (RM)
1 (19)	≥ 0.65 < 0.70	20.80	228.06
2 (17)	≥ 0.70 < 0.75	23.27	316.77
3 (49)	≥ 0.75 < 0.80	26.57	414.64
4 (84)	≥ 0.80 < 0.85	26.41	450.21
5 (53)	≥ 0.85 < 0.90	28.29	453.50
6 (28)	≥ 0.90 < 0.95	29.26	506.00
7 (5)	≥ 0.95 ≤ 1.00	48.84	524.00
F-statistic		5.05***	6.41***

Values in brackets are no. of farms in each class
***significant at 1% level

Table 5. Estimated loss from technical inefficiency: least efficient and top performers

Sample group	Mean technical efficiency score	Mean actual output (RM)	Mean potential output (RM)
Bottom 5%	0.67	459.52	683.08
Top 5%	0.96	6 188.85	6 428.66
Average	0.82	1 725.03	2 103.69

From the computations made as shown in *Table 5,* the least efficient performers were found to lose as much as 48.7% of their actual output. Nevertheless, on an area sample average, the losses were 21.9% for the entire survey area.

Conclusions

The study reveals that technical inefficiencies are present in the study area. This gave rise to a considerable gap between the actual and the potential output. Computation of the individual efficiency indices showed that only a small proportion of the farmers were on the efficient frontier indicating that the majority of the smallholders have output levels below their potentials. These results, therefore, imply that it is possible to increase the production of cocoa by drawing on the experience of the more efficient farmers. This can be done through better and effective management practices as well as better organization of the farm activity at large without major new investment, at least in the short-run.

The observed dispersions in efficiency indices also point to the need of improving cocoa production through extension efforts which need to be focused especially on the managerially 'worst' farms.

The study also reveals that there exists a positive relationship between technical efficiency and profitability. This implies that the differences in efficiency at the producer's level are likely to effect the individual's profits. Therefore, it is vital to examine the level of technical efficiency of each individual producer if the identification and the elimination of technical inefficiency is necessary for the success of programs intended to stimulate higher profitability within the group of producers.

It is also evident that generally more efficient farmers achieved high level of output with relatively low level of labour input, larger land size and at the same time managed to obtain a higher gross margin per acre than the less efficient farmers. In line with this outcome, this study suggests that more efforts should be directed at group farming since a bigger holding will be in a capacity to exploit the economies of scale.

The relationships between land size and efficiency are positive and significant. Resources such as fertilizer, living capital, farm implement and labour play important role in affecting farm productivity. All these showed that the observed differences in efficiency may be attributed to the differences in quantity and quality of the farm resources and perhaps due to the distribution of risk aversion among the farmers in the production process.

This study, however, did not explicitly examine the effects of risk and uncertainty in the empirical analysis. It is suggested that future work should include this element in the analytical framework.

Nevertheless, it is hoped that this limitation does not seriously distort the conclusions derived from this study.

References

Anon. (1995). *Economic Report 1994/1995* Kuala Lumpur: Ministry of Finance, Malaysia

Aigner, D. J. and Chu, S. F. (1968). On estimating the industry production function. *American Economic Review* ***58:*** 826–39

Aigner, D. J., Lovell, C. A. K. and Schmidt, P. (1977). Formulation and estimation of stochastic production function models. *Journal of Econometrics* ***6:*** 21–37

Battese, G. E. (1992). Frontier production functions and technical efficiency: A summary of empirical application in agricultural economics. *Agricultural Economics* ***7:*** 185–208

Battese, G. E., Coelli, T. J. and Colby, T. C. (1989). Estimation of frontier function and the efficiencies of Indian farms using panel data from ICRISAT's village level studies. *J. Quant. Econ.* ***5:*** 327–48

Battese, G. E. and Corra, G. S. (1977). Estimation of production frontier model with application to the pastoral zone of eastern Australia. *Aust. J. Agric. Economics* ***21:*** 169–79

Bauer, P. W. (1990). Recent developments in the econometric estimation of the frontier. *Journal of Econometrics* ***46:*** 39–56

Chew, T. A. (1984). Fitting production functions to perennial crops. *Pertanika* ***7(1):*** 97–9

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society* ***120 (3):*** 253–81

Forsund, F. R., Lovell, C. A. K. and Schidmt, P. (1980). A survey of frontier production functions and on their relationship to efficiency measurement. *Journal of Econometrics* ***13:*** 5–25

Greene, W. H. (1980). Maximum likelihood estimation of econometric frontier functions. *Journal of Econometrics* ***13:*** 27–56

Gujerati, D. (1978). *Basic econometrics* Tokyo: McGraw-Hill Kogakusha, Ltd.

Mohani, T. and Abd. Malik, I. (1991). Industri koko: Masalah, prestasi dan prospek. In *Komoditi utama Malaysia* (Redzuan Othman and Mohd Sheffie Abu Bakar, ed.) p. 126–51. Kuala Lumpur: Dewan Bahasa dan Pustaka

Meeusen, W. and van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review* ***18(2):*** 435–44

Richmond, J. (1974). Estimating the efficiency of production. *International Economic Review* ***15(2):*** 515–21

Schidmt, P. (1986). Frontier production functions. *Econometric Review* ***4:*** 289–327

Timmer, P. C. (1970). On measuring technical efficiency. *Food Research Institute Studies* ***9(2):*** 99–171

Accepted for publication on 17 October 1996