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PRODUCTION FRONTIER AND TECHNICAL EFFICIENCY : THE CASE FOR BEEKEEPING FARMS IN MALAYSIA

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ABSTRACT

The objective of the present study is to determine the status of technical efficiency for a sample of beekeepers in Malaysia. This is because determining the efficiency status of farmers are very important for policy purposes. Efficiency also is a very important factor of productivity growth. In an economy where resources are scarce and opportunities for new technologies are lacking, inefficiency studies will be able to show that it is possible to raise productivity by improving efficiency without the resource base or developing new technology. Estimates on the extent of inefficiency can help decide whether to improve efficiency or to develop new technologies to raise agricultural productivity. In this study, a Cobb-Douglas production function was employed to beekeeping data. Using the method of Maximum Likelihood Estimation (MLE) procedure, we derived the stochastic frontier production function. The technical efficiency index computed shows a mean efficiency ratio of 0.625 implying that substantial inefficiency exists among the Malaysian beekeepers in the sample under study. Our results indicate that there are great potentials for the beekeepers to further increase output using the available inputs and technology.

INTRODUCTION

Beekeeping is a relatively new enterprise in Malaysia. It was first recommended to the farmers as a commercial venture in 1981. Beekeeping activity acts as a source of increasing farmers' income. Studies indicate that beekeeping activity is a viable and profitable venture to supplement farmers' income (Habibullah and Ismail, 1991). Thus, it is not surprising that beekeeping industry had generated widespread interest among the Malaysian farmers to increase and supplement their income.

The objective of this paper is to estimate a production function, that is, the input-output relationship among a sample of beekeepers in Malaysia. Estimation of input-output relationship for any particular economic activity is important, at least for three reasons. The estimated parameters of the production function will show (i) the elasticity of output with respect to particular inputs, (ii) the elasticity of scale, that is the elasticity of output with

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respect to a proportional change in all inputs, and (iii) the elasticity of substitution between inputs. Furthermore, the main concern of any economic activity is to achieve the maximum possible efficiency by transforming a set of given inputs into some outputs defined by the production function. It has been the general concensus that in the dveloping countries, farmers do not exploit resources fully. In other words, the farmers do not operate on the outer bound of their production function given the available technology. These farmers are said to be technically inefficient.

The concept of technical efficiency was first introduced by Galenson and Liebenstein (1955) and its empirical application was popularised by Farrell (1957). According to Farrell (1957), the concept of technical inefficiency refers to the amount by which actual output is less than the potential output for a given combination of input used in production. The potential output is the maximum output attainable from a given sets of inputs. Given a set of observations, the maximum output is the one produced at the 'frontier' relative to other outputs that lie beneath it. At that particular point on the 'frontier' there is a production function that represents that maximum output. In other words, the maximum output is produced from the 'frontier' production function. As such technical inefficiency will refer to the inability of a unit farm to produce at that outer bound of the farm's production surface.

The concept of technical efficiency can be clearly understood by refering to Figure 1. In Figure 1, the curve YM shows the maximum possible total output (at the frontier) as input X

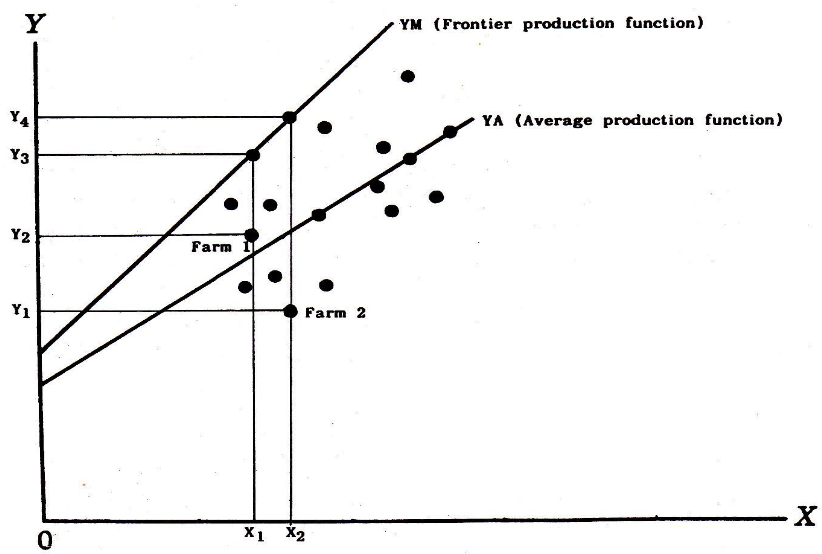

Figure 1. Technical Efficiency

is increased, while the curve YA shows the input response on an 'average' farm. The technical inefficiency is then shown by Y_2/Y_3 for a given input level X_1 for Farm 1. For Farm 2, technical inefficiency is given by Y_1/Y_4 using input X_2.

Numerous studies have attempted to determine the technical efficiency of farmers in developing countries because determining the efficiency status of farmers is very inportant for policy purposes. Efficiency is also a very important factor of productivity growth. In an economy where resources are scarce and opportunities for new technologies are lacking, inefficiency studies will be able to show that it is possible to raise productivity by improving efficiency without the resource base or developing new technology. Estimates on the extent of inefficiency also help decide whether to improve efficiency or to develop new technologies to raise agricultural productivity.

According to Shapiro (1983), for efficient farmers, government can expedite development by emphasizing new investments or technologies, rather than extension and education efforts which were aimed at less efficient farmers. Nevertheless, studies by Shapiro (1983), Belbase and Grabowski (1985), Prasad *et al.* (1991) and Jayaram *et al.* (1992) found evidence of technical inefficiency among the farmers in the developing countries. They recommended that government efforts would have to be directed in education, extension, social change and support. Emphasizing on these activities would improve the allocation and the use of available resources so that more farmers come closer to the efficiency level achieved by their counterparts.

METHODS OF STUDY

Recently, there are increasing interest in the application of frontier function in determining technical efficiency in agriculture sector. For example, these studies include Ali and Chaudhry (1990), Anderson and Frantz (1985), Belbase and Grabowski (1985), Esparon and Sturgess (1989) and Page (1980). All these studies are involved with the estimation of technical efficiency by estimating the production function frontier.

Specification of Beekeeping Production Function

Before we can estimate a frontier function, we have to specify the form of the beekeeping production function. In this study, a typical four-input Cobb-Douglas production function (for an alternative functional form, see for example Habibullah and Ismail, 1992; Siebert, 1980) is specified as follows :

$$Q = \alpha_o H^{\beta} N^{\theta} F^{\phi} M^{\gamma}$$

where Q represents output of honey in kilogramme produced per year. Independent variables are H (number of frames), N (labour measured in man-hours), F (food measured in acreage of nectar producing plants) and M (the management index). Parameters α denotes the technical efficiency level and β, θ, ϕ and γ are elasticities of the various inputs with respect to output level.

In this study we used the total number of frames instead of the number of hive boxes. We believe that this approach is more appropriate since the size of hive boxes is not uniform among beekeepers. The size of hive boxes used by beekeepers ranges from six to twenty frames. Thus, bee colony would vary with different sizes of hive with different ranges of frames used.

Beekeeping activity in Malaysia is at present done on a part-time basis. It is labour intensive and family business-oriented. The number of labour used varies from one to two persons. Usually husband-wife and/or father-sons are involved. Therefore, in this study we have used the time spent in hours per person in beekeeping activity per year to proxy for labour. This is done by asking the beekeepers as to how much time they spent in feeding, collecting, maintaining the hives, requeening and the like.

Food is a very important factor in beekeeping. Bee colony tends to fly away if there are insufficient food. The availability of food in the surrounding area is judged by the presence of nectar producing plants. The larger the surrounding area, the bigger is the pool of nectar producing plants and thus, this means that there are abundance of food for the bees. In this study, the availability of food in the surrounding area for bees are proxied by the total acreage owned by beekeepers and the total acreage of neighbouring farmers in which they stationed their bees.

Management plays an important role in beekeeping farming. For example, bees need regular requeening, feeding, pest control and equalizing between strong versus weak colony (see also Tingek and Muid, 1986). More recently, the role of management as an input in production function has been given greater emphasis in the literature. Recent studies that incorporated management input in production function include Dawson and Lingard (1982), Mukhtar and Dawson (1990), Dawson and Hubbard (1987), Nyong (1989), Makary and Rees (1981) and Mefford (1986).

The importance of management in production process has been pointed out by Leibenstein (1966). In a broader sense, management involves the function of planning, organizing, staffing, leading and controlling of the resources of the organization towards achieving the objectives. As such a 'good' farmer is in the best position to bring the operation on its production forntier compared to a 'bad' farmer. Griliches (1957) and Timmer (1970) pointed that estimation of production function excluding management input would result in biased estimates of the true parameters. Although the importance of management as an input in production process has been generally accepted in the literature, a satisfactory measure for management index is still an open issue.

Various methods have been used in economc studies on agricultural sector to incorporate and measure management input. The more popular method was the one introduced by Makary and Rees (1981) who applied the same to Egyptian agriculture. The method was also successfully used by Nyong (1989) to explain the Nigerian commercial bank performances.

Thus, following Makary and Rees (1981), in this study, the management index is derived using a two-step procedure where output Q is regressed on experience, education level and pest control practices. Experience is proxied by the age of farmer. Dummy variable was used for education and pest control practices. The estimated Q is then substituted into Equation (1) for further estimation (see Habibullah and Ismail, 1990).

METHOD OF ESTIMATION AND THE DATA

There are numerous ways of estimating a production frontier. Surveys on various methods were made by Forsund *et al.* (1980) and Thiry and Tulkens (1989). Generally, there are four methods that can be used to estimate the production frontier. These are : (i) the estimation of a non-parametric frontier as introduced by Deprins *et al.* (1984); (ii) a non-statistical estimation of a deterministic parametric frontier applied by Aigner and Chu (1968); (iii) the statistical estimation of a deterministic parametric frontier applied by Schmidt (1976) and Greene (1980), using maximum likelihood (ML) and corrected ordinary least square (COLS) methods respectively; and (iv) the estimation of a stochastic parametric frontier popularised by Jondrow *et al.* (1982).

Although a variety of methods are used to measure production frontier, each of these methods has advantages and disadvantages and there is no obvious superior approach among these methods (Aly *et al.,* 1987). A study by Kalaitzandonakes *et al.* (1992) on Missouri cash grain farmers, employing three different methods, namely; the deterministic parametric frontiers, stochastic parametric frontiers and non-parametric frontiers, concluded that,

> 'A simple review of the methodological development on the estimation of frontier functions indicates that no single estimation approach dominates all others, as each approach possesses both advantages and disadvantages. Thus, no clear theoretical guidance exists in choosing a procedure for the estimation of production frontier. Yet, as demonstrated in the previous section, the choice of estimation method may have a significant influence on the calculated technical efficiency of firms in a given sample.'

Their findings were supported by other studies by Bravo-Ureta and Rieger (1990), Neff *et al.* (1993), Dawson (1985) and Ekanayake and Jayasuria (1987). In fact Neff *et al.* (1993) have cautioned the use of different methods when infering for policy purposes. They stressed that,

> 'On balance, the findings suggest that considerable care must be taken in using efficiency measures. The absolute level, the distribution and the relative rankings of farm efficiency are systematically influenced by the method employed. Insensitivity to these differences would lead to errant policies and inappropriate identification of farms most in need of extension programmes.'

In view of the above, in this study, we have selected the most common method used in estimating frontier function that is, the stochastic parametric frontier. The maximum likelihood estimation procedure was employed to obtain parameter estimates.

We define Equation (1) in logarithm form as follows :

$$\ln Q = \ln \alpha_o + \beta \ln H + \theta \ln N + \phi \ln F + \gamma \ln M + \varepsilon \quad (2)$$

where

$$\varepsilon = \nu - \mu \quad (3)$$

Parameter ε is the composed error terms where ν is the two-sided random error and μ is the one-sided efficiency component (Aigner *et al.* 1977; Meeusen and van den Broeck, 1977). Parameter ν and μ are assumed to be independent of each other, where ν is assumed to be normally distributed ($\nu \sim N(0,\sigma_v^2)$), and that μ assumed to be negative and follows a half-normal distribution ($\mu \sim | N(0,\sigma_\mu^2)|$). According to Battes and Corra (1977), the negative error μ, in the model is interpreted with reference to a farm's technical inefficiency of production while the random (symmetric) error ν, which can be considered as a 'measurement error', associated with uncontrollable factors related to the production process.

The parameters of ν and μ can be estimated by maximizing the following log-likelihood function :

$$\ln \ell = K \ln (2/\pi)^{1/2} + K \ln \sigma^{-1} + \Sigma \, \Sigma_{k=1}^{k} \ln [1-F(\varepsilon_k \lambda \sigma^{-1})] - [1/(2\sigma^2)] \, \Sigma_{k=1}^{k} \varepsilon_k^2 \quad (4)$$

where ε is the sum of ν and μ, σ is equal to $(\sigma_\mu^2 + \sigma_v^2)^{1/2}$, λ is the ratio of σ_μ over σ_v, F is the standard normal distribution function, and K is the number of beekeepers in the sample.

Given the assumptions on the distribution of ν and μ, Jondrow *et al.* (1982) showed that the conditional mean of μ given ε is equal to

$$E(\mu_k \mid \varepsilon_k) = (\sigma_\mu \sigma_v / \sigma) \{[f(\varepsilon_k \lambda \sigma)/[1-F(\varepsilon_k \lambda \sigma)]]-(\varepsilon_k \lambda / \sigma)\} \quad (5)$$

where f and F are the standard normal density and distribution functions evaluated at $\varepsilon_k \lambda / \sigma$. Measures of technical efficiency (TE_k) for each beekeeper can then be calculated as

$$TE_k = \exp(-E[\mu_k \mid \varepsilon_k]) \text{ so that } O \leq TE_k \leq 1. \quad (6)$$

The advantage of using the stochastic production frontier model is the introduction of a disturbance term representing noise, measurement error, and exogenous shocks beyond the control of the production unit in addition to the efficiency component.

Sources of Data

In this study the data were collected from a survey conducted in 1989 on coconut farmers. We surveyed 116 beekeepers in eight areas of four states in Peninsular Malaysia. These areas are Pontian and Batu Pahat in the state of Johor; Tanjong Karang, Sabak Bernam and Sungai Besar in Selangor; Teluk Intan and Bagan Dato in Perak and Merlimau in Malacca. These states were chosen because it was reported that active beekeepers came from this area (MBRDT, 1986, 1987, 1988).

However, out of 116 beekeepers surveyed, 52 beekeepers were selected only. There are two reasons for selecting only the 52 beekeepers. First, these beekeepers are considered active, producing honey more than 2.4 kilogramme per year, and secondly, the occurrence of missing data are lesser compared to the inactive beekeepers.

ANALYSIS OF RESULTS

The empirical estimates of the stochastic production frontier for the beekeeping farms are presented in Table 1. For comparison purposes both the 'average' production function estimated using ordinary least squares (OLS) and the frontier likelihood function are presented. We can see that all coefficients show expected positive sign implying that an increase in inputs will ultimately increase the output level. All variables in both production functions are significantly different from zero at the five percent level. Summation of the partial elasticities of production indicates return to scale of 2.8 for the 'average' production function and 3.8 for

Table 1 : Empirical Estimates of the 'Average' (OLS) and Frontier Production Functions

Variables	OLS	FRONTIER
$\ln \alpha$	0.004 (0.005)	1.116 (0.902)
β	0.573 (3.926)*	0.508 (2.798)*
θ	0.812 (5.630)*	0.746 (6.306)*
ϕ	0.584 (4.268)*	0.555 (3.270)*
λ	0.836 (3.345)*	0.871 (2.980)*
R^2	0.710	-
F	28.73	-
$\lambda = \sigma_\mu/\sigma_v$	-	2.315 (2.301)*
$\sigma = (\sigma_v^2 + \sigma_\mu^2)^{1/2}$	-	0.713 (5.283)*
σ_υ^2	-	0.42873
σ_v^2	-	0.07996
Log-Likelihood	-	-35.02

Note : Figures in the parentheses are t-statistics. The star (*) indicates statistical significant at the five percent level.

the stochastic frontier function. The value of return to scale greater than one suggests that increasing return to scale prevails. A one percent increase in all inputs resulted in an increase of 3.8 percent in output level for the stochasitic frontier function.

A direct comparison of the parameters estimated for the 'average production function and the stochastic frontier function shows fairly close similarity between the intercepts and inputs coefficients. As can be seen in Table 1, the intercept differences between the two production functions suggest that the stochastic frontier function represents a neutral shifts from the 'average' production function. On the other hand, the slope coefficents which display slight differences between the two production functions might be due to the inefficient estimates of OLS. Further, by the specification of the likelihood function, the difference between a production function estimated by OLS and the frontier function can be statistically shown by the significance of the t-statistic for λ. As shown in Table 1, λ is statistically different from zero implying that there exists a significant difference between the two production function.

The significance of the parameter λ is able to show that there exists sufficient evidence to suggest that technical inefficiencies are present in the data. As shown in Table 1, the estimates of the error variances σ_{μ}^2 and σ_v^2 are 0.42873 and 0.07996 respectively. Therefore, it can be easily seen that the variance of one-sided error, σ_{μ}^2 is larger than the variance of random error σ_v^2. Thus, the value of λ (i.e. $\lambda = \sigma_{\mu}/\sigma_v$) of more than one clearly shows the dominant share of the estimated variance of the one-sided error term μ over the estimated variance of the whole error term. This implies that a great part of the residual variation in beekeeping output is associated with the variation in technical inefficiency rather than with 'measurement error' which is associated with uncontrollable factors related to the production process.

Following to Battese and Corra (1977), we can also estimate the total variation in output from the frontier that is attributable to technical efficiency using the parameter Ω, where Ω equals σ_{μ}^2/σ^2. Using this formulation, it can be noted that Ω is 0.8428. This means that about 84 percent of the discrepancies between observed output and the frontier output are due to technical inefficiency. In other words, the shortfall of observed output from the frontier output is primarily due to factors which are within the control of the beekeepers.

In Table 2, we presented the technical efficiency index using Jondrow *et al.* (1982) procedure. The level of efficiency appears to be very low. The minimum estimated efficiency is 20.5 percent while the maximum is 91.4 percent and the mean level of technical efficiency is 62.5 percent. According to Grabowski *et al.* (1990), a farm is considered technically inefficient even if the farm registered a technical efficiency index of 82 percent. By this standard, therefore, the number of beekeepers considered efficient technically is only less than 2 percent of the total beekeepers in the sample under study.

On the other hand, in Table 3 shows the estimates of the technical efficiency index by farm size. The table reveals that technical efficiency rises as farm size increases. This suggests

Table 2 : Farm Specific Technical Efficiencies in the Stochastic Production Frontier

Efficiency Index	No. of Beekeepers	Percentage of Beekeepers
100-90	1	1.9
89.99-80	4	7.7
79.99-70	15	28.8
69.99-60	14	27.0
59.99-50	5	9.6
49.99-40	6	11.5
39.99-30	4	7.7
29.99-0	3	5.8
	52	100
Mean		62.5
S.D.		17.4
Min		20.5
Max		91.4

that beekeepers have not exploited their resources fully and they can increase their productivity by raising the technical efficiency through increased input usage.

Table 3 : Results of Technical Efficiency by Farm Size

Classes of Farms	No. of Beekeepers	Technical Efficiency
All Farms	52	62.5
Sub-Groups :		
< 11	6	58.2
≥ 11 < 25	20	61.5
≥ 25 < 40	16	63.7
≥ 40	10	65.0

CONCLUSION

The objective of the present study is to determine the status of technical efficiency for a sample of beekeepers in Malaysia. In this study, a Cobb-Douglas production function was employed on beekeeping data. Using the maximum likelihood estimation procedure, we derived the frontier production function. The technical efficiency index computed shows that the sample of Malaysian beekeepers under study are highly technical inefficient, with a mean efficiency ratio of 0.625. Therefore, our result indicates that great potential exists for the beekeepers to further increase output using the available inputs and technology. For example, our result clearly shows that as farm size increases, technical inefficiency decreases. In other words, it implies that yield potentical can be accelerated with the increase in farm size.

In conclusion, our research findings indicate that there is a big scope to increase technical efficiency of the beekeeping farms with the existing level of inputs. This means that without any additional cost, the technical efficiency can be increased substantially. Suitable extension and credit facilities supplemented by active association of the research scientists with beekeepers can be helpful to increase the level of output of the beekeepers. Thus, efforts should be directed in education, extension, social change and support services in order to improve the technical efficiency of the beekeepers in Malaysia.

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