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Analysing Technical Efficiency of Charolais mixed breed (Lembu Sado) Farms in Terengganu

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The ruminant industry in Malaysia is an important sector since it produces a source of protein for the country and also provides employment opportunities. The number of people eating meat in Malaysia is on the rise, but the country's current capacity for meat production cannot keep up with the rising demand. As a result, taking into account the level of technical efficiency can assist farmers in reducing the amount of inputs they use while keeping the output level stable, which ultimately results in an increase in production. The purpose of this study is to identify the level of technical efficiency of farms in Terengganu that raised Charolais mixed breed cattle or Lembu Sado cattle as well as to determine the relationship between technical inefficiency and the characteristics of farm owners or managers of Lembu Sado. For the purpose of data collection, structured questionnaires were given to a total of 86 respondents residing in and around the state of Terengganu utilizing procedures for convenience sampling. For the purpose of this study, a cross-sectional survey approach was utilized, and primary data on farm yield, input usage, and farmer demographics were collected. R software in its version 4.1.6 was used to carry out the Data Envelopment Analysis, and Stata Software in its version 16.1 was used for the second step, which involved running the truncated bootstrap regression analysis. According to the findings, the average level of technical efficiency across all Lembu Sado farms is 0.74. This demonstrates that these farms have the potential to reduce their farming inputs by 26.4% while maintaining the same level of output. The findings of the second stage point out that education, farming experience and finance from the government have a negative association with technical inefficiency scores while, off farm income has a positive relation with technical inefficiency scores.

Keywords: technical efficiency, data envelopment analysis, Lembu Sado, Terengganu

INTRODUCTION

The Malaysia ruminant industry is an important industry in the agricultural sector. This industry provides lucrative employment and source of animal protein for the Malaysian consumption. The ruminant sector consists of buffalo, beef cattle, goat and sheep subsectors. Malaysian cattle population is dominated by beef type cattle. Currently, the population of large animal in Malaysia such as cattle and buffalo is about 683,501 and 107,347 heads respectively (DVS, 2019). Cattle population constitutes 92,566 heads in Kelantan and 88,549 heads in Terengganu as per 2019 reports (DVS, 2019). The self-sufficiency ration for beef is 21.7% in 2020 (Zayadi, 2021). It is still acceptable if compared to dairy milk's self-sufficiency ratio which is only 6% in 2015 (Mohd Karim et al., 2016). However, Malaysian

government still has to import their meat to fulfill the local demand.

The most important local breed of cattle bred in Malaysia is the Kedah-Kelantan (KK). The KK cattle account for approximately 85% of the total number of beef cattle in Malaysia (DVS, 2014). This breed is small in size and varies in mature weight from about 280 to 300 kg in male and from 180 to 250 kg in females. Despite of the high calving rate, the productivity of KK cattle is still showing poor performance. Since 1971, Malaysia government has been trying to develop the cattle industry by importing exotic blood (Johari and Jasmi, 2009). Department of Veterinary Service (DVS) Malaysia is given responsibility to import several extrinsic breeds for use as purebreds and for crossbreeding such as Santa Gertrudis, Angus, Hereford, Shorthorn and Droughtmaster breeds. Some of the larger European continental beef breeds were sourced in the form of frozen semen, including the Charolais and Limousin. Mixed-bred cows have shown higher growth rate and body weight compared to straightbred (Islam et al., 2021). To date, the Charolais and Limousin have become a popular choice for crossbreeding with Kedah-Kelantan (KK) especially in Terengganu and Kelantan through artificial insemination (AI) method. The offspring of this hybrid is known as Lembu Sado in Malaysia East Coast region. The mature weight of Lembu Sado beef cattle, which are of the large-sized Lembu Sado breed, might vary. When they are in average condition, bulls will typically weigh between 500 and 1000 kg, while females will weigh between 300 and 600 kg. They tend to mature more quickly and have a greater muscle mass.

Lembu Sado farming, which involves the crossbreeding of Charolais and KK cattle, predominates in the state of Terengganu. Lembu Sado are bred specifically for beef production in order to improve the growth rate of lean meat, the quality of the meat, the fertility of the animals, and their ability to maintain their adaptability. The cultivation of Lembu Sado in Terengganu is still carried out in the backyards of homeowners on small farms, which is the traditional method of farming in the state. Small herd sizes, with an average of five to ten cows, are a distinguishing feature of the cattle herds that are owned by Lembu Sado farmers. There are roughly 5000 Lembu Sado farmers in Terengganu at the moment, the majority of them are only engaged in the endeavor on a part-time basis. Lembu Sado are raised using a variety of production methods; nonetheless, they are often kept semi-intensively and treated like "pet animals" by receiving the best possible care in terms of both their diet and their overall health. After being allowed to graze in a confined space, these cows are brought inside the barn at night to receive more food and shelter. During the day, they are allowed to graze in the open.

Measuring farm's efficiency is important as it could be the first logical step to reduce wastage of inputs used. Technical efficiency (TE) is explained as the potential of a firm to produce the highest level of output from a given level of inputs or using a minimum quantity of inputs while maintaining the same level of output, under a given technology (Farrell, 1957). The concept of efficiency was proposed by Farrell (1957). Technical efficiency measure is extensively used in farming system analysis to study the farms' technical performances (Roco et al., 2017; Theodoridis et al., 2014). Technical efficiency compares the gross of output and the level of input, which is in our study, Lembu Sado farms inputs include land, feed, labor, technologies, supplement, maintenance, medical fees and other variable cost and capital. There are many studies of technical efficiency on beef cattle farms for example; Fleming et al. (2010), Otieno et al. (2014), Veysset et al. (2015), Cecilia et al. (2016), Martinez Cillero et al. (2018) and Qu et al. (2020). The study on technical efficiency is helpful to Lembu Sado farmers because it can identify the level of efficiency for every farm and the sources of the technical inefficiency. Technical efficiency of Lembu Sado farms becomes a principal element in economic profitability as it measures the ability of the farm to reduce the input and save the operating cost.

The purpose of this study is to identify the level of technical efficiency of smallholder Charolais mixed breed or Lembu Sado farms in selected districts in the state of Terengganu, as well as to determine the sources of the farms' technical inefficiency. In Malaysia, there has been no effort made to carry out a technical efficiency analysis of the Lembu Sado farming industry. This research makes a contribution to the livestock performance by assessing the efficiency levels of the Lembu Sado cow production in Malaysia and evaluating the factors that can influence the level of technical inefficiency. The technical efficiency measures will highlight the best practices and lessons that can be learned by farmers in the development of the Lembu Sado industry. They will also provide strategies to enhance the livestock industries in Malaysia in general, which will eventually result in an increase in the self-sufficiency level (SSL) of livestock in Malaysia.

MATERIALS AND METHODS

Through the use of a questionnaire survey, we were able to collect data from 86 Lembu Sado farmers. The Department of Veterinary Services in Terengganu provided us with the exhaustive list of Lembu Sado farmers' contact information. A seminar was held for Lembu Sado farmers at the same time as the questionnaires were distributed. This allowed us to select our respondents using a sample technique known as convenience sampling. This sampling approach was also used by Rohin et al. (2020) where the questionnaires were distributed in certain area, researcher explained the matter of the research and collected the questionnaire once respondent has completed the questionnaire. The inputs used, such as feed, land, and labor, as well as inputs and output, farm revenue, the material, and maintenance, are included in the questionnaire. Also included are the characteristics of the farmers.

This study utilizes a two-stage approach to data collection and interpretation (Gül et al., 2016; Suhaimi et al., 2017; Mareth et al., 2019). The first step, data envelopment analysis is used to determine the levels of technical efficiency exhibited by a group of 86 farmers from the state of Terengganu. In the second step of the process, a truncated bootstrap regression model is used to investigate the factors that contribute to technical inefficiency. Technical efficiency can be defined as either increasing output while maintaining the same level of input (an output-oriented approach) or decreasing input while maintaining the same level of output (input-oriented).

Data Envelopment Analysis

Data envelopment analysis (DEA), a non-parametric method that is used to assess the relative efficiencies of homogenous sets of decision-making units (DMUs), for performance measurement, analysis, and benchmarking, is the most frequent way for measuring the efficiency of technical processes (Tauer, 1993; Weersink et al., 1990). Charnes and colleagues were the ones who initially put up the DEA model (1997). DEA was applied as an input-oriented model in our research because we predicted that the management of Lembu Sado farms would find it less difficult to contract their input consumption. It is possible to classify DMUs as either efficient (with a score of 1 for technical efficiency) or inefficient (technical efficiency scores less than one). DEA was carried out in R software version 4.1.6.

Technical efficiency. The explanation below was modified from Coelli et al. (2002). The model is demonstrated for the situation where there are data on *L* outputs and *S* inputs for each of *K* firms. For the *i*-th firm, output and input data are represented by the column vectors y_i and x_i respectively. The *L* x *K* is output matrix, *Y* and *S* x *K* is input matrix, *X* and represent the data for all *K* firms in the sample. The DEA model used for calculation of technical efficiency is:

$$\min_{\theta,\lambda} \theta$$

Subject to

$$\begin{aligned} -y_i + Y\lambda &\geq 0, \\ \theta x_i - X\lambda &\geq 0, \\ K'\lambda &= 1, \\ \lambda &\geq 0, \end{aligned}$$

where θ is a scalar, $K1$ is an $K \times 1$ vector of ones, and λ is an $K \times 1$ vector of constants. The value of θ obtained is the technical efficiency score for the *i*-th firm. It will satisfy: $\theta = 1$, with a value 1 indicating a point on the frontier and hence a technically efficient firm, according to the Farrell (1957) definition. While, to measure technical inefficiency scores, value 1 should be minus technical efficiency scores. Note that the linear programming problem must be solved K times to obtain a value of θ for each firm in the sample. The study accounted five inputs and one output to measure technical efficiency. DEA was performed in R software version 4.6.1. Description for all variables is shown in Table 1.

i. Herd size – number of cattle that the farmer owned.
ii. Land – size of land in acres used by farmers for farming activities and planting grass.
iii. Labor – adult male-equivalent man-day and is the summation of family labor and hired labor. Labor measured in number of persons.
iv. Feed – the total compounded feedstuff given to cattle and measured in MYR. Annual expenditure on amount feed used for Lembu Sado cattle was calculated.
v. Other expenditure – expenditures on other materials and services for example farm maintenance, veterinary services and medicines, breeding expenses and other expenses measured in MYR.

Table 1. Summary statistics of output and inputs used in DEA model.

Variable	Unit	Mean	Standard deviation

Total revenue	MYR (10,000)	4.85	9.13
Herd size	Number of cattle	2.87	4.88
Land	Acre	1.98	1.49
Labor	Person	6.88	6.61
Feed	MYR (10,000)	1.01	1.16
Other expenditure	MYR (1,000)	6.70	8.29

Truncated Bootstrap Regression Model

In order to identify the association between farmer characteristics and technical inefficiency scores, truncated bootstrap regression model was run in Stata software version 16.1. This model was introduced by Simar and Wilson (2007). This model is adopted for the second step of the analysis. The truncated bootstrap regression model is presented below:

$$\hat{\delta}_i = Z_i\beta + \varepsilon_i$$

Where the dependent variable $\hat{\delta}_i$ is the bootstrapped inefficiency score, Z is a vector of independent variables, β its associated vector of coefficients, and ε_i the idiosyncratic error term.

Table 2 shows the summary statistics of variables used in truncated regression model.

Table 2. Summary statistics of variables used in truncated regression model.

Variables	Mean	Standard deviation
Household size	2.93	0.26
Education	2.30	0.08
Farming Experience	6.01	0.63
Off farm income	1.01	0.03
Finance from government	0.08	0.02

RESULTS AND DISCUSSION

The following segment presents the results of the study and discusses the outcomes.

Technical Efficiency Results

An input-oriented DEA model was used to estimate the technical efficiency scores. Technical efficiency score summary statistics are presented in Table 3. 31.4% farms were technically efficient i.e., technical efficiency score equals to one. 34.9% of the farmers operated at below 60% technical efficiency. This indicates that only 27 Lembu Sado farms in Terengganu are efficient in managing their inputs while 30 Lembu Sado farms are not efficient in utilizing their inputs and they can still save some more of their inputs in order to be efficient. Technical efficiency score ranged from 0.072 to 1, with an average measure of 0.74. In other word, on average, Lembu Sado farms in Terengganu can lessen their inputs of production by 26% and still can generate the same level of output. One farm score below 10% technical efficiency indicates that this farm is very inefficient in utilizing its inputs.

Table 3. Frequency distribution of technical efficiency scores.

Efficiency Scores	VRS
1	27
0.90-0.99	9
0.80-0.89	9
0.70-0.79	3
0.60-0.69	8
0.50-0.59	12
0.40-0.49	8
0.30-0.39	4
0.20-0.29	4
0.10-0.19	1
0.00-0.09	1
Total DMUs	86
Minimum	0.07
Maximum	1.00
Mean	0.74

Truncated Bootstrap Results

In the second step, the estimated technical inefficiency scores (technical efficiency minus one) were regressed on farmer characteristic factors using truncated bootstrap regression analysis. The results are shown in Table 4.

Table 4. Results of truncated bootstrap analysis.

Variables	Coefficient	*p*-Value
Constant	0.681***	0.007
Household size	0.013	0.604
Education		
Primary and Secondary	-0.365*	0.085
Diploma and above	-0.879***	0.008
Farming Experience	-0.011**	0.035
Off farm income	0.286*	0.070
Finance from government	-0.103	0.775

Notes: *,**, and *** represent levels of significance of 10%, 5%

and 1% respectively.

Education (primary and secondary school, and diploma and above) has a negative and significant association with technical inefficiency. Our result indicates that the more educated the farmer, the technical inefficiency becomes less. Farmers who have a formal education i.e., better knowledge, are able to acquire and process the new information and technology, hence they are more efficient in using the inputs (Suhaimi et al., 2017). This finding is consistent with Asfaw (2021) for tomato farms and Abate et al. (2019) for red pepper farms.

Farming experience has a negative association with technical inefficiency. Our result suggests that farmers who had more years in farming experience can reduce the technical inefficiency. In other words, farmers who had more experience in managing farms, are more efficient using the farm inputs. Experience in farming activities helps farmers in estimating the input used in production. This result is in line with Mengui et al. (2019) for potato farms in Cameroon and Mwalupaso et al. (2019) for maize production in Zambia.

Off farm employment can have both positive and negative associations with efficiency. Income generated from off farm employment can be used to purchase production inputs which may lead to positive impact. On the other hand, off farm employment may lead to inefficiency if the farmer is too busy with other jobs besides farming activities. The result from this study shows that off farm income has a positive relation with technical inefficiency indicating that increase in off-farm work by the farmer is associated with a significant increase in technical inefficiency. This result is in line with reports by several authors such as Tenaye (2020) and also consistent with a study by Sabasi et al. (2019) who discovered that off-farm job increases the technical inefficiency in U.S. dairies.

CONCLUSION

This study has shown the level of technical efficiency for a sample of 86 Lembu Sado farms in Terengganu. Subsequently, in the second step analysis, the association between technical inefficiency and various characteristics of the farm manager were determined. Data envelopment analysis was used to measure the technical efficiency scores.

The analysis discloses average levels of technical efficiency equal to 73.6%. The outcome suggests that Lembu Sado farms can keep their existing production level and save 26.4% of inputs used. This finding indicates that there exists room for improvement in technical efficiency among Lembu Sado farms. They can utilize their inputs efficiently and save the cost of inputs for others farm activities. On the other hand, policy makers can use this finding to improve the efficiency of Lembu Sado farmers by giving training in order to use proper mixed inputs.

In a second step of analysis, a truncated bootstrap regression model was used to the equation, where technical inefficiency scores were regressed with farm owner characteristics: household size, education, experience, off-farm income and finance from the government. The results of the second step analysis shows the following: farming experience and education have a negative association with technical inefficiency while off farm income has a positive association with technical inefficiency. Our finding suggests that the government can consider providing training (i.e., knowledge) to Lembu Sado farmers, therefore they can learn on how to save their inputs in cattle production.

This study however has limitations; we have a limited number of observations and variables to explain the differences on technical inefficiency. In the future, other studies could include more variables in terms of farm characteristics such as type of farm, distance farm from house and ownership of farm.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All authors designed and collected the data. YMY and NAMS analyzed the data and wrote the manuscript. NA and NMN reviewed the manuscript. All authors read and approved the final version.

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