Technical Efficiency and Return to Scale of Dairy Farm in Sleman, Yogyakarta

(Efisiensi Teknis dan Skala Pengembalian Usahatani Sapi Perah di Kabupaten Sleman, Yogyakarta)

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Abstrak

Usahatani sapi perah di Indonesia secara ekonomi mempunyai prospek yang bagus, karena produksinya belum mencukupi permintaan susu dalam negeri. Hal ini disebabkan usahatani tersebut masih berskala kecil dengan menggunakan teknologi yang masih tradisional, akibatnya tingkat produktivitasnya masih rendah. Kajian ini mengestimasi efisiensi teknis dan skala pengembalian, guna menemukan cara untuk meningkatkan produksi susu segar. Kajian ini mengambil tempat di Sleman, Jogjakarta tempat usahatani sapi perah yang potensial berada. Efisiensi teknis diestimasi menggunakan produksi frontir stokastik, dan skala pengembalian diestimasi menggunakan teknologi produksi Cobb-Douglas. Hasil kajian ini menunjukkan bahwa produktivitas usahatani sapi perah secara signifikan dipengaruhi oleh variasi efisiensi teknis, dengan rata-rata 0,69. Oleh karena itu, masih ada kemungkinan untuk meningkatkan produktivitas usahatani sapi perah melalui peningkatan efisiensi teknis. Hal ini dapat dilakukan dengan meningkatkan jumlah sapi perah, atau skala usahatani. Pilihan ini sejalan dengan kondisi produksi susu segar yang menunjukkan skala pengembalian yang konstan. Jadi, meningkatkan skala usahatani adalah pilihan yang bijaksana karena pilihan tersebut tidak hanya meningkatkan tingkat produksi susu segar, tetapi juga meningkatkan produktivitas usahatani sapi perah.

Kata Kunci : Usahatani sapi perah, efisiensi teknis, skala usahatani.

Introduction

Dairy farm is economically promising since there are abundances of family labours and supports provided by the government in terms of technology, infrastructure, management and policies (Sunandar 2001). It is supported by Syamsu and Ahmad (2003) who stated that cattle's feeding is available enough and the level of utilisation is still under carrying capacity. As predicted by Janvry et al. (2002) that demand for meat in the developing countries is to increase as a consequence of population growth and rising incomes. Indonesia, domestic demand for milk, on average, is 851,300 litres a day, but only 61 per cent of that can be met by domestic production, and the rest is supplied by imported milk (Ditjennak 2000). As a consequence, livestock sub-sector including dairy farm has a good prospect of agribusiness. Another factor indicating that dairy farm is a profitable business is that household's income obtained from dairy farm is higher than that from rice or secondary food crop farming, and the dairy farm has a comparative advantage (Sunandar 2001).

One of the potential animal husbandries that need a particular attention is dairy farm. One of the reasons is that most of dairy farms are operated in small-scale with limited capital and traditional/conventional technology (Djoni 2003). As a consequence, the performance of the dairy production has not been in optimal operation. As studied by Djoni (2003) for instance, dairy farms in District of Tasikmalaya, West Java, were inefficient in terms of resource allocation. It was hypothesized that the other small-scale dairy farms in the other regions were still under the best performance. This study therefore was carried out to measure whether the dairy productions show high economic performance. The economic performance of dairy production is broken down into technical efficiency and return of scale. Those indicators are important to study because of the following reasons. Firstly, technical efficiency will provide information on how to increase productivity using the same level of resources. Furthermore, Belbase and Grabowski (1985) and Shapiro (1983) argue that efforts to improve efficiency may be more cost effective than introducing new technologies as a means of increasing agricultural productivity, if farm operators have not used existing technology efficiently. Secondly, returns to scale will provide information of whether expansion of scale of dairy production done by multiplying capital and variable inputs will have economic impact. Returns to scale also imply economies of scale because of duality in production theory (Jehle and Reny 2001; Pindyck and Rubinfeld 1998). The outcome of this study is expected to be able to provide significant contributions for improving dairy farm's performance.

Theoretical Framework

Technical Efficiency

Technical efficiency is one of the components in the process of agricultural modernization (Janssen and de Londonõ 1994). It shifts the production function on which producers operate closer to the production frontier, which can be estimated using stochastic and deterministic approaches. In agricultural studies, the stochastic approach is more suitable than another, because it incorporates a composed error structure with a two-sided symmetric term and a one-sided component and it also makes it possible to estimate standard errors and to generate test hypotheses (O'Neill et al. 1999). For empirical studies, Reifschneider and Stevenson (1991) and Battese and Coelli (1995) proposed a stochastic frontier model in which the inefficiency effects (U_i) are expressed as an explicit function of a vector of farm-specific variables and a random error. The model specification can be expressed as:

$$\ln Q_i = \ln A + \sum_{k=1}^{3} \beta_k \ln \mathbf{X}_{ki} + (V_i - U_i) \quad \ldots (1)$$

where Q_i is the production of the i^{th} farm; $\mathbf{X}_i$ is a input quantities of the i^{th} farm;[1] β is an vector of unknown parameters. The V_i are random variables that are assumed to be *i.i.d.*~ $N(0, \sigma_V^2)$, and independent of the U_i which are non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero of the $N(\mu_i, \sigma_U^2)$ distribution; where:

$$\mu_i = \mathbf{Z}_i\delta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and $\mathbf{Z}_i$ is a $p \times 1$ vector of variables which may influence the efficiency of a farm; and δ is an $1 \times p$ vector of parameters to be estimated. Utilising the parameterisation of Battese and Corra (1977) replace σ_V^2 and σ_U^2 with $\sigma^2 = \sigma_V^2 + \sigma_U^2$, and let define

$$\gamma = \sigma_U^2 / \sigma^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The parameter γ which represents a total variation of actual output deviating from the frontier must lie between 0 and 1. The farm-specific technical efficiency is estimated using the

[1]For example, if Y_i is the log of output and X_i contains the logs of the input quantities, then the Cobb-Douglas production function is obtained.

expectation of conditional random variable ε_i as shown by Battese and Coelli (1988). That is:

$$TE_i = \frac{E(Q_i \mid U_i, X_{ki})}{E(Q_i \mid U_i = 0, X_{ki})} = \exp\{-U_i\} \quad . . .(4)$$

It is obvious that the technical efficiency lies between zero and unity. When technical efficiency is equal to unity, the actual output lies on the stochastic production frontier.

Returns to Scale

Returns to scale refer to the degree by which level of production changes as a result of given change in the level of all inputs used. Salvatore (1996) stated that there are three different types of returns to scale: constant return to scale (CRS), increasing return to scale (IRS) and decreasing return to scale (DRS). Mathematically, the implication of returns to scale can be shown as follow. Let denote a production function as $Q = f(K,L)$. If K and L is multiplied by ψ, and then Q increases by φ as indicated in $\varphi Q = f(\psi K, \psi L)$. The production function exhibits CRS, IRS or DRS respectively, is dependent on whether $\varphi = \psi$, $\varphi > \psi$ or $\varphi < \psi$.

To determine returns to scale of dairy production, a Cobb-Douglas model is used in this study. Soekartawi et al. (1986) stated that the Cobb-Douglas model suitable to estimate agricultural production function. The model, moreover, has several advantages compared with the other models (Soekartawi 1990). In terms of a log-linear functional form, the Cobb-Douglas model is formulated as:

$$\ln Q_i = \ln A + \sum_{k=1}^{3} \beta_k \ln \mathbf{X}_{ki} + \varepsilon \quad . . . . . (5)$$

Where Q is a quantity of milk; A is total factor productivity; $\mathbf{X}_k$ is a vector of variable inputs consisting of k=1 is cows, k=2 is labour, and k=3 is feeding; ε is a disturbance error representing uncontrolled factors excluded from the model; and β_k, k=1, 2, 3 is coefficients to be estimated.

The condition of returns to scale will be determined by value of $\Re$, that is:

$$\Re = \sum_{k=1}^{3} \beta_k \quad . . . . (6)$$

When $\Re$ is equal to one, it means that the dairy production exhibits CRS. This implies that doubling level of capital and inputs results in double level of output. But, when $\Re$ is greater (less) than one, it means that the dairy production exhibits IRS (DRS). This implies that doubling level of capital and inputs results in more (less) than double level of output. If the dairy production exhibits CRS or IRS, it will be reasonable for farm's operator to immediately multiply the levels of capital and other inputs from the existing levels. But, if the dairy production exhibits DRS, farm's operator need to consider the cost of production if they want to make larger the scale of farm.

Research Methods

Study Site and Commodities

This analysis was based on a conduct of study in 2001 in a district of Sleman, Jogjakarta Province, at which the dairy farm exists. The main product was milk, and the joint product was calf. Data on dairy farm was collected by interviewing farm's operators using the structured questionnaires. The activities related to the operations of dairy farm during a year were recorded. In the study, the number of farm's operators interviewed was 32. The definitions and measures of variables used in this study and the summary statistics are shown in Table 1 and Table 2.

Table 1. Description and measures of variables

Variable	Description
Milk	Production of milk a year (litre)
Calves	Value of calves which is sold a year (000 IDR)
Cows	Number of cows which are owned by farm's operators
Labour	Number of labours which are employed a year (man-day)
Feeding	Value of feeding a year (000 IDR)
Wealth	Area of coffee plantation which is owned by farm's operators (hectare)
Price of milk	Prevailing price of milk that is accepted by farm's operators (IDR/litre)

Source: primary data

Table 2. Summary statistics for key variables

Variable	Average	Standard Deviation	Minimum	Maximum
Milk	8201.09	3601.38	3285	16425
Calves	5314.06	3557.62	1500	19000
Cows	5.03	2.07	2	11
Labour	335.93	93.61	121.59	526.80
Feeding	2047.85	892.93	506.25	3937.50
Wealth	4,757.81	2,953.60	750	10,000
Price of milk	1117.19	56.24	1000	1200

Source: Authors' calculation

Hypothesis

Related to the technical efficiency, it was hypothesised that variation in milk production among farm was due largely to variation in technical inefficiency, which was, to some extent, affected by scale of the farm, wealth of the farm's operator, and production of calves. The formal test for hypothesis of variation in technical efficiency was formulated as:

Null hypothesis (H_0): $\gamma = 0$

Alternative hypothesis (H_a): $\gamma > 0$

The formal test for hypothesis that technical efficiency was dependent on scale of the farm, wealth of the farm's operator, and production of calves was formulated as:

Null hypothesis (H_0): $\delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$

Alternative hypothesis (H_a): one of them $\neq 0$.

If those H_0s are rejected, variation in technical efficiency matters, and the variation are due to scale, wealth, and calf production. The stochastic production frontier and technical inefficiency effect will be simultaneously estimated using FRONTIER 4.1.

Related to returns to scale, it was hypothesised that there was a CRS production process in dairy farm. Testing for hypothesis indicating that production of milk exhibits CRS is formally formulated as:

Null hypothesis (H_0): $\Re - 1 = 0$

Alternative hypothesis (H_a): $\Re - 1 \neq 0$

where $\Re = \beta_1+\beta_2+\beta_3$. If H_0 is rejected, the production of milk does not exhibit CRS. The Cobb-Douglas production function and testing for constant returns to scale will be estimated using STATA 8.0. Decision rule of whether the hypotheses formulated above are rejected or not is determined using critical values of statistical inferences measured at one per cent, five per cent and ten per cent of significant levels.

Results and Discussion

Table 3 shows an estimated stochastic production frontier and a technical inefficiency model. It can be seen that the value of γ approaches unity, which is very high and highly significant. This means that variation in actual level of milk deviating from potential level was due mostly to difference in technical efficiency. In other words, technical efficiency matters in determining variation in producing milk among farms. Log-likelihood (LR) test which is highly significant indicates that the variables included in both frontier production and technical inefficiency models simultaneously play significant roles in affecting production of milk.

From the estimated production frontier, the coefficients on cows and feeding are positive and significant. The interpretation of those was that one per cent increase in number of cows will cause an increase in milk production by a maximum of approximately 0.42 per cent. Likewise, one per cent increase in amount of feeding will cause the milk production increases by a maximum of about 0.23 per cent. In contrast, the number of labour has negative and significant coefficient. This means that if the number of labour is increased by one per cent, the milk production will decrease by a maximum of approximately 0.38 per cent. From the technical inefficiency effect, it could be seen that the only factor studied here which significantly affected the technical inefficiency was the number of cows. This implies that the larger scale of dairy farm is more technically efficient in producing milk. However, the number of calves and the amount of wealth had no impact on technical efficiency, meaning that farms with different those operate at the same level of technical efficiency.

Table 3. Frontier production function and technical inefficiency model

Variables		Coefficient	t-ratio
Stochastic Production Frontier			
Constant	β_0	9.15710	756.28**
ln Cows	β_1	0.4165	901.43**
ln Labour	β_2	-0.3782	-16.64**
ln Feeding	β_3	0.2310	14.17**
Technical inefficiency effect			
Constant	δ_0	1.2388	3.58**
Calves	δ_1	-0.0003	-0.53^{ns}
Cows	δ_2	-0.2242	-3.17**
Wealth	δ_3	-0.3339	-0.75^{ns}
	γ	0.9999	4791032**
	Log-likelihood	-2.0041	
	LR-ratio	19.91**	

Note: dependent variable stochastic frontier is ln milk; dependent variable for technical inefficiency model is μ ; **) significant at α =0.01, *) significant at α =0.05, ^{ns}) not significant
Source: Authors' estimation

Table 4. Descriptive analysis of technical efficiency

Summary statistics		Distribution	
Average	0.6895	Technical efficiency	%
Std. Dev.	0.2221	< 0.40	9
Min	0.2556	0.4-0.70	44
Max	0.9998	> 0.70	47

Source: author's calculation

Table 5. Cobb-Douglas production function

Variables		Coefficient	t-ratio
Constant	β_0	8.7187	5.97**
ln Cows	β_1	0.6452	3.88**
ln Labour	β_2	-0.5385	-0.64^{ns}
ln Feeding	β_3	0.3084	0.59^{ns}

$\beta_1+\beta_2+\beta_3=1$ $F(1, 28) = 2.20^{ns}$

R-squared = 0.3648

F(3, 28) = 5.36**

Note: dependent variable: ln milk; **) significant at α =0.01, *) significant at α =0.05, ^{ns}) not significant

Source: Authors' estimation

Table 4 shows the summary statistics and distribution of technical efficiency. On average, the technical efficiency of dairy farm that produces milk is 0.69; with more than 50 per cent of dairy farms still have technical efficiency less than 0.70. Therefore, there was still considerable room for boosting productivity through improving technical efficiency with the existing technology. It could be done by increasing scale of dairy farm, or increasing the number of cows.

Table 5 shows an estimated Cobb-Douglas production function. Overall, the production function was significantly estimated, with around 36 per cent of total variation in milk production was explainable with variations in inputs. The number of cows had a significant effect on milk production, but the labour and feeding were not significant[2]. This indicated that the labour and feeding were no longer constraints in the dairy farm.

This was supported by the fact that there was abundance in labour supply and availability of cattle's feeding, in particular grasses. Such conditions indicated that increasing number of cows could escalate production of milk. Related to return to scale, testing hypothesis did not reject the restriction of $\beta_1+\beta_2+\beta_3=1$. This means that production of milk exhibited CRS. The implication was that the dairy farm could be expanded by multiplying all capital and inputs proportionately without any loss in level of milk production. It seemed that there was synchronization between technical efficiency and returns to scale. Thus, a good action that supports

[2] These results are slightly different from the production frontier in terms of significance, but they are the same in terms of the sign. This is because the production frontier in Table 4 represents the maximum of milk production; whereas the production function in Table 5 represents the average of milk production. The difference does not really matter because in overall they are simultaneously significant based on LR-test and F-test that show statistically significant.

such condition was to increase the scale of dairy farm. The action would not only increase production of milk, but also increase productivity as a result of improvement in technical efficiency. If the number of cows is increased, the technical efficiency will increase. This means that the production of milk will increase. The increase in production of milk came from two sources. Firstly, production of milk increased because of an increase in number of cows. Secondly, the production of milk increased because of an increase in technical efficiency which implies that with the same level of input use will result in higher level of milk production.

Conclusion

From the analyses of estimated frontier production function and return to scale, the conclusions that could be drawn were as follow.

- Variation in technical efficiency was a key factor in affecting milk production, and the level of technical efficiency was, on average, 0.69, with more than fifty per cent of farms were operated at under average level of technical efficiency.
- The number of cows escalated technical efficiency. This implies that dairy farms with larger number of cows are more technically efficient.
- The dairy farms exhibited CRS.

The implication of those results is that, with state of the dairy technology, there is still considerable room for improving dairy farm productivity through increasing technical efficiency. Increasing the scale of the farm is an appropriate choice to increase productivity. The choice will have double impacts: increase in level of milk production and increase in technical efficiency leading to increase in productivity of dairy farm.

Acknowledgment

The author would like to acknowledge the farmers in Hamlet of Kaliadem who have provided plenty of worthwhile time in gathering data. They have been very helpful in sharing their ideas with newcomers to this topic. The author hopes the results of this study will be used as a worthwhile feedback for the farmers to improve their own farms through both policy makers and academic activities.

The author also wants to thank the following best friends for their supports: Dewi who has given assistance in data collection, Danik and Inung Putih who have invited us in this research. Last but not least, we thank Pak Musofie who has given us an entry point to a dairy research project.

References

Battese, G.E and Coelli, T., 1988. 'Prediction of firm-level technical efficiency with a generalized frontier production function and panel data', *Journal of Econometrics*, 38: 387-399.

Battese, G.E. and Coelli, T. 1995. 'A model for technical inefficiency effects in a stochastic frontier production function for panel data', *Empirical Economics*, 20: 325-32.

Battese, G.E. and Corra, G.S. (1977), 'Estimation of a production frontier model: with application to the pastoral zone of eastern Australia', *Australian Journal of Agricultural Economics*, 21: 169-179.

Belbase, K. and Grabowski, R., 1985. 'Technical efficiency in Nepalese agriculture', *Journal of Development Areas,* 19: 515-525.

Ditjennak (Direktorat Jendral Peternakan), 2000. Informasi Peluang Investasi Agribisnis Peternakan di Indonesia, Direktorat Jendral Peternakan Jakarta.

Djoni, 2003. Kajian efsiensi ekonomis penggunaan faktor-faktor produksi usaha ternak sapi perah di Kabupaten Tasikmalaya. *Jurnal Agribinis*, VII(1): 44-47.

Jansen, W. and N.R. de Londonõ. 1994. Modernization of peasant crop in Columbia: evidence and implications. *Agric. Econ*. 10: 13-25.

Janvry, A, G. Graff, E. Sadoulet, and D. Zilberman, 2002. Technological Change in Agriculture and Poverty Reduction, Concept paper for the WDR on Poverty and Development 2000/01 (http://www.wtowatch.org/library/admin/uploadedfiles/Technological_Change_in_Agriculture_and_Povert.htm,). 6 Nov 2002.

Jehle, G. A. and P.J. Reny. 2001. *Advanced Microeconomic Theory*. Addison-Wesley, Boston.

O'Neill, S., Matthews, A. and Leavy, A., 1999. Farm Technical Efficiency and Extension, Trinity College Dublin Economic Papers, 9912, paper presented at the Irish Economics Association Conference in April 1999 ,http: //econserv 2. bess.tcd.ie/TEP/ tepno12SON99.PDF (20 Sep. 2004).

Pindyck, R.S. and Rubinfeld, D.L. 1998. *Microeconomics*. Prentice Hall International, Inc. Upper Sadle River, New Jersey.

Reifschneider, D. and Stevenson, R., 1991. 'Systematic departures from the frontier: a framework for the analysis of firm inefficiency', *International Economic Review*, 32: 715-723.

Salvatore, D., 1996. *Managerial Economics in A Global Economy*. McGraw-Hill, New York.

Shapiro, K.H., 1983. 'Efficiency differentials in peasant agriculture and their implications for development policies'. *Journal of Development Studies* 19: 179–190.

Soekartawi, 1990. *Teori Ekonomi Produksi dengan Pokok Bahasan Analisis Fungsi Cobb-Douglas*. Rajawali Press, Jakarta.

Soekartawi, 1995. *Linear Programming: teori dan aplikasinya khususnya dalam bidang pertanian*. Rajawali Pres, Jakarta.

Soekartawi, Soehardjo, A., Dillon, J., L., and Hardaker, B. J., 1986. *Ilmu Usaha-tani dan Penelitian untuk Pengembangan Petani Kecil*. UI Press, Jakarta.

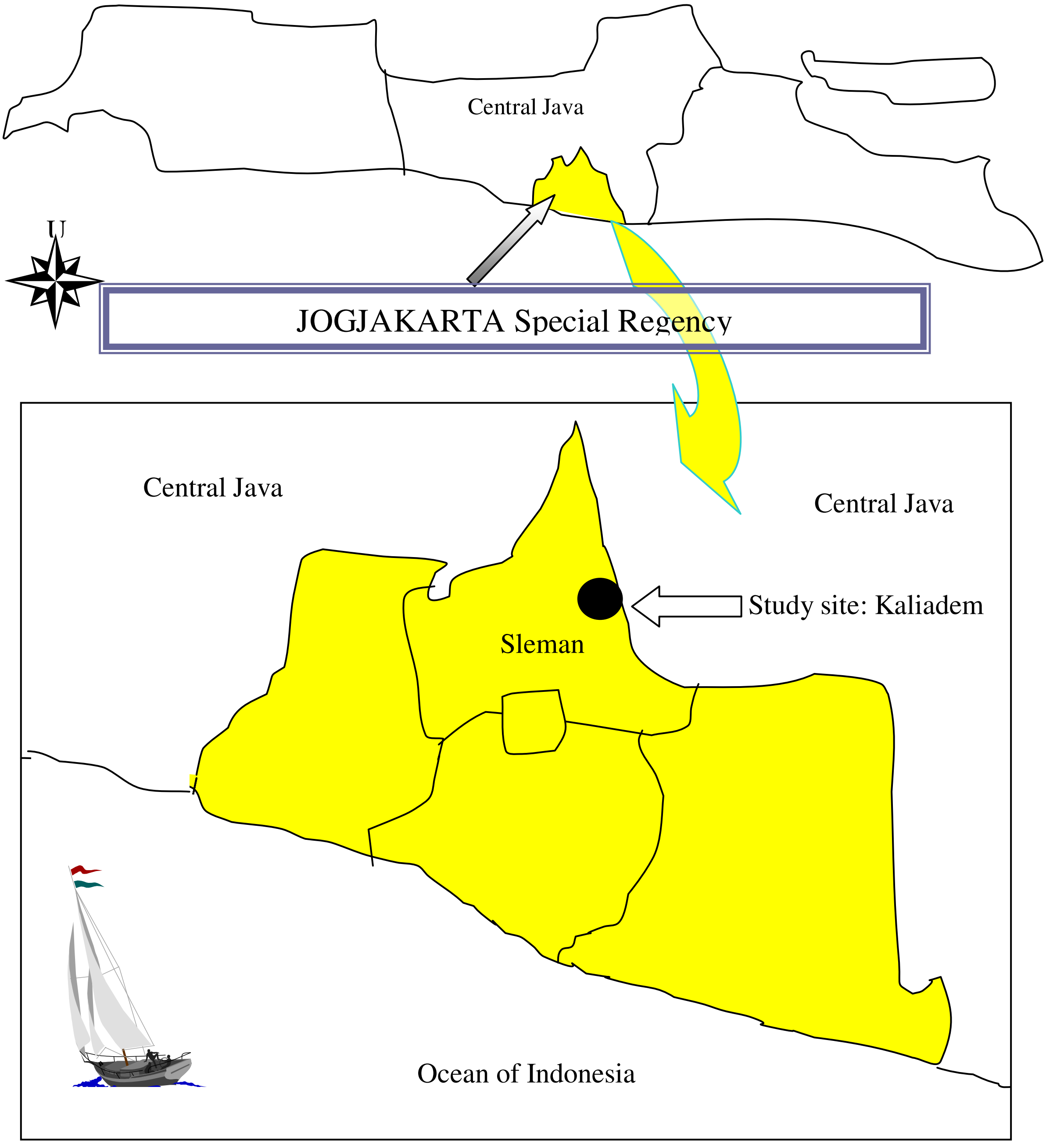
Sunandar, N., 2001. *Analysis Dampak Kebijakan Import Susu Nasional dan Keunggulan Komparatif Usaha Ternak Sapi Perah di Jawa Barat*. Thesis S-2 Gadjah Mada University, Yogyakarta.

Syamsu, J.A and Ahmad, M., 2003. Keunggulan kompetitif wilayah berdasarkan sumberdaya pakan untuk pengembangan ternak ruminansia di Sulawesi Selatan, *Jurnal Agribisnis,* VII(1): 11-19.

Appendixes

The Location of study

Java island of Indonesia



FRONTIER Output

```
Output from the program FRONTIER (Version 4.1c)

the final mle estimates are :

                 coefficient     standard-error    t-ratio
  beta 0          0.91570993E+01  0.12108020E-01  0.75628377E+03
  beta 1          0.41653750E+00  0.46208433E-03  0.90143178E+03
  beta 2         -0.37819374E+00  0.22721792E-01 -0.16644539E+02
  beta 3          0.23101099E+00  0.16300946E-01  0.14171631E+02
  delta 0         0.12388198E+01  0.34609834E+00  0.35793868E+01
  delta 1        -0.25842258E-04  0.48424655E-04 -0.53365911E+00
  delta 2        -0.22415806E+00  0.70869115E-01 -0.31629866E+01
  delta 3        -0.33389964E+00  0.44374227E+00 -0.75246300E+00
  sigma-squared   0.32362128E+00  0.12421205E+00  0.26053935E+01
  gamma           0.99999999E+00  0.20872329E-06  0.47910322E+07

log likelihood function =  -0.20041629E+01

LR test of the one-sided error =   0.19909645E+02
with number of restrictions = 5
 [note that this statistic has a mixed chi-square distribution]
number of iterations =     32
(maximum number of iterations set at :   100)
number of cross-sections =     32
number of time periods =      1
total number of observations =     32
thus there are:      0  obsns not in the panel
mean efficiency =   0.68948686E+00
```

STATA Output

```
. do "C:\WINDOWS\TEMP\STD010000.tmp"
. reg lsusu  lsapi ltk lpk
      Source |       SS       df       MS              Number of obs =      32
-------------+------------------------------           F(  3,    28) =    5.36
       Model |  2.27196753     3  .757322511           Prob > F      =  0.0048
    Residual |  3.95624524    28  .141294473           R-squared     =  0.3648
-------------+------------------------------           Adj R-squared =  0.2967
       Total |  6.22821277    31  .200910089           Root MSE      =  .37589
------------------------------------------------------------------------------
       lsusu |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lsapi |      .6452   .1661506     3.88   0.001      .304856     .985544
         ltk |  -.5384763   .8420166    -0.64   0.528    -2.263269    1.186316
         lpk |   .3083677   .5254555     0.59   0.562    -.7679792    1.384715
       _cons |   8.718679   1.459582     5.97   0.000      5.72886     11.7085
------------------------------------------------------------------------------
. hettest, rhs
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: lsapi ltk lpk
         chi2(3)      =     0.13
         Prob > chi2  =   0.9882
. test lsapi+ltk+lpk=1
 ( 1)  lsapi + ltk + lpk = 1

       F(1, 28) =    2.20
       Prob > F =    0.1492
```