Determination of the bio-economical efficiency of milk production throughout data envelopment analysis models

R. Cobo and O. Borroto

Instituto de Ciencia Animal, Apartado Postal 24, San José de las Lajas, Mayabeque, Cuba
Email: rcobo@ica.co.cu

In order to demonstrate the potentialities of the data envelopment analysis (DEA) and its value for interpreting milk production, the efficiency frontier of the selected Basic Units of Cooperative Production (BUCP) is presented. The application of the econometric tools to interpret the results easier and take decisions and show an effective comparison in efficiency terms whether for the use of resources or maximization of results is presented. For developing this research, the techniques of the data envelopment analysis (DEA) were used and the weight assignment of the variables through the statistical model of impact measuring (SMIM) was corrected. The SPSS V.19.0 (2010) software was used for the data processing according to the SMIM and the Frontier Analyst to conduct the DEA. Besides, calculation sheets from Excel were used to form the matrix of original data. The information of six BUCP between January 2008 and August 2010 was used, gathering information monthly. The variables explaining higher percentage in the system variability were known, and the technical efficiency and the efficiency frontier according to the variables selected were determined.

Key words: *efficiency, econometry, milk production, data envelopment analysis.*

Dairy production, as well as other sectors of the Cuban economy, as experienced extreme crises, with the inconvenient that its recovery depends not only on certain infrastructure investments although they are necessary. The recovery of the sector includes a large number of socio-economical variables (Ponce 2003) that cannot be avoided when solving the insufficiencies. This production is conducted under environmental conditions on the basis of specialized management of animals and plants.

The conditions of Cuban agriculture force to keep the strictest observation about the use of resources, production efficiency and taking decisions to correct or potentiate the results (Cobo *et al*. 2011). Among the tools to ease the bioeconomial analysis of production is econometry (Ventosa-Santaulària 2006). It is mainly used to interpret macroeconomic aspects, although it may be also useful for microeconomy studies (Araya and Orozco1996). From the second half of the 20th century, statistical techniques to determine the entities efficiency have been developed (Pereira Filho 2000). That is the case of the data envelopment analysis (DEA). There are two ways to conceive the DEA models: the DEA-CCR of Charnes *et al*. (1978) that presents constant yields at scale (CYS), and the DEA-BCC of Banker *et al*. (1989) that shows variable yields at scale (VYS). They intend to determine the efficiency of the problems stated, which can be decomposed in pure technical efficiency and efficiency at scale. Sometimes it is about interpreting the efficiency term in milk production through the analysis of some indicators that combine partially input and output elements in the productive process (Pardo Sempere 2001). The slant present in these analyses ignores the influence on obtaining the product and of its production, as well as the combination ways of the different supplies used. This is the most convenient method to analyze the efficiency of this type of production, as it examines the global relation of the obtained products and the resources used.

The objective of this study was to determine the bioeconomic efficiency frontier in the milk production through the DEA. This procedure shows a different approaching in the results analysis for taking decisions.

Materials and Methods

The real data of an enterprise organized in six basic units of cooperative production (BUCP) named A, B, C, D, E and F in the period from January 2008 to August 2010 were used.

Due to a group of variables of different nature influencing on the milk production process, selecting those whose behavior was possible to know during the cited period was necessary. The variables (simple or combined) integrated to the data basis were: milking cows, milk production (kg milk), cost/kg of milk, result in sales, result of the period, activity gross margin, productivity, kg of milk per hectare (kg/ha), stocking rate (LAU/ha) and useful area (ha/useful). These variables were selected after an analysis of the manager's interests.

The statistical model for impact measuring (SMIM) of Torres *et al*. (2006) was used to eliminate the weight assignment to the input and output variables subjectively. That is, not to assign the variables weight, according to the researcher criterion. The SMIM is applied up to obtaining the matrix of principal components, as the objective is to find the incidence of each variable in the explanation of the variability.

The DEA techniques, described by Charnes *et al*. (1978) were applied. They are based on the studies of

Farrel (1957), who considered the inclusion of multiple resources and products. A DEA model supposes considering the used technical coefficients to work with entities (E), resources or inputs (M) and products or outputs (S) (figure 1).

$$
\begin{array}{cccccccc}
 & x_1 & x_2 & \dots x_m & y_1 & y_2 \dots & & y_s \\
E_1 & x_{11} & x_{12} & \dots x_{1m} & y_{11} & y_{12} \dots & & y_{1s} \\
E_2 & x_{21} & x_{22} & \dots x_{2m} & y_{21} y_{22} & \dots & & y_{2s} \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & & \cdot \\
E_n & x_{n1} & x_{n2} & \dots x_{nm} & y_{n1} & y_{n2} \dots & & y_{ns}
\end{array}
$$

Figure 1. Matrix of technical coefficients

where:
Entities $E = 1, 2, \dots ,n$
Resources or inputs $x = 1, 2, \dots ,m$
Product or outputs $y = 1, 2, \dots ,s$

The efficiency of each production entity refers to enterprises, individuals, firms, productive units, among

$$Max \ \frac{u_1 y_{i1} + u_2 y_{i2} + \cdots + u_s y_{is}}{v_1 x_{i1} + v_2 x_{i2} + \cdots + v_m x_{im}} \qquad (1)$$

It is subjected to the restrictions:

$$\frac{u_1 y_{i1} + u_2 y_{i2} + \cdots + u_s y_{is}}{v_1 x_{i1} + v_2 x_{i2} + \cdots + v_m x_{im}} \leq 1 \quad (i = 1, \dots, n)$$

others. The quotient to measure the efficiency of the entity to be optimized and that of all units is obtained maximized. That assessed is always lower than or equal to one (Tupy and Yamaguchi1998). The corresponding model is the following:

$v_1, v_2, \dots v_s \geq 0$
$v_1, v_2, \dots v_m \geq 0$
Where:
uj = weighting associated with the product (j=1,...,s)
vj = weighting associated with the resource use (j=1,...,m)

The analysis intended to conduct may find the positive coefficients and maximizing the rate (1) for the efficiency of the production entity. A lower or equal efficiency to that of the unit is achieved.

The model solution propitiates the efficiency quantification of each productive entity in respect to the others, as well as the weight values that allow such efficiency (Arzubi2003).

The statistical software SPSS V.19.0 (2010) was used, apart from the tools Excel of Windows 2003, to organize the information and the Frontier Analyst® Version 4.2 calculating and representing the efficiency frontier.

Results and Discussion

The DEA procedure used to determine the efficiency of the selected BUCP was conducted from the results of the SMIM up to the determination of the weight matrix of the principal components selected. The data matrix of the input and output variables considered for each BUCP and years was of 72 x10, with KMO of 0.64. This, according to Kaiser (1970, 1974) indicates a regular size of sample. According to the model elaborated by Torres *et al*. (2008), three components with eigen value higher than one were selected.

The results presented in table 1 indicate that elements related with the variability of this productive system are explained in 81.80%. In the principal component 1 (PC 1), the variables of highest weight were the milking cows, kg milk, kg/ha and LAU/ha, which explained 34.44% of the total variability of the system. The principal component 2 (PC 2) explained 32.40%, and the variables with highest weight were the sales results in the period, activity gross margin and productivity. The component 3 (PC 3) referred the 14.96% of the variability, with only one weight variable, the total cost/kg of milk. Only the variable useful area did not have important weight in the three principal components selected.

The DEA to determine the efficiency of highest weight in the explanation of the variability system was structured in several stages and through different models. The models used explained the technical efficiency per production unit, with constant yield at scale (CYS). This model intends to find the BUCP that could be reference for the rest, in respect to its technical efficiency. According to Coll and Blasco (2009), when comparing the value of each unit with optimum value, defined by the estimated frontier production (efficient isocuanta), the unit obtains the maximum result from a group of inputs. For this model, the milking cows and the LAU/ha were selected as input variables. As output variable, the milk production in kg was taken.

Table 2 presents the efficiency (%) for the BUCP analyzed. The C was the one having the worst efficiency, with 50.9 %, and D had the highest with 100%.

The mean efficiency of these units was similar to that obtained by Grasset (1997) and Brodersen and Thiele (1998), cited by Pardo Sempere (2001) in studies of entities dedicated to milk production. It also agrees with recent reports of Del Hoyo (2009 and 2011).

Pardo Sempere (2001) analyzed these means values and determined that they may be in correspondance with the sample size, which was higher in the previous referred studies. Other possible cause could be the selection criterion, as the variables and their weigths were not selected from subjective criteria as in the cited studies. However, the mean results are below those reached by Fraser and Cordina (1999), who found mean efficiency of 85.5% in studies of dairy exploitations

Table 1. Weight values of the studied variables in each principal component and variance explanation

Variables	Components		
	CP1	CP2	CP3
Milking cows	0.915	0.163	0.088
kg of milk	0.911	0.243	-0.043
Cost/kg of milk	0.162	0.133	-0.891
Result in sales	0.275	0.821	0.390
Result of the period	0.252	0.750	0.411
Activity gross margin	0.123	0.949	-0.155
Productivity	0.153	0.940	-0.067
kg milk/ha	0.939	0.190	-0.115
LAU/ha	0.808	0.098	0.180
Useful area, ha	0.197	0.265	0.546
Total	3.44	3.24	1.50
% of the variance	34.44	32.40	14.96
% acumulated	34.44	66.84	81.80

Table 2. Efficiency of DEA at CYS

BUCP	Efficiency, %
A	70.8
B	84.2
C	50.9
D	100.0
E	76.5
F	59.8
Mean	73.7%

of New Zealand. In respect to milk production under tropical conditions, the difference on pastures availability for cattle feeding between the rainy and dry season could have influenced on these results, so further studies to deepen in this aspect are needed.

The references for this analysis are based on the performance of milk production under other feeding and management conditions in general, without avoiding those of environmental and racial ones. Comparing these results with previous studies conducted in Cuban cattle rearing was not possible as no researches using this technique in Cuba were found. The closest reference to the Cuban milk production conditions is the research conducted by Del Hoyo Cid (2011), who applied the DEA in milk production of 25 dairy units in Central America.

Out of the BUCP analyzed, four had inferior efficiency to 80%. According to Jaforullah and Whiteman (1999), productive entities with efficiency values inferior to this number should be considered as an alert indicator for those in charge of taking decisions in the dairy production.

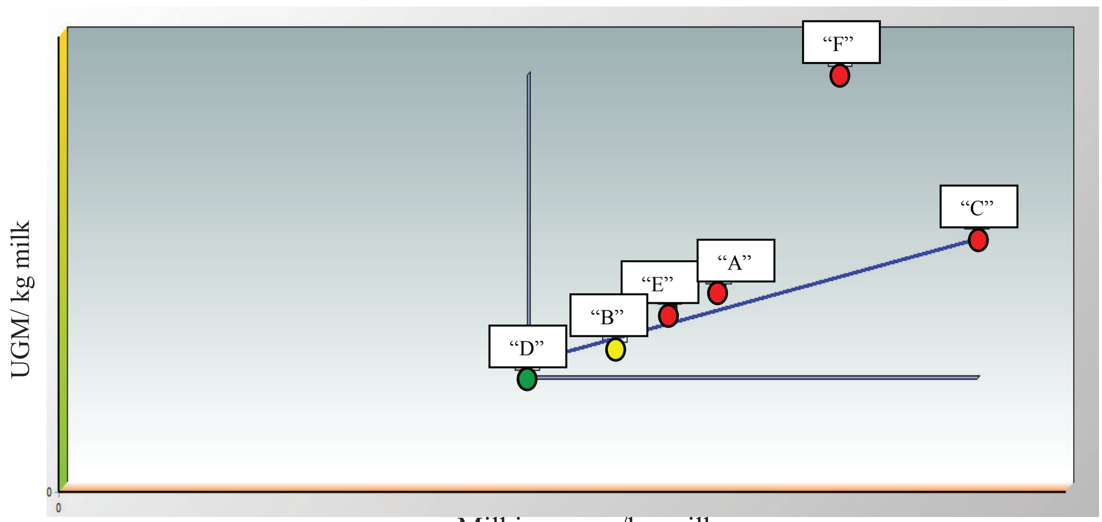

Figure 2. Efficiency frontier of the DEA

The figure 2 shows the efficiency frontier for the selected variables of input and output. The BUCP "D" defines this frontier of technical efficiency. The "C" is highlighted, the one at longer distance with inefficient level of 49.1%. The rest has inefficient in respect to the units in the frontier of 29.2 %, 15.8 %, 49.1 %, 23.5 % and 40.2 %, respectively.

In this model of the DEA at CYS, the efficiency of the BUCP "D" is justified by the behavior of efficiency weight that correlated the input and output variables. In the productivity rate between the input variable milking cows and that of the output, representing production (kg of milk/ha), the weight of resource use for this entity was of 0.4. This demonstrated that the highest production volume could be reached with the minimum use of resources. However, for the rest of the BUCP, it was as followed: A) 0.6, B) 0.5, E) 0.8y F) 0.6 and 0.7. In respect to the weight of the relation between the second income variable (LAU/ha) and that of the output, the performance was: D) 0.005, A) 0.01, B) 0.07, C) 0.1, E) 0.9 and F) 0.2. Due to the orientation towards the model product, these numbers mean lower need of supply of the input variables to achieve the levels in those of the output.

This study allows assessing the DEA utility to determine the technical efficiency of the productive units under study. It is demonstrated that the SMIM is a useful tool to know the weights of the input and output variables. Besides, with this type of analysis, their subjective assignation is eliminated. The efficiency frontier could be determined with this procedure, apart from its graphical presentation, making the results comprehension easier.

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