Analysis of dairy farms' efficiency by using Data Envelopment Analysis (DEA)

Tímea Gál[1]

In Hungary the dairy sector is in a long-term critical period, the stock has been in constant decline. The consumption of milk and dairy products in Hungary is slightly rising compared to the world tendency, and it is fallen behind the level in 1990. The milk consumption per capita in 2006 was 75 litres less than the EU-15 average.

Dairy enterprise is a very risky activity: the profitability of the enterprise is affected by the fluctuation of feed and animal health products prices from the side of inputs, and by the fluctuation of end-product prices. Under these circumstances it is vital for the cattle breeders, in order to survive, to harness the reserves in the breeding as effectively as possible.

In our research I made a multi-faceted efficiency analysis of an agricultural holding's three dairy farms. The chosen method for the analysis was Data Envelopment Analysis (DEA). The selection of the method is justified by the fact that there is not such a reliable database by which I could define production functions, and that DEA makes possible to manage several inputs and outputs, i.e. multiple decision problems, simultaneously. By using DEA the sources that causes shortfalls can be identified, analyzed and quantified on farms that does not operate efficiently, thus it can help the corporate decision support successfully.

In the model inputs are the cost data per one litre milk – feed, medicinal product use, logistic cost -, and the main parameters concerning the keeping and rearing. Outputs are indicators concerning milk production, milk quality and others.

I prepared the model in MS Excel, the linear programming model series were programmed by Visual Basic. After solving the model, in light of the shadow prices we can determine why either of the farms is not efficient.

Keywords: DEA analysis, efficiency, bovine sector

[1] Tímea Gál, PhD student, University of Debrecen, Centre of Agricultural Engineering and Economics, Coordination Centre for Logistics (Debrecen)

1. About DEA in general

The idea of *Data Envelopment Analysis* (hereinafter DEA) method is originated by Farrel (1951), who wanted to develop a method that is more suitable for measuring productivity. However, in 1978 Charnes et al. reformed this as a mathematical programming problem. This technique is a relatively new *"data-oriented" process*, which can be applied for measuring the performances of decision making units (DMU's) producing from several inputs several outputs (Cooper et al. 2004). Recent years the method of DEA has been used in many applications for performance measurement. It has been used for measuring the efficiency of a service's internal quality (Soteriou-Stavrinides 2000; Becser 2008), efficiency measurement of banks (Sherman-Ladino 1995; Tóth 1999), of educational (Tibenszkyné 2007) and other public bodies, and also for measuring the efficiency of business parks (Fülöp-Temesi 2000). However, its application in agricultural practice was not significant. The efficiency analysis of animal farms and agricultural production processes can be carried out by *simulation methods* (Szőke et al. 2009; Kovács-Nagy 2009), however, the quality of available database does not always allow the full mapping of technological processes. In these cases DEA is a more efficient tool.

DEA process has two known approaches: *input-oriented* (cost-oriented) and *output-oriented* (result-oriented). In case of the input-oriented approach we examine how much and which proportion the inputs should be used to minimize the cost at the same emission level. In the output-oriented approach we determine the partial increase of outputs without changing the quantity of inputs (Farrel 1957; Charnes et al. 1978).

This is complicated by the fact that we must take into consideration at efficiency measurement that not every input benefits in the same way: if we calculate with the intake on the same level we count with *Constant Return to Scale* (CRS), if not, with *Variable Return to Scale* (VRS) (Cooper et al. 2004).

2. Description of DEA model

It is an often arising question on a farm that in the course the operation of enterprise how efficient its units are working. The investment analysts are interested in the efficiency of competing participants within an industrial enterprise. DEA is a *linear programming application* by which the above-mentioned problems can be solved. In the course of DEA analysis we get the result that at what efficient level the inputs are transformed into outputs, so it is suitable to find the unit (plant, university, restaurant, etc.) which has the "best-practice" (Albright-Winston 2007). I apply the method of DEA to determine the frontier efficiency by the efficiently operating units (Tofallis 2001; Bunkóczi-Pitlik 1999).

Efficiency can be measured by output/input indices, thus:

$$E_i = \frac{\sum_{j=1}^{n_o} O_{ij} w_j}{\sum_{j=1}^{n_i} I_{ij} v_j} \quad \text{where} \tag{1.1.}$$

E_i : the efficiency of the i^{nth} unit

O_{ij} : the value of the i^{nth} unit's j^{nth} output factor

n_o : number of outputs

w_j : the evaluation of one unit of the j^{nth} output

I_{ij} : the value of the i^{nth} unit's j^{nth} input factor

n_j : number of inputs

v_j : the evaluation of one unit of the j^{nth} input

Objective function of the model:

$$\sum_{j=1}^{n_o} O_{ij} w_j \Rightarrow MAX\,! \tag{1.2.}$$

For every examined unit we solve a separate LP exercise by which the economic content of the objective function is the same, namely my aim is to maximize the value of the units' weighted outputs. After having solved all LP models, we get the best evaluation (input and output weights) as a result (Ragsdale 2007).

Constraints:

1. The efficiency of any unit cannot be greater than 100%.

$$\sum_{j=1}^{n_o} O_{kj} w_j \leq \sum_{j=1}^{n_i} I_{kj} v_j$$ (k=1,2,..., the number of units to be taken under the analysis)

that is

$$\sum_{j=1}^{n_o} O_{kj} w_j - \sum_{j=1}^{n_i} I_{kj} v_j \leq 0$$

2. For the sake of the calculations input prices should be scaled in a way that the input cost of the inth economic unit shall be 1 (Ragsdale 2007).

$$\sum_{j=1}^{n_I} I_{ij} v_j = 1 \qquad (1.5.)$$

3. Case study on dairy farms and the results of the analysis

In this DEA model I examined the efficiency of *three dairy farms*. These farms belong to one agricultural holding in the county of Hajdú-Bihar. For setting up and solving the model I used the holding's production and financial data for 2008. I took into consideration the variable costs and the average number of dairy cows as input factors, and the milk production for 305 days, from the milk quality data the average milk fat and milk protein content and the turnover as outputs. The aim of the analysis was *to examine the competitiveness* of the three farms within the holding, and in case of the inefficient farms to explore the critical factors, and to determine the direction of the occurring further analyses.

For the sake of the easier clarity in the linear programming model I marked the constraints with red colour, the variables with green colour and the objective function with blue colour. The maximum output values that I got by solving the LP model are in the DEA efficiency column (Figure 1.). On this basis it can be stated that considering the given input and output constraints the first and the third farms are operating efficiently, while the third one is not (DEA efficiency value is less than 1).

Figure 1. The DEA model that is suitable for doing efficiency analysis on dairy farms

	Outputs				Inputs					
Farm code	Milk for 305 days	Milk protein	Milk fat	Turnover	Variable costs	Number of dairy cows	Weighted output	Weighted input	Difference	DEA efficiency
	litre	%	%	M Ft	M Ft	heads				
1	8900	3,2	3,4	719	665	1050	1,6935	1,6935	0,0000	1,0000
2	8480	3,1	3,41	352	314	525	0,8468	0,8468	0,0000	1,0000
3	8630	3,25	3,39	389	379	620	0,9341	1,0000	-0,0659	0,9163
Weights	0,00000	0,01198	0,00000	0,00230	0,00000	0,00161				

	3
Output	0,9341
Input	1,0000

objective function

Source: Own model by using farm data

The analysis of shadow prices provides a further help to answer why the third farm is not operating efficiently compared to the first two farms. The LP model's shadow prices for the third farm can be seen in Table 1.

Table 1. Shadow prices after solving the LP model of Farm 3

Cell	Name	Final value	Shadow price
D16	Input 1	1,0000	0,9341
L7	Farm 1 Difference	0,0000	0,0565
L8	Farm 2 Difference	0,0000	0,9900
L9	Farm 3 Difference	-0,0659	0,0000

Source: Own calculations

Using the *shadow prices* of Farm 1 and Farm 2, which are considered efficient according to DEA, as weights we can 'make' such an input and output average vector that regards to a complex, hypothetic farm. The input and output characteristics of this farm can be compared with the current data of Farm 3, so the shortcomings and the factors that worse the efficiency can be explored (Table 2.).

Table 2 The characteristics of the composite farm 'made' by using shadow prices as weights

Farm code	Outputs				Inputs		Weights
	Milk for 305 days	Milk protein	Milk fat	Turnover	Variable costs	Number of dairy cows	
	litre	%	%	M Ft	M Ft	heads	
1	8900	3,20	3,40	719	665	1050	5,65%
2	8480	3,10	3,41	352	314	525	99,00%
3	8630	3,25	3,39	389	379	620	0,00%
Composit farm	8899	3,25	3,57	389	349	579	

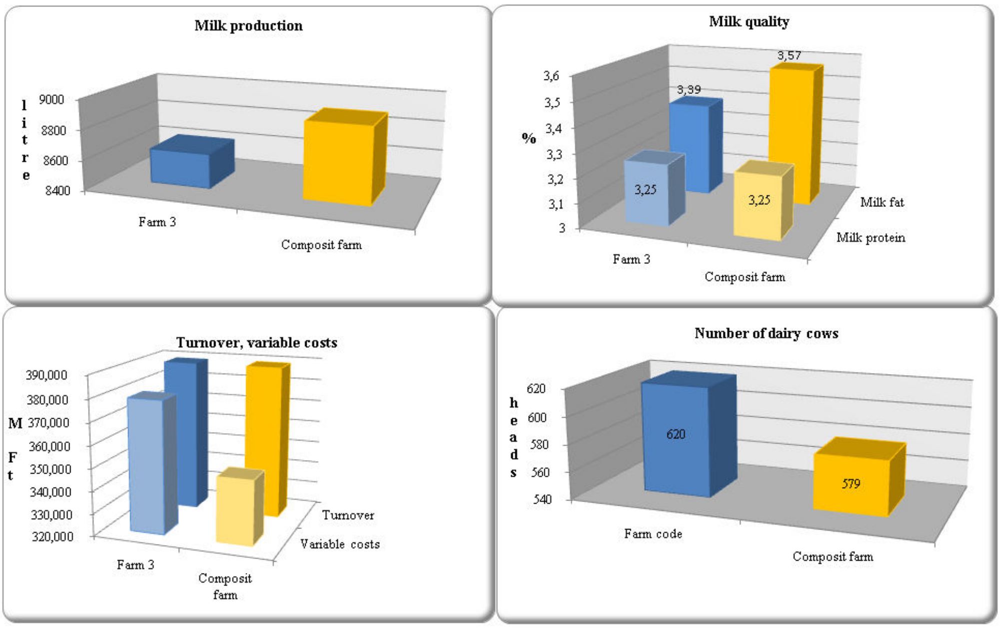
Source: Own calculations

For the input factors, both the number of dairy cows and the variable costs, a lack of balance can be seen between the composite farm and Farm 3. The number of dairy cows and the variable costs shall be also cut down. It can be observed that this should be done without reducing turnover, which presupposes the betterment of milk production and the quantity of milk fat from the quality parameters as well (Figure 2.).

The above data suggest that there are several significant technological, management or animal health problems, since the specific turnover for one cow is the lowest, 627 thousand Ft/year (687 thousand Ft on Farm 1, 667 thousand Ft on Farm 2). At a constant level of turnover we shall reach cost-reduction, yield-growth and quality improvement.

The results of the analysis suggest *the need for further examinations*. For the sake of production results and the improvement of quality considering the animal health and technological factors the proposal solution can be further fined, shaded.

Figure 2. Input and output factors on the inefficient Farm 3 and on the composit farm



Source: own calculations

References

Albright, S.C. – Winston, W.L. 2007: *Management Science Modeling*. Revised Third Edition, Thomson, 18-192. p.

Becser, N. 2008: Szolgáltatásminőség modellek. BCE Vállalatgazdaságtani Intézet, 89. sz. *Műhelytanulmányok*, 2008. január, 19.

Borsi, B. 2005: *Tudás, technológia és a magyar versenyképesség*. PhD. értekezés, 26-30. p.

Bunkóczi, L. – Pitlik, L. 1999: A DEA (Data Envelopment Analysis) módszer alkalmazási lehetőségei üzemhatékonyságok mérésére. *IA'99*, Debrecen,

1999. augusztus 26. http://miau.gau.hu/miau/08/dea.doc Letöltve: 2009. szeptember 5.

Charnes, A. - Cooper, W. - Rhodes, E. 1978: "Measuring the efficiency of decision-making units." *European Journal of Operational Research,* Vol. 2, 429–444. p.

Cooper, W. W. – Seiford, L. M. – Zhu, J. 2004: *Data Envelopment Analysis. International Series in Operations Research & Management Science,* Vol. 71. Chapter 1. 1-39. p.

Farrell, M. J. 1957: The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society,* Vol. 120, 253–281. p.

Fülöp, J. – Temesi, J. 2000: A Data Envelopment Analysis (DEA) alkalmazása ipari parkok hatékonyságának vizsgálatára. *Szigma* 32, 3-4, 85-110. p.

Kopasz, M. 2007: Útban a versenyképesség felé. *AVA3 konferencia*, Debrecen, 2007. március 20-21., www.avacongress.net/ava2007/Program_Booklet.pdf, Letöltve: 2009. szeptember 5.

Kovács, S. – Nagy, L. 2009: An application of Marcov chain Monte Carlo simulation. *Internal Congress on the aspects and visions of applied economics and informatics* (AVA4), Debrecen, 1333-1338. p.

Ragsdale, C. T. 2007: *Spreadsheet Modeling & Decision Analysis: A Prectical Introduction to Management Science*. Fifth Edition, Thomson, 102-113. p.

Sherman, H. D. – Ladino, G. 1995: Managing Bank Productivity Using Data Envelopment Analysis (DEA), *Interfaces* 25, No. 2, 60-80. p.

Szőke, Sz. – Nagy, L. – Kovács, S. – Balogh, P. 2009: Examination of pig farm technology by computer simulation. *Internal Congress on the aspects and visions of applied economics and informatics* (AVA4), Debrecen 1317-1325. p.

Tibenszkyné, F. K. 2007: *Az oktatás hatékonyságának mérése a ZMNE 2006-ban végzett hallgatóin Data Envelopment Analysis (DEA) módszer használatával*. Doktori PhD. értekezés, ZMNE, 149-165. p.

http://193.224.76.4/download/.../phd/.../tibenszkyne_forika_krisztina.pdf Letöltve: 2009. szeptember 5.

Tofallis, C. 2001: Combining two approaches to efficiency assessment. *Journal of the Operational Research Society* 52, 11, 1225–1231. p.

Tóth, Á. 1999: Kísérlet a hatékonyság empirikus elemzésére. *MNB füzetek* 1999/2, 11-33. p.