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ECONOMIC EFFICIENCY OF DAIRY FARMS WITH INTENSIVE AND GRAZING PRODUCTION SYSTEMS[1]

Rade Popovic[2]

Summary

The objective of this research was to examine efficiency of the most common milk production systems in central Serbia. Sample with 8 farms is not statistically representative, but allows use of Data envelopment analysis (DEA). Such technique allows measurement of whole farm efficiency and gives benchmarks for further farm analysis. DEA compare levels of input and outputs for a given dairy farm with all other analysed dairy farms, determining levels of efficiency for all farms with collected consistent data set. A DEA model to measure economic efficiency was developed. It measure efficiency of producing physical (milk) and economic outputs (income) by use of physical (labour and cows) and economic inputs (feed cost).

Results revealed that economic efficiency was achieved by three from eight farms. In total, milk production system with grazing period had higher level of efficiency 0,796 comparing with intensive production system with 0,579. But, in intensive milk production system one farm showed efficiency. This indicates that some other input variables like farmer's management capabilities influenced on efficiency.

Key words: *Economical efficiency, milk, Serbia, production system, dairy farm.*

JEL classification: *Q12*

1. Introduction

Dairy enterprise is the most complex between all farm enterprises. Inputs like: feed, labour, land, cows, equipment, mechanisation, buildings and managerial skills are combined to produce outputs: milk, calves and manure. Which

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combination of inputs farmers use to produce output depends of chosen production system. Generally, dairy production systems worldwide variate in range from low input – low output to high input – high output. In last decade dairy farmers all over the world faced high volatile of milk prices and increasing feed prices. Such trends strongly influenced especially on economics of intensive dairy production systems.

Milk production in Serbia is still dominantly based on family farms with herd size 1 to 5 cows. Although farm structure is slowly changing in recent decades, in 2010 those farms owned 77% of all cows in Republic of Serbia and produced 68% of total milk production. Small dairy farms usually utilize two production systems: tie stall barn throughout whole year, and tie stall barn with grazing period from May to October. Significance of this milk production segment raised several questions about future sustainability of such production systems, their efficiency, competitiveness etc.

Efficiency of some enterprise can be measured as partial and total. Examples of partial measures are: kg milk per cow, kg feed used to produce 1 kg of milk, milk sold per labour unit, etc. This measures of partial efficiency can cause a misleading indication of overall efficiency when consider isolated. Yet, if farmer decide to improve efficiency in use of one input it will influence use of other inputs.

Measure efficiency of the farming system as a whole is better alternative. Use of such approach asks for appropriate methods. The most applied methods in analysis of non-aggregated data are Data envelopment analysis (DEA) and Stohastic frontier analysis (SFA) (Coelly, Rao, O'Donnell, Battese, 2006). They are representatives of non-parametric and parametric methods, respectively. DEA is one of newest methods which can be applied in measurement efficiency of one decision-making unit (DMU) compared to other DMU in sample. Term DMU, cover in flexible manner any entity as a part of collection that utilizes similar inputs to produce similar outputs (Cooper, Seiford, Tone, 2006). It is very flexible model able to use from several to vast number of DMU. DEA is nonparametric method of calculating the efficiency of individual DMU such as dairy farm for performance measurement, analysis and benchmarking (Weersing et. al., cited in Stokes, Tozer, Hyde 2007).

The main advantage of DEA over SFA is that DEA does not require the specification of a functional form for the formation of production frontier (Kelly, et. al. 2013). Beside that DEA can be applied on smaller samples to measure relative efficiency. From farmer point of view, DEA information about specific sources of input or output inefficiency can be used to compare with identified benchmarks. Availability of data and mentioned advantages of DEA makes it preferred method in this research.

2. Material and methodology

Focus in this paper is on group of small dairy farms. Research was conducted in central Serbia, on two the most represented production systems: small dairy farms with tie stall barn and small dairy farms with grazing period. Data are collected on beginning of 2012 from 8 dairy farms in Kolubara Region. Each production system is represented by 4 farms. Period of analysis is 2011 production year for several reasons. It is year with average production conditions, milk prices were relatively stable on higher level and at national milk market were no extreme conditions (like in 2013 with afla-toxin affair).

Main characteristic of analysed production systems are presented in Figure 1. The difference between those two production systems is in chosen feeding, milking and marketing subsystems. Other subsystems are similar as breeding, calves rearing, milk collecting and housing. Looking on output side significant difference exist in milk yield of those two production systems. Beside those differences it can be concluded that both analysed production systems are on same technology level.

Inputs, from farm managers point of view can be grouped in controllable and non-controllable (Stokes, Tozer, Hyde, 2007). Controllable inputs are those over which manager has control, such as: production system, farm land area, barn type, breed type, labour use, number of cows, milking system, etc. Non-controllable inputs are those where manager has no control, as it is weather, prices of inputs and outputs, etc. Also, inputs can be separated according economic significance in cost structure on: important and side inputs. Inputs with highest shares in total cost of production are those on which manager has to look more carefully. In milk production feed costs are usually representing 50%, and labour cost can reach over 15% on small farms (Popovic, 2006; Popovic, Knezevic, 2012), so those two inputs are the most important here.

Chosen DEA model implemented to examine efficiency of dairy farms system in central Serbia is Charnes, Cooper, Rhodes model with input orientation (cited in Stokes, Tozer, Hyde 2007). Model estimates inefficiency with respect to inputs as opposed to the outputs. It is implemented as a linear program expressed for each DMU *j* as:

$$\min \theta_j \tag{1}$$

$$\theta_j x_{jm} \geq \sum_{k=1}^{K} x_{km} \lambda_{jk} \quad \text{for all m} \tag{2}$$

$$\sum_{k=1}^{K} y_{ki} \lambda_{jk} \geq y_{ji} \text{ for all i} \tag{3}$$

$$\lambda_{jk}, \theta_j \geq 0 \tag{4}$$

Factor	Small farms with tie stall barns	Small farms with grazing period
Milk yield	From 3,400 to 5,200 l	From 2,700 to 4,500 l
Breed	Dominantly Simmental	Dominantly Simmental
Breeding	Artificial insemination	Artificial insemination
Calving	Through all year	Winter or early spring
Calves	0.93 calves per cow, sold on market after 10 days or 2-3 months depends of market situation, female reared for replacement as needed	0.92 calves per cow, sold on market after 10 days or 2-3 months depends of market situation, female reared for replacement as needed
Culling rate	14 – 17%	17%
Labour	330 hours/cow/year	300 hours/cow/year
Bulk feed	Whole year fed in barn with mainly corn silage or corn stover, red clove hay, seldom meadow hay and feed by-products.	Grazing from May to end of October; in rest period use mostly meadow hay, red clove hay and seldom corn silage
Concentrate	From 4 to 5.5 kg concentrate mainly mixed on the farm from own cereals, roasted soybean and bought: soybean meal, wheat bran, sunflower shell, mineral supplements	From 3.5 to 4.5 kg concentrate mixed on the farm from own cereals and bought: soybean meal, wheat bran, sunflower shell, mineral supplements
Housing	Cows tied all year round in stalls barn	Cows tied in barn during winter and raining days
Milking	Cows are milked two times in the barn by portable machines without pulsators	Cow are milked two times in the barn by hand or portable machines without pulsators
Milk collecting	Several close living farmers collect milk on one farm in cooling tank provided by dairy plant	Several close living farmers collect milk on one farm in cooling tank provided by dairy plant
Milk marketing	Dairy plant	Dairy plant and local market

Source: Popovic, Knezevic, 2012 and Goss et. al. 2010

Figure 1 Characteristics of dairy production systems practiced on small farms, based on two samples with 4 farms each

where, θ is scalar and represent efficiency score for each DMUj. Inputs are indexes with m so that x_{jm} is the amount of input m used by DMU j, and x_{km} is the amount of input m used by each of the other K DMU. Outputs are indexes with i, so that y_{ji} represents the amount of output i produced by each of the other K DMU. Linear

program must be solved K times, once for each farm in the sample. A value θ is than obtained for each farm.

The objective of linear program is to find an optimal set of weights denoted by λ_{jk} that satisfy the $m \times i$ constrains and give an efficiency score denoted by $0 \leq \theta_j \leq 1$.

DEA model were calculated using MS Excel Solver, with assumption of constant return to scale. Such assumption requires that every increase of input will result in a proportional output increase. Model was solved for each DMU, comparing its inputs and outputs against all other DMU in data set.

There are several important issues that have to be satisfied before using DEA. First is definition of DMU, which is in this case dairy farm from same herd size group and technology level. Second, all DMUs should use same input set to produce same set of outputs. In other words it means use of same or similar production system. According Sale and Sale (2009), ideally all important inputs are used and outputs are produced by all DMUs. Third, data should avoid double-counting approach, so each input and output should measure unique elements of production system. Fourth, region of production can affect efficiency, so DMUs in sample should be from same region. And last, but not list like in application of any other model the core issue is in quality and reliability of data.

3. Results

Collected data were stratified to production systems. Farms numbered from 1 to 4 represent small farms with tie stall barn, and from 5 to 8 small farms with grazing period. Both production systems have a same production technology level. All examined farms are from same region, what maintaining homogeneity of data set.

Selected physical as well as economic inputs and outputs data are shown in Table 1. Labour full time employed (FTE) represent unit of labour with 2,400 working hours per year. In literature FTE varied from 2,400 to 3,000 working hours per year (Jeffrey, Grant 2001, Hyde, Dunn 2002, Colman, Farrar, Zhuang 2004). It counts only labour for activities in dairy enterprise: milking, feeding, cleaning, herd management, manure disposal and building and equipment maintenance. Labour included indirectly in producing crops and forage for feed is not calculated to avoid double counting in costs since local market feed prices were applied. Land as input is not included here separately because cost of land is included in feed cost. Number of cows represents average number throughout year. Feed cost includes costs of concentrate and forage. Physical output is represented by average milk yield in kg, and economical with net income from dairy enterprise.

If data are available, DEA could use many other physical inputs like: ha of land, kg or dry matter of concentrate and forage, kg of fertilizer for pasture etc., and

economic inputs: values of physical inputs, other direct cost, overhead cost, etc. On output side additional physical outputs can be: number of sold calves, tonnes of manure, kg of live weight excluded cows, etc., and as economic outputs can be used values of: milk sold, milk solids, livestock sold, etc.

Table 1: Inputs and outputs used in Data envelopment analysis models

	Input 1	**Input 2**	**Input 3**	**Output 1**	**Output 2**
DMU	**Labour (FTE)**	**Cows**	**Feed cost (RSD)**	**Milk production (kg/cow/year)**	**Net income (RSD)**
1	0,277	2	112.515	3.389	29.467
2	0,456	4	283.363	3.378	66.061
3	0,570	3	269.048	5.195	269.914
4	0,624	5	386.279	3.439	70.735
5	0,592	5	326.709	4.506	393.913
6	0,364	3	166.848	3.564	116.143
7	0,524	4	230.190	2.670	71.923
8	0,144	1	66.932	3.525	31.270

A DEA model is developed to measure economic efficiency of producing physical (milk) and economic outputs (income) by use of physical (labour and cows) and economic inputs (feed cost). All efficiency score in DEA are in range from 0 to 1. Where, score 1 shows efficient farm, and result closed to 0 shows inefficient farm. Result of economic DEA model reviled that 3 out of 8 dairy farms were identified as DEA efficient. Those farms do not have input or output inefficiency and their DEA efficiency scores are equal to 1. Dairy farms 5 and 8 are from production system with grazing period. Farm 3 is from intensive production system, and has highest milk yield in the group. In average, efficient farms produce 4.541 kg milk/cow, and 77,233 RSD/cow of net income, using 0.435 FTE, 3 cows and 73,632 RSD/cow feed value. Inefficient farms use 0.449 FTE, 4 cows and 65,511 RSD/cow feed value to produce 3,387 kg milk/cow and 19,685 RSD/cow of net income. Milk yield is 1,154 kg higher in case of efficient farms, as well as feed costs and net income per cow.

Looking over calculated efficiency data farms from production system with grazing period (5 to 8) have in average higher efficiency score 0.796, than farms with intensive production system (1 to 4), which scored 0.579. Dairy farms with tie stall barn use: 75,086 RSD feed value/cow and 0.138 FTE/cow to produce 3,966 kg milk and 31,156 RSD of net income/cow. Dairy farms with grazing period use: 60,821 RSD feed value/cow, 0.125 FTE/cow to produce 3,673 kg milk and 47,173 RSD of net income/cow. It infer that reason of higher efficiency lies in relation

lower use of inputs (labour and feed) with moderate output (milk yield), that results in higher net income. Good management practice is observed on few farms, but in both production systems, so it is source of efficiency for farms 3 and 5.

Table 2: Result of economic Data envelopment analysis model

DMU	Efficiency	Slack labour (FTE)	Slack feed (RSD)	Actual milk production (kg)	Target milk production (kg)	Target net income (RSD)
5	1,0000	0	0	4.642	4.642	0
8	1,0000	0	0	3.631	3.631	0
3	1,0000	0	0	5.351	5.351	0
6	0,7656	0,0299	0	3.671	3.867	0
1	0,5949	0,0204	0	3.490	3.631	1.802
7	0,4173	0,0240	0	2.750	3.744	0
2	0,4104	0	24.424	3.479	3.728	0
4	0,3095	0	24.355	3.542	3.741	0

Sources of inefficiency of other farms are slack of labour and slack of feed cost. Slack value of inputs indicates its amount by which a DEA model constraint is not satisfied with equality, and represents amount of input which is overused relative to how efficient farms use the input. Model didn't report any slack of number of cows. Target milk production and net income level shows at which level of output inefficient farms will become efficient, with use less of slack inputs.

Inefficient farms 6, 1 and 7 use some amount of labour more than efficient once, and farms 2 and 4 overuse feed. Farm 7 has biggest difference in milk target, almost 1,000 kg, and it can be due low genetic of herd.

One problem observed in this research is about of appropriate number of inputs and outputs used in DEA with smaller number of DMU. When more inputs and outputs includes in model with smaller number of farms, results of economic efficiency tend to be all very close or equal to 1. So, it was reason to keep focus only on main inputs and outputs for DEA model in this research. It leads to conclusion that use of more inputs and outputs, both physical and financial, are more appropriate for bigger number of farms in sample.

4. Conclusions

The aim of article was to investigate economic efficiency in two most represented dairy production systems in central Serbia. Data envelopment analysis with constant return to scale assumption was applied. Results reviled that efficient farms

exist in both production systems. But, production system with grazing period has higher overall efficiency score. Production strategy low input low output provide more net income for dairy farmers oriented to use grazing period in milk production. Besides that, possibility of use crossbreeds, as genetically improvement gives benefits to pasture grazing system in the way that cows are healthier and more resistant. Further, on cost side there is lower rate of replacement cows and lower production costs.

Looking in wider scope it is well known that on world milk market the highest efficiency is achieved in countries where intensive grazing production systems are dominant, like in New Zealand, Australia and several South America countries. Dairy farmers in mentioned countries practice production system which is based on relation low level of inputs and moderate level of outputs. Grain price trends in previous years gives the stronger position of this production system since it become more economically sustainable. Additionally, grazing milk production system has fewer burdens in ecological and social sustainability aspects.

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