IDENTIFYING BENCHMARKS IN MILK PRODUCTION

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Abstract

This article is a study of the use and importance of benchmarks in the dairy industry's milk production segment. Employing Data Envelopment Analysis (DEA), a technique of Mathematical Programming, we analyzed a sample of 54 milk production systems used by members of the Central Cooperative of Rural Producers of the State of Minas Gerais, Brazil (CCRP-MG). We found an estimated average technical efficiency of 83.7%, which shows that it is possible to reduce production factor costs to 16.3% of total costs without compromising the activity's average gross revenue. We also found average scale efficiency to be 85.7%, showing that it is possible to raise the systems' average gross revenue about 13.3% through production scale adjustments.

Key-Words: benchmarks, milk production, mathematical programming, technical efficiency, efficiency to scale.

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1. Introduction

Production managers must know if an idealized program to improve system operations will be executable. The urgency, direction, and priorities of a planned production improvement will be partially determined by the actual performance of the existing productive system: is the system's performance judged to be good, bad, or fair. Thus, evaluation using some type of the performance measure is a pre-requisite for system improvement. The use of a benchmarking approach to compare milk production systems is of fundamental importance in the milk production system evaluation process.

The term benchmark is derived from land surveying, in which the benchmark is a physical mark used as a reference point. In 1989, the Xerox Corporation used the term "benchmarking competitive competitor" to describe a process. The term is now commonly used in the business arena.

According to Slack et al. (1996), there are many different types of benchmarking that are not necessarily mutually exclusive. Among them, we can cite:

Internal Benchmarking – a comparison between operations or parts of operations within the same organization. For example, a big manufacturer with many factories can compare each factory against some benchmark or use a particular factory as a benchmark to evaluate the others.

External Benchmarking – a comparison of one operation in one organization with the same type of operation in another organization.

Non-Competitive Benchmarking – a comparison between outside organizations that do not directly compete in the same market.

Competitive Benchmarking – a direct comparison between competitors in the same or similar markets.

Performance Benchmarking – a comparison between levels of performance reached in different operations. For example, one organization can compare their own performance in terms of some or all of their own objectives of performance – quality, high production, costs – to the same performance variables found in other organizations.

Practical Benchmarking – a comparison between the operations or production processes of one organization with those used by other organizations. For example, one big retail store can compare its inventory control systems and procedures to those used by other department stores. The objective of this type of benchmarking is to find if practices used by other organizations to improve efficiencies can and should be transferred to the operational practices of their own organization.

Milk producers intuitively look for benchmarks when examining milk production systems (MPS) used by other private producers or on governmental experimental farms. Unfortunately, it cannot be assumed that the MPS visited were benchmarks. This is the big question: how to identify milk production systems that qualify as benchmarks?

Linear programming, supported by the modern economy of production, can be used as an instrument to identify production systems to benchmarking. Starting with an input-output sample from several systems, linear programming allows the construction of a frontier of efficient production systems made up of one or a combination of efficient producers that are analogous with a particular MPS, thus permitting comparison between the particular system and like systems. It should be noted that the estimation of the frontiers in microeconomy presupposes system optimizing behavior, in other words, an efficient transformation of inputs (rations, labor, medicines, etc.) into outputs (in milk production, the value of production or the dairy activity's gross revenue).

Benchmarking can be a valuable instrument for the producers. It can also facilitate the work of the researches and rural extension services, since the efficient production systems or frontier systems (benchmarks) are technology demanded and the inefficient systems are technical assistance and rural extension demanded.

Data Envelopment Analysis (DEA) is the linear programming method is most commonly used to construct frontiers. A detailed description of the method can be found in Seiford and Thrall (1990), Lovell (1993), Ali and Seiford (1993), Lovell (1994), Charnes et al (1995), Seiford (1996), Souza et al. (1996), Alves and Gomes (1998) and Gomes (1999). Alves and Gomes (1998) and Gomes (1999) used DEA to estimate, respectively, the economic efficiency and the technical efficiency of milk production systems in the State of Minas Gerais, Brazil.

2. Methodology

2.1 Source of Data

Our research uses cross sectional data gathered from a sample of 54 milk production systems (MPS) selected among producers allied with the Central Cooperative of Rural Producers of Minas Gerais – CCRP-MG (Itambé). The selected producers all participated in the rotational elephant-grass pasture financing program.

The research area was the municipal districts of Sete Lagoas, Pompéu, Bom Despacho, Abaeté, and Pará de Minas in the west-central region of the Brazilian state of Minas Gerais. The research period was twelve months ending in either April or June of 1999. The decision variables used to construct the frontier of efficiency are typical of the classic production function and act as proxies for the amount of product sold and the amount of capital and labor used.

The gross-revenue (GR) of the MPS was used as proxy for the annual amount of milk sold by the MPS and other incomes (culled animals and sold manure). As a proxy for the amount of labor used in the production process, we adopted the value of expenses for salaries and duties (ESD). The amount of food consumed at the MPS was considered to be the actual cost of concentrated food, silage, and pasture maintenance (CCSMP). The actual cost of vaccines, medicines, cleaning items, and artificial insemination material were combined as a separate variable (CVMAIN). The capital applied to pastures (RCAPP), cattle (RCAPC), and installations, machines, and equipment (RCAPIME) represented the amount of fixed capital utilized in the each system's productive process. Remuneration for the cost of capital used in the productive process was considered as a tax of 6% per year on the actual value of the total capital spent.

2.2 Theoretical Model

Coelli (1996) considered the best way to exploit DEA is by using proportions. For each firm the proportion of all products used in all production factors was obtained, such as $u'y_i / v'xi$, where u is a vector Mx1 of weight of products (y_i) and v is a vector Kx1 of weight of the production factors (x_i).

For the problem of linear programming, optimal weights were estimated in the following manner:

$$\text{Max } (u'y_i / v'x_i), \quad (1)$$

Submitted to

$$u'y_j / v'x_i \leq 1, \qquad j = 1,2,\ldots,n,$$
$$u, v \geq 0 \qquad v'x_i > 0$$

This requires one to obtain values for u and v so that the measure of the efficiency of firm "i" will be maximized, with the restriction that all efficiency measures would be smaller or equal to 1. One problem with this particular type of proportion is that it has an indefinite number of solutions. To avoid this, we can impose the restriction $v'x_i = 1$, that provides:

$$\text{Max}_{u,v} (\mu' y), \quad (2)$$

submitted to:

$$\nu' x_i = 1,$$

$$\mu' y_j - \nu' x_j \leq 0 \, , j=1,2,...,n,$$

$$u, v \geq 0$$

Where μ e ν reflects the transformation of u and v. This form is known as a *multiplier* of linear programming problem.

Using the duality principles in linear programming, we can derive an equivalent envelope for this problem:

$$\min_{\theta \lambda} \theta \qquad (3)$$

Submitted to:

$$-y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0,$$

Where θ is a scale, the value of which will be the efficiency measure of firm "i". Parameter λ is vector Nx1, the values of which are calculated to obtain an optimal solution. For an efficient firm, all of the values of λ will be zero. For an inefficient firm, the values of λ will be the weights, used in the linear combination of other efficient firms, that have an influence on the projection of the inefficient firm on the calculated frontier. This means that for an inefficient unit there is at least one efficient unit, and its calculated weights will provide a "virtual firm" of the inefficient firm by means of linear combination. The efficient units when combined provide a virtual firm for the inefficient firm, and they are known as pairs or benchmarks of that firm (Gomes, 1999).

This pattern evolves fewer restrictions than the pattern of the multiplier (K+M < N+1) and is therefore the preferred solution. The value of θ obtained will be the score of efficiency for firm "i" and the condition that $\theta \leq 1$ will be satisfied with the value of "1" indicating a point on the frontier and thus an efficient firm. Note that the problem of linear programming should be solved N-times, once for each firm in the sample.

The measure of efficiency obtained from equation (3) is oriented to the production factors, assuming constant returns to scale (CR) for the technology.

Besides the assumption of CR, we can consider variable returns to scale (VR) for the technology. The assumption of CR is only appropriate when all firms are operating at an optimal scale. This way, the problem of linear programming with constant returns to scale, as represented in the equation (3), can be easily modified to attend the assumption of VR by the addition of a restriction of convexities: $N1'\lambda = 1$, as it was demonstrated in the equation (4):

$$\min_{\theta,\lambda} \theta \qquad (4)$$

Submitted to:

$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$N1'\lambda = 1$$
$$\lambda \geq 0,$$

Where N1 is a vector N x 1 of units. This restriction forms a convex curve that "envelopes" the points in a more adjusted way than the coned curve of CR, and so it provides scores of technical efficiency bigger or equal to the ones obtained using the CR model. The restriction of convexity ($N1'\lambda = 1$) essentially assures that the inefficient firm is only "benchmarked" with a firm of equal size. The projected point to the firm over the frontier of DEA will be a convex combination of observed firms. So, in the case of the DEA with CR, the firm can be benchmarked against the firms that are substantially bigger (or smaller) than itself (Coelli, 1996). In this case the λ weights can be added to a value bigger than 1.

Given the assumption of VR to the technology, the technical efficiency scores obtained over the assumption of the CR can be decomposed in two components: (i) first the inefficiency to the scale and (ii) pure technical inefficiency, as represented by equations (5) e (6):

$$ET_{CR} = ET_{VR} \times E_{SCALE} \quad (5)$$

$$E_{SCA} = ET_{ECR} / ET_{VR} \quad (6)$$

Where:

ET_{ECR} is the technical efficiency obtained over the assumption of CR;

ET_{VR} is the technical efficiency obtained over the assumption of VR;

E_{SCA} is the efficiency of scale;

The efficiency of scale measurement obtained in equation (6) does not indicates if the firm is operating in an area of increasing or decreasing returns to the scale. This problem can be avoided by solving for an additional DEA problem with non-decreasing returns to the imposed scale. For that, we modify equation (4) by substituting for $N1'\lambda = 1$ with $N1'\lambda \leq 1$, obtaining:

$$\min_{\theta'\lambda} \theta \quad (7)$$

Submitted:

$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$N1'\lambda \leq 1$$
$$\lambda \geq 0,$$

The increasing and decreasing returns from scale are calculated considering the difference between the technical efficiency scores obtained by the solution of the DEA problem in equation (4) and the ones obtained by the solution of the DEA problem in equation (7). Equal scores indicate firms operating with decreasing returns to scale and the opposite with increasing returns. For more details, see Coelli (1996).

The restriction $N1'\lambda \leq 1$ assures that firm "i" will not be "benchmarked" against substantially larger firms but can be compared to smaller firms.

2.3 Procedures used to calculate the MPS efficiency scores

The solutions to the linear programming problems of equations 3, 4 and 7 provide the efficiency scores used in this research. In the referred equations, X is the production factors' (inputs) matrix (ESD, CCSMP, CVMAIN, RCAPP, RCAPC, RCAPIME) with dimensions of (K x N). Y is the vector of products (GR) with dimensions of (M x N) and represents the data of all MPS in the sample. The symbol x_i represents the vector of the column of production factors, and the symbol y_i is the vector of the column of products representing firms "i". The Greek letters θ, e, and λ were previously defined.

The program used to solve the linear programming problems was DEAP - A Data Envelopment Analysis Program – developed by Coelli (1996).

3. Results and Discussion

The technical efficiency and scale scores of the 54 milk production systems and their respective "benchmarks" are shown in Table 1. The scores for efficiency were obtained assuming constant returns to scale (CR) and variable returns to scale (VR). Those MPS showing increasing returns (IR) and decreasing returns (DR) are also identified in Table 1. The benchmarks relate to technical efficiency scores obtained under the assumption of variable returns to scale.

Assuming constant returns to scale for the 54 producers, the average technical efficiency was 0.713 or 71.3%. This indicates that the producers can, on average, reduce up to 29.7% of their production factor expenses without compromising the revenue obtained from the sale of milk.

The average technical efficiency assuming variable returns to scale was 83.7%, indicating that the producers can, on average, reduce up to 16.3% of their production factor expenses without compromising the revenue obtained from the sale of milk.

The average efficiency to scale was 0.857 or 85.7%. Thirty seven MPS, approximately 68.52% of the sample, were in the area of increasing returns. This means that these MPS can increase their gross revenue by raising their production scale. Another 5 MPS, representing around 9.3% of the sample, are operating in the area of decreasing returns. These systems can raise their gross revenue by reducing their production scale. The other 12 systems, representing 22.22% of the sample, obtained constant returns to scale.

Gomes (1999), using DEA to estimate the technical efficiency and scale of 241 milk producers production systems in Minas Gerais, found technical efficiency and scale values of 91% and 94% respectively, above the values obtained through our study. In both studies, the technical efficiencies and scale estimated are above the values expected for milk production systems in Brazil.

Presuming constant returns to scale, we found that 12 MPS, 22.2% of the sample, reached the maximum for technical efficiency. By presuming variable returns to scale, 25 MPS, 46.3% of the sample, reached the maximum for technical efficiency.

Table 1 shows the reference systems or "benchmarks" for each MPS against the other analyzed MPS, sort of a benchmark border in which a group of systems define each specific sample MPS. For example, milk production system 1 could rationally be benchmarked against systems 29, 39, and 50.

From this type of analysis we can construct an individualized report fundamentally import to the production management of each production system. As an example, a brief individual report for MPS 1 is presented in Table 2 and MPS 2 in Table 3.

Table 1
Summary of Efficiency

MPS	CR	VR	Scale	IR or DR	Benchmarks	MPS	CR	VR	Scale	IR or DR	Benchmarks
01	0.661	0.678	0.976	DR	29,39,50	28	0.412	0.625	0.659	IR	36,32,7
02	0.428	0.471	0.909	IR	34,43,33	29	1.000	1.000	1.000	----	29
03	0.376	0.573	0.656	IR	26,43,39,12	30	0.587	0.598	0.982	DR	50,54,37,39,29
04	1.000	1.000	1.000	----	4	31	1.000	1.000	1.000	-----	31
05	0.535	0.551	0.971	IR	33,39,34	32	0.516	1.000	0.516	IR	32
06	0.649	0.654	0.993	IR	54,38,34,33	33	1.000	1.000	1.000	----	33
07	0.451	1.000	0.451	IR	7	34	1.000	1.000	1.000	------	34
08	0.561	0.627	0.893	IR	43,34,26	35	0.388	1.000	0.3888	IR	35
09	0.598	0.635	0.941	DR	29,39,50	36	0.761	1.000	0.761	IR	36
10	0.748	0.793	0.943	IR	37,54,18,43,38	37	1.000	1.000	1.000	----	37
11	0.519	0.526	0.985	IR	50,37,18	38	1.000	1.000	1.000	------	38
12	0.569	1.000	0.569	IR	12	39	1.000	1.000	1.000	------	39
13	0.838	0.854	0.982	DR	50,29,25	40	0.840	1.000	0.840	IR	40
14	0.799	1.000	0.799	IR	14	41	0.293	0.578	0.507	IR	39,31,43,12
15	0.516	0.616	0.837	IR	39,27,37	42	0.783	0.860	0.910	IR	14,43,18,39,37
16	0.699	0.900	0.777	IR	34,7,18,31,43,14	43	0.909	1.000	0.909	IR	43
17	0.640	0.922	0.694	IR	43,27,37	44	0.408	0.425	0.959	IR	54,50,37,39,18
18	0.965	1.000	0.965	IR	18	45	0.550	1.000	0.550	IR	45
19	0.603	0.649	0.928	IR	37,50,18	46	0.802	0.836	0.959	IR	50,39,18
20	0.837	0.838	0.999	DR	33,54,29,37,39	47	0.505	0.859	0.587	IR	27,38,36,32,51
21	0.806	0.836	0.964	IR	18,39,50	48	0.704	0.710	0.991	IR	18,50
22	0.708	0.793	0.893	IR	18,37,32,38	49	0.861	0.877	0.982	IR	37,43,39,18
23	0.618	0.621	0.995	IR	54,50,39,37,18	50	1.000	1.000	1.000	----	50
24	0.415	0.426	0.973	IR	50,18	51	0.795	1.000	0.795	IR	51
25	1.000	1.000	1.000	----	25	52	1.000	1.000	1.000	------	52
26	0.852	1.000	0.852	IR	26	53	0.489	0.875	0.559	IR	7,31,43
27	0.487	1.000	0.487	IR	27	54	1.000	1.000	1.000	----	54

Source: Research data

Table 2 - Individual Report of Results and Analysis: MPS 1.

Summary of the MPS				
Variables	Observed Value	Radial Movement	Slack	Projected Value
GR	139,953.60	0.00	0.00	139,953.60
ESD	21,963.00	-7.082.14	-4,933.33	9,947.54
CVMAIN	6,357.60	-2,050.06	-916.14	3,391.41
CCSMP	34,598.09	-11,156.42	-3,286.24	20,155.43
RCAPP	597.48	-192.66	-0.000	404.82
RCAPC	11,640.00	-3,753.41	0.000	7,886.60
RCAPIME	23,920.90	-7,713.48	-7,847.23	8,360.20

Benchmarks: MPS 29, 39 and 50 — Weights (λ): 0.004; 0.326 and 0.671

Technical Efficiency (θ): 0.678 or 67.8 % — Scale Efficiency: 0.976 or 97.6 %

Source: Research data

Table 2 shows that MPS 1 had a technical efficiency average of 67.8 % in relation to its benchmarks, meaning that relative to its benchmark production systems MPS 1 spent 33.2 % more than needed to obtain its gross revenue of R$ 139,953. This can be verified by estimating the ratio between the sums of the projected expenses (obtained by the difference between the observed expenses and the sum of the values of the radial movement and the slack)[3] and the observed expenses. For each R$ 1.00 invoiced, MPS 1 spent R$ 0.71 (observed expenses for production factors and remuneration of capital / gross revenue) while its main benchmark, MPS 50 ($\lambda = 0{,}671$)[4], spent R$ 0.55 for each R$ 1.00 invoiced (Table 3). Excess spending could have gone to labor, feed, animal health care or artificial insemination or can be considered as lost remuneration if capital had been inefficiently invested in pastures, cattle, machines or equipment.

[3]See Coelli et al. (1998) and Gomes (1999) for an explanation of the slack in the linear pattern of the non-parametrical border obtained by DEA. The value of the radial movement represents the firm's inefficiency relating to the border. The measurement of efficiency of the firm is a radial measurement. For more details, consult Coelli (1996).

[4] The main benchmark or the efficient producer that has the biggest influence in the efficiency measure of the inefficient producer, is the one that has the biggest weight (l); projection of the inefficient point to another efficient point found in the group of solutions of the linear programming problems.

Table 3 - Individual report of results and analysis: MPS 50.

Summary of the SPL				
Variables	Observed Value	Radial Movement	Slack	Projected Value
GR	108,752.00	0.000	0.000	108,752.00
ESD	13,306.40	0.000	0.000	13,306.40
CVMAIN	3,793.42	0.000	0.000	3,793.42
CCSMP	27,624.66	0.000	0.000	27,624.66
RCAPP	390.90	0.000	0.000	390.90
RCAPC	5,267,40	0.000	0.000	5,267.40
RCAPIME	9,917.07	0.000	0.000	9,917.07

Source: Research data

4. Conclusions

This research tries to emphasize the importance of the empirical identification of milk production benchmarks. The benchmark serves the purposes of researchers and extension services, facilitating identification of the technological and training needs of each analyzed milk production system. The method used to identify benchmarks generates individual reports that aid in the evaluation the technical efficiency and production scale and provide each system's management a reference to advance the rational use of milk production factors. Adoption of this analytical method by technical support services allied with milk cooperatives and private dairy companies will contributed to a substantial economy of scarce recourses.

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