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Efficiency and selection of benchmarks in milk production in Minas Gerais - Brazil

This study proposes to identify efficient production units in Brazilian dairy farming. For this purpose, Data Envelopment Analysis and its extensions were applied on the information gathered at 659 milk producing properties. The results obtained reveal the importance of technical efficiency at improving technical and economic performance of such properties. It is observed that the main benchmarks present higher results than the averages of the efficient properties. These results demonstrate the importance of working efficiently and that efficient practices should be disseminated in the dairy segment, directing the programs of rural extension and technology diffusion, creating a virtuous and beneficial cycle, not only for the producer, but for the whole milk production chain.

1. Introduction

Economic and social development is closely related to knowledge and innovation, playing key roles in present-day societies. This proposition is presented as an internationally adopted model, making it necessary to review and promote strategies that guarantee advances in the various productive activities.

One of these strategies is the study of productive chains, systems formed by a set of economic sectors that establish market relations among themselves, which, articulated in the productive process, involve all production activity and commercialization of a product, so that, in the course of the chain, there is added value. The chain of production can also be understood as «a succession of dissociable transformation operations capable of being separated and linked to themselves by technical chaining» (Batalha, 2007: 6).

The studies of productive chains, which can be traced back to those of Perroux (1977), have been characterized by the understanding and explanation of the marked competition of organizations in complex, dynamic and uncertain environments. Several analytical theories and methodologies have been well-founded and presented, albeit with most of them affirming the need for

a more systemic and chained vision in relation to the variables affecting this organization's competitiveness (Araújo and Silva, 2014).

In this way, the studies based on productive systems have been widely used for proposing policies and strategies aimed at optimizing these systems. The idea of a production chain is useful as a method for analyzing firm strategies, as a space for analysis of technological innovations and as an instrument for elaborating strategies (Simioni *et al.*, 2007).

Dairy farming in Brazil is one of the chief productive chains, holding great economic and social significance. In recent years, it has undergone considerable changes on technical, as well as operational and institutional levels, through numerous modifications of strategies and public policies developed and applied to the sector. All these changes provoked reactions and adaptations in the institutional environment of the productive chain, directly interfering in the commercial, structural and organizational context of the Brazilian dairy sector (Oliveira and Silva, 2012).

Milk activity in Brazil has its particular characteristics, being little specialized, relying on family work and scarce resources. However, given the high complexity of this production chain, there is a need for producer specialization as well as the incorporation of technological innovations that are justified by sanitary and productivity issues (Zoccal *et al.*, 2005).

In 2013, milk production was the fifth largest in the Gross Value of Production (GVP) of Brazilian agriculture, placing the country as the fifth largest producer of fluid milk and fourth of powdered milk (IFCN, 2014) and playing a relevant role in the country's economic and social development. About five million people are working in the milk sector (CNA, 2011), with 1.35 million producers (IBGE, 2012). About 80% of the establishments are farms with production of up to 50 liters per day, representing only 26% of the national production, Minas Gerais, Brazil's main milk producing state (IBGE, 2012).

Despite the prominence in production, Brazil is not included among the countries that produce milk with high productivity. This low productivity can be explained by a single production structure characteristic: they are mostly made up of small producers that basically use land and labor (Nascimento *et al.*, 2012).

To achieve satisfactory results, agricultural activity is increasingly exposed to the challenges posed by globalization of the economy, so that a high level of competitiveness in terms of costs, price and quality must be kept in line with market dynamics, which, in turn, has made it increasingly necessary to manage this activity (Viana and Ferras, 2007).

Given the importance of the dairy segment in regional economic development, it is necessary to seek a new direction in the diffusion process of efficiency, technology and information. Standing out is the need to present a

methodology of analysis in order to define and select efficient sources and agents for this objective. Such reinforces the need for considerable changes so as to raise the sector's productivity and to achieve a productive structure that meets the levels of competitiveness consistent with the market.

Faced with this search for a basis for decision making, an approach based on efficiency analysis can be a promising alternative in the process of identifying efficient agents and, consequently, in the elaboration of strong policies for the dairy production segment.

This work intends to verify the technically efficient agents to direct the diffusion strategies of new technologies and information. Given that the production stage represents the main obstacle to improving the productive chain of milk in Brazil the focus of this study is primarily on the milk producer. Taking these observations into account, it is possible to propose a model of efficient agent selection, directing the programs of rural extension and technology diffusion.

Besides this introduction, containing the initial considerations and objectives of the research, this work is structured in four more parts: part 2 provides a brief theoretical framework for the analysis; part 3 structures the methodology used in the search of results; while part 4 presents the results and discusses the research; and finally, part 5 provides some final considerations.

2. Rural extension, development and technological diffusion

Although initially greatly related to the evolution of firms and the organization of the industry, according to Rogers (1976), the studies on the dynamics of technological diffusion came from the observation of events related to agribusiness, with the article by Ryan and Gross (1943) on the diffusion of hybrid corn seeds among Iowa growers in the United States, being considered a revolutionary paradigm within the research on technological diffusion. In studies of Rogers (1976), Dosi (1982), Nelson and Winter (1982), Cassiolato (1994) and Possas, Salles-Filho and Silveira (1996), it can also be observed that the process of technological diffusion may be perceived in sectors of agricultural activities.

This concept of technology diffusion in rural areas has been modified by agricultural research as well as by technical assistance and rural extension, creating a broad communicative process, involving researchers, extensionists, producers, among other social agents, policies and rural development agencies.

Within the theoretical framework of rural development, four important orientations can be highlighted for this analysis: Rostow's Theory of Growth

(1959), Lewis' Economic Dualism theory (1969), Schultz's High Input Agriculture theory (1965) and the theory of Induced Technological Change of Ruttan and Hayami (1984). This developmental issue provoked the debate about integrated and systemic rural development, encompassing the idea of sustainability and growth of related activities (Caporal, 1998). Thus, the term rural extension is a crucial factor in meeting the demands then proposed.

Since the implementation of the cooperative model of American extension, many rural extension conceptualization initiatives have been carried out. Concepts evolved over time, along with the changing circumstances and particularities of the dynamics and socioeconomic and cultural structure of each country. The international literature on the subject, makes no separation between the terms technical assistance and rural extension (Peixoto, 2008).

The classic model of extension, made official by the US government, functioned as a link between experimental research stations, usually university based, and rural populations. Rural extension provides new knowledge to the farmers who apply it and returns the problems raised in production to the experiment stations. Rural extension services in this model worked in agreement with the neoclassical theoretical current, in which technical progress was seen as the only way to promote development and the process of modernization itself, leading to a factor of social change (Lima, 2001).

The diffusionist-innovative model, according to Fonseca (1985), was an adaptation of the classical model to the underdeveloped world, combining theories about systems and social structures with the individual capacity to innovate. The concept of capacity to innovate is the mental process through which individuals pass from the first acquaintance of innovation until they decide to adopt or reject it (Rogers and Shoemaker, 1971).

Diffusionism led to the concern that, in the shortest possible time, agents could modify their behavior by adopting practices considered scientifically valid for solving their problems, and thus achieving socioeconomic development (Fonseca, 1985). In this model, the farmer was expected to be a receiver of desirable conducts, based on actions proposed by the extension worker and implemented through techniques of stimulus, induction, persuasion and conditioning of the receiver, in order to reach the objectives designed by the agent of diffusion (Ruas, 2006).

For Peixoto (2008), the term rural extension can be conceptualized in three different ways: as *process*, as *institution* and as *policy*. As a *process*, rural extension means, in a literal sense, the act of extending, carrying, or transmitting knowledge from its source to the final recipient, the rural public. However, as a *process*, in a broad sense, and currently more accepted, rural extension can be understood as an educational process of communication of knowledge of any nature, whether technical or not. In the second sense, the expression

rural extension is understood as the *institution*, entity or public organization that provides services. The term rural extension can also be understood as a public policy, referring, in this case, to rural extension policies, drawn up by governments over time, through legal or programmatic mechanisms, but which can be carried out by public and/or private organizations.

Most of the studies that deal with the subject of rural extension concentrate efforts on understanding the historical trajectory of institutions, on analysis of the extensionist action and on proposing desirable profiles and models of action. However, nowadays, work on the rural extension process converges to studies related to the transfer of information and technology.

In this way, identifying efficient agents while always seeking the expansion of their influence provides a favorable framework for the flow of communication and efficient practices, being fundamental to the execution of rural extension policies, whether public or private.

3. Methodology

For the empirical procedures of this study, data envelopment analysis will be the method for calculating efficiency measures and benchmarking, being refined by the *outliers* detection method and non-parametric efficiency frontier tests.

3.1 Efficiency measures and benchmarks: data envelopment analysis

The technique of data envelopment analysis (DEA) is a non-parametric approach, involving mathematical programming in its estimation, which was developed by the authors Charnes, Cooper and Rhodes (1978) for the relative efficiency analysis of producing units, known in the literature as DMUs (decision making unit). By producing unit is meant any system that transforms inputs into products, which in the present work refers to the milk producers.

The basis for DEA model estimates is relative to linear programming problems. The objective is to construct a convex reference set from the DMUs' own data, and then classify them as efficient or inefficient, having as reference this formed surface, unlike the econometric methods that analyze a producing unit in relation to an average producing unit. Thus, data envelopment analysis aims at finding the best production unit, i.e. the one that combines resources more efficiently, so that it reaches the optimal production level (Pareto-Optimum). This analysis assumes that, if a milk producing property *A* can produce α product units, other properties may also, if only they operate efficiently.

The initial assumption of the approach is that the measure of efficiency requires a common set of weights that will be applied to all DMUs. However, there is some difficulty in obtaining a common set of weights to determine the relative efficiency of each DMU, since the DMUs can establish values for the inputs and products in different ways, and then adopt different weights. It is necessary, then, to establish a problem that allows each DMU to adopt the set of weights that is more favorable in terms of comparison with the other units. In order to select the optimal weights, a mathematical programming problem is specified for the i-th DMU, which after linearization, applied to duality in linear programming and assuming constant returns to scale, is given by:

$$MAX_{\varphi,\lambda} \quad \varphi,$$
$$sujeito\ a:$$
$$-\varphi y_i + Y\lambda \geq 0,$$
$$x_i - X\lambda \geq 0, \qquad\qquad [1]$$
$$\lambda \geq 0,$$

where $1 \leq \varphi < \infty$ corresponds to the proportional increase in the product under consideration, keeping constant the use of the inputs in question. Parameter λ is a vector (n x 1), whose values are calculated in order to obtain the optimal solution. For an efficient DMU, all values of λ will be zero, whereas for an inefficient DMU, the values will be the weights used in the linear combination of other efficient DMUs, which influence the projection of the inefficient one over the calculated boundary.

If all DMUs are operating at an optimal scale, the hypothesis of constant returns to the scale is quite appropriate. However, the variable return model (BCC), proposed by Banker, Charnes and Cooper in 1984, suggests a new efficiency frontier methodology which admits variable returns of scale, i.e. it replaces the axiom of proportionality between inputs and outputs by the maximum of convexity. By establishing border convexity, it allows DMUs that operate with low input values to have increasing returns to scale and those that operate with high values have decreasing returns to scale. Thus, the linear programming problem with constant returns can be modified to meet the assumption of variable returns by adding the constraint of convexity, $N_1'\lambda=1$, where N_1 is a vector (n x 1) of unit numbers.

For each inefficient unit, DEA models provide their respective benchmarks, determined by the projection of these units at the efficiency frontier. This projection is done according to the orientation of the model, being orientation to inputs when it is desired to minimize the resources, keeping the

values of the products constant, or orientation to products when it is desired to maximize the products without reducing the inputs.

The model chosen for this study is that of variable returns to scale, since this allows for separation of the results in relation to the pure technical efficiency and the efficiency of scale. In addition, product orientation was used, in which the properties of the dairy activity seek to maximize the product, keeping the constant inputs. The use of product orientation was due to the difficulty in reducing some types of expenditures, such as family labor, and capital stock, such as land.

It is verified that, as in any empirical technique, the DEA model is based on assumptions, needing to be recognized and considered, such as sensitivity to measurement errors, impossibility to compare efficiency scores between different studies, and sensitivity to specification of factors and to the size of the group under analysis.

3.2 Method of detection and removal of outliers

Given the fact that a critical problem of DEA method is highly sensitive in the presence of outliers and sampling errors, this study used the methodology developed by Sousa and Stosic (2003) to detect the presence of possible outliers that could affect the border efficiency. The study by Sousa and Stosic (2003) devised a combination of two re-sampling methodologies, in order to proceed with a specific analysis for the DEA. From the methods called *jackknife* (deterministic) and *bootstrap* (stochastic), the authors established the procedure they coined "*jackstrap*". At a first instance, the *jackknife* is utilized by means of an algorithm that measures the influence of each DMU in the efficiency calculation, i.e., each DMU is removed separately from the sample after which the efficiencies be calculated without their presence. In a second moment, we use the *bootstrap* resampling method stochastically, taking into account the information of the influences obtained by the *jackknife*.

The estimator obtained in this way is called *leverage* (ℓ), and enables an automatic analysis of the sample, dispensing with a manual analysis that is imprecise and not feasible in large samples. Formally, the leverage of Sousa-Stosic can be defined as the standard deviation of the efficiency measures before and after the removal of each DMU in the sample set. In this way, the leverage of the j-est DMU may be defined as:

$$\ell_j = \sqrt{\sum_{k=1; k \neq j}^{K} (\theta_{kj}^* - \theta_k)^2 \Big/ K - 1} \qquad [2]$$

where the índex k are the DMUs, varying from 1 to K, the índex j represents the removed DMU and θ are the efficiency indicators. In this way, $\{\theta_k|k=1,\ldots,K\}$ represents the set of original efficiencies, without alteration to the sample, and $\{\theta_{kj}{}^*|k=1,\ldots,K;k\neq j\}$ represents the set of recalculated efficiencies after individual removal of each DMU.

It is assumed that the DMUs characterized as *outliers* have a leverage considerably above the global average. Thus, if ℓ_j be much above this average, suspicion rises that the DMU be an outlier. When the DMU j is localized within the efficient border, it happens that $\theta_{kj}{}^*-\theta_k=0$, and then $\ell_j=0$, meaning that the observation in question is not influential. On the other hand, in the critical case of a DMU of which the influence be extreme, its removal results in at least one of the remaining units representing an efficiency value equal to 1, that is $\Sigma(\theta_{kj}{}^*-\theta_k)^2=K\text{-}1$, and then $\ell_j=1$. Thus, the leverage index finds itself within the interval [0,1].

With the information given by *leverage* we can then identify and eliminate *outliers'* observations. To do so, it is necessary to use a specific criterion related to the deviation of the index from its overall mean. Sousa and Stosic (2005) suggest a multiple of the global average, $\tilde{\ell}_0=c\tilde{\ell}$, where $\tilde{\ell}$ represents the overall average of the *leverage* and c is a constant that assumes the value 2 or 3 in general, or, alternatively, $\tilde{\ell}_0=0.02$ is adopted as a cut-off criterion. Thus, DMUs with *leverage* above that value would be characterized as *outliers* and thus removed from the sample.

3.3 Non-parametric tests of efficiency frontiers

Before running the models for calculating efficiency measures, it is necessary to verify whether milk production properties, even with different production strata, are part of the same efficiency frontier or whether each production stratum generates its own frontier. To check for differences between the efficiency boundaries of milk production properties when separated by production strata, we proceeded with the nonparametric Mann-Whitney test. This test evaluates whether, among two groups of random variables, one of them is stochastically larger than the other, and is applied to verify if two independent samples belong to the same population (Banker, Zheng and Natarajan, 2010). In the present case, the milk properties were divided into three strata according to the daily production of milk in liters: up to 500 liters/day (small properties), between 500 and 1000 liters/day (average properties) and over 1000 liters/day (large properties).

3.4 Procedure and object of study

The empirical development of this study consists of six stages. Firstly, we used the outlier detection tests to ensure the reliability of efficiency scores and then proceeded by removing these outliers of the following procedures. In the second stage, we carried out the non-parametric efficiency frontier tests, considering the different production volumes in this study. In stage three, data envelopment analysis (DEA) was used to obtain efficiency measures. Stage five consisted of separating producers in quartiles[1] efficiency, according to the values of technical efficiency measures, comparing groups of producers based on quantitative and qualitative characteristics. In the fifth stage, we compared the groups of producers considering some technical and economic performance indicators, assessing differences between these producers and quantifying the inefficiencies in the use of inputs by inefficient producers.

Finally, in addition to the identification of effective agents, it is worth highlighting which of these agents are *benchmarks* for inefficient DMUs, that is, the efficient production units that act as reference for the inefficient ones in obtaining efficiency, designing these units at the border. Thus, in stage six, we made a detailed analysis of the three decision-making units most identified as reference for the inefficient properties group, verifying their dimensional, locational, as well as technical and economic performance characteristics. This stage guarantees the elaboration of a virtuous process of diffusion of efficient practices, directing this process to the entities that most provide the diffusion of these practices and the gains for the whole productive segment.

The data used in this study were collected by the Educampo Leite Project and refer to 659 milk producing properties distributed over nine of the twelve mesoregions of the State of Minas Gerais in the year 2013. The data gathering was realized through visits by technical professionals of the "Project for the Dairy Cattle Properties", ensuring a periodic monitoring while providing an intensive managerial and technological assistance model that goes beyond the traditional concept of technical assistance.

Conceived by the Brazilian Micro and Small Business Support Service (Sebrae), the Educampo Leite Project, aiming at rural entrepreneurs, seeks to develop all aspects of property management, turning them more efficient and competitive, through orientation and technical and managerial training of rural producers groups. Currently, the project has 27 cooperatives and agri-industrial partners, serving 1067 producers in 210 municipalities of Minas Ge-

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[1] Values given from the set of observations ordered in ascending order, which divide the distribution into four equal parts.

rais. In 2012, its producers accounted for 1.22% of milk production in Brazil and 4.71% of milk production in Minas Gerais.

It is observed that there are considerable variations in the productive dimensions of the sample, although the farms present similar productive processes and the same format of technical assistance (Tab. 1). This characteristic reinforces the importance of analyzing whether dairy farms, even with different production strata, are part of the same efficiency frontier. In addition, the amplitudes in the "size" variables provide indications that there is potential for gains of scale for some producers, justifying the use of the variable return model.

Tab. 1. Statistical analysis of the farm sample

Specification	Unit	Minimum	Average	Maximum	Coefficient of variation (%)
Milk production	L/day	83.61	1,039.46	11,266.29	*101.99*
Cows in lactation	Heads (monthly average)	10.00	68.54	441.29	*75.63*
Total number of cows	Heads (monthly average)	10.96	90.97	529.08	*74.34*
Area used for livestock	Hectares	7.70	100.61	726.00	*88.23*
Labor	Workers/year	242.00	1,142.61	6,299.00	*68.10*
Invested capital	US$	57.46	709.41	4,349.52	*80.76*

Source: Search results.

For the models to be executed, it was necessary to construct two data matrices, one containing the inputs used by the producers, and another one related to the product. In this work we used six inputs *(inputs),* three flow inputs and three inventory inputs in the generation of a product (output), with all variables expressed in monetary values (US$) for February 2014 prices. Those are:

Inputs
a) Flow inputs: represent the operating costs of dairy activity. These costs include all expenses incurred during the production process, plus the market value of the family labor. Within this group of inputs, three representative variables were used, very common in analyzes of performance of dairy activities. Those are:

X_1: Spent with concentrated in dairy farming. These include spendings on animal fodder with high nutrient concentration, and therefore, high energetic value. They represent 39.58% of the operational costs;

X_2: Spent on permanent labor in dairy farming. These include expenditures on both hired and family labor. They represent 17.11% of the operational costs;

X_3: Other expenses of the dairy activity. These include all expenses resuting from the dairy activity, except for those expenses with concentrate and labor. They are expenses with pasture, cane and grass, silage, medicines, hormones, milking equipment, transportation, energy and fuel, insemination, machine repairs improvements, taxes and services, among other expenses of costing[2]. They represent 43.31% of the operational costs.

b) Stock inputs: represent the capital invested in the dairy activity. They can be broken down into three main components. Those are:

X_4: Land capital stock. It represents 54.65% of the total invested capital;

X_5: Animal capital stock. It represents 27.33% of the total invested capital;

X_6: Machinery capital stock, improvements and forages. It represents 18.02% of the total invested capital.

Product *(output)*

Y_1: Gross income of dairy farming. Gross income is comprised of the sum of proceeds from sales and proper consumption of milk and animals. We decided to measure the product in terms of production value rather than physical production, since the unit sales value of the products differs greatly. That being so, the use of physical quantities may distort the reality of production systems when the objective is to compare them.

3.5 The use of DEA to evaluate efficiency in dairy farms

The research on efficiency in dairy farms has been highlighted in the international literature, mainly due to the importance of this activity in several economies. Different methodologies are used in the measurement and analysis of farm efficiency, with emphasis on stochastic frontier methods, used in important studies of the 1980s and 1990s (Battese and Coelli, 1988; Ahmad and Bravo-Ureta, 1996), and DEA methodology and its extensions, which have gained evidence since the 1990s and have since become consolidated as the

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[2] These costs were aggregated due to the fact of them representing individually a minor participation in the total costs of the milk production. The fact of aggregating fixed and variable, direct and indirect costs does not prejudice the results of this research (Matsunaga, 1976).

main methodological framework for the identification of efficient DMUs and the possible causes for eliminating productive inefficiencies.

In terms of DEA applications for dairy production, there are studies that have analyzed important regions in milk production in different countries. For Canada, Weersink, Turvey and Godah (1990) employed the variable return model to measure the technical efficiency of a sample of dairy farms in Ontario. Cloutier and Rowley (1993) and Mbaga *et al.* (2003) analyzed the technical efficiency of the Quebec region at different time periods.

The works for producing regions of the United States are also evident in the literature. Tauer (1993, 1998) analyzed milk production in New York farms, identifying higher levels of efficiency in the long term, with productivity gains over time. Several studies also analyze the milk basin of the state of Pennsylvania (Stokes, Tozer and Hyde, 2007; Heinrichs *et al.*, 2013; Mugera, 2013). Something they have in common is the existence of high levels of technical inefficiency, higher than 70%.

For the European countries, the outstanding works analyzed the dairy farms in Austria (Kirner, Ortner and Hambrusch, 2007), Finland (Lansink, Pietola and Bäckman, 2002), Ireland (Kelly *et al.*, 2012a; 2012b), Portugal (Silva e Berbel, 2004), Sweden (Hansson 2007, 2008; Hansson and Öhlmér, 2008), and Turkey (Uzmay, Koyubenbe and Armagan, 2009, and Demircan, Binici and Zulauf, 2010). All of them calculated the efficiency measures for a sample of dairy farms, obtaining, for the most part, average levels of productive efficiency as low results. This shows the structural differences among the farms analyzed, although belonging to the same region or country.

Other major producing countries as Australia and New Zealand also present relevant studies. Fraser and Cordina (1999), Fraser and Graham (2005), and Balcombe, Fraser and Kim (2006) are examples of important work analyzing dairy farms in Australia. However, Jaforullah and Whiteman (1998) is a pioneering article of efficiency analysis in the New Zealand dairy sector, much cited in more recent work.

Specifically, for the Brazilian case, the work of Alves and Gomes (1998) emerges as one of the first and most important regional articles. The works of Tupy and Yamaguchi (2002) and Gonçalves *et al.* (2008) also deserve recognition. All of them analyze groups of dairy farms, identify efficiency measures, and evidence the possibility of significant improvements in milk production if inefficiencies are reduced.

The present study differs from previous ones in that the selected group refers to milk producers who receive intensive technical assistance. In other words, they are producers that can be used to measure the efficiency of the technological diffusion process, by allowing greater accuracy in identifying the most efficient units, which will serve as benchmarks for the others. In ad-

dition, it shows in which more inefficient productive units the assistance must be intensified, through the realization of individualized strategic planning.

4. Results and Discussion

4.1 Preliminary procedures

Due to the sensitivity of DEA in relation to the presence of outliers and to ensure the reliability of efficiency *scores*, we proceeded with data analysis for the purpose of verifying the presence of observations with values considered atypical.

Based on the cutting criteria suggested, four of the analyzed properties showed influential, i.e., presenting leverage values greater than 0.02. In all these DMUs that are considered outliers, there is at least one product or ingredient showing significant differences in the averages for the group under study. This occurrence of discrepant observations in relation to the mean is enough to displace the border and increase the average level of this efficiency artificially, compromising the level of efficiency of the other DMUs.

Thus, the four outliers were excluded from the sample to avoid possible losses on the efficient frontier and consequently on the results of the study. However, we must highlight that the properties considered outliers should not be disregarded in the policies directed to the regional dairy farming. Yet, a previous and detailed analysis of the factors that render the identified discrepancies must be made.

In a second step, in order to check for possible differences between the properties' efficiency boundaries when separated by production strata, the results of the Mann-Whitney *U* test showed that the null hypothesis to which the groups under consideration belong to the same population, is not rejected in the three comparisons made. Thus, there are no significant differences in the efficiency frontiers of the groups in question, since the average daily milk production size does not affect the calculated efficiency. In this light, the following analyses will be presented on a single efficiency frontier, regardless of the existing production volume.

4.2 Measures of efficiency of milk producing properties

From the efficiency measures, initially, the properties can be classified into two groups: the first, called "efficient", composed of 104 properties that achieved maximum technical efficiency (pure efficiency); and the second, called "inefficient", composed of 551 properties whose efficiency measure was less than 100%. In the latter group, 60 properties (9.16%) presented an effi-

ciency indicator lower than 0.6, with the lowest efficiency index being 33.9%. This shows that, although the product is homogeneous, there is much variation in the technical efficiency of the dairy segment. The average efficiency of the evaluated producers is 79.8%, with a substancial part of the sample (44%) being efficient between 0.7 and 0.9, while the standard deviation of efficiency is approximately 0.15. Considering only the producers with some level of inefficiency, i.e., those with efficiency levels different from 100%, the average technical efficiency measure is reduced to 76%.

Considering this presence of considerable variations in the technical efficiency of the productive segment under study, we proceeded with the separation of milk producing properties into quartiles according to the technical efficiency. Table 2 shows the mean values of the product and of the inputs used to calculate the efficiency measures of the milk segment properties.

Tab. 2. Average annual values of the product and the inputs of the milk producing properties separated in quartiles according to the technical efficiency (values in US$ thousand/year)

Specification	Q1	Q2	Q3	Q4	General Average
Gross income	122.35	216.12	255.79	290.51	221.34
Spent with concentrated	45.30	75.55	85.24	94.52	75.20
Labor expenditure	26.04	33.49	35.93	34.53	32.51
Other expenses	54.65	84.38	92.41	97.53	82.28
Stock of land capital	367.87	440.48	393.32	348.88	387.67
Stock of capital in animals	143.39	195.23	214.18	222.47	193.89
Capital stock (impr. + mach. + for.)	113.95	136.14	130.70	130.56	127.86

Source: Search results.

Considering these results, we can observe that the gross income of the most efficient properties is approximately 137.45% higher than that of the most inefficient ones and 31.25% above the general average, determining the power that a correct allocation of the inputs provides in the optimization of the product. The average production in liters of milk in the efficient properties is also higher than the production of inefficient ones, in the order of 14.04%, identifying a positive relation between production and efficiency.

Regarding flow inputs, the average concentrate expenditure by efficient producers is higher than that of inefficient producers. However, the fact of presenting higher expenditures with concentrate does not imply inefficiency

of these properties, since there is a proportionally higher production level and, consequently, they are more productive. This level of production is not necessarily due to the volume of concentrate used, but rather to the quality of this input. In the case of labor, there is a direct relationship between efficiency and labor costs up to Quartile 3, with the most efficient quartile having a slight reduction in expenses for this factor. However, adequate allocation of hired and family labor on more efficient properties provides greater productivity compared to less efficient properties. The expenses included in the "Other expenses" input also showed a positive relation with the level of efficiency.

With regard to inventory inputs, a relationship between land use and efficiency is not identified. The stock of land capital for the quartile with the highest level of efficiency is the lowest among the four groups of producers. However, this fact does not reduce the level of efficiency of Quartile 4 producers, since the efficiency acquired in the use of land for milk production provides productivity per unit of land measure and ensures that it can be directed to the cultivation of other productive activities. As for the stock of capital in animals, we can observe more investment by the most efficient producers. This fact may be related to the possible management techniques of the stock and management that controls the volume of milked milk, maintaining the quality and productivity of the animals. As for machines, improvements and forages, the capital invested in the most inefficient DMUs is less than the average capital invested in the most efficient ones. All these differences in the capital stock show that the correct allocation of resources among the different categories of stock, as well as the productivity inherent in such allocation, can define whether a given DMU is characterized as efficient or not.

According to the relationship between technical efficiency and daily milk production, most of the 202 properties with the lowest daily milk production (up to 500 l/day) are technically inefficient (79.21%), despite these also having the highest number of efficient DMUs (42 properties). In relation to the 208 intermediate production properties (500 to 1000 l/day) and 245 DMUs with production above 1000 l/day, it is verified that these also have, for the most part, some degree of inefficiency (87.98% and 84.90%, respectively). This result demonstrates that the stratum of daily production has no significant relevance in defining the property to be efficient or not. However, when analyzing the average degree of efficiency, it is verified that it is superior in properties with production above 1000 l/day with an average of 84% efficiency, followed by properties with intermediate production with efficiency index of 0.78 and finally the properties with production strata up to 500 l/day (76% efficiency).

This higher average efficiency index of the properties with higher production is due to the greater capacity of negotiation, both in the acquisition

of inputs, since they buy and produce in greater quantity, as in the sale of the product, and in their ability to guarantee gains related to storage and distribution.

Finally, in a locational analysis, it can be said that there was no predominantly efficient region or set of regions, since efficiency means are not so discrepant and that regions with higher averages are dispersed over the State. In general, all the regions presented technical problems, necessitating them, therefore, to resort to the methods of this study.

The efficiency results are in agreement with the empirical researches in the literature, in which a considerable potential of improvements in the technical and scale performances of the dairy farms was found. However, due to differences in methods, in the input and output specifications, and especially in the database, it is not possible to argue whether the selected dairy farms are better or worse compared with farms in other regions or countries. In other words, the average level of efficiency obtained in a given study, for example, should not be compared with that of other studies, since the complexity and homogeneity of the sample is closely related to the results found.

4.3 Technical and economic performance

After analyzing the technical efficiencies and observing their relations towards the use of inputs, product generation, production strata and location, it is necessary to check if the efficiency standards are equally verified in the technical and economic performance of the DMUs under study.

The following analysis is based on technical and economic performance of properties according to technical efficiency. Table 3 presents these performance indicators separated by the efficiency condition.

In relation to the average productivity, we observed that the greatest difference between more efficient and more inefficient DMUs is based on land productivity, which in the most efficient units (Q4) shows a result 88.77% higher than that of the most inefficient ones (Q1). With respect to labor productivity, a 57.45% variation between more efficient and more inefficient properties is observed. On the other hand, productivity in the totality of the herd and lactating cows presented small variations among the three quartiles with the highest efficiencies, but still considerable values between quartiles 1 and 4 (23.31% and 33.45%, respectively).

From the economic performance of the DMUs, also presented in Table 3, one can draw plans and goals in the relation between income and expenses of the dairy segment.

Tab. 3. Indicators of technical and economic performance. according to technical efficiency quartiles

Specification	Q1	Q2	Q3	Q4	Average General
Productivity					
Lactating cows (L/day)	12.14	14.79	15.37	14.95	14.32
Total cows (L/day)	8.82	11.49	12.10	11.77	11.05
Permanent labor (L/man-day)	224.36	317.38	371.54	353.25	316.77
Land (L/ha/year)	3,331.04	4,576.85	6,093.76	6,287.90	5,075.05
Economic performance					
Gross income (US$/L)	0.56	0.58	0.58	0.62	0.59
Effective operating cost (US$/L)	0.45	0.40	0.38	0.35	0.40
Total operating cost (US$/L)	0.54	0.46	0.44	0.41	0.46
Gross unit margin (US$/L)	0.01	0.10	0.13	0.17	0.10
Net margin per unit (US$/L)	-0.09	0.03	0.06	0.10	0.03
Return on equity without land (% per year)	*0.47*	*4.16*	*9.55*	*14.53*	*7.19*
Return on equity with land (% per year)	*0.20*	*1.78*	*4.30*	*7.39*	*3.42*

Source: Search results.

It is observed that the average gross income per unit produced in the most technically efficient properties (Q4) is US$ 0.04 higher than Quartile 3 producing units and US$ 0.06 higher than the most inefficient DMUs. This value is significant, considering the average price of milk and its derivatives in the consumer market. In addition, the effective and total operating costs are lower in the more efficient DMUs, further aggravating the economic conditions of milk production properties with a greater inefficiency degree. The effective operating cost (EOC[3]) of the most inefficient properties is higher than the total operating costs (TOC[4]) of the most efficient properties.

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[3] Effective operational cost (EOC): refers to direct expenditures, such as contracted labor, concentrates, pastures, silage, minerals, medicines, energy and fuel, artificial insemination, mechanical services, among others, measured in US$ per liter of milk.

[4] Total Operating Cost (TOC): composed of the EOC plus the amounts corresponding to family labor and the depreciation of machinery, improvements, service animals and fodder, measured in US$ per liter of milk.

The presence of higher average gross income and lower operating costs in the most efficient DMUs reflected in gross[5] and liquid[6] margins of the properties, putting them far superior to unit margins of the most inefficient properties. In global terms, these margins present even more significant differences between efficient and inefficient, considering the presence of negative net margin in Quartile 1.

Property evaluation based on technical efficiency also identifies the difference based on returns on the invested capital, at 14.53% per year for the most efficient DMUs, if capital on land is not considered and 7.39% per year when all invested capital, including land, is considered. In contrast, for the most inefficient properties, returns on invested, capital with and without capital on land, except for the return of the landless capital of Quartile 3, shows values lower than basic investments, such as savings.

In the face of the given analyses, we can observe that efficiency and technical and economic performance are directly related, reinforcing the need to apply procedures that direct the inefficient properties to the efficient frontier.

4.4 Projection of inefficient properties at the efficient production frontier

Because the efficiency measure obtained for each DMU occurs in a comparative way, it is possible to detect the efficient properties responsible for particular organizations being considered inefficient *(benchmarks),* the DEA technique also presents itself as the methodology capable of identifying the inefficient points, so that the properties may identify them and, thus, succeed in eliminating them.

This section presents the projections in such a way that DMUs demonstrating some sort of inefficiency in resource allocation become efficient properties. Because the study works with product orientation, projections are made through the amount of product (gross income of the milk activity) that can be expanded, keeping the inputs already used, so that an inefficient DMU reaches efficiency.

Based on benchmarks for each inefficient property, Table 4 shows the possible gains of gross income after correcting inefficiencies.

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[5] Gross unit margin: refers to the difference between the gross income and the effective operating cost, in order to represent the cash flow of the property, measured in US$ per liter of milk produced.

[6] Net unit margin: the remuneration of the owner and the capital invested in land, improvements, machinery and animals, measured in US$ per liter of milk.

Tab. 4. Condition of technical efficiency and possible gross income gains after correction of inefficiencies (amounts in US$ thousand/year)

Specification	Inefficient DMUs
Original Gross Income (GI)	214.25
RB designed correcting by TE[1]	272.69
Possibility of gain (%)	*27.27*
RB designed correcting by SE[2]	224.97
Possibility of gain (%)	*5.00*
RB designed correcting by TE and SE	285.43
Possibility of gain (%)	*33.22*

[1] Technical efficiency; [2] Scale efficiency
Source: Search results.

As profit possibilities that correct technical efficiency for the same functional effects, the average percentage gains are valid for the efficiency products, irrespective of the yield on the scale of production. However, the possibility of gains of the efficient DMUs, that are not working on the production scale, is 6.21%.

Even if the analysis is done via the possible percentage gains on the product, we can observe the poor allocation of inputs and their possible underutilization in the inefficient properties. The possible gains are significant, with an average of 27.27% in the case of technical inefficiency correction and 33.22% in the case of both technical and scale adjustments, exceeding the average gross income of the originally considered efficient properties.

It should also be noted that the average gains that technical and scale corrections provide are greater than the sum of projected earnings, correcting only technical inefficiency or only inefficiency of scale. This fact demonstrates the important relationship between appropriate use of inputs and production volume, i.e. it is not enough to be only technically efficient, but, in order to obtain all possible gains, one must also consider the scale of production.

The use of product orientation was due to the difficulty in reducing some types of expenditures, such as family labor, and capital stock, such as land. Thus, the use of specialization and new management techniques can help in the projection of the properties considered inefficient for the efficiency frontier.

In any case, even including efficient producers in the calculation of averages, it must be noted that the possibility of increasing revenue by correcting problems is considerable. Potential gains in revenue are around 28%, high-

lighting that such gains are quite possible, since the projection is based on producers with similar activities, but higher efficiency.

Such projections reinforce the importance of working efficiently and strongly suggest that efficient practices should be disseminated in the dairy production segment, thus guaranteeing producers' permanence in the market as well as meeting the increasing demand for milk and dairy products.

4.5 Selection of efficient agents: the selected benchmarks

In order to identify the efficient agents for the process of equally efficient information and technology diffusion, it is necessary to highlight the decision-making units that most serve as references for the others, in order to use their characteristics and efficient practices in the construction of a virtuous cycle for the whole milk production segment.

In this study, of the 104 efficient properties, 86 were considered *benchmarks* for at least one inefficient property, with only 45 being reference for ten or more DMUs. However, three selected properties stand out among the efficient units, presenting themselves as references for a large number of inefficient entities.

Table 5 shows the three benchmarks selected among the properties analyzed, as well as their characteristics as to the size daily production and the area used for dairy farming.

Tab. 5. The three selected *benchmarks* and their dimensional characteristics

Specification	Benchmark 1	Benchmark 2	Benchmark 3
No. of pairs[a]	206	182	149
Average Production (L/day)	191	833	2,142
Area for livestock (ha)	60.3	425.0	95.5

[a] Quantitative properties that have the property in question as a reference (*benchmark*)
Source: Search results.

It is observed that Benchmark 1 is reference for 37.39% of the properties with some degree of inefficiency (206/551), with 72.78% of inefficient properties having at least one of these DMUs as a benchmark.

It should be noted that these properties differ in their productive dimensions and available livestock area under study. The average yield of our *benchmarks* ranges from 191 liters/day (Benchmark 1) to 2,142 liters/day (Benchmark 3), while the livestock area varies from 60.3 hectares (Benchmark 1) to

425 hectares (Benchmark 2). This information shows that the reference properties do not present specific characteristics, being small, medium and large properties, with different production sizes.

Another important factor in the analysis is that the selected reference properties are located in the Metropolitan Region, Vale do Rio Doce and Triangulo Mineiro / Alto Paranaiba (Benchmarks 1, 2 and 3, respectively), that is, are dispersed over the Minas Gerais mesoregions.

In order to broaden the characterization of the three selected reference units, Table 6 presents the product and the inputs used in the efficiency analysis.

Tab. 6. Product and inputs of selected reference properties (values in US$ thousand/year)

Output/inputs	Benchmark 1	Benchmark 2	Benchmark 3
Gross income	64.86	265.59	512.38
Spent with concentrated	6.58	16.21	133.79
Labor expenditure	8.79	27.26	54.55
Other expenses	15.10	72.87	121.70
Stock of land capital	96.41	452.99	267.23
Stock of capital in animals	47.04	312.66	352.33
Stock (impr. + mach. + for.)	57.50	184.08	191.72

Source: Search results.

The benchmarks have different characteristics as to the proportions of each input in relation to the product. Note that each DMU presented has at least a proportion considered the lowest among the reference properties studied here. For example, *Benchmark* 2 has the lowest proportion of spending with concentrates and labor in relation to gross income (6.10% and 10.26%, respectively), while the lowest proportions of the stock of inputs in relation to gross income were Benchmark 3. Such relationship between the inputs and the product in each decision unit reinforces the fact that the benchmarks have different uses proportions and ensure a greater number of possible adjustments to properties considered inefficient.

Another fact that can be reinforced is that different input ratios, and even larger volumes of these, may render efficiency, provided that they are properly allocated and therefore generate a higher gross income (output).

In order to characterize the main reference DMUs regarding their productivities and technical performance, Table 7 presents such indicators for each of the three properties under study.

Tab. 7. Indicators of technical and economic performance for the main reference units

Specification	Benchmark 1	Benchmark 2	Benchmark 3
Productivity			
Lactating cows (L/day)	10.09	7.02	19.62
Total cows (L/day)	7.75	4.08	16.49
Labor (L/man-day)	126.62	178.88	550.91
Land (L/ha/year)	1,154.94	715,51	8,189.40
Economic Performance			
Gross income from activity (US$/L)	0.93	0.88	0.66
Effective operating cost(US$/L)	0.17	0.17	0.28
Total operating cost (US$/ L)	0.26	0.21	0.33
Gross unit margin (US$/L)	0.55	0.50	0.29
Net unit margin (US$/L)	0.40	0.44	0.23
Return on equity with land (% per year)	*13.78*	*13.85*	*21.85*

Source: Search results.

As for the productivity of the presented properties, there is considerable variation among the reference properties, where the property with the highest production volume of the three mentioned (Benchmark 3) has the highest yields in all cases presented.

These considerable differences between herd, labor, and land productivity show that a single property cannot normally be the reference for a set of inefficient ones with different dimensional, locational, and practice characteristics. Thus, due to the heterogeneity of the 655 properties analyzed, diversity among the reference units also exists, which was verified in this study.

Also in Table 7, we must observe the economic performance of the three selected reference units; noting that in all indicators presented these units render more favorable results when compared to the means of the set of properties and also of the group of efficient ones.

The unitary gross income of the three main benchmarks ranges from US$ 0.66 to US$ 0.93 per liter of milk, while the average of this indicator from the set of all efficient properties is US$ 0.62 per liter. The cost indicators (EOC and TOC units) of these properties are also better than the average of the efficient DMUs, both of which are lower than the EOC and TOC units of the efficient properties as a whole. The gross and net unit margins of the three DMUs

analyzed here also exceed the average margins of the 104 efficient properties of the study.

However, what is more important in this analysis are the considerable differences in the rates of return between the three selected reference properties and the averages of these rates in the 100% efficient units. The lower capital remuneration rate to land among the three aforementioned properties is Benchmark 1 (13.78% per year) and this amount is 78.50% higher than the average rate among efficient units. This result reveals the importance of using efficient techniques in order to generate considerable economic benefits, ensuring adequate return on capital invested in the dairy segment.

Given this analysis of the three main benchmarks of the whole of the milk production properties studied, we can observe the importance of identification and dissemination of practices, information and technology, provided that these are efficient, while always considering the locational, dimensional differences and intensity in the use of production factors. Although the analysis of only three of 86 *benchmarks* detected, we can see to what extent different properties may become effective and spread such techniques to other properties with similar characteristics, yet inefficient.

5. Final considerations

The present work sought to verify the technically efficient milk production properties in order to direct the productive strategies in the milk production segment. For this purpose, the methodology of the data envelopment analysis, the *outliers* detection technique and the non-parametric efficiency frontier technique were used. The information used refers to 659 milk producers from the State of Minas Gerais, members of the Educampo Leite Project from Sebrae (655 producers after applying the technique of detection and withdrawal of outliers).

After verifying that the analysis could be performed on a single efficiency frontier, regardless of the volume of present production, the efficiency analysis was carried out. Under the assumption of variable returns to scale, it was verified that 104 investigated properties are considered 100% technically efficient, set against the 60 properties with the efficiency indicator below 0.6.

The analysis of pure technical efficiency shows that the gross income of the most efficient properties is approximately 137.45% higher than the most inefficient ones and 31.25% above the overall average, while all the expenses inherent in the inputs were lower in less efficient properties, while showing poor efficiency in the use of these inputs. Moreover, there are no clear distinctions of the presence of inefficiency among the strata of production and

location of properties, i.e., these features are not determining factors for the presence of efficiency.

Another point noted was that the efficiency standards are also checked for the technical and economic performance of the DMUs under study. The yield averages of more efficient properties outperform the most inefficient ones, especially in the productivity of land and labor. The assessments of the technical performance also highlight the importance of efficiency in the process, with all the favorable performance indicators to more efficient production properties.

In the light of the advantages observed in the presence of technical efficiency, projections for the DMUs that have some type of inefficiency in the allocation of resources were conducted so as to transform them into efficient properties. Potential gains in revenue are around 28%, highlighting that such gains are indeed possible, since the projection is based on producers with similar activities, though performing more efficiently.

Finally, it is observed that the three selected reference properties have better results than the average of the efficient ones, especially in relation to return on invested capital as well as to the productivity of production factors, indicating that the selection of information and technology diffusing agents must identify not only efficiency by itself, but also the degree of these agents for the reference segment studied. Another relevant factor is that there are different levels of production efficiency, despite the existence of a positive relationship between milk production and efficiency.

These results demonstrate the importance of efficient working routines, regardless of the size of the property, and for efficient practices to be disseminated in the milk production sector in order to ensure the permanence of producers in the market and meeting the growing demand for milk and dairy products. Still, in possession of these observations, one can select the diffusion agents considered efficient, targeting the rural extension programs, technical assistance and dissemination of technology, creating a virtuous and beneficial cycle, not only for the producer but for the whole milk supply chain. This analysis dynamics of the dairy sector converges with theoretical literature on the importance of technical assistance and the diffusion of technology and efficient practices in the sectoral, local, regional, and national sustainable development process.

It should be emphasized, however, that the milk activity can cause several impacts on the physical environment, causing, consequently, multiple negative and positive externalities, which are manifested in the soil, vegetation, water, air, fauna, flora, and even in the socioeconomic environment. Thus, all the strategic planning of technical assistance and rural extension must comprise the impacts generated by the milk production activity, because the impacts be-

tween environment and production process are bidirectional. The absence of the analysis of the environmental impacts generated by the dairy production activity is considered the limitation of the present study, mainly due to the lack of socioenvironmental diagnosis data.

With the identification of efficient milk producing properties, it is now necessary to draw up methods for the dissemination of techniques and practices that improve the technical and economic performance of inefficient agents. Future studies related to the diffusion of technology in the dairy production segment and the identification of social networks that facilitate such process are proposed. However, one must always take into account the efficiency of the production units, so that the existing diffusion is one of efficient techniques and practices.

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