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An analysis of the Brazilian dairy industry efficiency level

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Abstract

Milk is one of the most consumed agricultural products in Brazil, and its processing industry has a key role in absorbing its raw material, providing milk products, and generating jobs and income. Therefore, this study investigates the technical and scale efficiency levels of the Brazilian dairy industry from a multi-input perspective. Primary data from 40 dairy establishments distributed among the Brazilian regions was collected from online surveys. An exploratory analysis was performed to sample the characterization, using the Data Envelopment Analysis (DEA) with input-orientation to obtain the technical and scale efficiency scores of the Brazilian dairy industry based on the use of the inputs: energy (thermal and electrical), raw material (milk), and income generation (product). The results showed that the Brazilian dairy industry has 64.7% of pure technical efficiency and 73.8% of scale efficiency. In general, the main inefficiency is associated with the energy use (23.2%) and raw material (24.1%). These results should be considered essential for this industry as dairy establishments have demonstrated greater efficiency in adopting the most appropriate production scale (scale efficiency), and that they can be more efficient, especially by reducing their energy consumption, their processing losses, and increasing the raw milk earned value.

Introduction

According to the Food and Agriculture Organization (FAO) of the United Nations, in 2013, Brazil was the fourth largest raw milk producer, producing 34.3 million tons (FAO, 2016). More recent data from the Brazilian Institute of Geography and Statistics (in Portuguese) (IBGE, 2016a) indicated that in 2014, the country produced 35.2 million tons of raw milk, 70.4% of which was formally acquired by dairy processing industries (IBGE, 2016b) for a wide range of milk products. Moreover, in 2014, the dairy industry was the third largest in terms of revenues in the Brazilian food and beverage sector (ABIA, 2016). In that year, there were 6,395 dairy processing plants (MTE, 2016) that generated 55.2 billion reais of revenues (ABIA, 2016), created 128,000 jobs (MTE, 2016), and provided products of high nutritional value.

However, the Brazilian dairy industry still lacks competitiveness, with recurring closures and bankruptcy of dairy industries (Leite Brasil, 2012; MilkPoint, 2013; Exame, 2014). It is common for workers to lose their jobs and shareholders and investors to lose capital, which adversely affects industries along the dairy supply chains.

Since natural resources are increasingly becoming limited (Augustin *et al.,* 2013), dairy industries need to reduce their processing losses, such as raw materials and products (Maganha, 2006; Ali, Singh and Ekanem, 2009), waste generation (Maganha, 2006; CNI, 2012), and energy consumption (Maganha, 2006; CNI, 2007; Ali, Singh and Ekanem, 2009; CNI, 2012; Augustin *et al*., 2013; Alves *et al*., 2014). In addition, they must increase not only labor productivity (Carvalho, 2010; CNI, 2015) but also the earned value of raw milk (CNI, 2015) to become more competitive.

Still, both internally (Brunozi Júnior *et al*., 2012; MilkPoint, 2015) and externally (Ramírez, Patel and Blok, 2006), the increasing competitiveness of the Brazilian milk chain has more ruled in the milk collection concentration than in increasing production efficiency (Vargas and Fiegenbaum, 2014). Moreover, in many Brazilian regions, it has happened at a slow pace, reducing the Brazilian dairy's competitiveness rate.

This paper understands that strategic management is required to address this question in relation to dairy's processing structure, adopting compatible measures with the global development. At this point, understanding the efficiency levels is considered important for the development of the Brazilian dairy industry.

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Therefore, the present work aimed to (i) evaluate the efficiency level of the Brazilian dairy industry, (ii) find benchmarks for inefficient industries, and (iii) measure the potential of the financial economy associated with each analyzed source.

Materials and Methods

Data

This study focused on Brazilian dairy establishments formally registered at the Federal Inspection Service (in Portuguese) (SIF) of the Agriculture, Livestock and Supply Ministry (in Portuguese) (MAPA). Based on the information available of the establishments registered at SIF in the MAPA site (category, industry name, and address), 1,188 establishments were identified and divided into five categories . Data from a stratified random sample of this general population was collected between November 2014 and January 2015 through online semi-structured questionnaires.

Statistical analysis

Exploratory analysis

After data collection, an exploratory analysis was performed to check for unanswered questions and response errors. Descriptive statistics were used to evaluate the responses and measure the extrapolation capacity of the study's conclusions.

Efficiency analysis

Data envelopment analysis

The Data Envelopment Analysis (DEA) is a non-parametric technique used for evaluating an efficiency index in a given data set (Barnes, 2006; Stokes, Tozer and Hyde, 2007; Dimara *et al*., 2008). According to Charnes, Cooper and Rhodes (1978); DEA measures the relative efficiency of decision-making units (DMUs) with multiple inputs and outputs through an efficient frontier.

Therefore, DEA allows one to identify the efficiency production frontier as well as the DMUs that will serve as a benchmark for other units in the data set (Ferreira and Gomes, 2009) and to quantify the inefficiency slack of each inefficient DMU (Charles and Zegarra, 2014). The frontier position is a necessary but not sufficient condition for efficiency because, in addition to being on the efficient frontier, it is necessary to prevent waste in the DMU, which is characterized by null slack variables (Seiford and Thrall, 1990).

The advantages of measuring efficiency by DEA in relation to other approaches are the following: (i) it is an extreme-point method, which means that each DMU is compared only with the best DMU (Charles and Zegarra, 2014); (ii) it does not require any underlying assumption of the structural relationship between the inputs and the outputs (Schefczyk, 1993; Tingley, Pascoe and Coglan, 2005; Stokes, Tozer and Hyde, 2007; Ali, Singh and Ekanem, 2009; Romano and Guerrini, 2011; Charles and Zegarra, 2014); (iii) it allows one to incorporate the existence of multiple inputs and outputs (Helfand and Levine, 2004; Tingley, Pascoe and Coglan, 2005; Heinrichs *et al.*, 2013; Charles and Zegarra, 2014); (iv) it usually works well with small samples (Charles and Zegarra, 2014); and (v) the efficiency measures are radial or invariant units (Färe *et al.*, 1994; Lovell and Pastor, 1995).

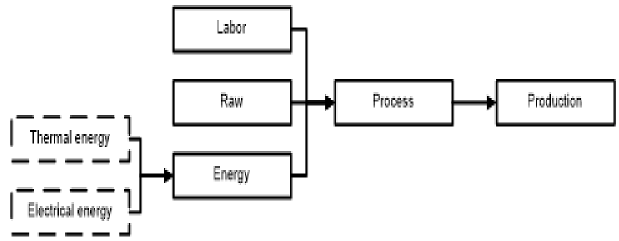

Figure 1. Illustration of the input conversion process in production simulated by the DEA model

Model

Figure 1 illustrates the efficiency model analyzed by DEA, where labor, raw materials, and energy are the inputs responsible for the product generation. Therefore, proxies were used that best represent each model variable: revenue (R$/year) for production; payroll (R$/month) for labor; processed milk volume (L/day) for raw material; and consumption of boiler fuel and electricity (R$/month) for energy.

The DEA input-oriented approach was used from the models of constant (Charnes, Cooper and Rhodes, 1978) and variable returns to scale (Banker, Charnes and Cooper, 1984), by the multi-phase method (Coelli, 1998). The constant returns to scale (CRS) model allows the measurement of technical efficiency, while the variable returns to scale (VRS) model compares each DMU only with others of comparable size (Barnes, 2006) and allows, in addition to CRS, unfolding of the technical efficiency into scale efficiency and pure technical efficiency (Khoshroo *et al*., 2013). Then, the pure technical efficiency of a DMU reflects its ability to obtain the highest level of products from a set of inputs if it is output-oriented, or its ability to obtain a set of products from the lowest level of inputs if it is input-oriented (Farrel, 1957). In turn, scale efficiency is associated with the most appropriate production level, due to the technology used (Dimara *et al*., 2008; Ferreira and Gomes, 2009).

An input-oriented DMU was chosen in this paper under the assumption that industries wish to avoid a lack of products in the market and to accumulate large stocks. Thus, it is assumed that industries actually produce the amount needed to meet the demands of their customers. Therefore, the best way to increase efficiency is to reduce their input consumption. According to Romano and Guerrini (2011), an input-oriented DMU should be used when there is a fixed level of products to be produced to reduce the inputs. In addition, Maganha (2006) emphasizes the importance of reducing costs and wastes since many Brazilian consumers of dairy products still consider price as the main factor in the purchasing decision. Finally, this paper also used the multi-stage method, proposed by Coelli (1998), aiming to nullify the cases of falsely efficient DMUs, and the restriction of non-increasing returns to scale to find a scale operation of a firm.

Results and Discussion

Sample

Questionnaires were emailed to 292 dairy industrial units and 40 responses were obtained. According to Banker, Charnes and Cooper (1984) and Golany and Roll (1989), this response number is in accordance with rule-of-thumb to use DEA. These responses are equivalent to a return rate of 13.7%. Using the generic sample formula described in Barbetta (2012), a sampling error of ± 15.5% was obtained for this work.

According to the information provided by representatives of the surveyed dairy industries, the industries have been in operation for 20.25 years on average, with a standard deviation of 13.44 years. The oldest establishment is 68 years old, while the youngest is only two-years-old. The daily total collection of the surveyed establishments is 3.4 million liters of milk , which is equivalent to 5.0% of the country's formal collection in 2014 (IBGE, 2016b).

Analyzing the Brazilian regions from the sample, the Southeast region provided the greatest number of responses (Table 1). In addition, there were few responses from the North, Northeast, and Central-west regions. However, the ratio between the expected and obtained respondents suggests this asymmetry is similar to the real distribution of establishments recorded at SIF among the Brazilian regions (MAPA, 2014).

Table 1. Regional distribution of respondents' establishments and dairy units registered in the SIF

Region	Number of establishments registered in SIF*	Expected respondents (%)	Respondents' establishments (%)
Midwest	144	12.1	5.0
Northeast	84	7.1	5.0
North	91	7.7	10.0
Southeast	638	53.7	50.0
South	231	19.4	30.0

* Source: MAPA (2014)

Regarding the responding dairies, 85.0% are private industries and 15.0% are cooperatives. This proportion is close to the actual figure from the SIF registrations (89.0% for private industries and 11.0% for cooperatives), which reinforces that the sample can be considered representative.

Regarding the size (BNDES, 2011), most establishments are "Micro" (27.5%) or "Small industries" (37.5%) while only 5.0% can be considered "Large industries". in addition, 7.5% of the establishments are "Medium-large industries", while the other 22.5% are "Medium industries". This illustrates the large diversity and the substantial number of micro and small industries existing in Brazil, corroborating the scenarios reported by Ferreira *et al.* (2008), Carvalho (2010), and Brunozi Júnior *et al.* (2012).

Data envelopment analysis

Initially, the existence of significant and high correlations between the output variables (revenue) and all the input variables was verified. Ferreira and Gomes (2009) suggested this statistical coefficient as criteria to select variables in a DEA model input-orientation. Therefore, as all input variables have moderate to high (>60.0%) and significant (p-value < 0.01) correlation with the output variable, the selected inputs can be considered appropriate to describe the output variation. Table 2 illustrates a summary of the descriptive analysis regarding these variables.

Then, this work used the DEA model with input-orientation and identified that the Brazilian dairy industries have a mean pure technical and moderate to high scale efficiency of 64.7% and 73.8%, respectively. However, their mean global efficiency scores are intermediate (48.0%). Only two establishments are globally efficient, that is, they have obtained pure technical and scale efficiency equal to 100%. However, nine dairies are purely technical efficient. Table 3 illustrates a summary

Table 2. Summary of the descriptive statistics of the variables used in the efficiency model

Variable	Minimum	Mean	Maximum	Standard deviation	Correlation with revenue (%)
Revenue (10^6.R$/year)	0.38	48.68	550.00	117.59	-
Processed milk (L/day)	800.00	85,137.50	745,000.00	158,795.53	97.97*
Payroll (R$/month)	7,880.00	292,799.47	5,000,000.00	874,028.01	94.66*
Energy consumption (R$/month)	1,840.00	68,993.60	620,000.00	132,197.40	65.87*
Electricity consumption (R$/month)	640.00	45,693.40	246,000.00	81,502.59	56.97*
Thermal energy consumption (R$/month)	42.00	23,300.20	405,000.00	53,956.47	69.12*

*Significant at the 5% probability level.

Table 3. Summary of the Brazilian dairy industries efficiency scores obtained from DEA

Variable	Minimum	Mean	Maximum	Median	Standard deviation
Global efficiency	0.025	0.480	1.000	0.491	0.248
Pure technical efficiency	0.159	0.647	1.000	0.665	0.271
Scale efficiency	0.098	0.738	1.000	0.840	0.265

of the Brazilian dairy industries efficiency scores obtained from DEA.

To compare the scores for pure technical and scale efficiency of each industry, the paired t-test was used. In this case, there were no identified significant differences between scale and pure technical efficiency at the 5% probability level (p-value = 0.132). This result gives no evidence that there are differences between the levels of slack associated with the adequate utilization of the available resources (pure technical efficiency) and that with the use of an adequate production scale (scale efficiency). It differs from the results obtained by Ferreira and Braga (2007b) and Ferreira, Braga and Lima (2008) in studies involving Brazilian dairy cooperatives. In this sense, according to the period of cited studies, the actually results may be an indicative of Brazilian dairy industries have evaluated in relation to the adequate utilization their resources .

Two dairy establishments (5.0%) have been working with its most productive scale size (constant scale returns). Six establishments (15.0%) with a decreasing scale return; which means that any increase in its production will increase average costs a diseconomies-scale regime. However, most of them (80.0%) have been working with an increasing scale return, which means that any increase in its production will decrease the average costs, i.e., an economy-scale regime. It corroborates the results obtained by Ferreira and Braga (2007a; 2007b).

Among the technically efficient dairies, establishments 13, 34, and 6 stand out as benchmarks. Together, these three dairies represent at least one of the benchmarks of 30 to 31 (96.8%) for inefficient establishments. However, there were four other benchmark establishments.

Establishment 13, which is technical and scale efficient, is a 35-years-old medium company , and processes a mean of 50,000 liters of milk per day, produces only one product (a concentrated product), and has 50 employees. In this case, the specialization in one added-value product looks likes the main differentiator in relation to the other dairies.

Establishments 6 and 34 are purely technical efficient. They are micro companies with 8 and 12 employees and process a mean of 3,000 and 800 liters of milk per day, respectively, and produce fresh and medium maturation cheeses (establishment 6) and concentrated products (establishment 34). Therefore, like establishment 13, the specialization in few added-value products looks like their differentiator. As cited in CNI (2015), the offer of differentiated products should increase their competitiveness. Carvalho (2010) highlighted the importance of the research and development in dairy establishments looking for strategies related to quality, brand, traceability, etc. In addition, Becker *et al.* (2007) reinforced the relevance of this purpose in small dairies.

Considering the weighted average of the potential to reduce each industry cost, according to the production volume (milk processed), the main inefficiencies upon which Brazilian dairy managers should act are associated with the processed milk volume and energy (thermal and electric) consumption. However, considering the average spending reduction for each industry, higher slack for all inputs was verified (Figure 2). Therefore, the differences of the potential expenditure reduction obtained by the arithmetic and weighted averages, respectively, may indicate a concentration of inefficiencies between the micro and small industries, which would have been "diluted" when they were calculated using the weighted average. It corroborates the findings of Ramírez, Patel and Blok (2006), which studied energy consumption in European dairy industries and identified signs that small dairies are

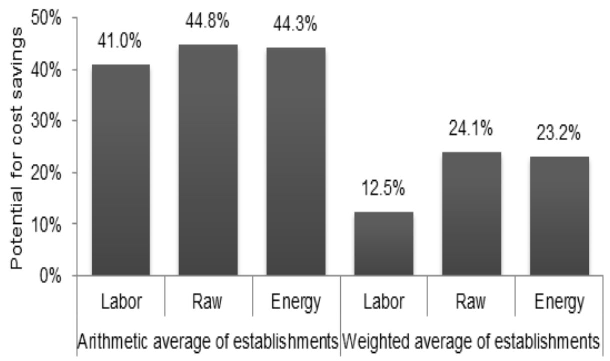

Figure 2. Average total potential of costs reduction per input.

less efficient than larger ones. In addition, Porter (1998) stated that competitiveness can be associated with high productivity.

Moreover, the tendency observed can be associated with economies of scale. Silva (2011), for example, founded that large dairies showed a coefficient of water consumption per liter of processed milk and chemical oxygen demand content in the effluent much lower than those observed for smaller dairies. Révillion *et al.* (2001) discussed the greater competitive advantages of larger ultra-high temperature processing (UHT) dairies in the Rio Grande do Sul State, Brazil; Dalton, Criner and Halloran (2002) identified reduced production costs with increased dairy size; and Becker *et al.* (2007) verified that small-scale dairies would face economic difficulties unless they use high-earned value strategies in their products. In a study with dairy producers, Stokes, Tozer and Hyde (2007) identified that larger properties were associated with the lowest efficiency scores.

From Figure 2, it can be inferred that among the analyzed inputs, hand labor is the most efficient input to be used in the Brazilian dairy industries, which can be associated with the low salaries of less-qualified laborers (CNI, 2015). Besides, the processed milk volume and the consumed energy concentrate the highest percentages of slack related to the inefficiencies. However, in relation to the processed milk volume, the identified slack can even be associated with the process losses and the low added-value to raw materials by most Brazilian dairies. The CNI (2015) cited that only a few employees are dedicated to research and development in Brazilian industries, which endorsed this study's hypothesis.

The thermal energy spending should be reduced if the Brazilian dairies started to use biomass fuels on a larger scale since biomass is less expensive than fossil fuels (Saidur *et al*., 2011). Alternatively, it should also be reduced if some of their own wastes (e.g., processing losses) would be used as a source of energy (Lamas and Giacaglia, 2013; Nogueira *et al*., 2015). However, the Brazilian dairies should review their production process (Alves *et al*., 2014) and start to invest in innovative technologies and equipment (EPE, 2007) to reduce their electricity expenditure. Besides, the high electricity costs (CNI, 2007) should encourage Brazilian dairies to look for alternative fuels aimed at electricity self-generation and invest in alternative energy sources (e.g., solar and biomass).

According to Alves *et al.* (2014), refrigeration systems are mainly responsible for energy consumption in productive processes for dairy product conservation. In these cases, the authors suggest the development of adequate thermal insulation and periodic maintenance.

Searching for a more efficient use of their resources is a common issue in the sustainability goals of any industry (CNI, 2012). Therefore, since this research measures the efficiency scores with operational variables, including economic, environmental, and social dimensions, it is understandable to make an association between pure technical efficiency scores and sustainability (Elkington, 1998), which is a key-factor to long-term industry development (Buys *et al.,* 2014).

The Brazilian dairies may use these findings to increase their efficiency, working in their optimal scale and making the best use of their inputs to meet the needs of their customers. In addition, these findings may support the development of the sector under the policies elaborated by government agencies and new researches in universities or institutes.

This paper did not consider data from raw milk quality in the DEA model. However, considering the microbiology and physical–chemical dimensions, the milk quality may influence the productivity and yield in the dairy process (Fromm and Boor, 2004; Flores-Miyamoto, Reij and Velthuis, 2014), increasing energy expenditure and decreasing revenues.

Conclusion

Brazilian dairy establishments have demonstrated greater efficiency in adopting the most appropriate production scale (scale efficiency) than in using the available resources (pure technical efficiency). Moreover, it was observed that increasing production, in most inefficient establishments in terms of scale would decrease the average costs. In relation to the best use of the available resources, the Brazilian dairies can become more efficient especially by reducing their energy consumption and their processing losses and increasing the raw milk earned value. The results also suggested that the focus on specialization in added-value products and operating in high scales may contribute to higher pure technical efficiency scores. In the long term, this paper demonstrates that the inefficiencies will be much more concentrated in the small dairies as they do not have specialized added-value products. Therefore, it can be one of the main causes of the recent decrease in the number of small dairies and the production concentration in a small number of large dairies.

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