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DATA ENVELOPMENT ANALYSIS (DEA) OF BRAZILIAN HOSPITALS' INVESTMENT PATTERNS

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ABSTRACT

This paper presents a descriptive, quantitative study aimed at identifying optimal hospital investment patterns in Brazil from 2006 through 2011.Operational data were collected from the Brazilian Single Health System Database (DATASUS) and financial data from accounting statements available online. Several techniques were used for data analysis, namely: descriptive statistics, Kruskal-Wallis tests, Spearman's rank correlation test, and Data Envelopment Analysis (DEA). Legal nature and state location impacted on the hospital's efficiency in the 2006-2011period. The results indicate that non-profit hospitals are oriented to providing services to a larger number of people than for-profit hospitals, which in turn are strongly driven by financial results in their use of resources. Five of the hospitals had optimal investment patterns according to the models developed in this study.

Keywords: Hospitals. DEA. Investments.

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1 INTRODUCTION

For Ozgulbas and Koyuncugil (2009), improving health services is a key issue for public policy. In this sense, authors like Guerra (2011) emphasize that hospitals are considered essential in the provision of health services. Despite their importance, aspects related to inventory management place the provision of the medical and hospital services among the most complex activities in the market (MEDEIROS et al., 2009). According to Struett (2005), hospitals are multi-product, intricate organizations, with several highly interdependent production processes, whose results are coordinated to supply their main product: diagnosis and treatment of the patient (STRUETT, 2005).

Due to the range of services provided by hospitals, managers face increasing demands to guarantee the quality of the services provided. Control practices are therefore needed to detect situations in advance that may affect patients and their families—or the organization as a whole (NOVARETTI, 2014). The management of risks in hospital procedures and the prevention of adverse events concerns managers as well as health workers (NOVARETTI, 2014). It is thus important to create policies to improve hospital management. However, Brazilian hospitals often face serious management problems (SOUZA et al., 2009; GUERRA et al., 2012). It is also worth noting the geographical size of the country, which results in a series of regional particularities that also influence hospital management in Brazil (O'DWYER et al., 2013). The specific characteristics of each hospital, such as size and legal nature, are also contributing factors (VELOSO, MALIK, 2010).

It should be noted that financial management is an essential aspect of hospital management (GRUEN and HOWARTH, 2005). Several studies have highlighted the importance of good management of this area in hospitals, with emphasis on the use of financial indicators for analyzing performance (ZELLER et al., 1996; BITTAR, 2001; OZGULBAS, KOYUNCUGIL, 2009; VELOSO, MALIK , 2010).

In addition, Ancarani et al. (2009) emphasize the importance of efficiency analysis in hospital services. While Guerra et al. (2012) examine the use of techniques such as Data Envelopment Analysis (DEA) for evaluating hospital efficiency. Despite the importance of the topic, the management of these organizations is little discussed in existing literature (ANCARANI et al., 2009). Despite being the predominant component of the Brazilian health system, hospital management until recently has not received much attention from policymakers or researchers (GUERRA, 2011).

This article presents the results of a study that aimed to identify optimal investment patterns for Brazilian hospitals between 2006 and 2011, based on the following specific objectives: (a) to develop DEA models that can determine the efficiency of Brazilian hospitals; (b) to identify the relative influence various factors have on the efficiency of hospitals; and (c) to identify the hospitals with the highest efficiency levels.

This paper is divided into five sections (including this introduction). Section 2 presents a review of the existing literature on the essential concepts needed to understand the research. Section 3 describes the methodology used in the study and section 4 describes and analyzes the results. Finally, section 5 presents the conclusions of the article.

2. LITERATURE REVIEW

2.1. FINANCIAL ANALYSIS

Silva (2012) states that the use of financial indicators makes it possible, for example: (i) to simultaneously analyze organizations from the same sector, geographic region and size over a specific period of time, to make comparisons between them or to verify whether they comply with the norms of the sector; and (ii) to analyze the historical progress of an organization through annual comparisons. Another important way financial indicators can be used is to predict organizational crises based on liquidity, profitability, and solvency indicators (LIN et al., 2011). It should be noted that according to Gitman (2010), one isolated index is not enough to determine the performance of an organization. However, the same author also states that for the analysis of specific aspects, a small number of indicators is sufficient. It is therefore necessary to establish criteria for choosing the most suitable indicators from all available options.

Among the various financial indicators, the most commonly used are those that measure liquidity, debt, and profitability (BIROLO, 2010). Souza et al. (2010) classifies the most frequently mentioned indicators in the literature as indicators of: (i) Asset efficiency; (ii) Profitability; (iii) Capital Structure; (iv) Liquidity; and (v) Profitability.

Financial analysis, however relevant it may be, does not cover all the factors that impact on the financial health of organizations, which can be reluctant to providing the necessary information, as well as the hypothesized lag in information in financial statements (SILVA, 2012). In this context, Lin et al. (2011) note that the use of indicators does not take into account potentially influential non-financial characteristics such as the management style of an organization.

2.2. FINANCIAL MANAGEMENT OF HOSPITALS

Hospitals can be seen as service-providing organizations, which can be assessed (MANZO et al., 2011) based on financial economic indicators, as is the case with companies (ZELLER et al., 1996; GRUEN; HOWARTH, 2005).

One point to be considered in hospitals is that their management is based on the relationship between subcultures of technical specialists (physicians, physiotherapists, nurses, etc.) and administrative staff (VENDEMIATTI et al., 2007). According to Vendemiatti et al. (2007), a subculture can be understood as a "collective understanding" of a subsector of an organization, the members of which maintain constant interaction with each other and identify as a distinct group within an organization. Such subgroups thus employ their own understanding to formulate guidelines of what would be best for the team. Because of the hierarchy of employees, both in the hospital and in the subculture, employees can make decisions on their own, which can disrupt the overall routines of the hospital, making their management more difficult.

Because of their complexity, hospitals face several management problems. Almeida (2009) states that many hospitals use family management systems, where personal and family ties are taken into account when hiring managers, rather than the candidate's experience. Canazaro (2007) highlights the fact that important positions in these organizations are occupied by doctors, who lead most of the organizational processes on top of performing their routine activities. These points help explain why hospital managers are often most concerned with solving short-term problems and maximizing the use of resources. Many fail to make use of management tools, such as financial indicators, to aid medium and long-term decision-making. Several

financial indicators in hospitals have been used in national and international studies, but with no conclusion on which are the best for use in empirical research (CANAZARO, 2007). Souza et al. (2009) list some of the most suitable indicators for analysis of hospital organizations, taking into account their relevance and the availability of information.

Bittar (2001) stresses the importance of using financial indicators to analyze hospitals, with a particular emphasis on return on assets (ROA), which refers to the net income (profit or loss) divided by the average total assets of the organization (MATARAZZO, 2010). Many authors also cite the importance of other performance measures, such as earnings before interest and taxes (EBIT). Silva (2012) conceptualizes EBIT as an operational performance measure, which considers net operating revenues after deduction of operating costs and expenses. The EBIT margin, in turn, represents EBIT as a ratio to the net revenue of the organization.

The study described in this article also used other financial information: fixed assets, revenue, and operating expenses. According to the Accounting Pronouncements Committee (Comitê de Pronunciamentos Contábeis – CPC), fixed assets are considered as a tangible asset held for use in the production or supply of goods and services, and are expected to be used for more than one fiscal year (CPC, 2009). Revenue is defined as "increases in economic benefits during the fiscal year in the form of inflows, increases in assets or decreases in liabilities that result in increases to shareholders' equity and which do not come from the owners of the entity" (CPC, 2011). Finally, operating expenses can be understood as periodic expenditures required to maintain the operations of the organization. Iudícibus et al. (2010) cite examples of operating expenses as: employee salaries, property rental, depreciation of equipment, etc.

2.3. DATA ENVELOPMENT ANALYSIS (DEA)

DEA can be understood as a non-parametric linear programming technique that evaluates the efficiency of Decision Making Units (DMUs) (YANG et al., 2012). According to Azevedo et al. (2012), a DMU is a unit capable of transforming inputs into outputs.

According to Valdmanis et al. (2008), DEA is used to establish an efficiency frontier by solving linear programming problems that identify the best DMUs in terms of maximizing their outputs (given their inputs). This model was initially developed by Charnes et al. (1978) and extended by Banker et al. (1984) (CHUANG et al., 2011).

The model developed by Charnes et al. (1978) is known as CRR and considers constant returns to scale, assuming that an increase to the inputs would have a proportional effect on the outputs. On the other hand, the model created by Banker et al. (1984), known as BCC, considers variable returns to scale and does not follow the aforementioned assumption.

An important detail in the latter model concerns the orientation to inputs or outputs. According to Mark et al. (2009), input-oriented models consider that input quantities can be reduced without changing the output, while output-oriented models consider that the output quantity can be maximized without changing the quantity of inputs (MARK et al., 2009).

According to Ozcan et al. (2010), the changes required for inefficient units to reach the efficiency frontier can be achieved by reducing input or increasing output. In addition, input-oriented models assume that managers have control over inputs, while output-oriented models assume that they have control over inputs.

DEA is based on the concept of relative efficiency, which can be defined as the ratio between the weighted sum of the outputs and the weighted sum of the inputs (COOPER et al., 2004; CHIU, LU, KAO, 2011). According to Yang et al. (2012), this model converts inputs and out-

puts into measures of relative (i.e., comparative) efficiency, as well as constructing a deterministic frontier, classifying the DMUs as efficient or inefficient. The DMUs located at the efficiency frontier have a relative efficiency of 1 (100%), while those located below the frontier (i.e., inefficient) have efficiency measures that range from 0 to 1 (LOBO et al. 2011).

According to Saurin et al (2013, p. 27), DEA was initially applied "in public institutions where the difficulty of allocating prices to inputs and products made it impossible to measure their efficiency." Currently, DEA has a wide range of applications in different areas (CHIU et al., 2011), such as: transport (AZEVEDO et al., 2012), soccer clubs (BARROS et al., 2010; DANTAS; BOENTE, 2011), and hospitals (CHILINGERIAN, SHERMAN, 2010). The research related to this last topic, which is the focus of this paper, includes national studies by Lobo et al. (2011) and Guerra et al. (2012), and international works by El-Jardali et al. (2011), Sulku (2011), and Yang et al. (2012).

3. METHODOLOGY

This study can be classified as descriptive in nature with a quantitative approach. The research was based on secondary data. Operational data were collected from the Brazilian Public Health System Database (DATASUS). Financial data were collected from financial statements issued by hospitals and made publicly available by the state where the organization is based, or even on the hospitals' own websites. In total, information was collected from 31 hospitals and analyzed for a six-year period, from 2006 to 2011. This is a non-probabilistic sample, chosen for convenience (ALENCAR, 2007). The selected organizations have very different characteristics regarding legal nature, size, geographic location, and number of beds. It should be noted that the data contained in the hospitals' financial statements were updated according to the National Broad Consumer Price Index (IPCA), measured by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística – IBGE) for the month of December 2012 (IBGE, 2013).

The selected hospitals and their analysis codes are as follows: Albert Einstein (DMU 1), Saint Kitts Charity and Philanthropy Association (DMU 2), Ary Flauzino Foundation for Cancer Research and Control - Cancer Foundation - RJ (DMU 3), Uberaba Research and Teaching Foundation (DMU 4), Zerbini Foundation (DMU 5), 9 de Julho Hospital (DMU 6), AC Camargo Hospital (DMU 7), Hospital das Clínicas, Faculdade de Medicina de Ribeirão Preto USP (DMU 8), Nossa Senhora de Lourdes Hospital and Maternity Unit (DMU 9), Hospital Erastor Gaertner (DMU 10), General Hospital of Guarulhos (DMU 11), General Hospital of Pedreira (DMU 12), Hospital Metropolitano de Urgência e Emergência (DMU 13), Hospital Novo Atibaia (DMU 14), Hospital Regional de Franca S.A. (DMU 15), Hospital Samaritano (DMU 16)Hospital Santa Rita (DMU 17), Hospital São José (DMU 18), Hospital Samaritano Cruz (DMU 19), Real and Benemérita Portuguese Beneficence Association (DMU 20), Santa Casa de Belo Horizonte (DMU 21), Santa Casa de Maceió (DMU 22), Santa Casa de Misericórdia de Fortaleza (DMU 23), Santa Casa de Misericórdia de Porto Alegre (DMU 24), Santa Casa de Misericórdia de São Francisco (DMU 25), Santa Casa de Misericórdia de Tatuí (DMU 26), Santa Casa de Misericórdia de Valparaíso (DMU 27), São Domingos (DMU 28), Bandeirantes Assistance Society (DMU 29), Santa Cruz Brazilian and Japanese Beneficence Society (DMU 30), Paulista Association for the Development of Medicine, Hospital São Paulo (DMU 31).

Various techniques were used for data analysis: descriptive statistics, the Kruskal-Wallis test, and DEA. According to Carlos (2004), the descriptive statistics method consists of creating

tables, graphs, and measures that are explored to provide a better understanding of the information. According to Maroco (2010), the Kruskal-Wallis test is defined as a non-parametric technique for testing whether two or more samples provide similar populations or different populations. Finally, DEA was used to obtain comparative efficiency scores for the hospitals and to thus identify the factors that determine optimal investment patterns. The study described in this paper used an output-oriented BBC DEA model. The BBC model considers variable returns to scale, disregarding the proportionality between inputs and outputs, assuming that the DMUs under analysis are different in size. The output-oriented approach considers that the quantity produced can be maximized without changing the amount of inputs used. The method was implemented using an Integrated Decision Support System (ÂNGULO MEZA et al., 2005).

4. RESULTS

4.1. DEA MODEL DEVELOPMENT

Two DEA models were proposed in the study: Model I (Table 1) and Model II (Table 2). The inputs and outputs of each model were proposed to identify optimal investment patterns in hospitals. In both models, the inputs were "investment in fixed assets" and "operating expenses". As previously described, the former represents investments by hospitals (long-term) in structures that guarantee their operations. Operating expenses, meanwhile, is classified as the periodic expenditure needed to maintain day-to-day operations.

The outputs of Model I were "revenue" and "number of beds." The model aims to highlight the efficiently hospitals are able to increase their revenue and the number of beds with the least investment in fixed assets and periodic expenditure. The outputs of Model II, meanwhile, were "EBIT margin" and "ROA." In this model, the aim was to evaluate the efficiency of hospitals in terms of profitability and rate of return. In other words, hospitals that present the best results in relation to operational investments and periodic expenses will be considered most efficient.

Table 1 - *Inputs* and *Outputs* of Model I.

Inputs	Outputs
IInvestment in Fixed Assets	Revenue
Operating Expenses	Number of Beds

Source: The Authors.

Table 2 - Inputs and Outputs of Model II.

Inputs	Outputs
Investment in Fixed Assets	ROA
Operating Expenses	EBIT Margin

Source: The Authors.

Before proceeding with the models, the general characteristics for the variables were determined according to Table 1. The values are expressed as averages of the six years studied (2006–2011), considering all the hospitals in the sample.

Table 1 shows that the sample data are heterogeneous, since except for revenue, the coefficient of variation was higher than 1 for all inut and outputs. It is also noted that on average, the ROA and the EBIT margin presented negative values, indicating financial problems for the hospitals studied. It should be noted that the coefficient of variation was not calculated for the ROA and EBIT margin since these variables presented negative averages, which makes analysis of this dispersion indicator impossible.

Table 1 - General overview of the variables.

Statistic	**Inputs Models I and II**		**Outputs Model I**		**Outputs Model II**	
	Investment in Fixed Assets	Operating Expenses	Revenue	Number of Bed	ROA	EBIT Margin
Mean	64,922,473.86	17,437,563.99	139,524,236.43	253.748	-9.52%	-2.21%
Standard Deviation	82,602,95.27	20.729.397,84	135,406,582.65	255.76	0.2082	0.2769
Coefficient of Variation	1.2723	1.1888	0.9705	1.0079		

Source: Research data.

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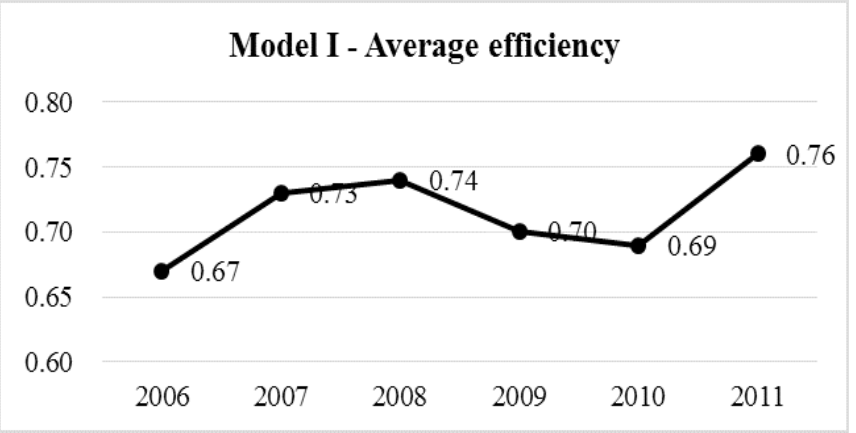
4.2. PRESENTATION AND DISCUSSION OF MODEL I

In Model I, the average overall efficiency for the period was 0.71. The units with the best scores in all years were DMUs 4, 11, 16, and 20. As shown in Figure 1, the highest average efficiency occurred in 2011 (0.76) and the lowest average occurred in 2006 (0.67). Although DEA establishes this measurement comparatively between the DMUs, the determining factors behind these results should be verified year by year.

Figure 1: Average efficiency – Model I.



Source: Prepared by the authors

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For the year 2006, DMUs 4, 7, 11, 16, 18, 20, 24, 27, and 29 were considered as efficient by the model, due to presenting the highest possible efficiency score (1.00). On the other hand, DMUs 25, 26, and 30 showed the lowest values, largely due to low revenues (among the five lowest in the sample), also considering the inputs of Model I.

In 2007, the efficient hospitals were largely the same as in 2006: DMUs 4, 6, 8, 11, 16, 18, 20, 23, 24, 27, 29, and 31. The variables considered in the model undergo relatively little change in just one year, especially the investment in fixed assets and number of beds. DMUs 15, 25, and 28, On the other hand, obtained the lowest efficiency values, mainly due to the number of beds being reduced and low performance in relation to revenue.

Hospital efficiency in the years 2008 and 2009 presented similar behaviors. The same DMUs were identified as efficient in both 2008 and 2009: 4, 8, 11, 16, 18, 20, 21, 23, 27, and 31. Meanwhile, DMUs 14, 25, and 28 presented the lowest values in 2008, and DMUs 25, 27, and 28 were lowest in 2009.

In 2010, DMUs 4, 8, 11, 13, 16, 20, 21, 23, and 29 were efficient, and the lowest efficiency values were observed for DMUs 25, 27, and 28. DMUs 4, 8, 11, 20, 21, 23, 29, 30, and 31 showed the maximum efficiency (1.00). And DMUs 14, 25, and 28 showed minimum efficiency values.

Analysis shows that the DMUs that were efficient in all sample years (DMUs 4, 11, and 20) behaved differently. DMU 20 had high investment fixed assets and high expenses. However, it had the highest revenue values in all the years studied, as well as one of the highest numbers of beds. Thus, its efficiency value was mainly a result of the products presented. DMUs 4 and 11, however, did not have such high revenue, but they had high numbers of beds, expenses, and investment in fixed assets, showing that these organizations made good use of their resources.

Among the worst hospitals, hospitals 25 and 28 obtained particularly poor results in all the years studied. For hospital 25, this was mainly due to the low number of beds, combined with unsatisfactory revenue. Moreover, expenses and investment in assets were both low. The main

reason for the low efficiency score was the output, rather than the inputs. The low score achieved by hospital 28 was also related to the product, but at the same time, expenses and investment in fixed assets were high. This hospital is therefore not efficient in the application of inputs to produce outputs, with other hospitals showing a better ratio between these factors.

It is important to emphasize that there was a significant statistical difference (less than 1%) considering the legal nature of these organizations (i.e., public, private for-profit, and non-profit) and the efficiency obtained by Model I (Table 2). There was also a statistically significant difference (less than 1%) between the efficiency of hospitals and the state in which they are located.

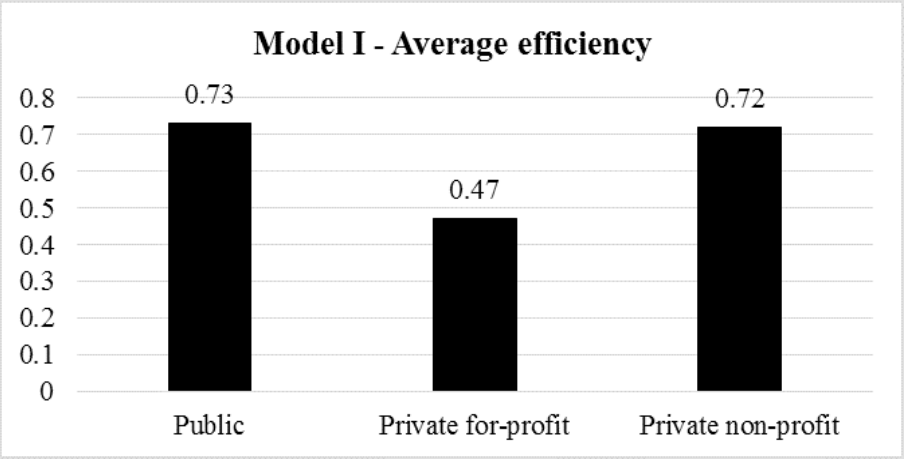
Table 2 - Kruskal-Wallis test result for Model I.

Variable	Legal Nature	State
Chi-squared statistic	21.903	34.886
P-value	0.000	0.000

Source: Research data.

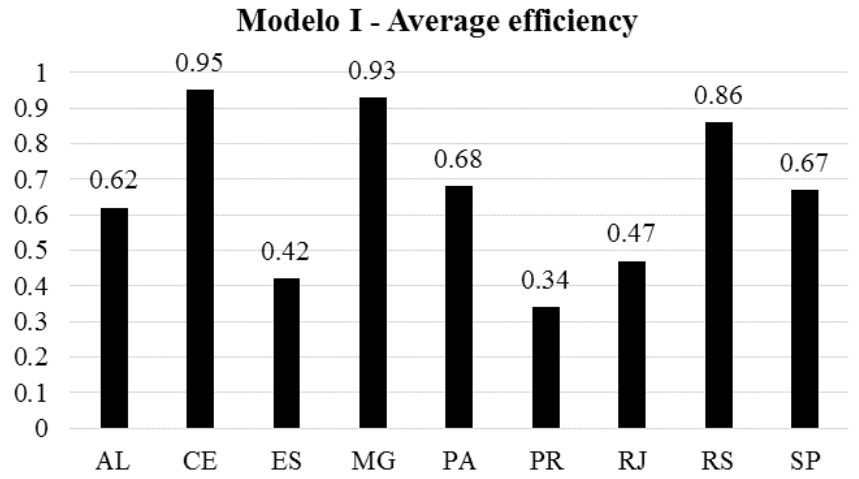
Private for-profit hospitals had a lower result than the others (as shown in Figure 2). The hospitals in the states of Ceará and Minas Gerais obtained higher efficiency results than those in the state of Paraná (see Figure 3).

Figure 2: Mean efficiency by legal nature – Model I.



Source: Prepared by the authors

Figure 3: Mean efficiency by state – Model I.

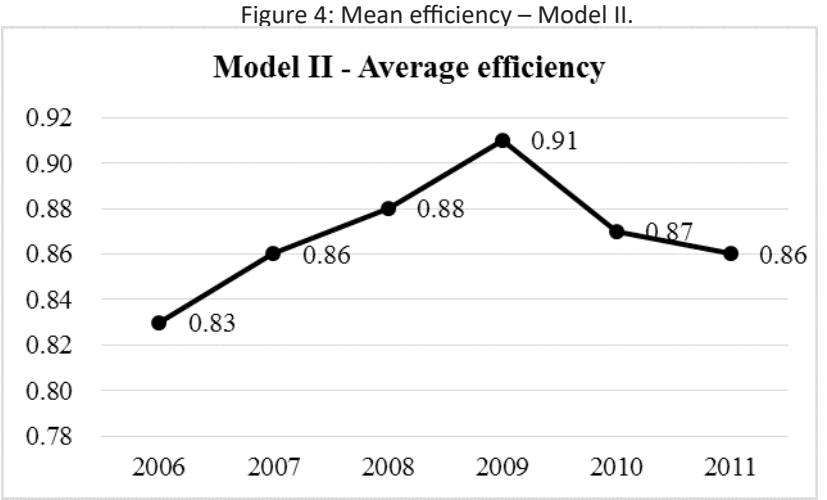


Source: Prepared by the authors

4.3. PRESENTATION AND DISCUSSION OF MODEL II

In Model II, the average score presented different behavior to Model I. The overall efficiency average was 0.87, reaching its highest value in 2009. In this second model, DMUs 16 and 27 had the best results; different to Model I, where the best DMUs were at 4, 11, and 20. This can be explained by the different emphasis of Model II, which focuses on determination of the efficiency based on profitability indices.

Figure 4: Mean efficiency – Model II.



Source: Prepared by the authors

For the year 2006, DMUs 4, 9, 16, 18, and 27 were the most efficient (1.0), while the lowest values were found at DMUs 2, 5, and 25. In 2007, DMUs 4, 7, 8, 9, 16, 17, 18, 27, and 30 obtained the maximum score, while DMUs 21, 25, and 31 presented the lowest efficiency values of the year.

Some DMUs, such as 4 and 18, stood out in both models, while DMU 9 did not stand

out in the first model, but was highlighted as particularly efficient by Model II. This happened because the hospital presented mean values for the variable inputs and outputs in the first model, but it obtained comparatively high values for EBIT margin in Model II.

In 2008, DMUs 4, 7, 8, 9, 15, 16, 18, and 27 showed the highest annual efficiency (1.00), while DMUs 3, 24, and 26 showed the lowest values. In 2009, DMUs 7, 8, 11, 16, 18, 27, and 30 showed the highest efficiency, and the lowest values were those identified for DMUs 5, 23, and 25.

Thus, the worst performing DMUs in 2008 and 2009 were different. This discrepancy, noteable in DMUs 5, 23, and 25, was caused by changes in operating expenses, EBIT margin, and ROA between the two years. Note that in general, there are more differences in efficiencies from one year to the next in Model II, since it uses variables that change more frequently (EBIT margin and ROA) compared to Model I (number of beds and revenue).

In 2010, the efficient DMUs were: 2, 4, 7, 9, 11, 13, 16, 17, 18, 27, and 28, while DMUs 23, 25, and 31 presented the lowest efficiency values. Finally, DMUs 7, 8, 11, 17, 28, and 30 showed maximum efficiency in 2011, while DMUs 12, 21, and 31 obtained the worst values.

The high number of efficient DMUs for the year 2010 is due to the fact that no organization stood out far beyond the others. For example, hospital 4 had the lowest value for operating expenses, but also had a low value for EBIT margin. The DEA method establishes a comparative efficiency compared to other DMUs in the sample, with those that present the best results considered efficient, but this comparative measure is limited to the DMUs of the sample.

DMUs 16 and 27, which obtained the best efficiency results for Model II, both presented comparatively high values for EBIT margin in all of the years studied. However, DMU 16 also stood out because of its low operating expenses throughout the period. In turn, DMU 27 was also noted for its low investment in fixed assets throughout the period.

It should be noted that there was no statistically significant difference (less than 1%) between the legal nature of these organizations (i.e., public, private for-profit, and non-profit) and the efficiency obtained in Model II (Table 3). On the other hand, statistically significant differences (less than 1%) were found when the hospital's state of location and efficiency were established.

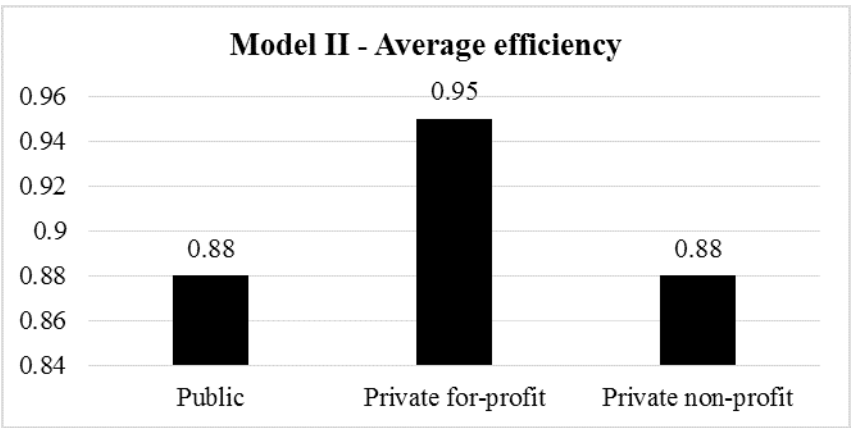
Table 3 – Result of Kruskal-Wallis test for Model II.

Variable	Legal Nature	State
Chi-squared statistic	3.808	23.793
P-value	0.149	0.002

Source: Research data.

As shown in figure 5, private hospitals showed a higher average efficiency compared to the others. Considering their legal nature, one possible explanation is that such organizations apply management practices with a greater focus on profit, while for others, the main objective is to implement medical procedures for the best patient treatment.

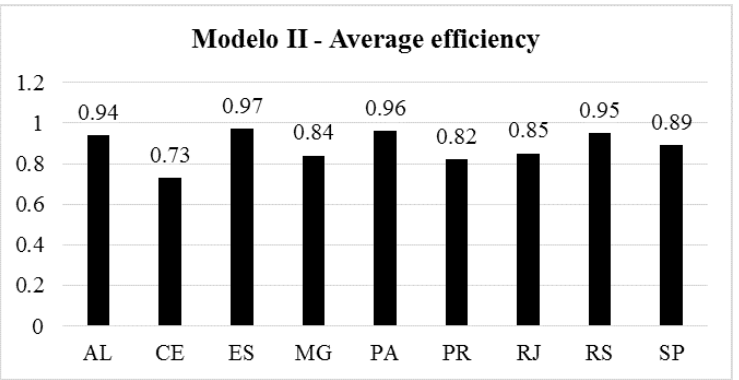
Figure 5: Mean efficiency by legal nature – Model II.



Source: Prepared by the authors

The hospitals in Espírito Santo presented higher efficiency results than those in the state of Ceará (Figure 6). These values are not conclusive because the sample is not probabilistic, but in any case, it is believed that geographic factors impact hospital efficiency.

Figure 6: Mean efficiency by state – Model II.



Source: Prepared by the authors

5. CONCLUSIONS

This article presents the results of a study that aimed to identify optimal investment patterns for Brazilian hospitals between the years of 2006 and 2011. In this sense, two models based on DEA analysis were developed and analyzed.

The results show that the size, legal nature, and state where the hospital is located influenced efficiency between the years 2006 and 2011. In Model I, which analyzed efficiency in terms of revenue and number of beds, public and non-profit organizations showed a superior result than for-profit hospitals. The latter, however, presented better results when efficiency was measured in terms of profitability and rate of return (Model II). This could be due to the fact that non-profit hospitals are tasked with serving larger numbers of people, while for-profit organizations use their resources with a strong focus on financial results.

Some hospitals stood out in the efficiency analysis due to their high output values compared to other units, but these results were mainly due to the low relative value of the inputs. The same phenomenon occurred for the organizations with the worst results. In some cases, many hospitals were identified as efficient because they formed a homogeneous group that stood out from the rest. It is important to emphasize this point, because DEA establishes efficiency comparatively, and the best DMU(s) is(are) therefore considered efficient regardless of whether the results are actually desirable. Thus, the descriptive statistics demonstrated that the average ROA and EBIT margin values were negative, with many hospitals making a loss in the period.

Five hospitals presented investment patterns that can be considered optimal according to the models developed. In the case of Model I, the hospitals were as follows: Uberaba Teaching and Research Foundation, Guarulhos General Hospital, Samaritano and Real Hospital, and Benemérita Associação Portuguesa de Beneficência. All are located in southeastern Brazil, have more than 100 beds, and are non-profit organizations (except the General Hospital of Guarulhos, which is public). On the other hand, in Model II, the following hospitals presented excellent performances: Samaritan Hospital and Santa Casa de Misericórdia de Valparaiso. Both are non-profit and are located in the state of São Paulo. However, unlike the previous model, Santa Casa de Misericórdia de Valparaíso had only 55 beds throughout the entire period of analysis.

Due to the importance of hospitals to the health system, it is essential that there is a constant search for improvement in the management of health services, as shown by authors such as Ozgulbas and Koyuncugil (2009) and Guerra (2011). The analysis described in this article thus contributes significantly to the research on hospital efficiency (especially regarding investments). The use of DEA can help significantly in the study of these essential organizations, as verified by Guerra et al. (2012). In addition, the proposed models provided coherent, significant results that are applicable to other contexts.

As limitations of the research, it is worth mentioning the fact that DEA does not allow generalization beyond the sample under analysis. Hospitals designated as efficient in Models I and II would therefore not necessarily be considered as such in comparison to others, or in terms of other variables. Future studies could increase the sample size and/or focus on a specific region of the country. In addition, such research could apply the models developed in this study in an attempt to corroborate the results.

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