Do PPP hospitals outperform the corporatized ones? The Portuguese experience

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Abstract

In Portugal, public hospitals provide universal, general, and tendentiously free access to all Portuguese citizens, having only a handful of Public-Private Partnerships (PPPs). Since some significant reforms, which started in 2002, four hospitals were created under the PPP regime. The creation of those four hospitals presupposed a choice made in favour of another, being the other the establishment of regular public hospitals. In Portugal, the discussion on which one of these two models improves hospital performance increased, leading to the need to compare Public and PPP hospitals. The present document starts by presenting the Portuguese health care system. While focusing on secondary health care, the concept of PPP is brought up, and the four Portuguese PPPs are considered. This study uses Data Envelopment Analysis (DEA), which can be used to empirically measure hospital technical efficiency, and Malmquist index, a robust non-parametric index which can be applied to measure group performance, alongside recent data about Portuguese hospitals (FY2015-FY2019). The sample contains information about 28 hospitals, from which four are PPPs. The DEA results show that PPP hospitals have the best average performance. However, they also show that although public hospitals presented the best levels of productivity, they also had the highest efficiency spread.

Keywords: Public-Private Partnerships, Public Hospitals, Healthcare Management, Data Envelopment Analysis, Malmquist index for group comparison

1. Introduction

PPPs in the health care sector in the last years have experienced considerable growth. In Portugal, PPPs in health care have emerged in four major hospitals: Hospital de Cascais, Hospital de Braga, Hospital de Vila Franca de Xira and Hospital Beatriz Ângelo - Loures, in what is called the first health care PPP wave. Some of the PPPs are facing the end of their contracts, and the discussion in whether or not to renew those contracts or even to create new ones is in the spotlight.

Empirical evidence of the benefits of using PPPs in health care is mixed [25]. Little attention has been paid in the literature regarding differences between Public Hospitals and Public-Private Partnerships, especially in terms of the performance gap between them. The coexistence of both PPP and public hospital models demands in-depth analysis so a reasoned decision can be reached about the suitability of each model. It is necessary to have unbiased information available and compare the performance of both models, to achieve such a decision.

The primary goal of this study is to apply the most suitable benchmarking alternative to the most detailed set possible, in order to compare the two groups of hospitals and draw lessons from it. The objective can be simplified to the question made on the title "Do PPP hospitals outperform the corporatized ones?".

The rest of this study is organized as follows. Section 2 introduces the reader to the Portuguese NHS and Section 3 explains the concept of PPP and does a literature review. Section 4 explains and details the adopted methodology based on the literature review made. Section 5 details the variables and model specifications, while the results and discussion are provided in Section 6. Finally, Section 7 provides a summary of the results and some final remarks on the more relevant findings.

2. The Portuguese National Health Service

In 1974 a democratic revolution occurred in Portugal, putting an end to a dictatorship that lasted over 40 years. Two years later, the Portuguese Constitution was approved, being recognized citizens' right to health care by "the creation of a universal, free-of-charge National Health Service"[1] [2]. On July 28, 1978, an order was published, known as

[1] Decree number 10/04 of 1976, article 64

"*Despacho Arnaut*" which was an anticipation of the NHS since it allowed access to all citizens to medical-social services, regardless of their ability to pay.

Following the constitution and "*Despacho Arnaut*", in 1979, the law that enabled the right to health care was approved and, accordingly, the NHS was created[2]. The NHS guarantees universal, general and free health care services to all citizens. Universal access means access to all citizens regardless of their economic or social status (ability or willingness to pay), and general means to all areas and needs [20]. Although both of these last constitutionally principles (universality and generality) have prevailed to this day, the "free-of-charge" principle did not. A revision of the constitution was made in 1989[3], making the access "tendentiously free" instead of free, which means the users of the NHS now have to pay fees [2].

The NHS provides health care services at different levels, such as primary care, secondary care (or differentiated care), post-hospital care and rehabilitation (continued care), and palliative care (end-of-life care) [2].

Primary health care in Portugal consists of a network created by all Regional Health Administrations (RHAs) which aids, simultaneously, in health and disease prevention, management of severe health situations according to physical, psychological, social and cultural dimensions [20]. Secondary health care, also known as hospital care since it is provided by hospitals and hospital centres, is the most specialized type of care in the NHS [20]. The public sector in Portugal provides secondary care through public hospitals. The post-hospital rehabilitation care known as "continued care", is a network that aims at trying to stabilize and guarantee the full physical recovery of a patient after hospitalization[4] [2]. Palliative care is specialized medical care to handle people living with serious illnesses [2].

2.1. Secondary health care in Portugal: Hospitals

Secondary care, as said before, is mainly provided by the hospital's clinical staff. The report "*Estatísticas da Saúde* 2017" defines hospital as a health facility that provides medical and surgical treatment and nursing care for sick or injured people, and may contribute to disease prevention, scientific research, and teaching [18].

It is possible to differentiate hospitals into two different types, public and private. In a public hospital, its owner and main supporter is the state, which can provide universal or restricted access. A private hospital has a private entity as its owner and main supporter, for-profit or not, and may be of universal or restricted access.

In 2017, there were 225 hospitals in Portugal, which represents an increase of 27 hospitals when compared to 2007. The existing hospitals in 2017 were divided into 114 private hospitals (15 more than in 2007), 107 public hospitals and 4 PPP hospitals. Given that all PPP hospitals were also of universal access, the number of universal access hospitals per 100,000 inhabitants was 1.0 in 2017 [18].

2.2. Hospital management models

Between 1979 and 2002, all public hospitals were under the management of the Administrative Public Sector (*Sector Público Administrativo* (SPA)[5]) [11], which means that they were subjected to public/administrative law, being publicly managed and owned. Following the NPM ideology, which consisted in bringing and adopting management and organization principles from the private sector to the health system, and reinforcing the agreements with the private and social sectors [20]. At the end of 2002, 31 out of the 34 traditional SPA hospitals have already been transformed into public limited companies or hospital enterprises (Sociedade Anónima (Public Limited Company) (SA)[6]). SA hospitals have limited liabilities and are subjected to commercial/private law [13].

In 2005, all 31 SA hospitals and 5 SPA hospitals were transformed into corporate public entities (Entidade Pública Empresarial (Public Enterprise) (EPE)[7]) to maintain the unequivocal public nature of the hospitals, and enhancing the supervision and intervention of the Ministry of Health and Finance. Ten new EPE hospitals were created in 2007 [16]. SA and EPE management differs from public management because they have more autonomy in certain aspects. They do not follow a private management model because their autonomy is supervised. This is an intermediate situation regarding the type of management between a SPA hospital and a private hospital [16].

Meanwhile, it was announced by the government some hospital projects that would be launched under a PPP [24][8]. PPPs have private investment, public funding, private management, and public ownership. Under this PPP model, four hospitals were created, and some more were announced, but their creation was after dismissed.

[2] Law number 56/79, 15th September

[3] Law number 1/89, 8th July

[4] Decree-Law number 101/2006, 6th June

[5] In order to simplify notation hospitals that belong to the public sector are going to be referred as SPA hospitals

[6] This occurred under the Law number 27/2002, 8th November

[7] Decree-Law number 93/2005, 7th June

[8] Decree-Law number 185/2002, 20th August

3. Public-Private Partnership

PPPs were created and used for the first time in the United Kingdom in the 1970s. They appeared as a way to undertake major public projects without the prerequisite of exclusive public funding, while also sharing the risk with the private sector [25].

There is not a textbook definition of PPP. Sometimes it is only referred to as a traditional project carried out by the public sector, as it can be defined as a simple contract between the private and public sector. However, as Reich explains in his book [23], a good PPP definition always has three points. First, the existence of at least one private for-profit organization and one not-for-profit or public organization. Second, both entities want as a goal the creation of social value. Third, both entities share efforts and gains.

In Portugal, the government created a decree-law[9] where it is possible to find the definition of PPP: *"contract or the union of contracts whereby private entities, designated as private partners, undertake, on a long-term basis, towards a public partner, to ensure the performance of an activity aimed at the satisfaction of a collective need, and assume responsibility, in whole or in part, for the financing and operation thereof"*.

3.1. PPPs in health care

PPPs in health care can be used in the hospital sector since hospitals consume about half of the health sector budget. The different PPP projects in this sector are differentiated based on the group of activities included in the contract. Arrangements can go from just considering the management of the hospital infrastructure by a private entity to having a full-service provision at all levels of care [14]. In the health sector, there are mostly three models: Unite Kingdom (UK) model (model 1), Portuguese model (model 2) and Alzira model (model 3) [3].

UK model. A partnership made to create/restructure and operate hospital infrastructure. It is not linked with hospital and clinical management. This model can build or restructure the hospital depending on the option chosen. The wide acceptance of this model has to do with not including clinical management by the private sector, leaving the hospital's core business to the public sector [26]

Portuguese model. A contract that includes infrastructure and soft facilities services as the UK one, but also clinical and medical activities. Therefore, it is the responsibility of the private contractor to recruit, train and manage clinical staff[10], as well as to maintain, operate and purchase medical supplies. The Portuguese model was applied in all of the four hospitals of the first health care PPP wave[11].

Alzira model. It is characterized by having full-service provision at all levels of care. It is not limited to the hospital perimeter, as it also extends to primary care centres [14]. An example of this model is the Hospital de La Ribera, Valencia (Alzira), Spain [4].

3.2. PPP hospitals in Portugal

The first experience of implementing a private management model in a public hospital began in 1995 with the signing of a contract for the private management of a general hospital, Hospital Fernando Fonseca [9], in Amadora, a district hospital with 670 beds and integrated into the NHS. By government decision, this partnership ended in 2008 and was turned into an EPE hospital. Since 2001, this kind of contracts in health care became more frequent, being announced in that year the first wave of hospitals in a PPP regime.

The first wave is based on a management contract with two managing entities, one for building management and another for the clinical services component. Four hospitals emerged from this wave, Hospital de Braga, Hospital de Vila Franca de Xira, Hospital de Cascais, and Hospital de Loures. Table 1 briefly presents the main features of the first wave of hospital PPPs.

Table 1: Main features of the Portuguese first wave of hospital PPPs.

	Private partner responsible for the infrastructure management	Private partner responsible for the clinical management
Model	DBFOT, including clinical services	
Contract Issues	To design, build, and preserve (manage) the infrastructure and hard facilities (ancillary services)	To manage clinical staff and deliver health care to all citizens
Duration	30 years	10 years
Responsible	Hospital building management company	Hospital facility management company
Activity	Design, construction and maintenance of hospital facilities, hard facilities management and heavy fixed equipment	Hospital management, clinical service management, soft facilities management and mobile equipment
Payment	Based on services availability (penalties for service failures)	Based on contracted production (penalties for low quality)

Source: author. Adapted from [27] and [3, 9]

3.3. Past research on PPP hospitals in Portugal

Since the objective in this case study is focused on the Portuguese reality, a thorough review is made on the literature that encompasses Portuguese hospitals. The most important works studying the reality of hospital PPPs in Portugal were considered. From that review, some noteworthy works, such as, Ferreira [10] who seeks to understand if the existent hospital PPPs in Portugal have given

[9] Decree-Law number 86/2003, 26th April (amended by Decree-Law number 111/2012, 23th May)

[10] Although, if this model is applied to a running hospital (substitution hospital), the clinical staff as to be maintained under the new management.

[11] Currently some of them have or are scheduled to change the model type, having Hospital de Braga already change to a public hospital.

rise to value gains for the financing entity (the State) or have led to inefficient management of the financed resources. As a result, he concludes that, in order to achieve a successful PPP, improvements are needed in decision making, budgeting, transparency, accountability and participation, and increased state bargaining capacity.

Nunes and Matos [21], studied the performances of hospitals in a PPP regime, designing a benchmarking exercise with the DEA for the years 2013, 2014 and 2015. As results obtained that from the four hospitals analyzed, three of them were efficient in the three studied years, being only one considered inefficient. The aim of implementing PPPs in hospitals to improve hospital efficiency and productivity, according to the results of this study, was in part achieved. Most of the PPP hospitals were efficient when compared with themselves and with other hospitals of the NHS.

Ferreira and Marques [14] uses Benefit of Doubt (BoD) with data about Portuguese hospitals (FY2012-FY2017) to evaluate if PPP hospitals can deliver health care with social performance levels at least as good as public hospitals. Concludes that PPPs are not expected to have lower performance levels when comparing to public hospitals. However, there may be an interface problem leading to a potential conflict of interests between both.

4. Methodology

A comparison between homogeneous entities exhibiting similar production technologies can be made, using a frontier where most efficient organizations within the sample of organizations under analysis are placed. This frontier can be called the efficient frontier.

Models to estimate the efficiency frontier can be divided into two broad categories: parametric and non-parametric. Parametric models use econometric tools, and require specification of a particular functional form of the production function. Non-parametric models, place no conditions on the functional form, estimating the shape of the frontier using observed data and, thus, requiring smaller assumptions [17]. To this day, Stochastic Frontier Analysis (SFA), is the predominant form of the parametric models used. In the non-parametric case, most methods take the form of DEA and its derived models [19].

DEA, or some particular case of it, is the most used tool in works that measure performances of hospitals. Consequently, this study will use DEA to evaluate hospitals' performance. The Malmquist index is also often used to complement the DEA methodology, being also added to the methodology of this study.

4.1. Data envelopment analysis

DEA is a non-parametric model that can take multiple inputs and outputs using them in a linear programming (optimization) model that gives a single score of technical efficiency per observation. DEA plots the production frontier for a sample of health care providers using linear programming techniques [17]. The providers that lie on the frontier are considered efficient, and the ones who lie inside are inefficient.

DEA models can follow two distinct orientations: Input and Output orientation. When efficiency is input oriented there is a focus on reducing inputs to increase efficiency, holding outputs. However, in output orientation, the goal is the output augmentation to increase efficiency, holding inputs [22].

DEA also has two main approaches, Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). CRS reflects the fact that output will change by the same proportion as inputs are changed. VRS does not assume that the scale of economies maintain constant as the size of the service facility increases [22].

4.1.1. Mathematical formulation

The general mathematical formulation of DEA corresponds to the resolution of a set of *n* linear programs, in order to estimate the efficiency scores of Decision Making Units (DMUs). Since the objective of this work is to measure performances of different hospitals to compare them, the DMUs in this example are hospitals. Let's consider a set of m inputs, x_i^j, i = 1, . . . ,m, and a set of outputs, y_r^j, r = 1, . . . ,s, evaluated for *n* hospitals (j = 1, . . . ,n). Hospital *k* can be represented by the vector (x_i^j, y_r^j) [17]. It is required the creation of a group of other hospitals to evaluate the efficiency of a given hospital, *k*, against which comparison will be undertaken.

Technical efficiency of hospital *k* can be calculated by minimizing or maximizing the objective function θ^k. Hospital *k* is technically efficient if $\theta^k = 1$, $\theta^k \in [0, 1]$, that is, input consumption is optimal [8]. Otherwise, to become efficient hospital *k* must reduce its resource consumption and waste. The input-oriented and output-oriented DEA models can be described as follows:

DEA output-oriented:

$$\begin{aligned} &\max \Phi^k \\ &\text{s.t.} \\ &\textstyle\sum_{j=1}^{n} \lambda^j x_i^j \leq x_i^k,\ i = 1, \ldots, m \\ &\textstyle\sum_{j=1}^{n} \lambda^j y_r^j \geq \Phi^k y_r^k,\ r = 1, \ldots, s \\ &\textstyle\sum_{j=1}^{n} \lambda^j = 1 \quad \text{(V R S)} \\ &\lambda^j \geq 0,\ j = 1, \ldots, n \end{aligned} \tag{1}$$

where, n - number of hospitals; m - number of inputs; s - number of outputs; λ - scale coefficient $\in$ [0,1]; x - inputs; y - outputs.

4.2. Benefit of doubt

The label "Benefit of Doubt (BoD)" derives from one conceptual point of DEA, which is, knowledge on the right weighting scheme for hospital performance benchmarking can be acquired from the hospital data themselves [6]. Behind this lies the idea that, when hospital k performs well in a particular indicator, that policy dimension is relatively essential to the hospital. Thus, giving this interpretation of higher importance to relative strengths, hospitals will set their own "optimal" weighting schemes [6].

The BoD approach can be considered equivalent to the original DEA model since it considers all indicators as outputs, but a "dummy input" equal to one for all the hospitals [7]. Considering inputs equal to one, for example, the output-oriented model becomes:

DEA output-oriented:

$$\begin{aligned} &\max \Phi^k \\ &\text{s.t.} \\ &\textstyle\sum_{j=1}^{n} \lambda^j y_r^j \geq \Phi^k y_r^k, r = 1, \ldots, s \\ &\textstyle\sum_{j=1}^{n} \lambda^j = 1 (VRS) \\ &\lambda^j \geq 0, j = 1, \ldots, n \end{aligned} \tag{2}$$

The main advantage of applying the BoD is the flexibility that it provides in the weight choice. Any other weighting approach would worsen the position of the evaluated hospital relative to the other hospitals [7].

4.3. Malmquist index

The Malmquist index is usually applied to measure productivity changes over time. The most widely applied Malmquist index approach uses distance functions, usually through DEA, using them to construct quantity indices as ratios [19]. Then, it can be decomposed into two components, efficiency and technological change.

The most common way of formulating the Malmquist index is [12, 19]:

$$M_O^{t,t+1}\left(X_t, Y_t, X_{t+1}, Y_{t+1}\right) = \underbrace{\frac{D_O^{t+1}\left(X_{t+1}, Y_{t+1}\right)}{D_O^{t}\left(X_t, Y_t\right)}}_{=E(X_t, Y_t, X_{t+1}, Y_r)} \cdot \underbrace{\left[\frac{D_O^{t}\left(X_{t+1}, Y_{t+1}\right) \cdot D_O^{t}\left(X_t, Y_t\right)}{D_O^{t+1}\left(X_{t+1}, Y_{t+1}\right) \cdot D_O^{t+1}\left(X_t, Y_t\right)}\right]^{1/2}}_{=T(X_t, Y_t, X_r, Y_{t+1})} \tag{3}$$

As mentioned, the Malmquist index is defined using distance functions, hence D_{o} represents those functions in periods t and $t+1$. If $M_{\text{o}} > 1$, performance has decreased between period t and period $t+1$. E represents the change in the technical efficiency levels between t and $t+1$, whereas T represents technological change, changes in productivity levels due to technical progress, in the same period [12].

4.4. Malmquist index for group comparison

Malmquist index for group comparison, already used by Ferreira [11] and Camanho [5], focus on group comparison for a given moment in time [5]. The general approach to use the Malmquist index for group comparison starts with applying DEA methodology to identify the group frontiers. Then, using Malmquist indexes, it is measured group performance. With this, a new aggregated performance measure is obtained, which can be multiplicatively decomposed into the two indexes previously mentioned. The overall performance measure can be written as follows [5]:

$$I^{AB} = \underbrace{\frac{\left[\Pi_{j=1}^{\delta_{\text{A}}} D^A\left(X_j^A, Y_j^A\right)\right]^{1/\delta_{\text{A}}}}{\left[\Pi_{j=1}^{\delta_B} D^B\left(X_j^B, Y_j^B\right)\right]^{1/\delta_B}}}_{=IE^{AB}} \cdot \underbrace{\left[\frac{\left(\Pi_{j=1}^{\delta_{\text{A}}} D^B\left(X_j^A, Y_j^A\right)\right)^{1/\delta_A}}{\left(\Pi_{=1}^{\delta_A} D^A\left(X_j^A, Y_j^A\right)\right)^{1/\delta_A}} \cdot \frac{\left(\Pi_{j=1}^{\delta_B} D^B\left(X_j^B, Y_j^B\right)\right)^{1/\delta_B}}{\left(\Pi_{j=1}^{\delta_B} D^A\left(X_j^B, Y_j^B\right)\right)^{1/\delta_B}}\right]^{1/2}}_{=IF^{AB}} \tag{4}$$

IE^{AB} is a ratio that compares how efficiency spreads within groups, and IF^{AB} evaluates the difference in productivity between the frontiers of the two groups. This decomposition shows that improvements in performance can be caused by: low scatter in efficiency levels of the DMUs in one group when in comparison with another, and/or the best practice frontier is dominant. When IE^{AB} is less than one, there is better consistency in efficiency levels in DMUs of group A than in those of group B. When IF^{AB} is less than one means that productivity of the frontier of group A is greater than the one of group B [5]. The use of this Malmquist index version is likely to help to answer the research question: "Do PPP hospitals outperform the corporatized ones?". If one constructs two different clusters (one for PPPs and another for public hospitals), then they can be compared through the Malmquist index above. It is worth to mention that the applied model will couple the Malmquist index with the BoD with weight restrictions to include decision making preferences.

5. Data & variables

In order to evaluate the performance of hospitals, an extensive, and reliable database is needed. As such, the selection of the variables, as well as the sources, must be carefully made. In general, the choice of variables follows criteria like data availability and quality, as well as a comprehensive literature review. The data used in this study was primarily provided by the official database of the Portuguese Ministry of Health, the Central Administration of Health Systems (ACSS)[12], and also by the online platform *Transparência*[13].

[12] http://benchmarking.acss.min-saude.pt/

[13] https://www.sns.gov.pt/transparencia/

5.1. Variables

Based on the literature review made in Subsection 3.3, a crossing between the most used variables in the literature with the variables provided by the sources ACSS and *Transparência* was made. Some variables were not precisely the same, but proxies were made to overcome that obstacle.

Figure 1 provides the variables selected for this study. Three different types of Key Performance Indicators (KPIs) were created, efficiency, access, and quality. Efficiency is subdivided in services availability, which regards the existence of resources to be used when needed, productivity, providing ratios between outputs and inputs of the hospital, and financial KPIs, measurements that describe economic units. Access, in this particular case, access to healthcare services, is defined by the ability of one citizen to use a specific service whenever necessary and at her/his will. Quality KPIs refer to patients' care appropriateness and clinical safety, where the first regards the ability to provide patient-centred care services backed by evidence-based guidelines, and the second is the ability to prevent complications or even preventable deaths from happening during care.

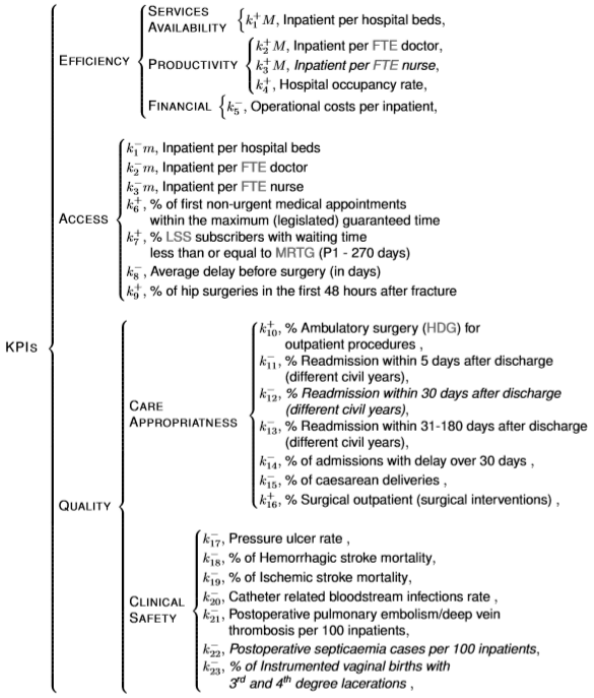

Figure 1: KPI's selected. Note: k^+ identifies the desirable variables while k^- identifies the undesirable ones. Variables in *italic* mean that they will be subsequently removed from the data base. FTE - fulltime equivalent; LSS - list of surgery subscribers; MRTG - maximum response time guaranteed; HDG - homogeneous diagnostic groups

Source: author

A statistical analysis of the sample was made for each KPI selected. Two tests were implemented to complement the statistical analysis, the two-sample t-test and Kruskal-Wallis test. In this case, it was used to compare the two groups of hospitals (public and PPP hospitals). These tests reject the null hypothesis at the 5% significance level.

From this analysis, only in three KPIs (k_1, k_{13}^-, and k_{20}^-), the null hypothesis was rejected, that is, both public and PPP hospitals show similar results.

Excluding some exceptions, both tests provide similar conclusions on the best performers, which may result from the considerable size of the sample. Based on the results obtained, some conclusions can be extracted regarding the types of KPIs:

- PPPs outperform public hospitals regarding the health care appropriateness;
- Public hospitals outperform PPPs concerning clinical safety, although not in all KPIs;
- In terms of access KPIs there is a superior performance of PPP hospitals, with exception to one KPI;
- There is no clear evidence supporting the hypothesis that one group outperforms the other.

These findings do not provide any consistent conclusion on the best type of hospital management, then, surfaces the need to use a benchmarking tool to optimise the weights given to each dimension. BoD and Malmquist index for group comparison are the tools that will provide a composite index allowing to discover which group (public or PPP) has a better overall performance.

It was calculated the Pearson's correlation coefficient, for the variables used in this work, to understand if variables are providing the same information, i.e., highly correlated. As a result, to reduce redundant information, two variables were removed from the dataset, that will now comprise 21 variables instead of 23.

All Tables, with the statistical analysis, are available online[14].

5.2. Data pre-processing

In this study, it is expected that higher levels of quality contribute to better hospital overall performance. When in the presence of two quality observations, the largest one provides higher utility to the hospital. This holds for all desirable variables. However, quality can be measured through undesirable dimensions as well. In this case, an appropriate rescaling must be done.

As noted before, this study assumes that the utility function associated to each quality level should be increasing, which means, $\forall k_{r(\ell)}^{q(\ell)} \geqslant k_{r(\ell)}^{p(\ell)} \implies U_{r(\ell)}(q) \geqslant U_{r(\ell)}(p), q, p \in \Omega$ [15].

All KPI's were rescaled to the interval [0,100]%, being hospital p $\in \Omega$ with $\tilde{k}_{r(\ell)}^{p(\ell)}$ = 100 the best performer in the KPI $r(\ell) \in \Gamma(\ell)$. Whereas, the worst

[14] https://drive.google.com/file/d/19dt7V4JoFxtkC6VwSnZob2xUFL7iOXdb/view?usp=sharing

performer is given by $\tilde{k}_{r(\ell)}^{p'(\ell)} = 0, \in \Omega$, in the same KPI.

5.3. Sample

As said, sources provide information for more than 40 Portuguese hospitals. However, hospitals that had a considerable amount of missing information were excluded from the sample. Given that, the sample comprises 28 hospitals (20 hospital centres, and 8 singular hospitals, of which 4 are PPP hospitals).

In terms of the period of the sample, it was taken into consideration that the last PPP to start their operations was Hospital Vila Franca de Xira, in March 2013, so it was considered to begin the timeline of the sample by January 2014, ending in the last month available which is September 2019. Since 2014 data has a considerable amount of missing data, in the variables selected, the beginning of the period was moved to January 2015. It is essential to mention that Hospital de Braga lost his PPP status in September 2019, becoming an EPE hospital.

5.4. Models

This study considers two different models (Models I and II) to analyze hospital efficiency. These models intended to improve the robustness of findings and conclusions of this research. The creation of these two models is a result of having key variables with data missing where their exclusion was not an option. Productivity (Inpatient per Full Time Equivalent (FTE) doctor) and economic (Operational costs per inpatient) KPIs do not provide any information on two PPP hospitals (Cascais and Loures).

- *Model I* variables with missing data are removed from the database (this model uses 15 out of 17 KPIs). Resulting in a sample of 1596 DMUs (relative to all 28 hospitals), from which 228 DMUs regard PPP hospitals.
- *Model II* hospitals with missing data are removed from the database (this model uses all KPIs). Resulting in a sample of 1482 DMUs (relative to 24 out of 28 hospitals), from which 114 DMUs regard PPP hospitals.

Each of these two models will unfold into two versions, *m* and *M*. The difference between them lays in the utilization of different equations, on KPI k_1 and k_2, upon data pre-processing. These two variables are unique because they can be classified as desirable or undesirable variables depending on the way they are interpreted. If considered as an access KPI, it is an undesirable variable, if it is taken an efficiency/productivity approach, it is considered as a desirable variable.

Models with *m* version will consider KPI k_1 and k_2 as undesirable ($k_1^- m$ and $k_2^- m$), whereas models with *M* version considers them as desirable ($k_1^+ M$ and $k_2^+ M$).

In conclusion, this study has two different models with two variants each: *Model I m*, *Model I M*, *Model II m*, and *Model II M*.

5.4.1. Model solving

All the computations of the DEA model and Malmquist indexes were performed recurring to the Matlab® R2018a[15] due to its high-performance properties. The computational framework was all created by the author with help provided by "Data Envelopment Analysis Toolbox", a package for Matlab, developed by Álvarez, Barbero, and Zofío (2016) [1], that comprises functions to calculate the main DEA models.

A test run was made discarding four variables (k_{20}^-, k_{21}^-, k_{22}^-, and k_{23}^-) and the results obtained were satisfying. Thus they were removed from the dataset, reducing the total number of KPIs from 21 to 17.

An improvement was achieved by removing those variables, but DEA (and all non-parametric methods) are particularly sensitive when using a high number of variables. Therefore, it was employed the Principal Component Analysis (PCA) technique to narrow down the number of variables. This operation resulted in having only one KPI (k_{PCA}) for each model. In all the PCAs made, the first component can explain more than 97% of the original KPIs, meaning that it is a worthy representation of the variance in the corresponding KPIs.

6. Results & discussion

After implementing both models, BoD and Malmquist index for groups comparison, and using the database collected and treated in Section 5, a comprehensive range of results will be drawn in this section.

6.1. BoD results

Results were exported from Matlab to Excel tables in order to further analyse them (those tables are provided online[16]). A statistical analysis, similar to the one made in Section 5 to the KPI's, was conducted for these results. It was added the confidence intervals, the coefficient of variation (CV), and the frequency of good social performers, which provides the probability of getting hospitals whose technical efficiency is, at least, equal to τ, here defined as τ = 90%. All the Tables can be seen online[17]. The four different models of the study will be discussed. However, due to the similarity in some

[15] https://www.mathworks.com/products/matlab.html

[16] https://drive.google.com/file/d/1bjnB9ZdYTuUybBSN4nenAPfSY3aJ1V9I/view?usp=sharing

[17] https://drive.google.com/file/d/15IdfX1zXjcnWsrLicjE4GkM3Em4POeNf/view?usp=sharing

results, only Model I m and Model II m will be discussed in depth.

6.1.1. Model I m

Model I m uses all data from hospitals but does not include KPIs k_2 nor k_5^-. It considers KPI k_1 as undesirable ($k_1^- m$). Concerning this model, see Table 2, which gives the basic statistics for all the efficiency scores between 2015 and 2019.

Table 2: Global performances basic statistics (Model I m).

2015/2019	Hospital Overall	Public Hospitals	PPP Hospitals
Entries	1596	1368	228
Maximum value	1.000	1.000	0.977
Maximum {CI}	0.864	0.859	0.895
Percentile 75%	0.885	0.879	0.916
Mean	0.863	0.858	0.891
Median	0.860	0.855	0.887
Percentile 25%	0.834	0.831	0.868
Minimum {CI}	0.861	0.856	0.888
Minimum value	0.749	0.749	0.798
F(τ =0.90)	15.60	11.70	39.04
Standard deviation (σ)	0.039	0.037	0.035
Coeficient ofvariation (CV)	0.05	0.04	0.04

CV measures heterogeneity among observations, it is calculated by dividing σ by the mean.
CI - confidence interval
Source: Author.

First impressions provided by Table 2:

- Only Public hospitals have efficient hospitals (performance = 1.00), the best PPP performer has an performance level of 0.977;
- The worst performer belongs to the public hospital group as well, with a performance score of 0.749. The lowest performance in a PPP hospital was 0.798;
- PPP hospitals have a higher average performance consistency (θ^{PPP}=0.891, [0.895; 0.888]$_{90\%}$) than public hospitals (θ^{PH}=0.855, [0.859; 0.856]$_{90\%}$);
- The standard deviation, in both groups, is considerably low, meaning that the performance results have low dispersion (or heterogeneity);
- The probability of finding good social performers (θ >0.9) is way higher for the PPP hospitals (39%) than the public hospitals (12%).

Results suggest that to become efficient, both public and PPP hospitals need to amplify their performances by 14% and 11%, respectively.

Figure 2 gives the average efficiency of each hospital model for every year of the study (2015 to 2019). By studying this figure, it is possible to understand how hospital performance developed throughout the years.

Despite, in 2016, having a small drop of less than 0,5%, public hospitals increase their performance in every year of the analysis, having an overall increase of 1,5%. PPPs also increase their efficiencies each passing year, except for 2016. The net improvement of the PPP's performance, along the studied period, is 0,5%. It is also clearly visible that, PPPs have a better performance in every year when compared with their public counterparts. The difference between both models is around 3 to 4%, but in the past three years, they appear to be converging. In 2019, the difference between the two models reached their lowest, 2,6%.

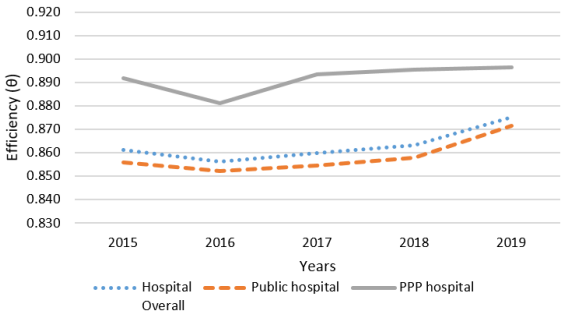

Figure 2: Hospitals yearly average performance variation between 2015 and 2019 (Model I m).
Source: author

Two statistical techniques consistent with the BoD methodology were used to assess the statistical significance, of the differences in performance, between both models for the several years under analysis. These were the student's t-test for means and Kruskal-Wallis non-parametric test for distributions. These tests determine if there are statistically significant differences between the two groups of hospitals.

Table 3 provides results for both tests for every year of the analysis (2015 to 2019), and all the years together (2015-2019).

Table 3: Statistical analysis: Student's t-test for means and Kruskal-Wallis non-parametric test for distributions for the performance values of Model I m.

	2015	2016	2017	2018	2019	2015-2019
Student's t-test for means						
p-value	0.0000	0.0000	0.0000	0.0000	0.0017	0.0000
Δ. lower bound	-0.0464	-0.0394	-0.0501	-0.0486	-0.0408	-0.0390
Δ. upper bound	-0.0252	-0.0185	-0.0282	-0.0264	-0.0096	-0.0285
T statistic	-6.6238	-5.4395	-7.0296	-6.6467	-3.1799	-12.7032
Best performer	PPP	PPP	PPP	PPP	PPP	PPP
Kruskal-Wallis non-parametric test for distributions						
p-value	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Best performer	PPP	PPP	PPP	PPP	PPP	PPP

Source: Author.

Similar outputs were obtained for both tests, having all the years presented p-values well below the significance level of 5%. Both tests reject the null hypothesis of similar performances of the hospital groups, which means that one group outperforms the other, in this case, the PPP hospitals.

Concluding, for this model (Model I m), both tests declare PPP hospitals as the best group for every year under analysis.

6.1.2. Model II m

Model II m is the model that uses all the KPIs, removing the hospitals that have missing data from the database (Hospital de Cascais and Hospital de Loures). It considers KPIs k_1 and k_2 as undesirable ($k_1^- m$ and $k_2^- m$). A similar table, to Table 2 for Model II m, is not portrayed since the same con-

clusions can be withdrawn. Starting by analyzing the yearly average efficiencies of the hospital models, it is possible to see, on Figure 3, that the PPPs are always above public hospitals in terms of performance.

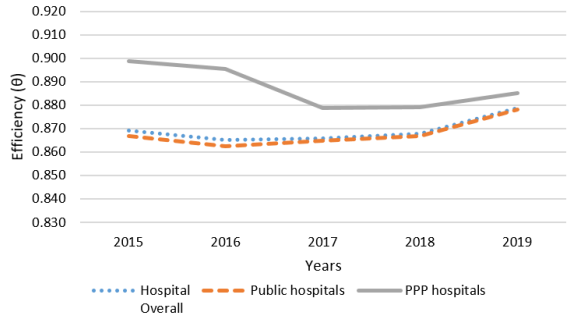

Figure 3: Hospitals yearly average performance variation between 2015 and 2019 (Model II m).
Source: author

By analyzing the individual evolution of public hospitals, it is possible to see that they increase their efficiency every year, except for 2016. Public hospitals have an overall increase of 1.1%. PPP's performance starts by having their maximum value in 2015, and from that year until 2017, has a drop-in efficiency of 2%. Their performance stays the same in 2018, increasing in 2019 0.6%. PPPs throughout this study had a decrease in efficiency with an overall drop of 1.4% from 2015 to 2019. Comparing both models, it is clear that PPPs outperform public hospitals every year, but that superiority has been decreasing. Starting with a favourable difference in performance for the PPPs of more than 3%, in 2015, that difference converges through the years to their minimum of only 0.7%, in 2019.

Results from the statistical tests made on the average efficiencies, for every year of the analysis can be found in Table 4.

Table 4: Statistical analysis: Student's t-test for means and Kruskal-Wallis non-parametric test for distributions for the performance values of Model II m.

	2015	2016	2017	2018	2019	2015-2019
Student's t-test for means						
p-value	0.0000	0.0000	0.0333	0.0695	0.4797	0.0000
Δ. lower bound	-0.0440	-0.0455	-0.0265	-0.0255	-0.0255	-0.0263
Δ. upper bound	-0.0195	-0.0198	-0.0011	0.0010	0.0120	-0.1390
T statistic	-5.1083	-4.9952	-2.1386	-1.8215	-0.7080	-6.3819
Best performer	PPP	PPP	PPP	similar	similar	PPP
Kruskal-Wallis non-parametric test for distributions						
p-value	0.0000	0.0000	0.0063	0.0106	0.1271	0.0000
Best performer	PPP	PPP	PPP	PPP	similar	PPP

Source: Author.

The outputs obtained for both tests are very similar, being only 2018 the exception. The student's t-test rejects the null hypothesis in 2015, 2016, 2017 and 2015-2019 since their p-values are below the significance level defined as 5%. In the years that the t-test rejects the null hypothesis, it also says that the best performer is the PPP hospitals' group. In 2018 and 2019, the null hypothesis can not be rejected, meaning that both types of hospital management have similar performance results. The Kruskal-Wallis test only differs from the t-test in 2018, rejecting the null hypothesis in that year, being PPP hospitals the best performers.

The impact of removing two PPP hospitals from the sample primarily affect the evolution of the performance of the PPP hospitals throughout the years. Whereas in Model I, they tend to grow annually (except for 2016), Model II drops the PPP performance almost every year (except for 2018). The evolution of public hospitals does not suffer considerable changes. However, due to the differences in the PPP performances, the gap between both models is considerably smaller in Model II, having repercussions on the statistical analysis. Model I statistical tests reject the null hypothesis for all the years, showing PPPs as best performers. Model II rejects the null hypothesis all the years (with PPP also has the best performer) except for 2019, meaning both hospital models have similar performances.

6.2. Malmquist index for group comparison results

This section provides the results of the Malmquist index for group comparison methodology. Results can also be found online[18].

Table 5 presents the results for I^{AB} and its subcomponents.

Table 5: Results for the Malmquist index for group comparison analysis.

	Model I m	Model I M	Model II m	Model II M
IE^{AB}	1.064	1.072	1.069	1.090
IF^{AB}	0.977	0.972	0.958	0.949
I^{AB}	1.040	1.042	1.024	1.035

Source: Author.

The results of the hospital comparison should not be only based on the information of the overall index (I^{AB}), but complemented with its subindexes (IE^{AB} and IF^{AB}).

Analyzing Model I m, the public hospital's efficiency spread is 6.4% higher than the PPP hospitals, i.e., their DMUs were located further from their own frontier. Public hospitals present the best productivity among all samples and have benchmarks 2.3% more efficient than PPPs. In the overall index, it is seen that PPPs outperform public hospitals by 4%. Similar conclusions can be taken from the results of the other models.

Concluding, despite public hospitals showing better productivity levels in all four models, the PPPs also have a considerable lower efficiency spread, therefore, being in the overall performance superior to the public hospitals.

[18] https://drive.google.com/file/d/10Rt8KHpaIAST725ij55BAx7N1ZpeDlJp/view?usp=sharing

7. Concluding remarks

The goal of this article is to find out whether the four PPP Portuguese hospitals outperform traditional public hospitals, and to understand if it is advantageous the utilization of PPPs in the hospital sector. Several important conclusions could be drawn from the developed empirical work.

In the global results, it is seen a considerable difference between social performance levels of both groups, being the performance of PPPs 2 to almost 4% higher, on average, than the public ones.

Statistical tests were made to understand if the differences between social performance levels of both groups are considerable or not. In Model I, the difference was always significant, clearly showing that PPPs consistently outperform the public hospitals. In Model II PPPs outperform public hospitals every year, except for 2019 where they have similar performances.

With the Malmquist index, it was observed that although public hospitals have presented the best productivity levels when compared with hospitals under PPP management, they are also the group with the highest efficiency spread. Nonetheless, the overall index indicates that the best hospital performance between both groups is from the PPP hospitals. These results support the previous conclusions where the PPP hospitals also outperformed the public ones.

Note that the reproducibility of these results should be restricted to PPP hospitals that follow the Portuguese model or the Alzira model, where the contract also has included the clinical services. The reason advise against the use of PPP under the UK model is because their clinical services are provided by a public entity, being only the infrastructure and ancillary services managed by a private entity. In these types of arrangements, it is not expected to have different performances from public hospitals. However, it is possible to have a conflict of interests between both.

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