Hospital Efficiency as an Aggregate of Services' Efficiency: A DEA Approach in Universidade Católica Portuguesa

Diogo Bernardo de Lacerda Queiroz e Almeida

Dissertação de Mestrado

Orientador na FEUP: Prof. Ana Maria Cunha Ribeiro dos Santos Ponces Camanho

Orientador na Universidade Católica Portuguesa: Prof. Maria Conceição A. Silva Portela

FEUP

Faculdade de Engenharia da Universidade do Porto

Mestrado Integrado em Engenharia Industrial e Gestão

2013-07-03

To my family and to Catarina

Resumo

Esta dissertação tem como principal objectivo conceptualizar um modelo para avaliar a eficiência dos serviços principais de um hospital e desenvolver um procedimento para agregar os valores obtidos para dar uma visão de topo da eficiência dos hospitais.

Para a realização deste trabalho foi necessária a revisão de literatura dos métodos de avaliação de eficiência mais usados assim como de métodos de agregação. Houve também uma revisão dos estudos de eficiência no âmbito da saúde para se analisar as melhores práticas.

O trabalho de investigação consistiu na criação de um modelo de DEA que permitiu avaliar a eficiência dos serviços principais de um hospital a partir dos vários recursos usados e serviços prestados. Os resultados obtidos da aplicação do modelo desenvolvido aos hospitais do Serviço Nacional de Saúde Português foram depois usados na criação de um indicador compósito. A aplicação do indicador compósito permitiu o seu refinamento para apresentar resultados mais credíveis.

Os modelos criados foram aplicados para avaliar a eficiência de custos dos diferentes serviços. O serviço de "Medicina Interna" foi usado para mostrar detalhadamente o modelo da avaliação dos serviços. Dos resultados obtidos conclui-se que em todos os serviços há espaço para melhorias. As reduções possíveis com maior peso são no gasto com fármacos, seguido do gasto com meios complementares de diagnóstico. Do modelo de agregação concluiu-se também que a eficiência média dos hospitais não mudava com o número de serviços mas que os hospitais eficientes tinham sempre um número baixo de serviços. Posteriormente, usando estes dados concluiu-se que há diferenças significativas entre os hospitais das ARS "Norte", "Centro" e "Lisboa e Vale do Tejo" com os hospitais da ARS "Norte" a apresentarem um nível de eficiência mais elevada.

Abstract

This work has the purpose to design a model to evaluate the efficiency of the primary services of a hospital and to develop a method to aggregate the efficiency values obtained to give a measure of the overall efficiency of hospitals.

To accomplish the objectives of this dissertation it was necessary to review the literature on efficiency assessment methods commonly used as well as aggregation methods. There was also a review of studies on efficiency measurement in health care to examine the current best practices.

The research consisted in the creation of a DEA model that could be used to evaluate the efficiency of the primary services of a hospital taking into account the various resources used and the services provided. The results obtained from the application of the models developed to the hospitals of the Portuguese National Health Service were then used to create a composite indicator. The application of the composite indicator allowed for its refinement to give more credible results.

The models developed were applied to evaluate the cost efficiency of the different primary services of the Portuguese Public Hospitals. The service of "Internal Medicine" was used to demonstrate the model developed to evaluate the services. From the results obtained it was concluded that there is room for improvement for all services. The most significant reductions are with cost with drugs followed by the cost with complementary diagnostic tools. From the aggregation model it was concluded that the greatest savings possible in this service were on expenditure with drugs. It was also concluded that the average efficiency of the hospitals did not change with the number of services but efficient hospitals always have a small number of services. Subsequently, using this data it was concluded that there are significant differences between hospitals of ARS "Norte", "Centro" and "Lisboa e Vale do Tejo" with ARS "Norte" having more efficient hospitals than the other two ARSs.

Acknowledgement

I start by thanking my supervisors Prof. Maria Conceição Portela and Prof. Ana Camanho. Their help to the development of this work was invaluable. They led my path successfully throughout these four months, always being there for me, explaining the methodology behind this work and also creating conditions to have healthy discussions about how to better approach some aspects of this work. Their energy and support was critical for this work.

To my colleagues from both colleges which provided the conditions for me to keep up my schedules without losing track of all classes and also for the support they always gave me.

To my friends from whom I got the all the fun and excitement between classes and for having the patient to hear all my complaining.

To the people with whom I share desks who created a good atmosphere to work. A special thanks goes to Ricardo Castro with whom I could discuss every idea who always gave another point of view of the problems I faced and who led me to question the obvious route.

A special thanks goes to Prof. Aníbal Justiniano for being such a great mentor and friend. I could always count with his expertise on a more clinical point of view of the work. Also for being such a good friend, teaching me every Thursday morning about the subjects that intrigued me the most.

I'd also like to thank Fundação para a Ciência e Tecnologia for the funding of my investigation which was essential to improve the quality of this work.

To my family goes a very special thanks. They raised me, educated me and gave me all the conditions that I needed. To my mother who gave up her carrier so I could have mine and who never let me give up. To my father who taught me how to reason and how to always take chances always having a useful advice to give. To my brother who helps me stay young and foolish all the time.

One last thanks goes to my girlfriend Catarina with whom I share everything and who helped stabilize my life showing me what really is important.

Index

List of Abbreviations

ACSS	Administração Central do Sistema de Saúde
AE	Allocative Efficiency
AR	Assurance Region
ARS	Administração Regional de Saúde
BCC	Banker, Charnes and Cooper
BOD	Benefit of the Doubt
CCR	Charnes, Cooper and Rhodes
CDT	Complementary Diagnostic Tool
CE	Cost Efficiency
CI	Composite Indicator
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRG	Diagnosis-Related Group
EPE	Entidade Pública Empresarial
ER	Emergency Room
GDP	Gross Domestic Product
ICU	Intensive Care Unit
INE	Instituto Nacional de Estatística
KPI	Key Performance Indicator
NHS	National Health System
OECD	Organisation for Economic Co-operation and Development
OT	Operating Theatre
PPP	Parceria Público Privada
SA	Sociedade Anónima
SFA	Stochastic Frontier Analysis
SPA	Sector Público Administrativo
TE	Technical Efficiency
VRS	Variable Returns to Scale
WHO	World Health Organisation

Figure Index

Table Index

1 Introduction

1.1 Presentation

The present work was developed in the Dissertation course of the Integrated Master in Industrial Engineering and Management of the Faculdade de Engenharia da Universidade do Porto (FEUP) in the second semester of the year of 2012/2013 and is part of the project “Hobe – Benchmarking de Hospitais Portugueses” which started in March 2011. It is currently financed by “Fundação para a Ciência e Tecnologia”. The work described in this dissertation took place at Universidade Católica Portuguesa, Centro Regional do Porto, under the supervision of Professor Maria da Conceição Portela. The FEUP supervisor of this dissertation was Professor Ana Camanho.

“Hobe – Benchmarking de Hospitais Portugueses” (http://hobe.mercatura.pt) has the purpose of providing an online benchmarking platform for the Portuguese hospitals that allows the user to compare an hospital’s practices with the best practices of other hospitals. The platform allows a comparison both at a hospital level or service level, it is fully customizable by the user, who can choose to compare Key Performance Indicators (KPIs) and an overall performance score that takes into account resources and results that will be implemented as a result of the work performed in this thesis. Because this project started two years ago, in 2011, this thesis continues the work previously done by Castro (2011): a review of the literature relevant to the project, a description of the most commonly used variables in the evaluation of healthcare efficiency using DEA, a characterization of the structure of the Portuguese hospitals and the idealization of a DEA model to be used in a hospital service.

1.2 Health Economics

Economics is a social science that studies the allocation of limited resources to an unlimited number of applications. Health economics is the application of the economic theory to the health sector and is concerned with the behaviour, choices, efficiency, consumption and production of health and can be divided into two branches: “Economics of Health” and “Economics of Healthcare”. The first is concerned with the study of health as a commodity (that is traded by the individual) and the second one concerned with the study of the provision of health care like medical services, nursing services, among other. The first application of economics to the health sector is probably by Kenneth Arrow (1963). In his work Arrow identified various characteristics that distinguish the health sector from the others: a high level of uncertainty (associated with the individual, the disease, the cost, the type of care), externalities (that lead to a higher intervention of the State), asymmetries of information (the doctor has access to more information than the patient), barriers to entry (the entrance to the market may require a large financial investment or the acceptance of lower salaries) and the usual distinction between the payer and the consumer.

The World Health Organization (WHO) definition of health (1948) states that “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”. One problem associated with health economics is how to value health because, from an ethical point of view, health is priceless. But resources are limited and have to be rationalized. A solution is to see health as a continuum variable that can be stocked, with a lower stock meaning a less healthy person and a higher stock meaning a healthier person. As such the focus should be in increasing the health of people with a low level of health because people with a high level of health need more investment to achieve a smaller benefit (Barros 2013).

Williams (1987) tried to represent the complexity of the analysis of health economics in a diagram (Figure 1) that shows the relations between the different processes involved.

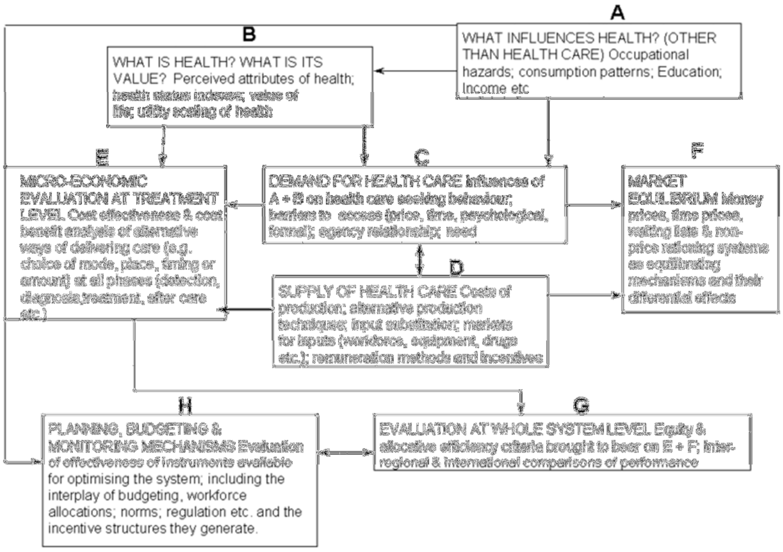

Figure 1 – Williams Diagram (Williams 1987)

The diagram starts with the factors that influence health (it should start by defining health because the factors that influence it can only be defined afterwards) and then defines health and how to value it. The demand for health care comes next (depends on the evaluation of health) and it is responded by the supply side of health care. This relationship leads to a macro-economic evaluation of the treatment (prevention, diagnoses and treatment) and to market equilibrium (achieved either through cost or time). Then, the evaluation of the whole system is made (the focus of this thesis) that leads to planning, budgeting and monitoring mechanisms. An important funder of this sector is missing from this diagram (the private insurers).

In recent years the importance of this subject has increased because among other things the expenditure with health is reaching high values. This is due to a greater life expectancy (which leads to more chronic diseases), an older population (more population needing more care), to more people living alone (the care process can't be given at home because there is no one to help) and to the technological development (which leads to newer more expensive tools) (Zweifel 2009).

1.3 Health in Portugal

1.3.1 *The National Health System*

The Portuguese National Health System (NHS) was created in 1979 with the promulgation of the Law n.º56/79. The conditions for its creation were set in 1974 with the "Carnation Revolution" and its rational defined in 1976 by the article 64 of the Portuguese Constitution which states in the n.º1 that "Todos têm direito à protecção da saúde e o dever de a defender e promover". The Beveridge model (Simões 2004) is behind this rational and some similarities can be found between the article 64 of the Portuguese Constitution and the fundaments of the Beveridge model. The Beveridge model has its origins in Great Britain and states that the

State should provide for the health of all the members of its population without discriminating by genre, age, income or occupation. There are five principles that are part of the health systems that adopt this model (Simões 2004).

1. The State is responsible for the health of its community and provides a free health service when they need;
2. The State provides a comprehensive health system that includes the prevention, diagnosis and treatment of diseases;
3. The State provides health for the members of its population;
4. The health provided is equal to all members of the population without discriminating by occupation, gender, age or income;
5. The health professionals are autonomous to take the best course of action for their patients and have access to the best medical equipment.

All of these principles can be found in the article 64 of the Portuguese Constitution. Although the Beveridge model is behind the NHS, other characteristics from other models helped define the NHS. These define the funding and the reimbursement. There are three sources of financing in the NHS (Simões 2004):

1. Private insurers provide insurance individually and adjusts the insurance premium according to the health characteristics of the individual;
2. Social insurers provide insure to a population and adjust the insurance premium taking into account the characteristics of the population it insures and the income of each individual to adjust the rate;
3. Taxes. In this case the State can have the function of both funder and provider of health or just as the funder being a private organization the provider.

There are also three ways to reimburse for the provided services (Simões 2004):

1. The funder reimburses against the service provided;
2. A contract between the provider and the funder that stipulates a contract and pay according to the defined conditions;
3. The funder is also the provider.

In the Portuguese case, the State is both the funder, provider and regulator.

1.3.2 *The Portuguese Law, Management and Efficiency*

The NHS was created with the state of the health of the population as its most important premise. However the Portuguese Law also has in many of its law articles the preoccupation to rationalize resources and increase the efficiency of the NHS. Some important moments regarding changes in management in the history of the NHS are noted and some of the legal documents that focus on efficiency are explored.

-In 1982 the "Administrações Regionais de Cuidados de Saúde" (ARS) were created to comply with the decentralization of the NHS stated in the article 64 of the Portuguese Constitution nº.4.

-In 1983 the creation of the ministry of health by the Decree of Law n.º344-A/83 due to the increasing importance of this area of activity.

-In 1988 the Decree of Law n.º19/88 introduces the concepts of management in the NHS due to the rise in costs in this sector. However, it states that these principles shouldn't affect the quality of the service.

-In 1990 the Law n.º48/90 approved the Basic Laws on Health that contains most of the laws on health. Among all the new introductions to the system, two must be highlighted. The introduction of user charges as a copayment mechanism, and the regulation of the private providers of healthcare.

-In 1999 there is a further decentralization of the NHS with the Decree of Law n.º286/99 to a local level, and this is achieved with the creation of the "Centros de Responsabilidade Integrados". There is also the creation of the "Agências de Contratualização dos Serviços de Saúde" to help separate the role of the state as a provider and as a financer of the NHS. There was also the creation of the "Sistemas Locais de Saúde" to help articulate the population with the NHS in order to rationalize and reduce costs.

-In 2002 Law n.º27/2002 is approved changing the Basic Laws on Health and introducing a new model of healthcare management resulting in the creation of the hospitals "Entidade Pública Empresarial" (EPE) and the "Parcerias Público Privadas" (PPP).

The article 64 of the Portuguese Constitution, n.º3, paragraph "b", states that the allocation of the health care resources must be made according to an economic rational and should have the efficiency as an objective. In Base I n.º2 the State guarantees the access of all the population to healthcare but acknowledges that this access is limited by the existing resources. In Base II n.º1 paragraph "e" there is the concern to maximize the benefit of the resources used, minimize the waste and help guide the management of the healthcare institutions. Cost reduction can also be a consequence but is not an objective since it can mean less/worse care for the patient. The Base VI n.º4 determines among other things that the Ministry of Health is responsible for the evaluation and inspection of the NHS. Base XII n.º3 creates the possibility to resort to private institutions when access is possible and the quality cost ratio is better. This leads to competition between the different organizations to increase efficiency. This is also present in Base XXXVII n.º1.Base XXVII is referent to the ARSs and among other things stipulates the continuous evaluation of the results obtained, guide the management of the healthcare institutions and match the resources to the needs. Base XXX concerns the evaluation of the NHS stating that the evaluation must be continuous and focus on quality and economic variables (Deodato 2012).

1.3.3 *Portugal in the International Arena*

The Organisation for Economic Co-operation and Development (OECD) was founded on 14th of November 1960 with the purpose of stimulating trade and economic evolution. Portugal was amongst the twenty countries that signed the Convention founding this organization. Among other things, OECD keeps track of the evolution of healthcare in dimensions such as quality and expenditure. The evolution of the expenditure with health keeps rising in all countries in OECD and has a considerable weight in the Gross Domestic Product (GDP). The reasons for this increase vary as explained in section 1.2.. In 2010 the expenditure with health in Portugal was 10.6% of the GDP, 1.2% above the average of the OECD countries. The Portuguese expenditure per capita however is lower than the average of the OECD meaning that Portugal actually spends less money the most countries of the OECD (Figure 2). The higher value as a percentage of the GDP is due to the lower level of the productivity of Portugal. From Figure 2 it is also visible that the public funding of health is lower in Portugal than the average of the OECD. In a quality perspective Portugal has an average performance in some dimensions and an above average performance in others. The life expectancy is of 79.8 years which is the average for the countries in OECD. Obesity, which is a risk factor for many chronic diseases like diabetes and cardiovascular diseases, has a higher rate in Portugal than in OECD countries (data from 2004, the rate in Portugal for self-assessed weight leads to an obesity rate of 15.4 which is higher than the obesity rate of 15 in the average OECD country). The consumption of alcohol is also above average (11.4 liters compared to the average of 9.4 liters). The infant mortality in Portugal (deaths per 1000 alive) is just 2.5, well below the average mark of the OECD of 4.3. The number of daily consumers of tobacco above the age of fifteen in Portugal is 18.6% (data of 2006) which is below the average value of OECD by 2.5% (OECD 2012). In the World Health Organisation (WHO) report of 2000 the Portuguese Health System ranked twelfth place in overall performance and twenty seventh as the most expensive (WHO 2000).

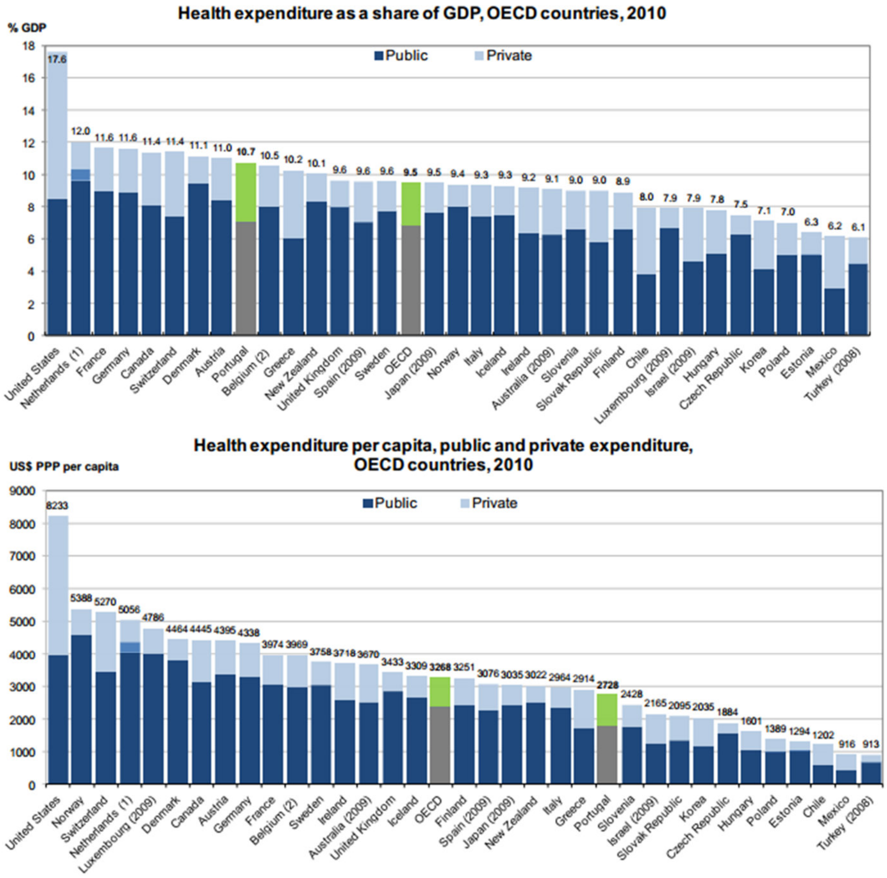

Figure 2 – Health Expenditures in OECD Countries (OECD 2012)

1.3.4 *The different Cost Drivers in Health in Portugal*

A representation of the importance of the different providers in the access to health is shown in Figure 3. It is visible that the State has a major role as health funder (is responsible for over 67% of the expenditure with health). However, the private households also have some importance in supporting health expenditure, as a consequence of either the increase in the user taxes or because more people without insurance are recurring to private institutions. The analysis of Figure 4 allows the comparison of the different organizational cost drivers and their importance in the total expenditure in health and in the NHS. Hospitals are responsible for a high percentage of the costs in health and are closely followed by the providers of ambulatory health care. The importance of the hospitals is even bigger in the case of the NHS.

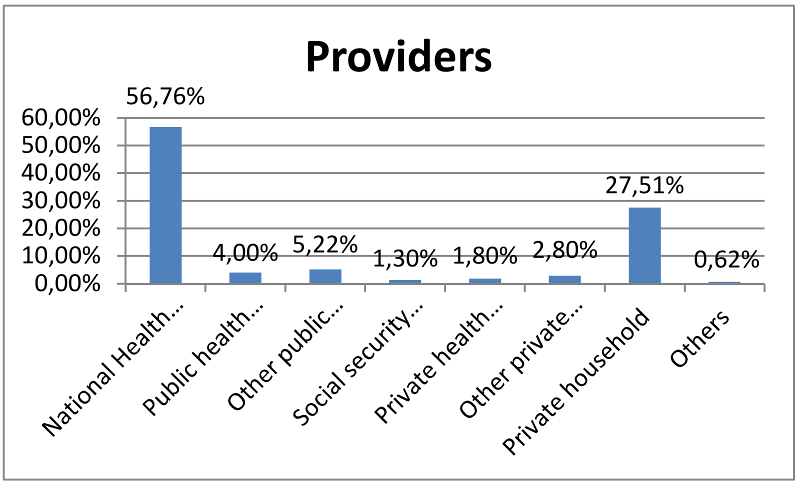

Figure 3 – Providers of the Portuguese Health (INE 2013)

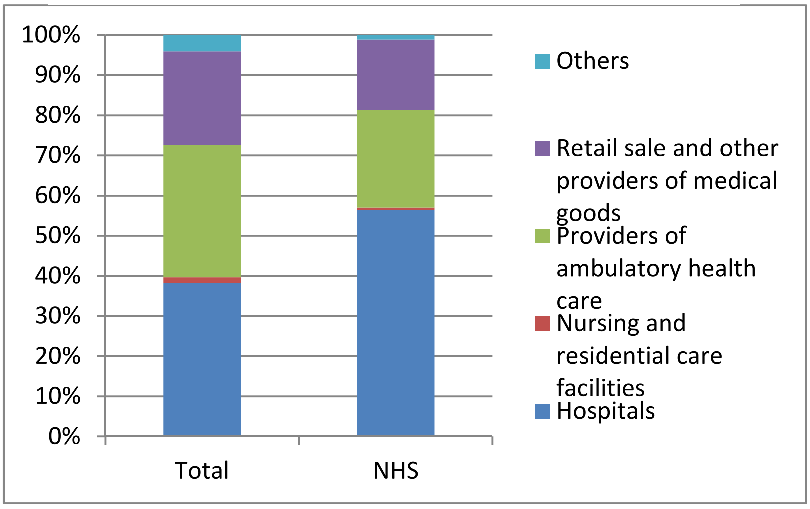

Figure 4 – Expenditure by Health Care Organisation (INE 2013)

A graphic with the representation of the trends in costs by organizational cost driver can be found in Figure 5. In opposition to what would be expected, the importance of the hospital seems to have increased. This shows that the cure process is as important in 2010 as it was in 2000 what might mean that the focus in prevention either hasn't had the results expected or the results will only be seen in a further future.

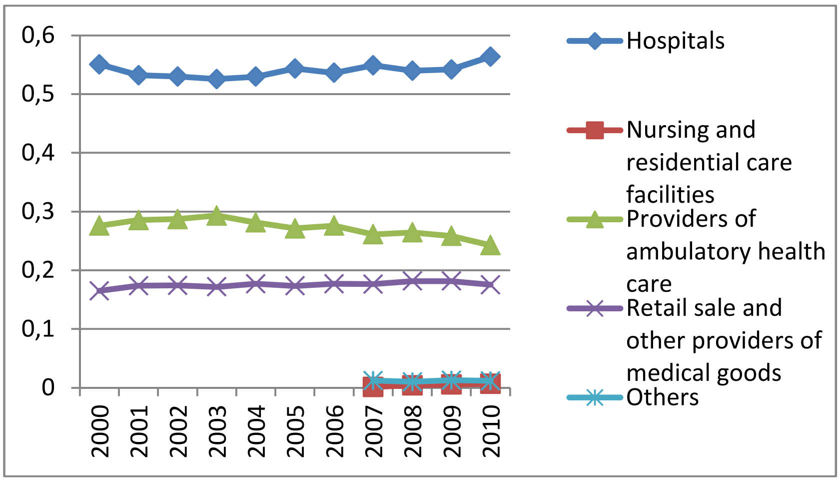

Figure 5 – Evolution of Expenditure by Health Care Organisation (INE 2013)

The development of the expenditure and the actual economic and social crisis have led the Program of the XIX Portuguese Government to focus on efficiency. There is a concern to rationalize the health system and increase its efficiency because " it is absolutely necessary to ensure the right to health protection" (Ministros 2011, 77). It includes measures as: integration of care, a more active participation of the population in their care, a more decentralized and autonomous management, evaluating the design of the organization and optimizing the transparency of the data in healthcare among other things (Ministros 2011).

1.4 Motivation

The quality of the Portuguese NHS is probably the greatest achievement of the country in terms of public services (Jorge 2009). But this quality has now an unbearable cost and with the current economic situation of the country a frightening but righteous question must be made: Can the NHS sustain its quality and equity and still reduce its costs? The government program of the XIX government states in its first few lines that its main objectives in terms of the NHS is the reduction and rationalization of costs and the improvement of efficiency in order to maintain the NHS as we know it today (Ministros 2011). In addition, more and more people demand information transparency and accountability of the NHS. The number of associations that defend the interests of the consumers, the pressure from the media and other parties is leading to this transparency (Castro 2011). As if this wasn't enough, the Memorandum of Understanding negotiated requires a reduction of five hundred and fifty million euros and an increase in the efficiency and effectiveness of the NHS. Additionally it also requires the introduction of benchmarking in healthcare (Finanças 2011).

From the various health care units that constitute the NHS, the ones that stand out because of their size, of their complexity, their importance and associated costs are the hospitals. As such a web platform that allows for the benchmarking of these organizations is very interesting. The use of both KPIs and an overall indicator of efficiency (the aim of this thesis) allow for a detailed view of the comparison between hospitals and services. Additionally, a web benchmarking platform is also the assurance that the different hospitals will be compared with the same basic panel of inputs and outputs, allowing for access to the information, to promoting the continuous improvement of the different units, as well as keeping track of their evolution over time. The concept of evaluation and benchmarking in a sector that has considered itself very different from all the others always got a lot of resistance from the parties involved. However this effort is essential to regulate and to improve the organizations. They inform and help the management teams of the different hospitals, however they shouldn't influence them to abandon strategic planning and start setting short term goals and targets based on these tools (Carvalho 2008).

1.5 Ethical Implications

The subject of evaluation in health care hasn't been properly studied from an ethical point of view. This section tries to raise the concern among scholars that have been putting so much effort in studying efficiency measurement but haven't been giving the proper attention to studying the implications of their work. The trouble with evaluation in health care has to do with the benchmarking of the outcomes of health care. The hospitals in Portugal are regulated by the State and they have a primary and secondary catchment area. The catchment area was designed to allow the hospitals to specialize, provide and adjust the services to its population needs. However this limits the choice of the patient since the patient is usually referred to the hospital of its area of residence and isn't free to choose any other hospital (unless in an emergent situation). If from a management point of view this makes sense (the hospitals were dimensioned to the population of its catchment area and specialized according to its needs) it also means that patients have their choices limited. Disclosing information to the public about the quality of care received in the different hospitals can be seen as ethically incorrect since the patient will know the quality of care of the hospitals but he won't be able to choose the hospital he can attend to because he will be limited by the catchment area of the hospital of his area of residence. In this sense, studies that evaluate and benchmark hospitals from a quality of care perspective should only be disclosed to the population that can use these studies to implement changes like the management teams of hospitals, doctors and policy makers because, to the general population, the disclosure of this type of information only leads to insecurity and distress to their limited courses of action.

1.6 Structure of the Dissertation

This first chapter introduced health economics (as the broader topic that comprises efficiency measurement in health care). It shows some of the specifications and difficulties of this branch of economics. A brief story of the Portuguese NHS was presented, as well as the laws that highlight the concern for efficiency in this sector. Health in Portugal was compared to the international arena (from both a quality perspective and an economic perspective), the concern with the ethical implications of clinical benchmarking were raised and finally the motivation behind this dissertation is explained.

Chapter 2 explains the basic concepts behind benchmarking, and then introduces the concepts of productivity and efficiency. The frontier methodologies more often used are introduced and compared. DEA, the methodology used in this dissertation, is then presented in more detail as well as its mathematical formulation for measurement of technical efficiency and then for the measurement of cost efficiency (the focus of this work). Finally there is a brief explanation about composite indicators and the type of composite indicator used in the work of this thesis.

Chapter 3 addresses the topic of health care evaluation and consists in two parts. In the first part there is a review of literature on efficiency measurement in health care, to characterize how this subject has evolved over time (attention from scholars, used methods, most common target of evaluation and the perspectives on the subject) as well as some studies that focus on the Portuguese case (specially about the policies implemented and the aspects that need more attention). The second part presents the platform developed in the project linked to this work, and shows some of its main features as well as what differentiates it from other solutions available on the market.

Chapter 4 presents the internal structure of the hospitals and then explains the rationale behind the model (perspective, choice of variables, filters for the data, efficiency model chosen, the importance of aggregation) and then applies this model to the services of the hospitals (with one service being used to explore the characteristics of the model). Finally, the services' efficiency is aggregated to provide an overall measure of hospitals' performance and the results obtained are discussed.

Chapter 5 presents the conclusions of this dissertation and suggestions for future work.

2 Efficiency analysis

2.1 Benchmarking

2.1.1 *Overview*

The comparison with others to improve processes probably begun with the prehistoric man and the manufacturing of weapons (Anderson-Miles 1994). However Xerox was the first to document an application of benchmarking (Camp 1989).

Benchmarking can be defined as a continuous process of comparison of performance between different organizations with the purpose of sharing best practices and improve performance. Its use has increased in businesses because it gives a better understanding of competitors and costumers, helps improve performance and enables innovation to flow across the different industries more rapidly (Beckford 1998). However, best practices are always evolving, because new technology, different processes and new standards in the products/services being produced continuously change the rules of the industry (Kay 2007).

Benchmarking has an impact that can come from decreased costs, increased customer satisfaction, increased access or speedier delivery, and affects different stakeholders (Anderson-Miles 1994). Its main benefits are the sharing of information between peers, the pressure to act and the objectivity of the retrieval of the information. Codling (1998) provides a list of benefits of successful benchmarking and how to attain them. Kay (2007) reviews the benchmarking literature and presents some conclusions about its benefits.

There are also problems associated with benchmarking that, although outweighed by the benefits, should be taken into consideration. For starters, there are a lot of requirements: successful senior management commitment, trained staff and allocation of the time of relevant employees are required (Beckford 1998). The main difficulties associated with benchmarking are: resistance to change, poor planning, lack of commitment from management and human resources, cost, competitive barriers, time constrains and short term expectations (Bendell 1993). To be successfully implemented, benchmarking should be seen more like a culture and less like a tool. Therefore, its practice inside the organization must be continuous, in order to really reap the benefits from such a methodology (Anderson-Miles 1994). In case of unsuccessful implementation of benchmarking, the waste of time, human and financial resources seen may lead to an image deterioration in the organisation, with benchmarking being seen just as another “flavour of the month” methodology (Cox 1998).

2.1.2 *Types of Benchmarking*

According to Camp (1989), benchmarking can be divided in Internal and External Benchmarking. Within this classification, External Benchmarking can be further divided into: Competitive Benchmarking, Functional Benchmarking and Generic Benchmarking. A brief explanation of each type of benchmarking is presented below. For a more thorough review see Camp (1989).

- Internal Benchmarking – The comparison is made within a unit of the organization which is set as the benchmark. Although easy to implement and to exchange information this kind of benchmarking is very limited by its scope. It is the best step to start benchmarking, because it allows the organization to examine itself (Kay 2007).

- Competitive Benchmarking – This comparison is made with direct competitors. This kind of benchmarking is hard to implement because of the difficulty that may exist to get the information required from the competitors. Yet this type of benchmarking also brings the best results with new ideas, methods, products and services becoming available to the organisations involved (Cox 1998).
- Functional Benchmarking – In the case the comparison is made with an organization or a unit within an organization that, although not a direct competitor, shares similar functions and sets the benchmark. The information is easily accessed but may require adaptations.
- Generic Benchmarking – There is a comparison with different processes from different organisations, and it can cross different business units. This type of benchmarking has the biggest potential to innovate but it also has several costs and is very complex.

Benchmarking usually relies on Key Performance Indicators (KPIs), which can be resources, outcomes or ratios between them. The intuitive use of KPIs makes them a favourite. However, although very popular, ratios have some limitations. First, ratios assume constant returns to scale, which is not always applicable. Second, the relationship between resources and outcomes might be difficult to establish. Third, the impact of a given resource on other resources and outcomes might be difficult to take into account, so the trade-offs may not be accounted for. As a result the use of ratios might result in less than optimal decisions (Camanho 1999). One curious situation known as Fox Paradox arises when ratios are handled lightly. An organization that shows the same or better efficiencies for individual ratios might show up overall as a less efficient organization (Fox 1999).

If all resources could be translated into a reasonable resource and all outcomes into a reasonable outcome then just one indicator would be needed to benchmark. However the various resources and outcomes vary in their importance and measurement units and scale which limits aggregation. Sometimes it's possible to find ways to measure resources and results in the same measurement unit, for example resorting to their prices. But information about the prices is not always available (such as in the context of healthcare outcomes). Weighting the resources and results is one way to translate all the resources and results into one single indicator. This leads to various mixes of resources and results having different values depending on the weights assigned (Bogetoft 2011). This is one disadvantage of aggregation because the results will have different meanings to different people. Other disadvantage with aggregation is the loss of information. If an overall view of the system is taken there is no way to look inside the "black box" of production and understand which processes are better or worse than those of the peers. No information is available to know what to improve.

2.2 Productivity and Efficiency

A Decision Making Unit (DMU) (Figure 6) is an entity that uses inputs (resources) and through internal processes produces outputs (products/services) (Bogetoft 2011). External factors can also influence the productive process but since their control is limited (or even non-existent) the productive process is often simply seen as a relationship between the inputs and the output.

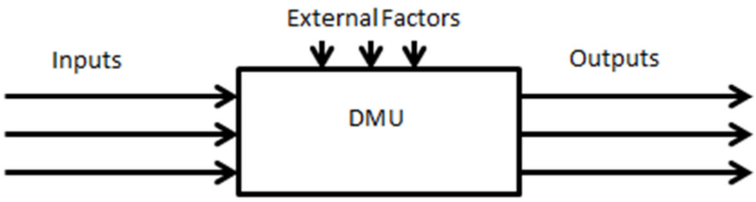

Figure 6 – Representation of a DMU

Productivity refers to the output achieved with the available input. In Figure 7, line S defines the productive frontier and represents the maximum available output achievable with all given inputs. Efficiency is measured against this curve and all points contained in it are efficient. However, the level of productivity is not the same for all points on the frontier. Point C is both efficient and has the maximum productivity because the slope of the derivative of the production function has a maximum in this point. On the other hand, point B is efficient but it is not the most productive (Mello 2005).

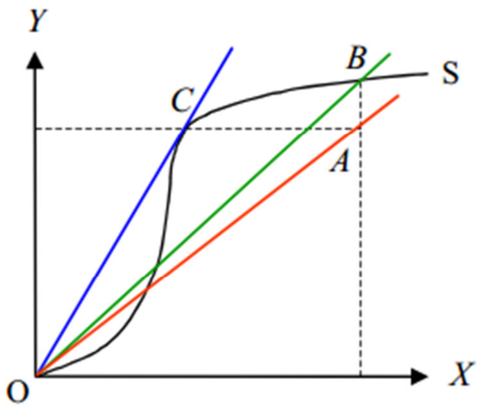

Figure 7 – Representation of Productivity and Efficiency (Mello 2005)

Koopmans (1951) defined efficiency as: “A producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output” (Fried 2008). Efficiency can have various definitions depending on the kind of efficiency being considered but it usually refers to technical efficiency (TE).

Some concepts of efficiency will be explained using Figure 8.

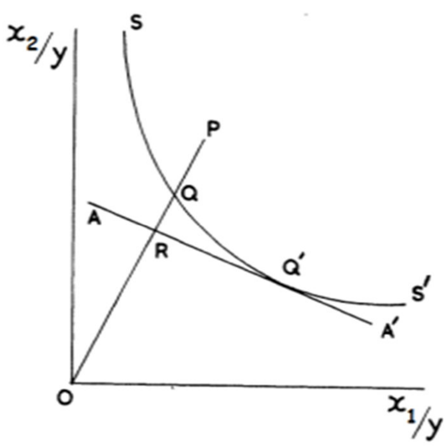

Figure 8 – Production Frontier and Isocost Line (Farrell 1957)

Consider that the productive process of this example needs two inputs (x_1 and x_2) to produce one output (y). Each axis represents the inputs required to produce one unit of output. Analysing Figure 8 we can see that: DMU P is technically inefficient according to Koopmans's definition, since both inputs can be reduced while keeping the same level of output; DMU Q, Q', S and S' are all Koopmans efficient, since no reduction to the inputs is possible without also reducing the outputs.

The TE of DMU P can be assessed as such:

$$TE = \frac{\overline{OQ}}{\overline{OP}} \tag{2-1}$$

Other types of efficiency can be assessed. When the prices of the inputs and/or outputs are known, it is possible to assess the allocative efficiency (AE). This makes it possible to compute the economic (revenue, cost or profit) efficiency. When the objective is cost minimization or when only the input prices are available, as it is with the data of this thesis, a cost efficiency (CE) approach can be taken (Fried 2008). CE can be defined as the ratio between the minimum cost possible to produce a level of output and the actual cost of the producer.

Cost can be assessed when the prices of the inputs and its quantities are available or when the total cost is available. When the prices of the inputs are known, there is the possibility to decompose the CE into AE and TE. When only the total cost is known only the CE can be calculated. This efficiency is measured with reference to an isocost line that is tangential to the TE curve in the points where production is possible.

In Figure 8, the only cost efficient DMU is DMU Q'. All the other technical efficient DMUs aren't cost efficient. The radial distance from the production frontier to the isocost line defines what is called the AE. Still using DMU P as an example, its AE can be defined as:

$$AE = \frac{\overline{OR}}{\overline{OQ}} \tag{2-2}$$

The economic efficiency is then defined as the distance of the DMU to the isocost line and thus can be defined as the product of the TE by the AE.

$$EF = \frac{\overline{OR}}{\overline{OP}} = \frac{\overline{OR}}{\overline{OQ}} \times \frac{\overline{OQ}}{\overline{OP}} = AE \times TE \tag{2-3}$$

2.3 Overview of efficiency assessment methods

The most common methods to assess efficiency and to perform benchmarking are either Stochastic Frontier Analysis (SFA) or Data Envelopment Analysis (DEA). Both methods are widely used and are developing rapidly. The two methods are based on the logic of the construction of an efficient frontier but they differ in several ways. SFA is a parametric stochastic method while DEA is a nonparametric deterministic method.

The advantage of nonparametric methods is that there is no need to know the form of the production function or the error distribution, so fewer assumptions must be made. But when these properties are known they offer a more robust analysis (Coelli 2005).

Stochastic models differ from deterministic models because they allow for the existence of statistical error. Deterministic values don't have this property, what makes them sensible to extreme values (Coelli 2005, Bogetoft 2011).

The choice between SFA and DEA depends whether it's more important noise separation or flexibility. While the SFA is more robust and less sensitive to random variations, DEA is a more flexible method that doesn't need so many assumptions. (Coelli 2005, Bogetoft 2011). Another advantage of DEA is its ability to handle multiple inputs and outputs which in the case of SFA is limited to multiple inputs and one output (or vice versa). This implies that in SFA there must be an aggregation of the outputs (or inputs) before the analysis can be conducted (Hollingsworth 2009).

Ideally, a stochastic nonparametric model would be the best because of flexibility and noise separation. But disadvantages like the need of more data, more time and processing power makes it preferable to use a method like SFA and DEA (Coelli 2005, Bogetoft 2011).

2.4 Data Envelopment Analysis - Overview

The Data Envelopment Analysis technique was originally proposed by Charnes, Cooper and Rhodes (1978) based on Farrell (1957) work on efficiency. DEA is a nonparametric mathematical programming method that can handle multiple inputs and outputs use them to create an efficient frontier. It can be used to evaluate performance and to benchmark. DEA has been used in a variety of contexts such as: education, healthcare, banking, manufacturing among others (Haynes and Dinc 2005)

Traditionally DEA is a benevolent method since it tries to maximize the performance of the each DMU by choosing the weights that benefit the most each DMU (Cooper 2002). An "inverted" DEA has also been developed which evaluates DMUs from a pessimistic point of view and has been applied in several cases where a pessimistic point of view is required (Hadley and Ruggiero 2006). A combination of both views has been used to create a model that gives the interval of efficiency of the DMUs (Johnson and McGinnis 2008, Entani, Maeda, and Tanaka 2002).

DEA provides information about the efficiency scores and the slacks associated to inputs and outputs. This allows for the projection of the inefficient DMUs on the efficient frontier. When using DEA, it must be noted that the activity of all DMUs must be homogenous, because otherwise the inputs and the outputs wouldn't be the same, which would lead to the impossibility of comparing efficiencies.

2.5 Data Envelopment Analysis – Mathematical formulation

To evaluate efficiency with DEA, we need to take into account three things: the inputs, the outputs and their weights. The CCR model (Charnes, Cooper, and Rhodes 1978) proposed in 1978 is the standard model and serves as the basis for more complex models. This model assumes constant returns to scale (CRS) and can be formulated with a fractional logic.

$$max\ \theta = \frac{virtual\ output}{virtual\ input} = \frac{\sum_{r=1}^{s} v_r y_{ro}}{\sum_{i=1}^{m} u_i x_{io}} \quad \textbf{(2-4)}$$

Subject to

$$\frac{\sum_{r=1}^{s} v_r y_{rj}}{\sum_{i=1}^{m} u_i x_{ij}} \leq 1, \ \ (j = 1, \dots, n) \quad \textbf{(2-5)}$$

$$v_r \geq 0\ \forall\ r \quad \textbf{(2-6)}$$

$$u_i \geq 0\ \forall\ i \quad \textbf{(2-7)}$$

The variables u_i and v_r represent the different weights attributed to the different inputs and outputs respectively and x_{ij} and y_{rj} represent the different inputs and outputs. The different indexes have the following interpretation: i represents the input, r represents the output and j represents the DMU (Cooper 2002).

The objective function gives the efficiency of the DMU that can be maximized either by maximizing the outputs, minimizing the inputs or both. The first restriction constrains the value of the efficiency by limiting its value to 1 (100%) for all DMUs. The second and third restriction are nonnegative constrains to the weights of the inputs/outputs (Cooper 2002).

The fractional model can be linearized, but in order to do that the model orientation must be defined. The orientation of the model concerns if the focus in on the side of the inputs or outputs. An input oriented model focuses on input minimization with the current production of outputs. This is usually the case in organizations that have to minimize their operational costs and still maintain their level of production. The output orientation has a symmetrical logic. This is the case of organisations with a fixed budget (or level of resources) that want to maximize their production (Cooper 2002). Both models can be combined when there is a certain level of control of both inputs and outputs. These models are represented by the slack based models like the additive model (Ozcan 2008). This thesis will focus on the input orientation for reasons explained in section 3.1.5.

Linearizing the objective function (2-4) and restriction (2-5) we obtain the following model:

$$max \sum_{r=1}^{s} v_r y_{ro} \qquad \textbf{(2-8)}$$

Subject to

$$\sum_{i=1}^{m} u_i x_{io} = 1 \qquad \textbf{(2-9)}$$

$$\sum_{r=1}^{s} v_r y_{rj} - \sum_{i=1}^{m} u_i x_{ij} \leq 0, \ \ (j = 1, \dots, n) \qquad \textbf{(2-10)}$$

$$v_1, v_2, \dots, v_s \geq 0 \qquad \textbf{(2-11)}$$

$$u_1, u_2, \dots, u_m \geq 0 \qquad \textbf{(2-12)}$$

The dual to this model is called the envelopment model (in opposition to the previous model that is called the multiplier model).

$$min\,\theta \qquad \textbf{(2-13)}$$

Subject to

$$\theta x_{io} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0 \ \ (i = 1, \dots, m) \qquad \textbf{(2-14)}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \ \ (r = 1, \dots, s) \qquad \textbf{(2-15)}$$

$$\lambda_j \geq 0 \, \forall \, j \qquad \textbf{(2-16)}$$

Here θ represents the efficiency value and its magnitude will always range between zero and one. The decision variables $\lambda_j$represent the intensity variables responsible for allowing the different DMUs to project themselves on the efficiency frontier. The dual model has an advantage over the multiplier model because it only needs to solve $m + s$ constrains in opposition to the multiplier model that needs to solve $n + 1$ constrains. This implies a lot less computational power.

The addition of one constraint allows for Variable Returns to Scale (VRS)

$$\sum_{r=1}^{s} \lambda_j = 1 \tag{2-17}$$

The addition of this constrain transforms the previous model into the Banker, Charnes and Cooper (BCC) model. The BCC efficiency will always be equal or higher than the CCR efficiency. (Cooper 2002).

A CE DEA model was proposed by Charnes, Cooper and Rhodes (1978):

$$min \sum_{i=1}^{m} c_{io} x_i \tag{2-18}$$

Subject to

$$x_i \geq \sum_{j=1}^{n} \lambda_j x_{ij} \quad (i = 1, \dots, m) \tag{2-19}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \quad (r = 1, \dots, s) \tag{2-20}$$

$$\lambda_j, x_{ij} \geq 0 \ \forall \ i, j \tag{2-21}$$

The price of the input i for DMU o is represented by c_{io} and is considered exogeneous. The variables that can be changed by the model are the inputs of the DMU under evaluation x_i and the intensity variables λ_j. This represents a CRS model of CE. If a VRS model is required the introduction of a constraint similar to (2-17) can be added to the model. One disadvantage of this model is that the AE is dependent only on the ratio between the different prices meaning that, for a productive process where the various DMUs produce the same outputs with the same inputs but the costs vary in a proportional manner, all the DMUs will be considered equally cost efficient. This matter is discussed and an alternative model is proposed in (Tone 2002), which should be used when prices are under control of the decision makers.

However, the previous model cannot be used in this dissertation because the prices of the inputs are not known. A model that requires only the costs must be formulated. This translates in a different CE model that can be formulated as such:

$$min \sum_{i=1}^{m} C_{io} \tag{2-22}$$

Subject to

$$C_i \geq \sum_{j=1}^{n} \lambda_j C_{ij} \quad (i = 1, \dots, m) \tag{2-23}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \quad (r = 1, \dots, s) \tag{2-24}$$

$$\lambda_j, C_{ij} \geq 0 \; \forall \; i, j \tag{2-25}$$

This model takes only the cost with the inputs of the DMU being analysed. This means that the TE and AE of the system is lost. On the other hand, the disadvantage of the previous model doesn't apply to this one because the total cost is the only data required implying that total costs will be perceived as inefficiencies, even if they are caused by higher input prices faced by some DMUs. The application of this model with DEA is facilitated if a model is formulated that takes only the total cost of the DMU

$$\min \theta \tag{2-26}$$

Subject to

$$\theta C_0 - \sum_{j=1}^{n} \lambda_j C_j \geq 0 \tag{2-27}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \quad (r = 1, \dots, s) \tag{2-28}$$

$$\lambda_j \geq 0 \; \forall \; j \tag{2-29}$$

2.6 Data Envelopment Analysis – Weights

2.6.1 *Overview*

One of the biggest advantages of DEA, the flexibility to choose the set of weights that maximize each DMU's efficiency, is also one of its big weaknesses. The freedom of choice can lead to large differences between the different weights and in extreme cases can even lead to some inputs and outputs being neglected in the assessment of the efficiency. (Cooper 2011)

This flexibility can be even worse when secondary inputs and outputs (from an expert's perspective) have high weights and the main inputs and outputs are neglected because the model allotted them null weights. This goes against the knowledge about the production process and means that the result can't be reasonably used (Cooper 2011).

The knowledge on the subject being analysed is important to set weight restrictions since in this way, some knowledge is involved in the choice of the weights of every input and output. Too many restrictions might make the model too rigid turning a DEA model to a weighted average. Other ways to set weights between the different inputs and outputs are the use of ranges of possible prices or even the use of trade-offs between them. One way to set the trade-offs with more confidence is to know the technology involved (Cooper 2011). Using trade-offs is a good way to set the weights, but they only reflect TE. The use of prices, on the other hand, reflect technical and AE since one monetary unit is equal among all inputs and outputs.

2.6.2 ***Types of Weight Restrictions and Mathematical Formulation***

There are different ways to incorporate weight restrictions into a DEA model. A literature review of these methods can be found in Allen et al. (1997). In this thesis we'll focus on two of the weight restrictions more often used: assurance regions (ARs) of type I and virtual weights.

ARs are weight restrictions that are applied directly to the weights and are dependent on the units of measurement of the inputs and outputs. They were first used by Thompson (1986). They are divided into AR of type I and AR of type II. AR of type I create a relationship between inputs or outputs and can be represented as follows (Allen et al. 1997):

$$\alpha_i \leq v_i / v_{i+1} \leq \beta_i \qquad \textbf{(2-30)}$$

The constants α and β represent the values between which the ratio of the weights v_i and v_{i+1} are valid. The introduction of AR of type I produces the same results either for input or output oriented models, provided it is defined under CRS. (Allen et al. 1997)

Virtual weight restrictions were first introduced by Wong and Beasley (1990). They take into account both the weight and the input (output) associated, to create a virtual restriction.

$$\phi_r \leq {u_r y_{rj}} \Big/ {\sum_{r=1}^{s} u_r y_{rj}} \leq \psi_r \qquad \textbf{(2-31)}$$

Equation (2-31) shows that the ratio between the virtual outputs (inputs) has two bounds. An advantage of virtual weight restrictions is that hasn't to take into account the measurement scale of the outputs (inputs). A disadvantage of virtual weight restrictions is that they can require a lot more computational power depending on how they are specified (Cooper 2011).

2.7 Composite Indicators

Composite indicators (CIs) are used to aggregate indicators in order to give a multidimensional view of the situation. CIs are used to benchmark because they require less time to interpret than a set of indicators. However this makes them susceptible to be misinterpreted. Additionally if its construction process isn't transparent it can also lead to poor decision making (OECD 2008).

The OECD report (2008) presents and discusses the several steps to construct CIs: theoretical framework, data selection, imputation of missing data, multivariate analysis, normalisation, weighting and aggregation, robustness and sensitivity, disaggregation, links with other variables and presentation. These guidelines help understand the construction process of a CI and how to create a CI that is both useful and transparent.

One of the many aggregation and weighting methodologies used to construct CIs is DEA. The first application of DEA to this subject was by Melyn and Moesen (1991). DEA is now commonly known and applied to the construction of CIs with the name of benefit of the doubt (BOD). The main difference between DEA and BOD is that the latter only looks at the outputs with no regard to the inputs. With this methodology each unit being evaluated is free to choose the weights that maximize its overall score (Morais and Camanho 2011).

$$CI_o = \max \sum_{r=1}^{s} v_r y_{ro} \tag{2.2-32}$$

Subject to:

$$\sum_{r=1}^{s} v_r y_{rj} \leq 1 \quad (j = 1, \ldots, n) \tag{2.2-33}$$

$$v_r \geq 0 \; \forall \, r \tag{2.2-34}$$

In this formulation the only variables are the weights of the outputs. The model is always specified under CRS. A CI has the disadvantage of letting the weights assume extreme values which can lead to some indicators not being weighted and others to account for the majority of the value of the CI. As such, weight restrictions to incorporate knowledge about the situation are fundamental for this methodology (Morais and Camanho 2011).

3 Hospital Efficiency and Performance

3.1 Literature Review

3.1.1 *Overview*

The topic of health economics is drawing more and more the interest of the scientific community. Efficiency measurement is one of the various subjects of health economics and its study is increasing. Figure 9 shows the evolution of the number of studies in health care efficiency (Figure 9 is based on the work of Hollingsworth (2008) and represents his review of the literature of efficiency measurement in health care by the year of 2006). Has it can be seen the number of studies is increasing at a high rate and as of 2006 there were over three hundred studies on the subject. From 2005 to 2009 Liu et al. (2013) review 107 studies in health care.

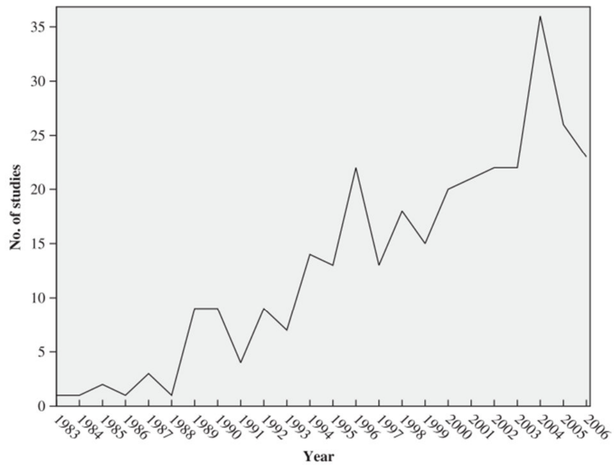

Figure 9 – Evolution of the Number of Studies in Efficiency in Healthcare (Hollingsworth 2008)

To Hollingsworth (2008) part of the increase in these studies is due to the ease of access to software that can run some of the usual methodologies used leading to “have software—will analyse” and due to the availability of data leading to a “have data—must analyse” approach which can hast the scholar and lead to bad specifications. A weak underlying basis results generally in unreliable estimates and suboptimal policy changes (Hollingsworth 2003). In fact, policy makers should select the studies that are aligned with their purposes (O'Neill et al. 2008) and interpret the data carefully because of the distinct features of health care (Hollingsworth, Dawson, and Maniadakis 1999). Even though the supply of studies in efficiency in health care is increasing, the utilization of these studies by policy makers is still reduced (Hollingsworth 2012). A review of the literature on efficiency measurement in health care can be found in (Hollingsworth, Dawson, and Maniadakis 1999, Hollingsworth 2003, Worthington 2004, Hollingsworth 2008, O'Neill et al. 2008, Hollingsworth 2009).

3.1.2 *Analysis of the methodologies*

In his last literature review, Hollingsworth (2008) documented the methodologies used to assess efficiency in health care along with the frequency with which they were used. Figure 10 shows the distribution of the metholodogies used and, even though DEA was the more frequently used methodology by 2006 the overall picture has been changing (from 1997 to 2006 its use dropped more than 15%). The other methodologies are more recent than DEA which justifies the distribution found but the increase supply of software capable of handling those methodologies is changing the panorama.

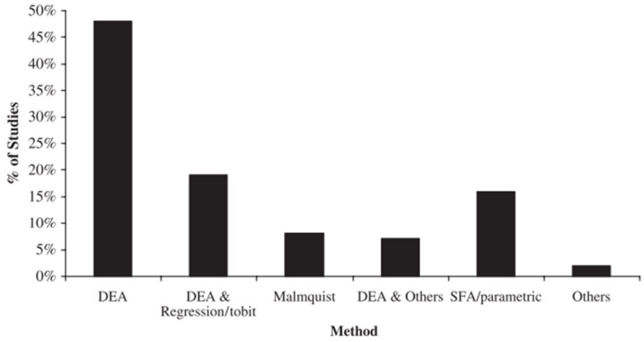

Figure 10 – Methodologies Used to Measure Efficiency in Health Care (Hollingsworth 2008)

The use of DEA alone is losing popularity partialy because of some of its limitations. One way to overcome them is to complement DEA with other methodologies like sensitivity analysis and tobit model to strengthen the results. Indeed, because each study has different assumptions, the results obtained can't be compared and can only serve as a trend of the evolution of the efficiency. Eventualy the problem of transparency, quality and comparability will be surpassed when a panel is developed that helps formulate the guidelines to design these studies (Hollingsworth 2012).

3.1.3 *Analysis to the application objects*

The study objects of the studies on efficiency in health care can vary significantly in terms of dimension from something as broad as the health system of a country to something as specific as an haemodialysis unit. From the analysis of Figure 11 it can be seen that hospitals are the most common object of study. The reasons for this may vary but possible explanations are: they represent a very important organisation for the population, they have a big weight in the expenditure with health as it was seen in section 1.3.4 and also, the information for other organisations only recently became available (Hollingsworth 2008).

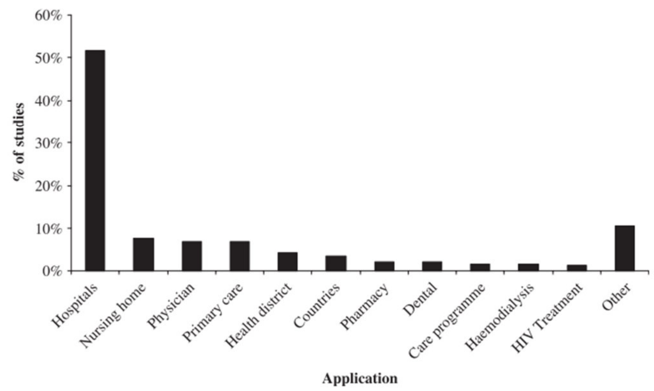

Figure 11 – Study Objects (Hollingsworth 2008)

3.1.4 *Analysis of DEA*

An analysis of the usefulness of the DEA to the health care sector is made for two reasons: it is the most commonly used methodology to measure efficiency in this context (the health care context is actually the second most common application of DEA (Liu et al. 2013)) and is also the methodology used in this dissertation. A discussion of the general advantages and disadvantages of this methodology can be found in section 2.3. The greatest concern of the application of DEA to the health care context is: the health care organisations are usually to complex and different to be considered homogenous, which is one of the requirements of DEA. Hollingsworth (2008) and Chilingerian and Sherman (2011) suggest a solution to overcome this inconvinient: focus the analysis on smaller units (hospital services or even practicioners). Other inconvinient is the difficulty associated with the definition of the production function in a health care context because the objective of the organization can vary (from profit maximization in private units, to quality care maximisation in public units, to research maximisation in an university hospital) leading to diferent inputs and outputs being used in different studies, which reduces the usefullness of the study for some organisations and makes the comparison of the studies very difficult. Additionally this methodology is higly sensible to measurement errors and missing data (Chilingerian 2011).

3.1.5 *Analysis of the perspectives*

In health care there are two perspectives of efficiency: the manager's perspective and clinician's perspective. Both are required in health care institutions and both are necessary for the function of the organisation (Figure 12). The management team allocates the resources available (usually constrained by a budget) to the different services in order to achieve the maximum outputs of these services. But the outputs produced by the management team are actually the inputs used by the clinical staff to produce the outcomes of the caring process. One difference between them is the orientation of the analysis made. The manager's productive process is usually input oriented since they don't control how many patients demand health services, but they do control the budget they have (in the case of the private organisations marketing can help increase the intermediate outputs by attracting patients to the hospital). The clinical staff doesn't control how many patients they need to care, only how well and how fast they can care for them.

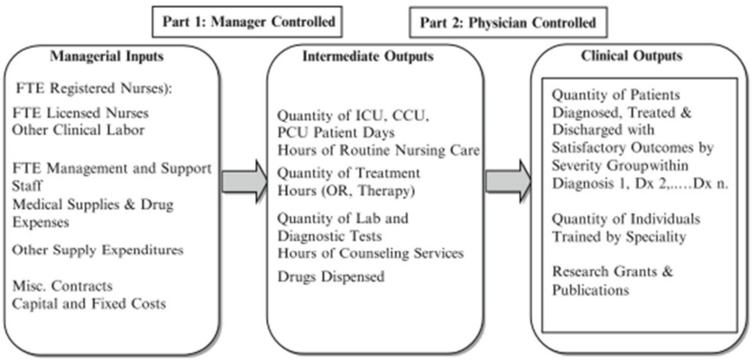

Figure 12 – Relation Between the Different Perspectives (Chilingerian 2011)

Indeed a hospital can be efficient from a clinical point of view but not from a management point of view. The opposite situation is also a possibility. For the hospital to be efficient it has to be efficient from both perspectives (management perspective and clinical perspective).

Most of the literature focus on a management perspective. In the review of Hollingsworth (2008) only 9% of the studies considered the health gains as the outputs (the rest used the intermediate outputs). However, this value has increased since his first review (5.5% (Hollingsworth, Dawson, and Maniadakis 1999)) showing an uppward trend to the use of outcomes to evaluate hospitals' efficiency. The difficulty associated with the clinical perspective is the measurement and quantification of the outcomes. This information in not usually available and when it is available is at a hospital level reducing the usefulness of the data. This is the reason to why this dissertation focuses only on the management perspective and intermidiate outputs.

3.2 Evaluation of the Portuguese Hospitals

3.2.1 *Introduction*

The portuguese hospitals have been increasingly the target of efficiency studies possibly due to the changes the Portuguese NHS system has suffered in the past years (like the introduction of private management in public hospitals). Studies have usually the purpose of either assessing the impact of a new policy or to sugest new policies according to the results found. Some of these studies are used in the following sections to analyse the impact of the introduction of some policies and also some effects in health care that need further study.

3.2.2 *Public and private management*

"Hospital Amadora-Sintra" was the first public hospital with private management (1995) and preceded the creation of the hospitals SA (later renamed EPE) which allowed for the comparison of public and private management in the health context in Portugal.

Barros (2003) compared this hospital to "Hospital de Almada" because of their similarities: they were both located in the region of Lisbon and had similar characteristics and size. The study used a DRG to compare the efficiency of the two hospitals. It is important to stress that in this study a new interesting methodology was used that consists in the comparison between the mortality function of the two hospitals and test for statistical significant differences. A probit model was used to describe the hospital's technology. Hospital Amadora Sintra performed better than Hospital de Almada but this might be due to a "learning curve effect" since the hospital was more recent. It should also be mentioned that both hospitals adjusted their technology to the needs of their population.

3.2.3 *Creation of the hospitals SA*

The introduction of private management in state-owned hospitals happened in 2002 and created a lot of discussion and many scholars studied the impact of such policy to assess if it had a positive impact.

One study worth mentioning belongs to Moreira (2008) that compared the public managed hospitals with the private managed hospitals using data from the years of 2001 to 2005 and using DEA. Three different groups (one with all the hospitals, one with the private managed hospitals and another with the public managed hospitals) were analysed for two different samples (one with all the hospitals and one with the selection of the most homogenous hospitals). The results show that the efficiency of the SA hospitals increased more than the efficiency of the hospitals SPA. However, because the SA hospitals started from a worse productivity level, this difference might not be due to changes in management. This new policy was also studied by Menezes et al. (2006) that, using data from 1997 to 2004. These authors used SFA and analysed the efficiency of the Portuguese hospitals. The results showed that the costs of the SA hospitals were superior to the costs of the SPA hospitals. However, and as the author mentions, this can be due to the worse productivity when management change was implemented. This study also included a measure of quality in the model and concluded that quality increased the cost of the hospitals. However the measure of quality wasn't based on outcomes but on whether the hospital had a certification on quality. Because the criteria of these certifications are unknown, this conclusion can be questioned. Other conclusions were that hospitals in Açores had higher costs and that fragmented organisations (with unconnected facilities) also had higher costs associated. One important fact is the conclusion that the population served and the region in which the organization is located are together responsible for 60% of the variation of the efficiency.

The differentiation between hospitals SA and SPA was also studied by Gonçalves (2008).In his comparison, using DEA and SFA and data from 2002 to 2004, he reached the conclusion that the efficiency of the hospitals SPA is higher than the efficiency of the hospitals SA. However the difference between the efficiency of both types of hospitals was bigger in 2002 than in 2004 meaning that the policy change might have influenced the evolution of the efficiency of the hospitals. In his work he also tested if the hospitals that were privatized had a similar efficiency than the other hospitals when the policy was introduced and reached the conclusion that the hypothesis was true. Using the Malmquist Index he verifies that the efficiency frontier increased being the hospitals SPA responsible by most of this evolution.

Rego et al. (2010) also studied the impact of the creation of hospitals SA using the data from 2002 to 2004. They used DEA and conceptualized two different models and three different samples (one with all values, one without the units with missing values and one without the partial hospitalization productive line). Although the first model used could be contested since is based in costs that are hard to assess (the costs are imputated which can distort the reality) they are in accordance with the second model that uses number of resources. The data suggests that SA hospitals had a bigger evolution than the SPA hospitals. However the difference between the efficiencies of the SA hospitals and SPA is too close to allow for any real conclusion indicating that more studies are required.

A more recent study by Barros et al. (2013) uses a latent class stochastic frontier analysis to assess the TE of the Portuguese hospitals using data from 1997 until 2008 which allows for a wider analysis of the policy implemented in 2002. They concluded that the SA hospitals are more efficient than the SPA hospitals. They also concluded that there were at least three diferent segments of hospitals and that policies should be adjusted to each segment accordingly. They concluded that the impact of quality in efficiency varies by segment and that serving more counties is associated to more efficient hospitals.

3.2.4 ***Congestion Analysis***

As with any other service, health care has supply and demand. The demand side varies in time and the supply side must be adjusted so that demand is always met. Sometimes the demand is overestimated leading to a surplus of resources that weren't used. The congestion effect appears in these situations. Congestion is an effect that consists in a decrease of produced outputs with an increase on the inputs.

Simões and Cunha Marques. (2009) studied this effect in the Portuguese hospitals. Besides analysing the efficiency of 68 hospitals using DEA they also studied the congestion on these hospitals using three methodologies. The authors explored the congestion of the system using CRS and VRS models and analysed the entire group of hospitals and the ones that showed congestion. Even though the results varied in the value of congestion for the different hospitals (ranging from 3.2% to 9.0) the conclusion was that 22 hospitals were congested meaning that the excess of inputs used were jeopardizing the results. The study only used data from 2005 which makes it impossible to see if those hospitals just weren't able to forecast the demand for their services of if there is another reason behind it. One weakness associated with this study is related to the outputs chosen because, with no case-mix correction, these could be biased. In their study they also found that the SA hospitals were on average less efficient than the SPA. The difference was not very big (between 2.5% and 5% for VRS and CRS respectively) and is referent to just two years after the policy implementation.

3.2.5 *The unavoidable costs*

The budgeting of the Portuguese hospitals has been done based on DRGs since 1990 with the purpose of promoting efficiency. But these payments only concern the caring of the patients. Other costs are also present in a hospital like research, teaching and training of doctor among others. These are considered unavoidable costs. The unavoidable costs are present in all hospitals but because they have an indirect impact in the patients' care they are seen as secondary in comparison to the direct care the patient receive. However to promote equity and efficiency these costs must be accounted for. In a study where this problem is acknowledge Oliveira et al. (2008) try to study the impact of unavoidable costs in the Portuguese NHS using a stochastic parametric model and conclude that 78% of the costs of hospitals are unavoidable and the allocation of funds should take this into account. Although the methodology suffered some limitations usually associated with parametric models the results obtained expose a problem that should be further explored. Other interesting conclusions are the identification of diseconomies of scale and that rural areas had higher costs associated.

3.2.6 *Other studies*

There are studies that focus on the evaluation of hospitals from different perspectives. The more interesting ones are mentioned in this section.

The focus on hospital's services allows for the identification of the strong points and weak points of the hospital by service leading to a better identification of the causes of inefficiency. However the analysis by services isn't very common. The only work found about the Portuguese hospitals belongs to Castro (2011). In his work he proposed a DEA model to measure the economic efficiency of a hospital's services that can be used for the primary services and emergency services of the hospital. The model was applied to the service of "Internal Medicine" using data of 2008 and two analysis were conducted, the first assessing all services with congruent data and the second to the services that had consistent data with both sources of information used. The results of both analyses were consistent and it was found that efficiency could be increased by over 25%. The possible savings were also identified and the cost drivers with biggest potential for saving were due to the spending with CDTs and Nurses.

The impact of the quality is usually absent from studies on efficiency in health care. Almeida and Fique (2011) studied the change in the efficiency frontier when quality indicators were used as outputs using data from 2009 and DEA. They compared two dimensions: quality as the satisfaction perceived by the user and quality as the level of congestion of the hospital. They conclude that either the satisfaction perceived by the user isn't useful to differentiate the hospitals or the most efficient hospitals are also the ones that have more quality. They also conclude that the congestion of the hospital isn't related to the efficiency of the hospital. The overall conclusion is that there isn't a trade-off between the efficiency and the quality of the hospitals. Additionally they conclude from their analysis that the results are biased if quality measures aren't taken into account. However these results should be interpreted with some caution because only 37 hospitals were used.

ACSS (2013) published a benchmarking report about the hospitals EPE and PPP and intends to publish this kind of reports quarterly. They focus on an economic, quality, access and productivity dimension and they cluster the different hospitals into homogenous groups. The results are presented with KPIs showing the hospitals that excel in these KPIs. However they don't provide any methodology to compare the overall performance of the hospitals. Additionally they provide the potential saving by the different type of costs and they also provide one analysis not found in any other study that focuses in the occupancy rate of the beds. Although this first study shows the concern with the subject by a public institution, the report needs a lot of improvement starting with the control of the information and then by analysing the subject more deeply and by having a model that clearly shows the overall performance divided by the different dimensions.

3.3 Platform of Web Benchmarking

"HOBE – Benchmarking de Hospitais" is an online web platform being developed with the purpose of providing a platform for the Portuguese hospitals to evaluate themselves against other hospitals. This comparison is achieved by different KPIs available and an overall efficiency score assessed with DEA. The rationale behind HOBE is that hospitals are composed by a series of services that can be aggregated to give the overall evaluation of the hospital.

The KPIs developed within HOBE can be divided into three categories: productivity, costs and quality. The productivity and cost indicators can be further divided into: resources and results. Besides giving the result of the KPI, it also shows its temporal evolution and the percentile in which the hospital or service is located. All the information can be on a service level or hospital level.

On June 25, 2013 the platform is still under development and although it is publicly available (at http://hobe.mercatura.pt), the access to the performance indicators requires a login (that is available for hospitals). The platform has an intuitive interface and is presented in the Portuguese language. The site has six different sections.

1. The main page presents the website and explains the rationale behind the project;
2. The benchmarking page briefly presents the basic concepts behind benchmarking, how the KPIs are divided and how DEA can be used to create aggregated indicators;
3. The indicators page presents the available indicators that can be used for benchmarking and their focus;
4. The frequently asked questions page is still in development and the only information it gives is that the service provided is free of charge;
5. The contacts page has the contact information of the people responsible for the project;
6. The last page is a dynamic page that allows the hospital to visualise its performance on each KPI. The information is then presented numerically and with different graphics that allow for an easier understanding of the scores. It allows to restrict the comparison by: ARS, funding, case mix, by size and by type (if general if specialized if university hospital).

As it stands, HOBE provides the management teams the opportunity to assess their performance against its peers. It offers a wide customization to adjust the evaluation to the management needs. It is also a free platform what makes it very attractive. Furthermore it is intended to use DEA to give the user a value of the overall performance of the hospital, resource that isn't used by the current suppliers of benchmarking tools in Portugal (IASIS and IQIP)

The objective of this dissertation is the creation of the DEA model to evaluate the different primary services of the hospital from a manager's perspective and create a tool to aggregate the efficiency of all services to give the score of the overall performance of the hospital.

4 Hospital Evaluation Model

4.1 Internal Structure of a Hospital

A hospital is an organization with an internal structure that is not homogenous among hospitals. External forces like the location, the size and characteristics of the population it serves determine the internal structure that the hospital needs to adopt to better accomplish its objectives. This makes it impossible for the hospitals to adopt identical internal structures. The hospital is constituted by different services: medical services and support services. Although all services are important for the organization to work, this chapter will only focus on the services that have a direct impact in the care process of the patient.

As a whole, the internal structure of a hospital is very complex, "one of the most complex systems known to contemporary society" (Glouberma 1996, 1). But the internal elements that compose the hospital are simple to comprehend. In Figure 13 there is a representation of the flow of the patient through a hospital. With the exception of the outpatient appointments Figure 13 allows for the identification of the major production lines in a hospital: emergency events, hospitalizations (partial, total and intensive care unit (ICU)) and surgeries (outpatient, inpatient surgeries and emergent). But this flow is actually a decohesed experience partially due to the divisions that characterize the actual internal structure of the hospitals (Hopp 2012).

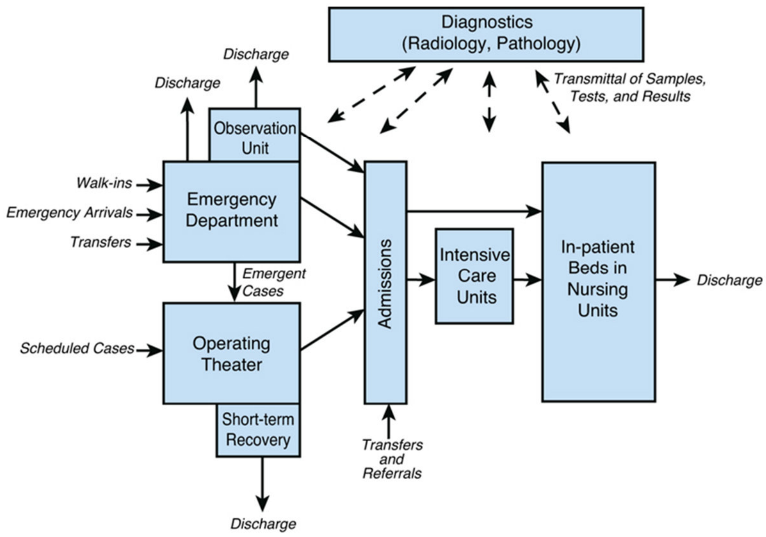

Figure 13 – Flow of the Patient in a Hospital (Hopp 2012)

The services provided by the hospital can be divided into two groups: the primary services provide the diagnosis and treatment for the patient and the transversal services support the primary services in the diagnosis and treatment. One service that is harder to define is the emergency room (ER). In the ER a patient's health is assessed and two outcomes can result from this evaluation: the patient is successfully diagnosed, treated and discharged or the patient is transferred to the appropriate service to be diagnosed (if the condition couldn't be successfully diagnosed in the ER) and treated. The ER can be seen as a primary service that cares for the patients but also as a transversal service that receives and transfers patients to the appropriate service.

The primary services include medical and surgical specialties like "Internal Medicine" in the first case and "General Surgery" in the second case. Medical services have the production lines of outpatient appointments and hospitalizations. Occasionally when the specialty associated with the service requires it (and if the size of the hospital justifies it), a production line of emergency events or ICU can be present. The surgical specialties have the same production lines than the medical specialties with the addition of the production line of surgeries. The transversal services of the hospital serve as complementary resources to the primary services and are used whenever necessary. They are associated with the diagnostic process like complementary diagnostic tests (CDT) and the cure process like the operating theatre (OT).

4.2 Perspective of the Model

There are two perspectives in the measurement of efficiency in health care (section 3.1.5). Although a study about efficiency in health care needed to evaluate both the perspective of the manager and the clinician to be complete, that was not possible to accomplish in this dissertation. The perspective adopted in this dissertation is the managerial perspective. The main reason behind this decision has to do with the available data. The public information available in ACSS is mostly accounting information which lacks the information concerned with the care received by the patients. This leads to an input orientation being used because the objective is keep the same output level while reducing the inputs (this was justified in section 3.1.5).

However from a manager’s perspective the model should be designed in such a way that an increase in efficiency does not result in a decrease in effectiveness or quality of the service. An indicator like the number of inpatients discharged can be twice as big if the patient is misdiagnosed and is admitted twice. In the same line of thought, if a patient is hospitalized for more time than needed the efficiency of the hospital might increase but at the cost of the quality of care. For this reason a model should reflect efficiency, effectiveness and quality of the hospital to assess its performance.

4.3 Model Proposed to Assess the Efficiency of the Services

Hospitals are large and complex organisations where inputs of some services are the outputs of other services. Due to of the complexity associated with modelling the entire internal structure of a hospital, this work will focus on the primary services (the ER is not included in the analysis) because they are responsible for over 50% of the costs (Castro 2011). In addition no output of a primary service is an input of another and the production processes are alike, meaning that a model can be specified and applied with just some minor adjustments

To model the production process of the services, the more important inputs and outputs must be identified. They can be identified by various criteria. The one adopted in this work is the relationship with the care received by the patient.

4.3.1 *Inputs*

The inputs were selected from the resources used in the care process that are similar in all hospital services. Activities like accounting and maintenance, among others were excluded because they aren’t part of the primary services. This would lead to a perspective more focused in an economic analysis than a care analysis.

Human resources are the most importance resources for the care of patients. From all the human resources involved in the care, two categories were chosen: medical doctors and nurses. They were chosen because they reflect the most used resource in the care process. Time should be used as a way of quantifying the use of the human resources because the various doctors/nurses might work a different number of hours. The time should be adjusted to the experience of the worker but because there is no direct way of quantifying the experience of worker, the time in the profession can be used as a proxy.

The complementary diagnostic tools (CDTs) are being used more and more in the diagnostic and treatment of the patients. These tools range from the x-ray to the CT scan, MRI, ECG, EEG, ionogram among others. Because they are so different, have different costs and practical uses a weighting factor must be introduced to enable the aggregation of these procedures. These weighting factors can be found in “Portaria nº 839-A/2009”.

The drugs used as therapeutic and the medical supplies that support outpatients and inpatients on the hospital were also taken into account because of their impact in the care and cure of the patient. But the drugs and medical supplies also vary in price and usefulness which leads to the problem of aggregating them. There is no weighting system defined by the Portuguese law. A weighting system could be implemented using either the cost associated, if they are in accordance with the existing guidelines or it has the most cost effectiveness ratio, all of them adjusted by the active ingredient.

The beds are fundamental for the hospitalization of the patients that require that service and thus the number of beds was used as an input. The cost with supplies and services (other than medical supplies) is used as a proxy for the number of beds when assessing the CE. When the number of beds is zero the cost with supplies and services is used nonetheless in the CE model to assess other indirect factors related to the caring process.

The last resource used in the caring process is the operating room. Usually more complex surgeries require more time and when complications arise more time is required. So the time with operating room is used.

4.3.2 ***Outputs***

The outputs are the different production lines in which the patients receive care. These are: outpatient appointments, hospitalizations (total, partial and ICU), surgeries and emergency events. They all should be accounted by the time they consume and corrected with the case-mix.

The outpatient appointments are divided in first outpatient appointments and follow-up outpatient appointments because they differ in the time they need (usually the first outpatient appointments require more time than the follow-up appointments). Ideally they should be case-mix corrected but it is not available.

The hospitalizations are accounted with the days of hospitalization produced. The number of inpatients is not relevant for this model since its focus is on time produced (it reflects the manager perspective in opposition to the number of inpatients treated that reflects the clinical perspective). A hospital that can produce ten inpatient days with one patient is as efficient as a hospital that can produce ten inpatient days with ten patients because the same days of hospitalization were produced. The hospitalization in ICU is also accounted with the days of hospitalization and is considered a different output because it has more requirements and bigger costs than the normal hospitalizations. Partial hospitalizations are accounted for their number. These outputs should also be case-mix corrected since the exact time is not available. However the case-mix is not available.

The number of emergency events is the only measure possible for this production line. A case-mix correction should be used because of the high variability associated to the patients in this production line.

Surgeries differ dramatically from one another and have different resources and consequences associated. Ideally they should be corrected by the case-mix. Because the case-mix is not available, the variability of the surgeries can be estimated by separating the different types of surgeries by the three possible categories. They are outpatient surgeries, inpatient surgeries and emergency surgeries.

4.4 Quality of the Data

The data used on this dissertation comes from the database of ACSS and is referent to the year of 2008. The data provided by ACSS contains bad information such as missing and wrong values. Castro (2011) analysed with detail the data provided by ACSS.

Wrong values and missing values can distort completely the efficiency results obtained from DEA. To add to the problem, the variability of the data is large which means that there is no way to know for sure if a value is a wrong value or if it is possible in the production process. The only way to assess if the data was correct would be to ask directly the hospitals for their database. But with temporal restrictions this was not possible. So, to try to prevent the results of this dissertation from being just a simple exercise, some rules were created to try to filter bad information.

When the value of an input (cost driver) was zero the hospital didn’t have that particular service analysed. The only exception was to the costs with the OT that were allowed to be zero if the production line was absent from the service. All the other resources (medical doctors, nurses, drugs, medical supplies, CDTs and supplies and services) had to have a positive value. All positive values were admitted because there was no methodology that could be implemented that would assure if the values were wrong.

The data on the outputs was harder to analyse. Because there is no way to be sure if a zero value is a missing value or simply the absence of that production line, no methodology was implemented to control missing values. Only one methodology was possible to implement from the side of the outputs and regarded the production line of surgeries. If a hospital presented surgery costs but didn’t have the production line of surgery the DMU was excluded.

Even with these two procedures there is no assurance that wrong values weren’t used. But the variability of the health care sector didn’t allow for the easy identification of bad information. Because the information was limited, it was preferred to give the benefit of the doubt to those values that appeared to be wrong.

4.5 Specification of the efficiency

The choice of the inputs and outputs to design the model shows the complexity of the productive process in a hospital where the inputs themselves can have a lot of variability (see section 4.3). In this matter, the use of a CE model comes with some advantages over the TE mode because all inputs are compared taking into account only their prices.

The inputs are expressed in cost terms making it possible to compare them in an economical perspective and to aggregate them. The need to use corrective factors for inputs such as CDT, drugs and medical supplies becomes unnecessary. Additionally, the use of the associated costs also allow for the recognition of the hospitals that have lower costs associated with their inputs. One particular advantage of CE in this dissertation is associated with the quality of the information available. The data lacked many values that were needed to assess the TE, like the number of CDT or the number of nurse hours, but it contained information about the costs of these inputs.

While the assessment of the TE defines as efficient a hospital that produces the maximum amount of outputs possible using its mix of inputs, CE is much stricter than the TE because to be cost efficient a hospital must be both technical and cost efficient, that is, produce the maximum amount of outputs with its mix of inputs and have the lowest cost with its inputs. A technical efficient hospital can be cost inefficient.

However, CE has some disadvantages as well. By using a purely economic view, the structure of the individual hospitals isn't taken into account. It's assumed that the mix of the efficient hospitals can be applied to the other hospitals which is a fundamental flaw. Different sized hospitals have different purchasing power. The resources available are also dependent on external factors. For example the medical doctors' availability varies and the salary also varies according to the time they work and if they work exclusively for the hospital.

Balancing the advantages and disadvantages of a CE model, this model was favoured in comparison with the model of TE.

4.6 Aggregation Model

The use of DEA in a healthcare sector is preferably applied at a service level because at a hospital level the heterogeneity of the organization makes the results obtained using DEA biased. The services vary in size and in the production lines available, they use different mixes of inputs to produce their outputs and as such they attribute different values to the different inputs and outputs. The hospitals have different sizes and services, which add to the heterogeneity of the organisation. By analysing the hospital without also considering the services, the results obtained won't reflect the internal structure of the hospital leading to possibly biased results.

The analysis of the services of a hospital allows for the identification of the strong points and weak points of the hospital giving the information where this organization needs to focus its efforts. However, for the evaluation of the hospital as a whole, these values don't provide the appropriate information. The efficiency values obtained for the different services need to be used to create an indicator that evaluates the overall performance of the hospital.

There are various ways to create a multidimensional indicator for a hospital like the average efficiency of the services, a weighted average efficiency of the services or use a CI that takes into account the efficiency of the services and the knowledge of the organization. The use of CIs was preferred to the other methods because CIs are recognized by OECD (2008) as a useful tool "for public communication" that have a theoretical framework behind it. They allow for the creation of a multi-dimensional indicator using various basic indicators. Furthermore, they can include knowledge about that analysis being made to steer them in the right direction.

To include some knowledge into the CIs, weight restrictions are used. The choice of weights could be based on various criteria: the one chosen in this thesis was to restrict the importance of each service in accordance to the volume of output produced, valuing more the services that care for more patients. But the outputs have different production lines associated, and they don't necessarily have the same impact or importance for the patient. ACSS defines a measure of the “standard patient” that takes into account all the production lines. Unfortunately this information was not available at the time of writing this dissertation. The approach used was to give the same importance to all production lines. This choice was made partially because there was no straightforward approach to differentiate the importance of the production lines This resulted in the creation of a variable called “Patient Volume” that is the sum of all the outputs.

To restrict the weights to the desired intervals ARs of type I were used. The restrictions compared the patient volume of each service to one service of the hospital that was being evaluated. This ratio would then give the importance of the service. Usually the service used was the service of “Internal Medicine” because it was the most common service for all the hospitals. When this service wasn’t available another service was used (preferably the one that was present in more hospitals). However the results are independent from the selection of the service that serves as a standard against which the comparison is made.

However, using a simple ratio with the volume of the outputs would result in a DEA with no flexibility to choose the weights turning it into a simple weighted average. This led to the introduction of a 10% flexibility range to the model. This way the DEA model has some flexibility and allows the hospitals to value its best services. Having n represent the number of services of the hospital, i representing the service being restricted, z representing the service being used as a comparison, O_i representing the volume of patients and $v_i$the weight assigned to the service we have:

$$0.9 \times \frac{O_i}{O_z} \leq \frac{v_i}{v_z} \leq 1.1 \times \frac{O_i}{O_z} \quad (i = 1, \dots, n \wedge i \neq z) \tag{4-1}$$

4.7 Efficiency Measurement of the Services

4.7.1 *Results at service level*

CE results were produced for each of the 19 services assessed in the Portuguese Public Hospitals. The data concerns a total of 48 hospitals, which had the information required to evaluate their services’ performances. The others had either missing values or inconsistent data and were not considered. The software used was Efficiency Measurement System. As it was seen from the work of Castro (2011), hospitals show VRS which leads to the evaluation of the services with a VRS model. For sake of brevity, we show in this thesis just the results of one of the services (Internal medicine), and the results regarding the remaining services can be found in the appendixes. First some properties of the inputs and outputs of the service are presented. The TE of this service is evaluated along with some of its properties. Then, the CE (the focus of the dissertation) is assessed. The relationship between the TE and CE is made and the benefits of the CE are shown. Finally the ideal production structure of the service is assessed along with the potential for savings (in the side of the costs) and the potential for improvement (in the side of the patients). The real and ideal structure, the potential for savings and the potential for improvement for the rest of the services can be found in the appendix.

Some descriptive statistics about the service of “Internal Medicine” can be found in Table 1. The analysis of these statistics gives some information about the quality of the data and also about the services. The number of inpatient days is higher than all outpatient appointments. In some cases tough the production line of hospitalization is not present. This is true for 2 hospitals. From the different costs, the cost with drugs has a wider range than all the others. In fact, the minimum cost is so low that the value could have been mistyped. In the case of the cost with drugs and supplies and services a small number of hospitals have a big cost in these categories that unbalance the value of the other hospitals since the median is much lower than the arithmetic mean. Additionally the importance of the cost with drugs and CDT is notorious.

Table 1 – Descriptive Statistics of the Service of "Internal Medicine"

	Mean	*Median*	*Standard Deviation*	*Maximum*	*Minimum*
Cost with Medical Doctors	831226	667422	836847	4111792	13597
Cost with Nurses	893192	746486	774705	3537303	17599
Cost with Drugs	1223929	657404	1525992	8536205	149
Cost with Medical Supplies	158897	125037	159129	806832	143
Cost with CDT	1446412	1056512	1535383	7980923	27687
Costs with Supplies and Services	425875	279588	365396	1581941	8577
Total Cost	4979531	3925348	4535140	20543884	148372
Inpatient days	27595	27556	21311	102931	0
Number of First Outpatient appointments	1630	1342	1442	8324	108
Number of Follow-Up Outpatient appointments	6552	5511	5274	20761	408

For the TE the values obtained show that 33 services are efficient (all strongly efficient since they all have zero slack). "Centro Hospitalar de Setúbal" has the service that serves as a peer for more services (11 services). It is followed by "Hospital de Leiria" and "Hospital de Valongo" and each one of these serves as benchmark for 9 hospitals. All of them are general hospitals and have the three production lines (shown in Table 1). Three services have a high level efficiency (ranging from 80% to 100%) and two have a low level of efficiency (ranging from 0% to 50%). The remaining ten services of "Internal Medicine" have an average level of efficiency (ranging from 50% to 80%).

Table 2 has some descriptive statistics about the TE obtained. The arithmetic mean is very high because of the excessive number of efficient units and the median is 100% because over half the services are considered efficient. The standard deviation has a low value because most values are located near 100%.

Table 2 – Descriptive Statistics of the TE of "Internal Medicine"

Mean	Median	Standard Deviation	Maximum	Minimum	Efficient	High Efficiency	Low Efficiency	Average Efficiency
90%	100%	16 %	100%	46%	33	3	2	10

One thing that should be mentioned is the choice of weights by the model. Because the model is free to choose the set of weights that maximize the efficiency, some inputs and outputs can be neglected. Table 3 contains the set of weights of three efficient services mentioned earlier and shows that there are various inputs and outputs that are not being weighted. Although this flexibility is an advantage of the methodology used, it's is also a disadvantage. Not one of these three hospitals values medical doctors (the weight of the associated cost is zero for all these DMUs). Because of this limitation, the results obtained for the TE should be interpreted carefully since the method isn't valuing all the inputs (which are essential for the productive process in most cases). However, with the introduction of weights the level of efficiency of all DMUs can only decrease. This means that the inefficient units will continue inefficient and one can see these results as a wakeup call for their situation.

Table 3 – Set of Weights for Three Different Services of "Internal Medicine"

	Centro Hospitalar Setúbal	*Hospital de Leiria*	*Hospital de Valongo*
Weight Cost with Medical Doctors	0,00	0,00	0,00
Weight Cost with Nurses	0,00	0,00	0,30
Weight Cost with Drugs	0,95	0,62	0,00
Weight Cost with Medical Supplies	0,00	0,34	0,00
Weight Cost with CDT	0,00	0,00	0,70
Weight Costs with Supplies and Services	0,05	0,04	0,00
Weight Inpatient Days	1,00	0,00	0,64
Weight Number of First Outpatient appointments	0,00	0,18	0,07
Weight Number of Follow-Up Outpatient appointments	0,00	0,82	0,29

The CE analysis of the service of "Internal Medicine" has one fundamental advantage when compared with the analysis of the TE. In the CE analysis, one monetary unit has the same cost whether it is invested in medical doctors, nurses or any other resource. This has two implications. First, all the inputs are weighted. Second, because the total cost is used and not the unit-cost multiplied by the volume of inputs, the system will not suffer from the fallacy mentioned in section 2.5. On the other hand, it also makes it impossible to understand if an inefficient hospital is inefficient because it has higher prices or if it has too many resources (this situation only happens when the prices diverges from hospital to hospital).

The CE frontier consists of 14 hospitals (a reduction of 19 units when compared to the TE) and they are all strongly efficient (there are no slacks on the side of the inputs or outputs). The hospital that serves as a benchmark for most services still belongs to "Hospital de Setúbal" serving as peer to 26 services. It is followed by "Hospital de Valongo" which serves as peer for 12 hospitals. The following hospital isn't "Hospital de Leiria" as in TE but "Hospital do Nordeste" which serves as peer for 11 services. "Hospital de Leiria" still is an efficient DMU but not so many units compare to it. Of all hospitals compared, 9 have a high level of efficiency, 12 have a low level of efficiency and 13 have an average level of efficiency. We can see that the efficiency either decreased or kept constant. There was an increase in the number of units of high efficiency (6 units), low efficiency (10 units) and average efficiency (3 units) (Table 4).

Table 4 – Descriptive Statistics of the CE of Internal Medicine

Mean	Median	Standard Deviation	Maximum	Minimum	Efficient	High Efficiency	Low Efficiency	Average Efficiency
72%	74%	25%	100%	27 %	14	9	12	13

Again, a remark about the weights should be made. From the analysis of Table 5 which contains the three services that serve as benchmark for most of the other units it's possible to see that the services aren't forced to weight all the outputs. As such, for example "Hospital de Valongo" doesn't weight the number of follow-up outpatient appointments.

Table 5 – Set of Weights for Four Services of Internal Medicine

	Weight Total Cost	*Weight Inpatient Days*	*Weight First Outpatient appointments*	*Weight Follow-Up Outpatient appointments*
Centro Hospitalar de Setúbal	1,00	0,82	0,10	0,08
Hospital de Valongo	1,00	0,89	0,11	0,00
Centro Hospitalar do Nordeste	1,00	0,71	0,18	0,11
Hospital Universitário de Coimbra	1,00	0,92	0,00	0,08

A representation of the relationship between the TE and the CE (Figure 14) shows that most units decreased their efficiency. The hospital in which this fall is more obvious is in "Hospital Universitário de Coimbra" which has a TE of 100% and a CE of 42.07%. This difference is due to the weights attributed to the inputs. "Hospital Universitário de Coimbra" weighted only "Medical Supplies" and "Supplies and Services" in the TE analysis. In the CE analysis all inputs were weighted the same way which brought down the efficiency of this hospital.

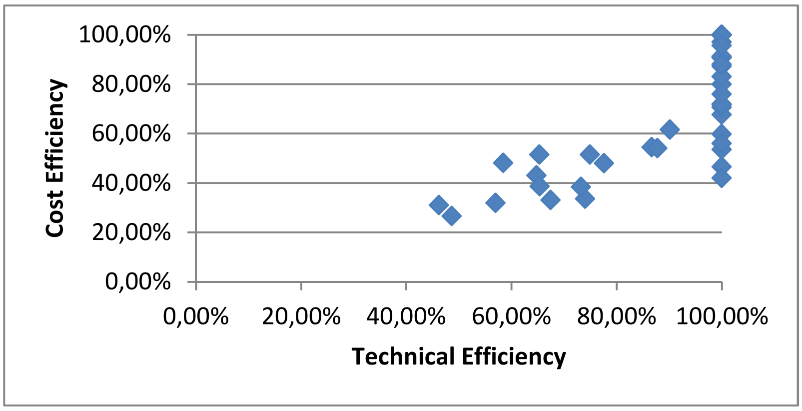

Figure 14 – Relation Between the Technical Efficiency and Cost Efficiency

Having the TE and CE the AE can be assessed. In this case, the AE is equal to the CE (42.07%) because the hospital is technically efficient. The difference between both efficiencies is around 18%. Overall, the allocative inefficient hospitals are more human resource intensive and the allocative efficient hospitals use more drugs and CDTs.

In the assessment for the CE for this hospital the output "Number of First Outpatient appointments" wasn't weighted and the "Number of Follow-Up Outpatient appointments" was poorly weighted (8%) being the inpatient days the output that was given the most importance (92%) meaning that only this last production line was considered to assess the CE.

There is the opportunity to increase the number of "First Outpatient appointments" by four hundred and fifty three appointments (the slack that exists in this DMU). The peers of this hospital are "Hospital do Nordeste" (with an intensity of 16%), "Hospital de Setúbal" (with an intensity of 52%) and "Hospital de Santarém" (with an intensity of 33%). A comparison between all the inputs and outputs of this hospital and its most important peer can be found in Figure 15. A normalisation was made with a ratio between the observed value of the input/output and the highest value of that inputs/output.

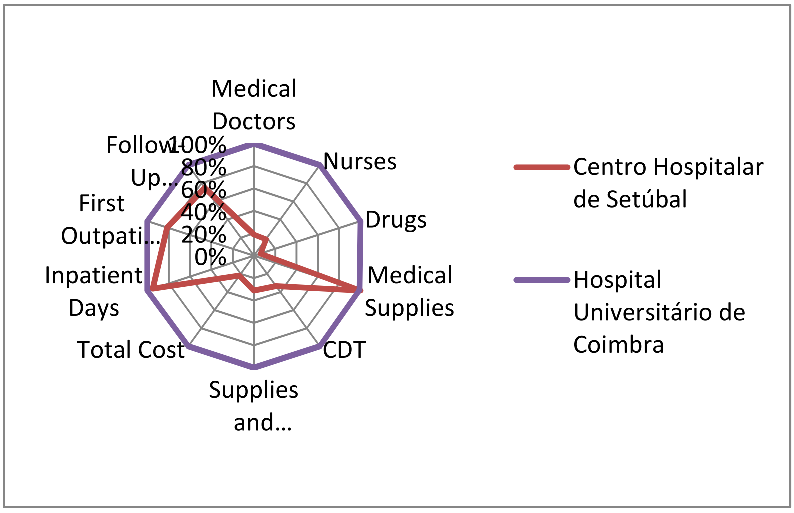

Figure 15 – Structure of Hospital Universitário de Coimbra and its peer

Table 6 shows the current cost structure and the ideal cost structure for "Hospital Universitário de Coimbra". A visual representation of the reductions and increases in costs can be found in Figure 16.

Table 6 – Hospital Universitário de Coimbra – Current Costs and Ideal Costs

Hospital Universitário de Coimbra	*Cost with Medical Doctors*	*Cost with Nurses*	*Cost with Drugs*	*Cost with Medical Supplies*	*Cost with CDT*	*Costs with Supplies and Services*	*Total Cost*
Current Costs	1728897	1213167	2226673	128448.7	2826387	161358.2	8284931
Ideal Costs	578207	724989.9	615420.1	153948	1117194	331566.5	3521326

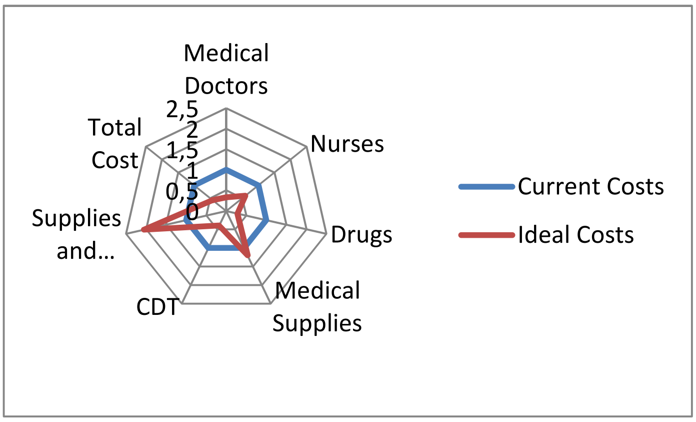

Figure 16 - Hospital Universitário de Coimbra – Current Costs and Ideal Costs

All the cost drivers with the exception of "Supplies and Services" and "Medical Supplies" can be greatly reduced. The final total cost is only 42.50% of the actual cost. There is an increase in some inputs because, to achieve the minimum cost, the mix of resources used by its peers was different. Therefore one can recommend the hospital to try to change the mix of its outputs. In any case, the minimum cost, is, in principle, possible to achieve with the current structure of production of the hospital.

An overall cost evaluation of the service of "Internal Medicine" for the 48 services can be made to identify how much savings would be possible (if the cost structure of all units would change to the ideal cost structure) and how many increases in the output would be possible. In

Figure 17 the differences between the ideal structure of the hospitals and the real structure of the hospitals are visible. All the reductions of the different costs vary between 12% and 34%. The cost driver that could reduce more its costs in comparison with its actual costs is “Supplies and Services”.

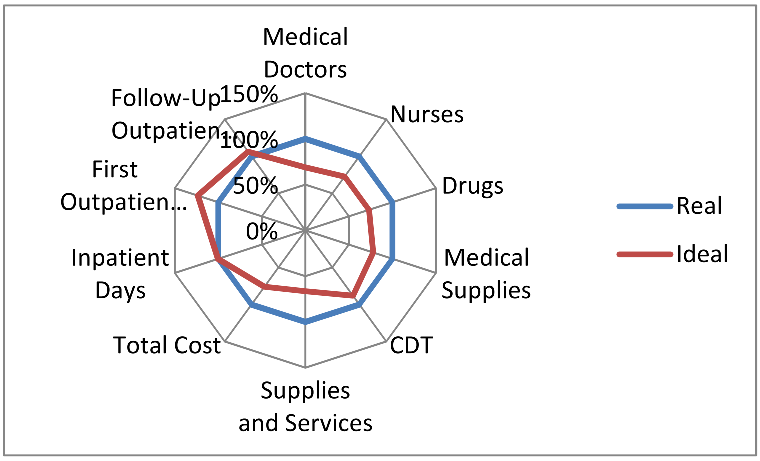

Figure 17 – Improvements in the Service of Internal Medicine

The cost driver that has more room for improvement is “Supplies and Services”. But the cost driver that represents more money wasted is “Drugs”. From Figure 18 it’s possible to conclude that only “Medical Supplies” wastes less money than “Supplies and Services”. The waste associated with the costs with human resources and drugs has a magnitude of 10^7 euros. From the data we can see that although it is easier to reduce the costs with Supplies and Services, the cost associated with drugs is the one with more potential for savings.

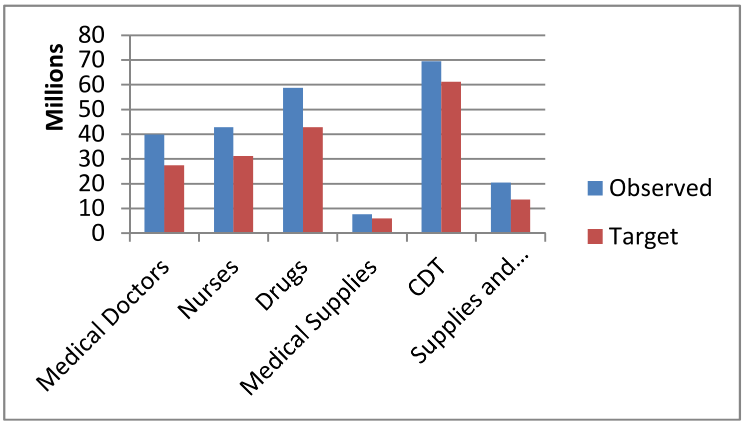

Figure 18 – Observed Costs and Target Savings for Internal Medicine

From the side of the outputs, the biggest improvement would be from the side of the “Number of First Outpatient appointments” followed by the “Number of Follow-Up Outpatient appointments”. The “Number of Inpatient Days” can hardly be improved in comparison to its actual production. From the overall value of the slacks given by the solution, the category of output that can increase its output the most is the “Number of Follow-Up Outpatient appointments” followed by the “Number of First Outpatient appointments”. This information can be visualized in Figure 19.

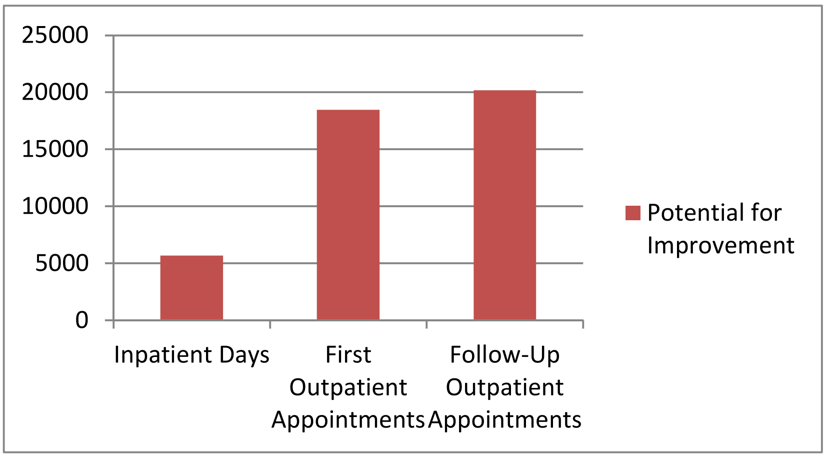

Figure 19 – Potential for Improvement in Internal Medicine

4.7.2 ***Analysis of All Services***

In this section an analysis will be conducted to the overall values obtained for the different services. First, some basic statistics are presented to give a perspective about the efficiencies of the different services. Additionally the number of hospitals where each service is present is identified and the patient volume for each service is also identified (as a percentage of the service with the highest patient volume). The existence of a correlation between the efficiency and the variability of the service is studied. Then the impact of the increase of efficiency in the different services was studied with the creation of a new variable that relates the efficiency with the patient volume resulting in the creation of a new variable called "Potential Gain". Afterwards the correlation between the efficiency, patient volume and potential gain is studied. Then it is studied if there is any relationship between the efficiency of the service and the patient volume. The wastes in costs are identified and then both the biggest potential for saving along with the biggest potential for improvements are identified for each service to try to identify possible trends.

The efficiency model created was applied to the 19 primary services present in the hospitals. The basic descriptive statistics that resulted from the application of the CE DEA model to the different primary services are summarized in Table 7. Each service was, in average, present in more than 30 hospitals (of a total of 56) but the values range from 12 hospitals (in the case of "Infectious Diseases") to 48 (in the case of "Internal Medicine"). There can be two reasons as to why a service wasn't analysed for all hospitals: the service was absent from the hospital (like the case of "Infectious Diseases" which is an unusual service present only in some hospitals) or the service wasn't analysed due to missing or incorrect data (this is probably the case with services like "General Surgery" and "Internal Medicine" that are common in almost all hospitals with the exception of the specialized hospitals). The mean of the efficiency of the different services has a high range ("Anaesthesiology" has the lowest value and "Nephrology" has the highest value). From the 19 services there are 8 with a high level of efficiency, there are 10 with an average level of efficiency and there is 1 with a low level of efficiency. The minimum value found inside each service also varies significantly, the highest minimum value belonging to "Neurology" and the lowest value belonging to "Anaesthesiology".

Table 7 – Descriptive Statistics of the Efficiency Values for the Different Services

	Mean	*Standard Deviation*	*Minimum*	*Nº of Hospitals*	*Patient Volume*	*Potential Gain*
General Surgery	88%	16%	47%	47	89%	0.11
Internal Medicine	72%	25%	27%	48	100%	0.28
Gynaecology/Obstetrics	84%	17%	38%	38	88%	0.14
Medical Oncology	72%	27%	12%	31	35%	0.10
Cardiology	74%	29%	16%	35	30%	0.08
Paediatrics	88%	18%	47%	36	77%	0.10
Orthopaedics	88%	16%	49%	39	67%	0.08
Infectious Diseases	88%	22%	24%	12	14%	0.02
Psychiatry	62%	31%	16%	21	17%	0.07
Imunohemotherapy	58%	33%	7%	28	21%	0.09
Haematology	81%	27%	9%	15	14%	0.03
Urology	76%	26%	24%	31	23%	0.05
Pulmonology	69%	29%	5%	31	23%	0.07
Nephrology	92%	19%	15%	20	15%	0.01
Ophthalmology	76%	30%	10%	28	61%	0.14
Neurology	88%	16%	59%	18	10%	0.01
Gastroenterology	77%	23%	26%	29	17%	0.04
Physical Medicine and Rehabilitation	51%	28%	10%	38	13%	0.06
Anaesthesiology	30%	39%	0%	33	11%	0.08

The standard variation of the values of efficiency can be used to compare the homogeneity of the services, with a high standard deviation meaning a service that is more heterogeneous because the mix of inputs and outputs used between the services varies more. The service with the lowest standard deviation is "Neurology" (15.65%) and the service with the highest standard deviation is "Anaesthesiology" (39.27%). An analysis was conducted to see if the standard deviation and the efficiency of the services are correlated. Figure 20 shows a graphical representation between efficiency and the standard deviation.

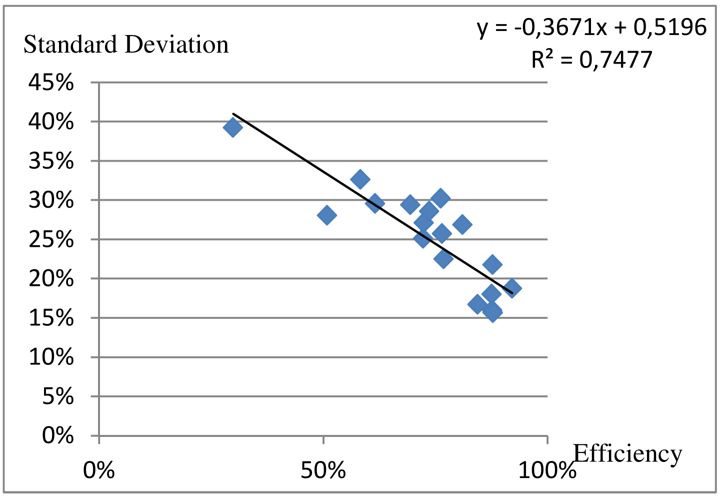

Figure 20 – Relationship Between Efficiency and Standard Deviation

The analysis of the figure shows that there is a correlation between the efficiency and the standard deviation (R^2=74.77% which means that the efficiency and the standard deviation are strongly correlated) and that the higher the efficiency of the service, the lower the standard deviation is (the services are more homogenous). This is expected because for the services to be more efficient the services need to have a closer level of efficiency what reduces the variability.

A service with a lower value of efficiency has more room to improve than a service with a higher value of efficiency because there are more aspects where the service can be improved. However having more room to improve doesn't mean that the service will benefit more the overall system than a service with less room for improvement since the size of the service defines the impact that a change in efficiency has in general terms. For example it would be better to increase the efficiency of the service of "Internal Medicine" by 1% than to increase the efficiency of the "Anaesthesiology" service by 9% (the patient volume of the service of "Anaesthesiology" is only 11% of the patient volume of "Internal Medicine"). As such, a variable that represents the potential gains if the service is improved to the efficient frontier was created (shown in the last column of Table 7. It consists in the average inefficiency of the service multiplied by the patient volume and.

$$Potential\ Gain = (1 - Efficiency) \times Patient\ Volume \qquad \textbf{(4-2)}$$

The service with more potential gain is the service of "Internal Medicine" followed by "Gynaecology/Obstetrics" and "Ophthalmology". A high potential gain reflects either low efficiency, high patient volume or both. Almost all the services with a low efficiency value also have a low patient volume resulting in lower potential gains, something that would be less evident if only the efficiency values were considered.

A multiple linear regression was used to see the impact of the efficiency and the patient volume in the potential gain (see Table 8). It can be concluded that both the efficiency and patient volume have an impact on the potential gain although the influence of the patient volume seems to be stronger.

Table 8 – Multiple Linear Regression of the Potential Gain with Efficiency and Patient Volume

	Coefficient	St. error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.144	0.032	4.44	4.2E-4	0.075	0.213
Efficiency	-0.180	0.045	-3.96	1.1E-3	-0.276	-0.083
Patient Volume	0.187	0.023	8.24	3.8E-7	0.139	0.235

An analysis of the relationship between the efficiency and the patient volume was conducted to assess if there is any correlation between them. From the analysis of Figure 21, a correlation between the efficiency score and the patient volume doesn't seem likely (R^2=12.23%) but this value merely discards the existence of a linear relation. Indeed, the analysis of Figure 21 shows that the services with a low efficiency have all a low patient volume. The services with a low level of inefficiency have both low and high patient volumes. Although the idea that patient volume depends on efficiency seems highly unlikely (the individual resorts to the service that its health condition requires) the opposite thinking is a possibility since, if a service has a high patient volume it needs to improve its efficiency if all patients are to be attended to.

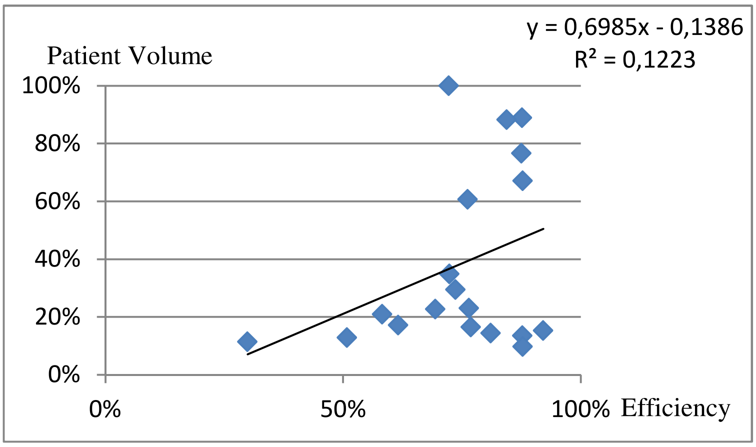

Figure 21 – Relationship Between Efficiency and Patient Volume

Figure 22 identifies the cost drivers that deviate more from their target cost structure (the axis represent the number of services). The most deviated cost driver for more services is “Supplies and Services” (for 8 services) followed by CDT. It means that these cost drivers need special attention because the investment made is clearly being wasted.

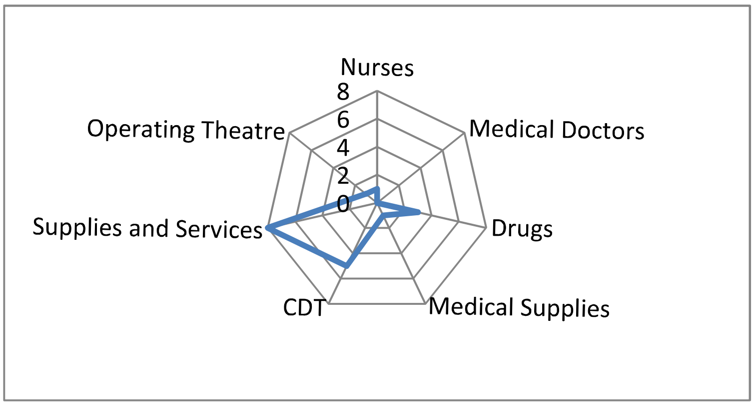

Figure 22 – Deviated Cost Drivers

The previously mentioned cost drivers are indeed the cost drivers that are more detached from their ideal value but they are not responsible for the biggest waste. Figure 23 shows the potential savings by cost driver. The biggest potential saving is with “Drugs” and is followed by “CDT”. It’s interesting to learn that the biggest potential for saving belongs to the two complements of the clinical activity that are known to be overused. The total potential for saving is close to 540 million euros.

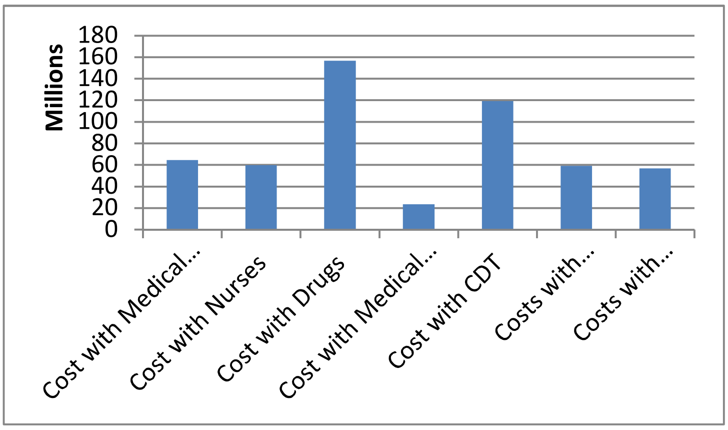

Figure 23 – Waste by Cost Driver of the Services Analysed

On the side of the outputs produced, the biggest potential for improvements can also be identified (the identification of the outputs is not as useful as the inputs because the outputs are assumed exogenous). Figure 24 shows the potential for improvement. The biggest potential for improvement belongs to the "Follow-Up Outpatient Appointments" followed by the "First Outpatient Appointments". It is interesting to observe that the "ICU Days" have a small potential for improvement compared to the other outputs. One additional comment must be made about the improvement in the surgeries. In opposition to what would be expected, the biggest potential for improvement is with "Inpatient Surgeries" and not "Outpatient Surgeries".

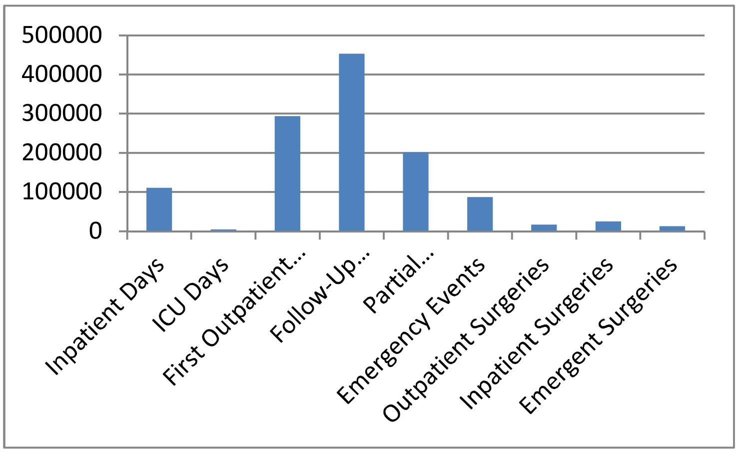

Figure 24 – Potential for Improvement of All Services Analysed

4.8 Efficiency Measurement of the Hospitals

In this section, there is going to be a description of the model created to aggregate the efficiency of the different services along with a description of the adaptations the model suffered. There is posteriorly a comparison between the method developed to aggregate the efficiency of the services and the traditional approach to the evaluation of hospitals. Finally there is a brief comparison between ARSs using the efficiency scores calculated.

After having the efficiency of the services measured, it is possible to use them to create a CI to measure the hospital performance. The number and type of the services that are part of the hospitals vary. A total of 56 hospitals were analysed. Figure 25 discriminates the number of hospitals by the number of services analysed.

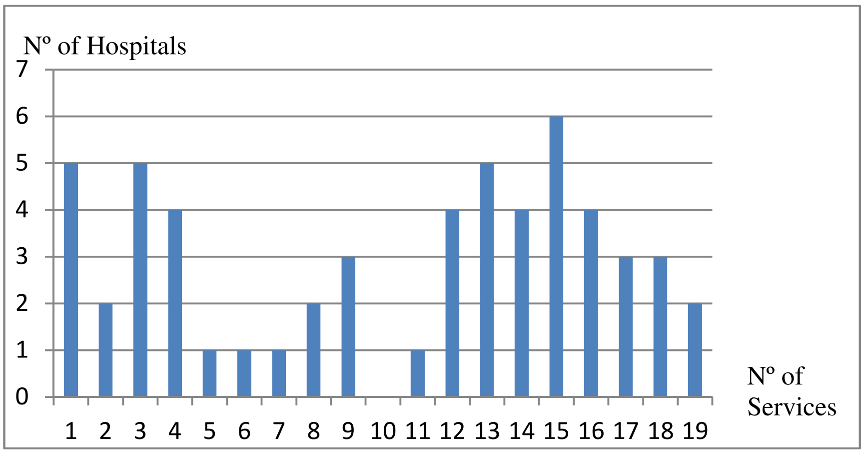

Figure 25 – Frequency of Hospitals by Number of Services

The number of services analysed doesn't reflect the total number of services of the hospital but the services with the minimum data required to be analysed. This leads to hospitals being analysed with less than all of their services. For example, 4 of the 5 hospitals with one service analysed are specialized hospitals but the fifth hospital just has valid information for one service to be analysed ("Hospital de Cantanhede"). This lack of information can distort the information, especially when the number of hospital services is small. The case of "Hospital de Cantanhede" is of special concern since it has 11 medical services analysed (Cantanhede 2013) but is evaluated from one service alone. This can distort the analysis of the hospital (either positively or negatively depending on the efficiency of the service analysed compared with the others).

There are more hospitals with many services than hospitals with few services. Using 10 services (no hospital has ten services analysed, they have either more or less) as the cut off value, there are 32 hospitals with more than 10 services and 24 with less. The most common hospital has 15 services analysed. Only 2 hospitals had 19 services analysed ("Centro Hospitalar de Setúbal" and "Hospital de Santarém").

The descriptive statistics of the values obtained are shown in Table 9. Of all the hospitals 53 were considered efficient. Only 1 hospital had a low efficiency and the remaining two had an average efficiency.

Table 9 – Descriptive Statistics of the Efficiency of the Hospitals

Mean	Median	Standard Deviation	Maximum	Minimum	Efficient	High Efficiency	Low Efficiency	Average Efficiency
97%	100%	12%	100%	16%	53	0	1	2

The model is free to choose the weights it assigns to the different services (which is the same as the importance it attributes) with some services with a weight of 0 (they don't influence the efficiency score of the hospital) and some with a weight of 1 (they define the efficiency of the hospital which should only be possible in specialized hospitals with just one service). As such, the analysis is too benevolent and has to be refined.

Weight restrictions were introduced in the model (Model 1). Using the case of "Maternidade Alfredo da Costa" (two services: "Gynaecology/Obstetrics" and "Paediatrics") as an example and using the service of "Gynaecology/Obstetrics" as the basis for the comparison, u_P and u_{GO} representing the weights of "Paediatrics" and "Gynaecology/Obstetrics", we would get:

$$0.9 \times \frac{8265}{144817} \leq \frac{u_P}{u_{GO}} \leq 1.1 \times \frac{8265}{144817} \Leftrightarrow 0.051 \leq \frac{u_P}{u_{GO}} \leq 0.063 \qquad \textbf{(4-3)}$$

Having defined the weight restrictions, the values obtained incorporate knowledge of the sector and the efficiency measurement becomes more reasonable. Before proceeding with the exploration of the results obtained, one thing must be clarified about the weight restrictions. When assigning the efficiency of one hospital, for example "Maternidade Alfredo da Costa" the weight restrictions of the other units are the same as the ones of "Maternidade Alfredo da Costa". However when the other hospitals are being evaluated themselves they use their one weight restrictions. This can lead to peers for other hospitals being actually less efficient than the one to which they serve as peers. The peers are only efficient when using the weights of the hospital being analysed.

Table 10 shows the basic statistics of the obtained efficiencies for the hospitals after the introduction of weight restrictions. There was a general decrease of the efficiency values. The number of efficient hospitals dropped from 53 to just 15, the hospitals with a high level of efficiency increased 27 units, there was the addition of 1 unit to the low level of efficiency category and there was an increase of 10 hospitals in the level of average efficiency. However the overall efficiency is still very high with a mean of 88%.

Table 10 – Descriptive Statistics of the Efficiency of the Hospitals – Model 1

Mean	Median	Standard Deviation	Maximum	Minimum	Efficient	High Efficiency	Low Efficiency	Average Efficiency
88%	93%	15%	100%	16%	15	27	2	12

To see if the number of specialties is connected with the overall efficiency of the different hospitals a graph was plotted (Figure 26).

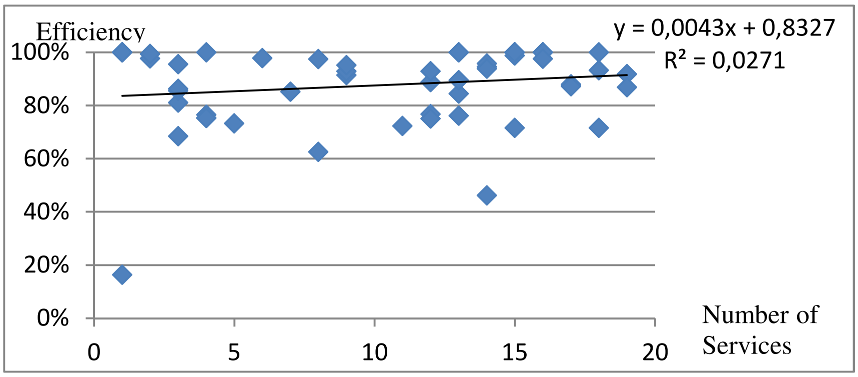

Figure 26 – Relation Between the Number of Services and Efficiency – Model 1

The values of efficiency don't seem to be correlated with the number of services of the hospital (R^2 =2.7% indicates that there is no correlation between these two variables). This goes against the common knowledge that specialized hospitals are more efficient than general hospitals. If the data can be trusted, the only dimension where the specialized hospitals can be more efficient is in terms of quality of care. Two hospitals stand out from the others: "Centro Hospitalar Psiquiátrico de Coimbra" with an efficiency of 16.30% and "Unidade Local Saúde Baixo Alentejo, EPE" with an efficiency of 43.52%. There is no relation between these two units, one has just one service and the other has fourteen services. Because "Centro Hospitalar Psiquiátrico de Coimbra" has just one service it is more susceptible to mistakes. However "Unidade Local Saúde Baixo Alentejo, EPE" really has a low efficiency because the majority of its services have a low level of efficiency with the exception of "General Surgery" which has an average level of efficiency (see Figure 27 where the efficiency levels of all services are shown). This unit should review its internal structure since waste is present in all its services.

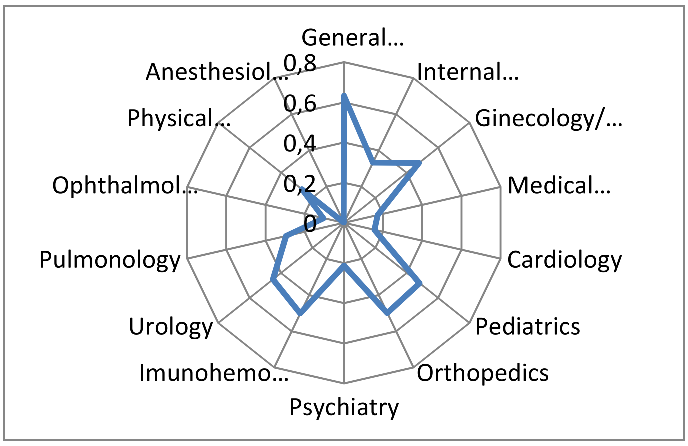

Figure 27 – Efficiency of the Services of Unidade Local Saúde Baixo Alentejo

Of all the hospitals that saw their efficiency decreasing with the introduction of weight restrictions, the one in which this decrease is more evident is "Hospital de Anadia" that went from efficient to an efficiency of 68.41%. This hospital was evaluated by three services: "General Surgery", "Internal Medicine" and "Paediatrics". The patient volume, the efficiencies and the virtual weights assigned when no restrictions were imposed to the weights as well as when they were imposed can be found in Table 11 for these services.

Table 11 – Analysis of Hospital de Anadia

Hospital de Anadia	*General Surgery*	*Internal Medicine*	*Paediatrics*
Patient Volume	6087	7408	1721
Efficiency of the Services	83%	47%	100%
Weights (Free)	0	0	1
Weights (Restricted)	0.51	0.31	0.17

This hospital has a high level of service efficiency of "General Surgery", a low level of service efficiency of "Internal Medicine" and an efficient service of "Paediatrics". When the DEA model was free to choose the weights, the choice was to weight only "Paediatrics". However, this service is the one that serves fewer patients. When the weight restrictions are applied the weights change dramatically. "General Surgery" has the highest value for the virtual weight because its output is just a bit lower than the one from "Internal Medicine" but the efficiency value is almost the double. This hospital should focus in improving the service of "Internal Medicine" not only because it has the lowest efficiency value for the hospital but also because it has the highest patient volume which leads to more patients benefiting from the improvement.

"Hospital de Anadia" has four peers: "Centro Hospitalar Alto Ave, EPE" (intensity of 17%), "Centro Hospitalar do Porto, EPE" (intensity of 23%), Centro Hospitalar Lisboa Central, EPE (intensity of 24%) and "Centro Hospitalar Trás-os-Montes e Alto Douro, EPE" (intensity of 6%). Figure 28 represents the efficiency for this group of hospitals in the evaluated services of "Hospital de Anadia" (some lines are overlapped so they can't be seen in the figure).

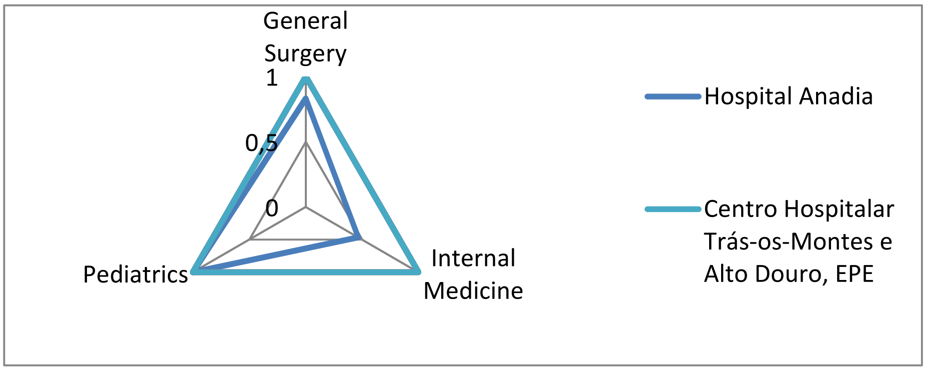

Figure 28 – Efficiency of the Services of Hospital de Anadia and its peers

Another hospital will be used to further explore this methodology. "Maternidade Alfredo da Costa" will be used again to show some properties of this analysis. This unit is highly efficient (99.41%) with its service of "Gynaecology/Obstetrics" being efficient and its service of "Paediatrics" having a high level of efficiency (88.06%). One curious thing is that from nine of its peers, four of them actually have a lower level of efficiency (Table 12).

Table 12 – Efficiency of Maternidade Alfredo da Costa and its peers

Maternidade Alfredo da Costa	CH Alto Ave	CH do Porto	CH Médio Ave	CH Setúbal	CH V.N.Gaia /Espinho	Hospital Barcelos	Hospital Castelo Branco	Hospital S. Sebastião	Hospital Viseu
99%	100%	100 %	97%	92%	100%	91%	89%	100%	100%

This situation is a possibility as previously explained. In fact, if we analyse the efficiency values of the services these hospitals share with "Maternidade Alfredo da Costa" it's possible to see that all its peers are efficient in these services. However, if all services are taken into account, there is a whole different picture. Using the example of "Hospital de Castelo Branco" represented in Figure 29 it is possible to see that this hospital has a lot of room for improvement in its medical services. In fact, some of its services like "Internal Medicine" or "Urology" have a low level of efficiency. Its services of "General Surgery", "Neurology" and "Gastroenterology" also have room for improvement.

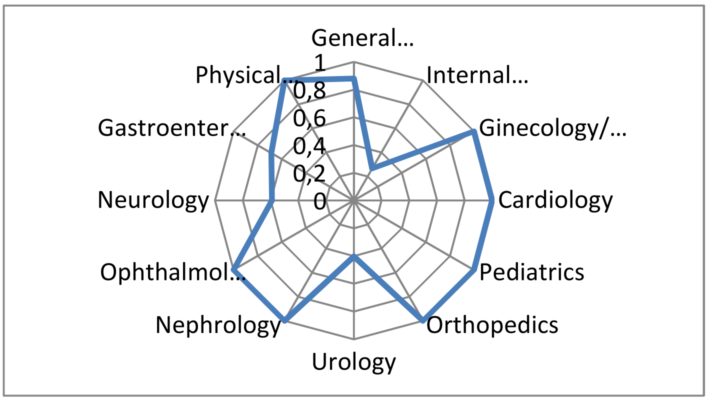

Figure 29 – Efficiency of the Services of Hospital de Castelo Branco

The facts found in the analysis of "Hospital de Castelo Branco" helps to confirm something. Since the production frontier is defined having as a basis the units analysed means that the production frontier is underestimated because there is no hospital efficient in the 19 services. "Centro Hospitalar do Porto" which is one of the fifteen efficient units, shows room for improvement (some of its services like "Cardiology", "Anaesthesiology" among others are actually low on efficiency) (Figure 30). The virtual weights of the different services are presented in Table 13. "Centro Hospitalar do Porto" is considered efficient because, with the weight restrictions imposed by its patient volume, no other hospital could perform any better than "Centro Hospitalar do Porto". All the medical services in which this hospital excels have a high patient volume (which is reflected by the weight associated).

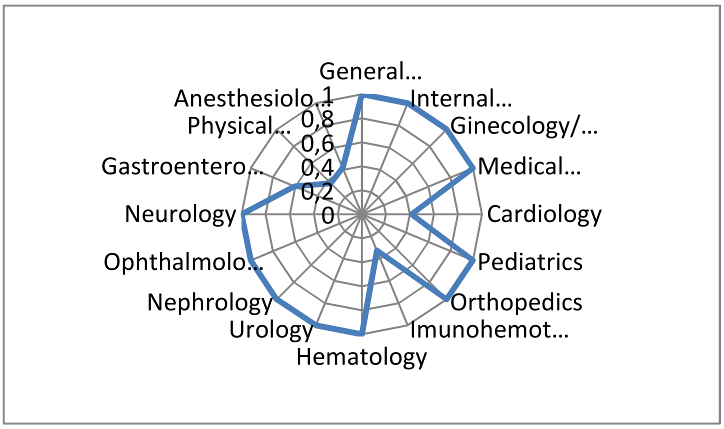

Figure 30 – Efficiency of the Services of Centro Hospitalar do Porto

Table 13 – Virtual Weights of Centro Hospitalar do Porto

General Surgery	Internal Medicine	Gynaecology/Obstetrics	Medical Oncology
0,09	0,10	0,21	0,03
Cardiology	Paediatrics	Orthopaedics	Imunohemotherapy
0,01	0,11	0,08	0,01
Haematology	Urology	Nephrology	Ophthalmology
0,06	0,06	0,06	0,10
Neurology	Gastroenterology	Physical Medicine and Rehabilitation	Anaesthesiology
0,05	0,02	0,01	0,01

A stricter production frontier can be created in order to assess the efficiency of all the hospitals with the introduction of an ideal hospital, one that is efficient in all medical services (Model 2). The introduction of this new hospital makes it possible for the previously efficient hospitals to assess their efficiency against a theoretical possible (changing the benchmarking from the best observed to the best possible). This model brings stricter results and the theoretical maximum efficiency but there is no way to assure that efficiency in all services is achievable. The choice between both models is up to the user. Table 14 has descriptive statistics about the new analysis. The average value for efficiency dropped almost 5% and the standard deviation kept almost constant. The number of efficient hospitals dropped showing that there are 5 hospitals that are really efficient (they are efficient in all their services but they do not have the 19 services). From the 56 units analysed 17 didn't change their overall score meaning that they were already being compared to a hospital efficient in all their services.

Table 14 – Descriptive Statistics of the Efficiency of the Hospitals – Model 2

Mean	Median	Standard Deviation	Maximum	Minimum	Efficient	High Efficiency	Low Efficiency	Average Efficiency
83%	86%	15%	100%	16%	5	30	2	19

The data distribution (Figure 31) stills seems to have no relationship with the number of services (R^2=0.36%) with perhaps one exception that can be visualized from the Figure 31. All the efficient hospitals have a low number of services (four with one service and one with four services) what wasn't visible in Figure 26.

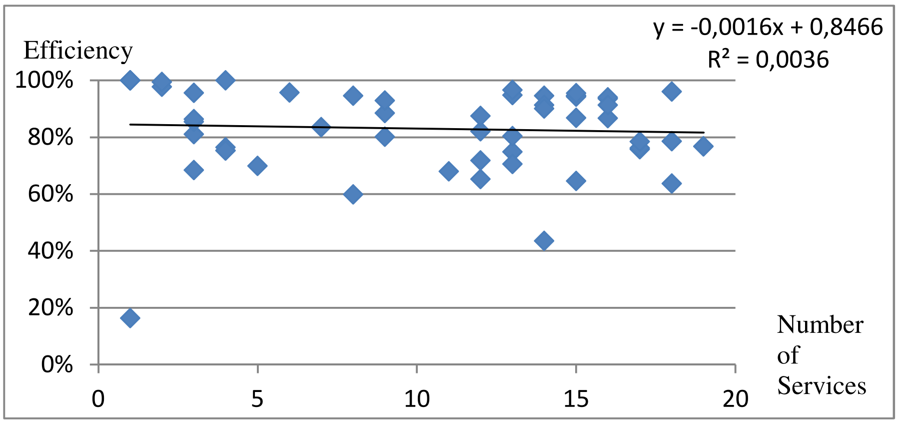

Figure 31 – Relation Between the Number of Services and Efficiency – Model 2

4.8.1 *A comparison*

Usually studies that focus on hospital efficiency take a top-down perspective analysing the hospital as a whole, not considering the efficiency of the different services. This top-down perspective is flawed because it doesn't take into account the internal structure of the hospital. To understand how the results differ between the top-down perspective and the CI, a CE analyses was performed looking only at a hospital level (ignoring the information about the services) with the objective to compare this method with the previous methodology. The same variables were used and all the different cost drivers had to be positive and bigger than one. A VRS model was used for the same reason used to justify the choice in the measurement of efficiency of the services.

The group of hospitals that had the minimum required information is constituted by 54 hospitals, two less than the analysis conducted before ("Hospital de Catanhede" and "Hospital Oliveira de Azeméis", both units presenting surgeries as outputs but no operating room associated costs. These values come from services that weren't considered in the services' analysis because of the minimum data criteria).

The overall data of this analysis can be found Table 15. The average value is high (88.23%) and the median has a value close to 100% means that a lot of values are close to this value. In fact the number of efficient units is half the units analysed (27 of the 54 hospitals). Curiously the standard deviation is almost identical to the previously analysis which means that the dispersion of the values obtained is almost the same in both analysis. The range of values in this analysis is inferior to the previous one (the only lower level efficiency unit of this analysis is "Unidade Local Saúde Baixo Alentejo, EPE"). The level of high level efficiency hospitals is also high. The average level of efficiency units is of 16 hospitals.

Table 15 – Descriptive Statistics of the Efficiency of the Hospitals of a Top Down Perspective

Mean	Median	Standard Deviation	Maximum	Minimum	Efficient	High Efficiency	Low Efficiency	Average Efficiency
88%	99%	16%	100%	32%	27	10	1	16

Figure 32 is a scatterplot representation of the efficiency by the number of the services. The relationship between the number of services and the efficiency doesn't seem to exist (R^2=1.03%) and no value of efficiency is exclusive to one size of a hospital.

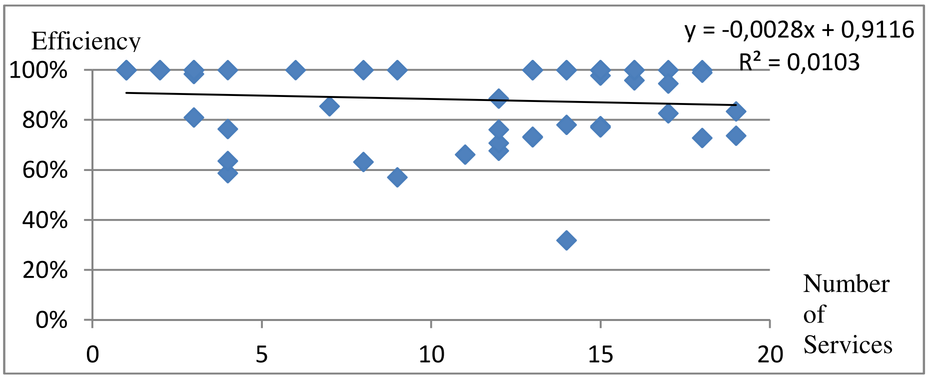

Figure 32 – Relation Between the Number of Services and Efficiency

The difference between the efficiency values obtained in this analysis and the prior analysis is of 9% and 10 % (for Model 1 and Model 2 respectively). The highest difference belongs to "Centro Hospitalar Psiquiátrico de Coimbra" which was considered highly inefficient in the previous models (16.30%) and in this model is considered efficient.

There are a few points that should be compared between this methodology and the CI methodology. The CI method allows for discrimination of the data to know in which services it can alter its cost structure. The hospital view method doesn't allow for this kind of discrimination. The CI method gives a more reasonable value since its weights its services in accordance to the volume of patients treated. The CI also allows for a deeper analysis of the information resulting in more DMUs evaluated in opposition to the traditional hospital analyses.

Data discrimination helps the hospital staff to understand its strengths and weaknesses, to know which services need improvement, from whom they should learn depending on the service being analysed, and the importance of each service for the hospital as a group of different services. One disadvantage of the CI is that, if the data is incorrect, the mistake disseminates much faster because the information isn't so diluted (the sum of the inputs and outputs is merely of the service in opposition to the hospital model where the sum of the inputs and outputs is that of the entire hospital). Another disadvantage is that CI gives the value of the efficiency of the hospital taking into account just the services analysed. If this number is low compared to the total number of services the efficiency assessed can be very different from efficiency obtained if all the services were used to create the CI.

4.9 Efficiency by ARS

The information that resulted from the model developed from the CI can be used to analyse the performance of the hospitals according to their ARS and see if there is any clear difference between the different regions. This analysis is of interest because the comparison of the efficiency by regions is common and is usually connected to political actions. The ARS of "Algarve" and "Alentejo" have only two hospitals in their jurisdiction in opposition to the other ARSs that have a higher number of hospitals. The small number of hospitals of those two ARSs can jeopardize this comparison. Nevertheless some conclusions can be taken from the analysis of the descriptive statistics found in Table 16.

Table 16 – Descriptive Statistics by ARS

	Alentejo	*Algarve*	*Centro*	*Lisboa e Vale do Tejo*	*Norte*
Number of hospitals	2	2	19	16	17
Average of efficiency	64.11%	59.86%	79.85%	83.61%	91.01%
Standard Deviation	0.46%	16.34%	18.19%	11.32%	8.26%

The highest average efficiency belongs to the ARS "Norte" followed by "Lisboa e Vale do Tejo" and then "Centro". ARSs of "Alentejo and "Algarve" have the lowest efficiency values. The variability inside ARS "Norte" is lower than the variability of the other ARSs (with the exception of ARS "Alentejo". With a superficial analysis it seems likely that there is a difference between the efficiency of the different ARSs but to corroborate these facts the hypothesis must be tested.

A test was designed to test if the production function follows a normal distribution (in an affirmative case that would mean that ANOVA could be used). Using the χ^2 test, the hypothesis is tested (Table 17). Because the average and standard deviation were estimated from the population and the data was grouped in 10 different ranges, the system has 7 degrees of freedom.

Table 17 – Statistics for the χ^2hypothesis test

Range	*Observed Frequency (Nk)*	*Probability*	*Expected Frequency (ek)*	*(Nk-ek)^2/ek*
]0.00, 0.63]	3	0.1	5.6	1.207143
]0.63, 0.70]	6	0.1	5.6	0.028571
]0.70, 0.75]	3	0.1	5.6	1.207143
]0.75, 0.79]	9	0.1	5.6	2.064286
]0.79, 0.83]	4	0.1	5.6	0.457143
]0.83, 0.87]	5	0.1	5.6	0.064286
]0.87, 0.91]	3	0.1	5.6	1.207143
]0.91, 0.96]	15	0.1	5.6	15.77857
]0.96, 1.00]	8	0.2	11.2	0.914286
				Q=22.93

The $\chi^2_7(\alpha$=0.05)=14.07 is inferior to the value of the statistic the hypothesis that the production function follows a normal distribution was rejected. Therefore the test of Kruskal-Wallis must be used to test if the distribution of the productive function is the same for the ARS. The number of hospitals of ARS “Alentejo” and “Algarve” is too low to allow for any credible test and for this reasons they are excluded from the analysis.

The Kruskal-Wallis statistic obtained is higher than the cutoff value to reject the hypothesis ($\chi^2_2(\alpha$=0.01)=5.99<56.31) which means that there are statistical differences between the different ARS. The Kolmogorov-Smirnov was used to assess between which ARS there was significant differences. There was no statistically significant difference between ARS “Centro” and ARS “Lisboa e Vale do Tejo” (P=0.988>0.05). There was a statistical significant difference between ARS “Norte” e “Centro” (P=0.012<0.05) and also between ARS “Norte” and ARS “Lisboa e Vale do Tejo” (P=0.05=0.05). This shows that the hospitals that are part of ARS “Norte” are more efficient than those of the other ARS.

The reasons behind these differences should be assessed to see if they are due to incontrollable factors or if there is indeed room for improvement in the different ARSs.

5 Conclusion and Future Work

The objective of this dissertation was to develop a model for the evaluation of the hospital's services and then a model that could be used to aggregate the services' efficiency to evaluate the overall performance of the hospital. The first objective was met with success and a model was conceptualized to evaluate the efficiency of the primary services (from a manager perspective). The model can be applied to all the primary services with just some minor adaptations. The second objective was also met with success and a CI was developed that used the efficiency of the services and that included some knowledge about the institutions. The development of the first model was only possible after a literature review on the subject of efficiency measurement in health care was conducted in order to identify the current practices and trends and to identify the strengths and weakness of the different studies to better specify the model created. The development of the second model proved to be more of a challenge because it's a topic that is underexplored. This led to the exploration of various different methodologies that could be used in the aggregation of the services' efficiency and the decision to choose the methodology that seemed more appropriate.

The application of the model for the efficiency analysis of the services in chapter 4 resulted in the identification of the different inefficiencies leading to the identification of which services need to improve their performance. Additionally the impact of the improvements was measured with the help of the number of patients that would benefit from those improvements. The service of "Internal Medicine" was then further explored to show how the efficiency model developed can help discriminate the actual cost structure of the service and if the service was to achieve an efficient status what cost structure it needed to have.

The application of the CI to aggregate the services' efficiency was also applied in chapter 4 to the different hospitals and resulted in the overall evaluation of the hospitals. In this chapter it was concluded that, for the evaluation to be stricter, one ideal hospital that is efficient in all of its services should be added to the comparison group. The results showed that there is room for improvement in all hospitals and it also showed differences among the different ARSs that should analyse the difference behind these differences.

The results of this dissertation are interesting but because of the quality of the data they should be interpreted with some caution. However, the model developed to assess the efficiency of the services and the CI developed to aggregate these efficiencies were conceptualized with a logic rationale. As such they should always get credible results when the data is trustworthy, the only services analysed and used are the primary services and all the primary services are used to evaluate the hospital.

This dissertation only approaches the first step on the subject of efficiency measurement in health care. There are still numerous things that have to be improved and analysed. The efficiency model has to be further developed so it can be extended to the transversal services so that the entire clinical process is analysed. One step that should be taken is the creation of a complementary model that assesses the efficiency of the system from a clinician point of view so that the overall efficiency of the hospital is assessed.

The aggregation of the efficiency of the different services should also be further explored because the method developed in this dissertation has some fragilities that should be addressed. The method to restrict the weights in the CI should uses the measure of patient volume defined earlier but this measure is crude since it attributes the same importance to all production lines what is a fundamental flaw. The measure of “standard patient” used by ACSS could probably solve this problem and give results that are in accordance to the view of this sector. Another point that should be mentioned is that, the aggregation method developed here is only useful from an output perspective. If the perspective is on the outcomes, the weight restrictions used have to be reformulated because they should be based on clinical measures like the quality adjusted life years (QALY). A challenge will surface when the two perspectives are used to aggregate the efficiency of the hospital.

There are some topics that should be further explored in the future. There are too few studies that analyse the evolution of the production frontier of hospitals in Portugal. This is a matter of concern that should be analysed in comparison to the evolution of other countries. Also, using the evolution of the production frontier, the results of the policy of the creation of the hospitals SA can be assessed. The structural costs are also a topic that should be further explored in order to be possible to assess the real possible improvements in efficiency for the hospitals. The ideal scale of the hospitals is also a matter that requires further study and that has very mixed results.

All this methods and models should be approved by their real users: the managers of the hospitals. If the model of used is not adequate for the needs of the hospital it won’t be used to implement policies and won’t show the real result of the efficiency of the hospital. Studies of efficiency should be modelled in a way that they are flexible enough to address the considered relevant by the user. It would also be important to include clinicians in the development of the models to assure that the efficiency isn’t achieved at the expense of the effectiveness and quality of care.

There are other institutions that have a considerable weight in the lives of people and in the expenditure with health besides hospitals. They have a different production function and for that the model conceptualized here isn’t applicable. These institutions (providers of ambulatory care) haven’t been studied with much detail and should start to be the focus of future studies because they represent the need of an ageing population.

References

Allen, R., A. Athanassopoulos, R. G. Dyson, and E. Thanassoulis. 1997. "Weights restrictions and value judgements in Data Envelopment Analysis: Evolution, development and future directions." *Annals of Operations Research* no. 73:13-34.

Almeida, Álvaro; Fique, José Pedro. 2011. "Evaluating Hospital Efficiency Adjusting for Quality Indicators: an Application to Portuguese NHS Hospitals." *FEP Working Papers*.

Anderson-Miles, E. 1994. "Benchmarking in healthcare organizations: an introduction." *Healthcare financial management : journal of the Healthcare Financial Management Association* no. 48 (9):58-61.

Arrow, Kenneth J. 1963. "Uncertainty and the Welfare Economics of Medical Care." *American Economic Review* no. 53 (5).

Barros, C. P., A. G. de Menezes, and J. C. Vieira. 2013. "Measurement of hospital efficiency, using a latent class stochastic frontier model." *Applied Economics* no. 45 (1):47-54.

Barros, Pedro P. 2013. *Economia da Saúde*. Second Edition Revised ed: Almedina.

Barros, PedroPita. 2003. "Random Output and Hospital Performance." *Health Care Management Science* no. 6 (4):219-227. doi: 10.1023/A:1026277507298.

Beckford, John. 1998. *Quality: A Critical Introduction*: Routledge.

Bendell, Tony; Kelly, John; Boulter, Louis. 1993. *Benchmarking for Competitive Advantage*. First Edition ed: Financial Times Prentice Hall.

Bogetoft, Peter; Otto, Lars. 2011. *Benchmarking with DEA, SFA and R*: Springer.

Camanho, Ana. 1999. *Performance Measurement and Improvement in the Management of Bank Branch Networks Using Data Envelopment Analysis*.

Camp, Robert C. 1989. *Benchmarking: the Search for Industry Best Practices that Leads to Superior Performance*: ASQC Quality Press.

Cantanhede, Hospital de. 2013. *Serviços - Valências Hospitalares* 2013 [cited 24th June 2013]. Available from http://www.hdcantanhede.min-saude.pt/valencias.html.

Carvalho, Mario Jorge. 2008. *Gestão e Liderança Na Saúde*: Vida Económica.

Castro, Ricardo Alves de Sousa. 2011. *Benchmarking de Hospitais Portugueses - Modelação com Data Envelopment Analysis*, UP.

Charnes, A., W. W. Cooper, and E. Rhodes. 1978. "Measuring the efficiency of decision making units." *European Journal of Operational Research* no. 2 (6):429-444.

Chilingerian, Jon A.; Sherman, H. David. 2011. "Health-Care Applications: From Hospitals to Physicians, from Productive Efficiency to Quality Frontiers." In *Handbook on Data Envelopment Analysis*, edited by William W.; Seiford Cooper, Lawrence M.; Zhu, Joe William.

Codling, Sylvia. 1998. *Benchmarking*: Gower Pub Co.

Coelli, Timothy J.; Rao, D.S. Prasada; O'Donnell Christopher J.; Battese, George E. 2005. *An Introduction to Efficiency and Productivity Analysis*: Springer US.

Cooper, William W.; Ruiz, Jose´ L.; Sirvent, Inmaculada 2011. "Choices and Uses of DEA Weights " In *Handbook on Data Envelopment Analysis*, edited by William W.; Seiford Cooper, Lawrence M.; Zhu, Joe William. Springer.

Cooper, William W.; Seiford, Lawrence M.; Tone, Kaoru. 2002. *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*: Springer.

Cox, Andrew; Thompson, Ian. 1998. "On the Appropriateness of Benchmarking." *Journal of General Management* no. 23 (3).

Deodato, Sérgio. 2012. *Direito da Saúde*: Almedina.

Entani, T., Y. Maeda, and H. Tanaka. 2002. "Dual models of interval DEA and its extension to interval data." *European Journal of Operational Research* no. 136 (1):32-45.

Farrell, M. J. 1957. "The Measurement of Productive Efficiency." *Journal of the Royal Statistical Society* no. 120 (3).

Finanças, Ministério das. 2011. Tradução do Conteúdo do Memorando de Entendimento Sobre as Condicionalidades de Política Económica.

Fox, K. J. 1999. "Efficiency at different levels of aggregation: Public vs. private sector firms." *Economics Letters* no. 65 (2):173-176.

Fried, Harold O.; Lovell, C. A. Knox; Schmidt, Shelton S. 2008. *The Measurement of Productive Efficiency and Productivity Growth*: OUP USA.

Glouberma, S.; Mintzberg, H. 1996. "Managing the Care of Health and the Cure of Disease Part I: Differentiation."

Gonçalves, Luís F. 2008. *Análise da Eficiência dos Hospitais SA e SPA Segundo uma Abordagem de Fronteira de Eficiência*, Instituto Superior de Ciências do Trabalho e da Empresa.

Hadley, L., and J. Ruggiero. 2006. "Final-offer arbitration in major league baseball: A nonparametric analysis." *Annals of Operations Research* no. 145 (1):201-209.

Haynes, Kingsley E., and Mustafa Dinc. 2005. "Data Envelopment Analysis (DEA)." In *Encyclopedia of Social Measurement*, edited by Kempf-Leonard Editor-in-Chief: Kimberly, 609-616. New York: Elsevier.

Hollingsworth, B. 2003. "Non-parametric and parametric applications measuring efficiency in health care." *Health Care Management Science* no. 6 (4):203-218.

Hollingsworth, B. 2008. "The measurement of efficiency and productivity of health care delivery." *Health Economics* no. 17 (10):1107-1128.

Hollingsworth, B. 2012. "Revolution, evolution, or status quo? Guidelines for efficiency measurement in health care." *Journal of Productivity Analysis* no. 37 (1):1-5.

Hollingsworth, B., P. J. Dawson, and N. Maniadakis. 1999. "Efficiency measurement of health care: A review of non-parametric methods and applications." *Health Care Management Science* no. 2 (3):161-172.

Hollingsworth, Bruce; Peacock, Stuart J. 2009. *Efficiency Measurement in Health and Health Care*. First Edition ed: Routledge.

Hopp, Wallace J.; Lovejoy, William S. 2012. *Hospital Operations: Principles of High Efficiency Health Care*: Financial Times Press.

INE. 2013. *Contas Satélite da Saúde* 2013 [cited 17th June 2013]. Available from http://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_contas_nacionais&contexto=cs&selTab=tab4&perfil=97154797&INST=116634832.

Johnson, A. L., and L. F. McGinnis. 2008. "Outlier detection in two-stage semiparametric DEA models." *European Journal of Operational Research* no. 187 (2):629-635.

Jorge, Ana. 2013. *Intervenção da Ministra da Saúde* 2009 [cited 22nd June 2013]. Available from http://www.portaldasaude.pt/portal/conteudos/a+saude+em+portugal/sns30anos/intervencao+anajorge.htm.

Kay, Jay FL. 2007. "Health Care Benchmarking." *THE HONG KONG MEDICAL DIARY* no. 12 (2).

Liu, J. S., L. Y. Y. Lu, W. M. Lu, and B. J. Y. Lin. 2013. "A survey of DEA applications." *Omega (United Kingdom)* no. 41 (5):893-902.

Mello, João Carlos Correia Baptista Soares de; Meza, Lidia Angulo; Gomes, Eliane Gonçalves; Neto, Luiz Biondi. 2005. Curso de Análise de Envoltória de Dados. In *XXXVII Simpósio Brasileiro de Pesquisa Operacional*.

Melyn, W. and Moesen, W. W. 1991. "Towards a Synthetic Indicator of Macroeconomic Performance: Unequal Weighting when Limited Information is Available." *Public Economic Research Paper*.

Menezes, António G.; Rendeiro, Marco F.; Vieira, José C. 2006. "Eficiência técnica dos hospitais portugueses 1997-2004: uma análise (regional) com base num modelo de fronteira estocástica."

Ministros, Presidência do Conselho de. 2011. Programa do XIX Governo Constitucional.

Morais, P., and A. S. Camanho. 2011. "Evaluation of performance of European cities with the aim to promote quality of life improvements." *Omega* no. 39 (4):398-409.

Moreira, Sara. 2008. "Análise dos Hospitais-Empresa: Uma Aplicação da Data Envelopment Analysis." *Boletim Económico*.

O'Neill, L., M. Rauner, K. Heidenberger, and M. Kraus. 2008. "A cross-national comparison and taxonomy of DEA-based hospital efficiency studies." *Socio-Economic Planning Sciences* no. 42 (3):158-189.

OECD. 2008. *Handbook on Constructing Composite Indicators: Methodology and User Guide*.

OECD. 2012. OECD Health Data 2012 How Does Portugal Compare. OECD.

Oliveira, M. D., and G. Bevan. 2008. "Modelling hospital costs to produce evidence for policies that promote equity and efficiency." *European Journal of Operational Research* no. 185 (3):933-947.

Ozcan, Yasar A. 2008. *Health Care Benchmarking and Performance Evaluation: An Assessment using Data Envelopment Analysis (DEA)*. Edited by Springer, *International Series in Operations Research & Management Science*.

Rego, Guilhermina, Rui Nunes, and José Costa. 2010. "The challenge of corporatisation: the experience of Portuguese public hospitals." *The European Journal of Health Economics* no. 11 (4):367-381. doi: 10.1007/s10198-009-0198-6.

Saúde, Administração Central do Sistema de. 2013. Relatório de Benchmarking | hospitais EPE e PPP dados a 31 de dezembro de 2012.

Simões, Jorge. 2004. *Retrato Político da Saúde - Dependência do Percurso e Inovação em Saúde: Da Ideologia ao Desempenho*: Almedina.

Simões, Pedro; Cunha Marques, Rui. 2009. "Performance and Congestion Analysis of the Portuguese Hospital Services." *Munich Personal RePEc Archive*.

Thompson, Russell G.; Singleton Jr., F. D.; Thrall, Robert M.; Smith, Barton A. 1986. "Comparative Site Evaluations for Locating a High-Energy Physics Lab in Texas." *Interfaces* no. 16 (6).

Tone, K. 2002. "A strange case of the cost and allocative efficiencies in DEA." *Journal of the Operational Research Society* no. 53 (11).

WHO. 2013. *WHO definition of Health* 1948 [cited 18th June 2013]. Available from http://www.who.int/about/definition/en/print.html.

WHO. 2000. The world health report 2000 - Health systems: improving performance. WHO.

Williams, A. 1987. "Health economics: the cheerful face of a dismal science." *Health and Economics*.

Wong, Y.-H. B.; Beasley, J. E. 1990. "Restricting Weight Flexibility in Data Envelopment Analysis." *The Journal of the Operational Research Society* no. 41 (9):829-835.

Worthington, Andrew C. 2004. "Frontier Efficiency Measurement in Healthcare: A Review of Empirical Techniques and Selected Applications." *Medical Care Research and Review* no. 61 (2).

Zweifel, Peter; Breyer, Friedrich; Kifmann, Mathias. 2009. *Health Economics*. Second Edition ed.

APPENDIX A: Service of Anaesthesiology

Table 18 – Efficiency Results for the Service of Anaesthesiology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	100.00%	0
2	Centro Hospitalar Barlavento Algarvio, EPE	0.93%	12 (1.00)
3	Centro Hospitalar Cascais	1.32%	12 (1.00)
4	Centro Hospitalar Cova da Beira, EPE	2.48%	12 (0.94) 20 (0.06)
5	Centro Hospitalar do Nordeste, EPE	0.80%	12 (1.00)
6	Centro Hospitalar do Porto, EPE	41.78%	7 (0.58) 12 (0.42)
7	Centro Hospitalar Lisboa Central, EPE	100.00%	5
8	Centro Hospitalar Lisboa Norte, EPE	1.31%	7 (0.09) 12 (0.91)
9	Centro Hospitalar Médio Tejo, EPE	3.74%	7 (0.07) 12 (0.93)
10	Centro Hospitalar Setúbal, EPE	10.68%	7 (0.02) 12 (0.32) 20 (0.65)
11	Centro Hospitalar Torres Vedras	0.17%	12 (1.00)
12	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	27
13	Hospital Águeda	51.67%	12 (1.00)
14	Hospital Alcobaça	5.49%	12 (1.00)
15	Hospital Aveiro, EPE	9.02%	12 (0.89) 20 (0.11)
16	Hospital Barcelos, EPE	66.09%	12 (1.00)
17	Hospital Curry Cabral	2.17%	12 (1.00)
18	Hospital Évora, EPE	1.29%	12 (1.00)
19	Hospital Faro, EPE	0.51%	12 (1.00)
20	Hospital Garcia de Orta, EPE	100.00%	5
21	Hospital Leiria, EPE	14.85%	12 (1.00)
22	Hospital Montijo	2.30%	12 (1.00)
23	Hospital Oliveira de Azeméis	100.00%	0
24	Hospital S. Sebastião, EPE	95.76%	7 (0.39) 12 (0.61)
25	Hospital Santarém, EPE	3.80%	12 (0.96) 20 (0.04)
26	Hospital Universitário Coimbra, EPE	1.27%	12 (1.00)
27	Hospital Vila Franca de Xira	7.96%	12 (1.00)
28	IPO Coimbra, EPE	40.03%	12 (0.78) 20 (0.22)
29	IPO Lisboa, EPE	100.00%	0
30	IPO Porto, EPE	4.45%	12 (1.00)

	Hospital	*Score*	*Benchmarks*
31	Unidade Local Saúde Baixo Alentejo, EPE	0.23%	12 (1.00)
32	Unidade Local Saúde da Guarda, EPE	15.73%	12 (1.00)
33	Unidade Local Saúde de Matosinhos, EPE	0.61%	12 (1.00)

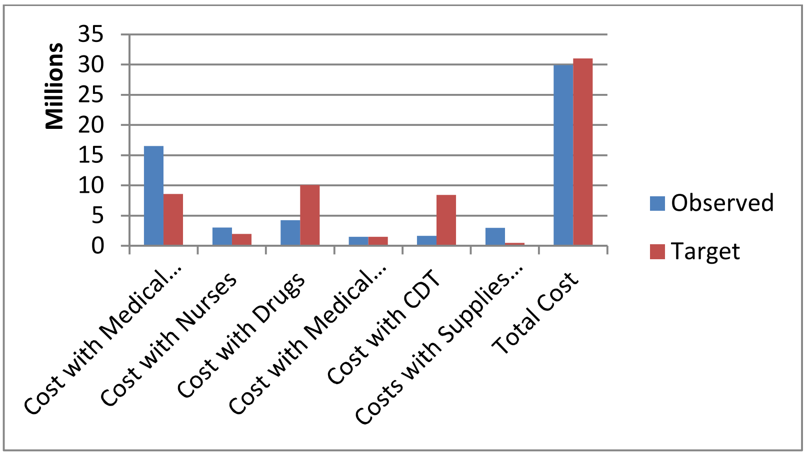

Figure 33 - Observed Costs and Target Savings for Anaesthesiology

APPENDIX B: Service of Cardiology

Table 19 - Efficiency Results for the Service of Cardiology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	90.83%	5 (0.88) 8 (0.07) 31 (0.06)
2	Centro Hospitalar Barlavento Algarvio, EPE	39.21%	3 (0.48) 6 (0.20) 25 (0.33)
3	Centro Hospitalar Cascais	100.00%	12
4	Centro Hospitalar Coimbra, EPE	83.89%	8 (0.02) 14 (0.37) 31 (0.48) 33 (0.13)
5	Centro Hospitalar Cova da Beira, EPE	100.00%	6
6	Centro Hospitalar do Nordeste, EPE	100.00%	4
7	Centro Hospitalar do Porto, EPE	41.49%	8 (0.05) 22 (0.49) 33 (0.46)
8	Centro Hospitalar Lisboa Central, EPE	100.00%	4
9	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
10	Centro Hospitalar Médio Tejo, EPE	87.11%	3 (0.23) 5 (0.19) 22 (0.40) 33 (0.19)
11	Centro Hospitalar Setúbal, EPE	24.74%	12 (0.15) 14 (0.76) 33 (0.09)
12	Centro Hospitalar Torres Vedras	100.00%	5
13	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	56.47%	3 (0.39) 5 (0.16) 22 (0.21) 33 (0.25)
14	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	10
15	Hospital Águeda	76.63%	3 (0.28) 12 (0.07) 24 (0.64)
16	Hospital Aveiro, EPE	69.04%	3 (0.08) 14 (0.34) 32 (0.57)
17	Hospital Barcelos, EPE	47.58%	24 (0.15) 25 (0.85)
18	Hospital Castelo Branco	99.78%	3 (0.67) 6 (0.27) 14 (0.06)
19	Hospital Curry Cabral	26.07%	14 (0.64) 24 (0.36)
20	Hospital Évora, EPE	100.00%	0
21	Hospital Faro, EPE	19.31%	3 (0.24) 5 (0.24) 14 (0.50) 33 (0.02)
22	Hospital Garcia de Orta, EPE	100.00%	6
23	Hospital Leiria, EPE	57.70%	3 (0.64) 6 (0.33) 25 (0.03)
24	Hospital Montijo	100.00%	5
25	Hospital Ovar	100.00%	5
26	Hospital S. João da Madeira	80.01%	24 (0.46) 25 (0.54)
27	Hospital S. João, EPE	51.36%	5 (0.30) 8 (0.10) 14 (0.44) 22 (0.16)
28	Hospital S. Marcos Braga	40.63%	12 (0.19) 14 (0.15) 22 (0.56) 33 (0.10)
30	Hospital Santarém, EPE	48.80%	3 (0.15) 12 (0.20) 22 (0.54) 33 (0.11)
31	Hospital Universitário Coimbra, EPE	100.00%	2

	Hospital	*Score*	*Benchmarks*
32	Hospital Vila Franca de Xira	100.00%	1
33	Hospital Viseu, EPE	100.00%	8
34	Unidade Local Saúde Baixo Alentejo, EPE	15.58%	3 (0.47) 24 (0.53)
35	Unidade Local Saúde da Guarda, EPE	77.53%	3 (0.55) 5 (0.44) 14 (0.01)

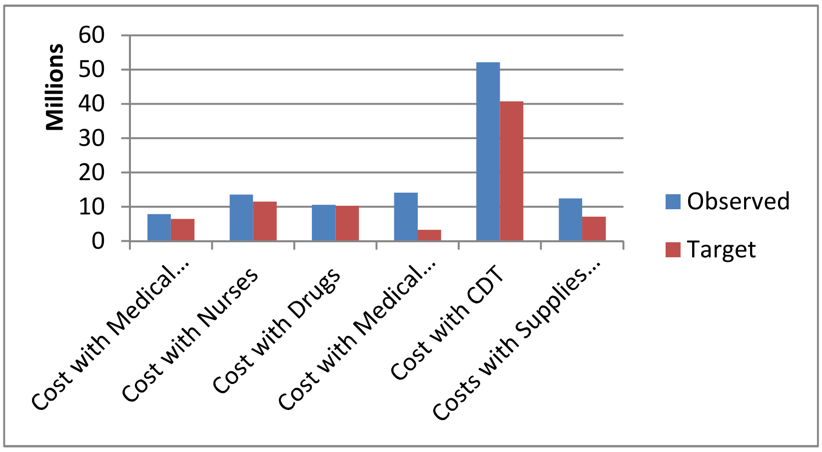

Figure 34 - Observed Costs and Target Savings for Cardiology

APPENDIX C: Service of General Surgery

Table 20 - Efficiency Results for the Service of General Surgery

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	100.00%	3
2	Centro Hospitalar Barlavento Algarvio, EPE	68.44%	16 (0.14) 18 (0.34) 41 (0.27) 42 (0.26)
3	Centro Hospitalar Caldas da Rainha	64.73%	31 (0.44) 41 (0.49) 42 (0.07)
4	Centro Hospitalar Cascais	65.85%	11 (0.48) 18 (0.38) 40 (0.14)
5	Centro Hospitalar Coimbra, EPE	100.00%	0
6	Centro Hospitalar Cova da Beira, EPE	80.71%	16 (0.16) 32 (0.03) 38 (0.46) 42 (0.21) 46 (0.14)
7	Centro Hospitalar do Nordeste, EPE	85.03%	11 (0.14) 16 (0.51) 41 (0.11) 42 (0.23)
8	Centro Hospitalar do Porto, EPE	100.00%	1
9	Centro Hospitalar Lisboa Central, EPE	100.00%	0
10	Centro Hospitalar Lisboa Norte, EPE	100.00%	1
11	Centro Hospitalar Médio Ave, EPE	100.00%	7
12	Centro Hospitalar Médio Tejo, EPE	100.00%	0
13	Centro Hospitalar Setúbal, EPE	72.04%	16 (0.52) 38 (0.31) 42 (0.17)
14	Centro Hospitalar Torres Vedras	70.68%	16 (0.49) 31 (0.30) 40 (0.08) 41 (0.08) 42 (0.06)
15	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	100.00%	1
16	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	13
17	Hospital Águeda	97.84%	16 (0.11) 32 (0.28) 38 (0.61)
18	Hospital Alcobaça	100.00%	5
19	Hospital Anadia	83.28%	31 (0.16) 38 (0.84)
20	Hospital Aveiro, EPE	76.89%	16 (0.44) 38 (0.34) 42 (0.21)
21	Hospital Barcelos, EPE	100.00%	0
22	Hospital Castelo Branco	88.13%	16 (0.25) 18 (0.09) 32 (0.37) 42 (0.18) 46 (0.10)
23	Hospital Curry Cabral	47.19%	1 (0.14) 8 (0.04) 11 (0.61) 36 (0.21)
24	Hospital Estarreja	97.02%	16 (0.04) 31 (0.14) 38 (0.77) 40 (0.05)
25	Hospital Évora, EPE	65.88%	16 (0.55) 32 (0.18) 42 (0.27)
26	Hospital Faro, EPE	52.18%	32 (0.23) 38 (0.27) 42 (0.50)
27	Hospital Garcia de Orta, EPE	95.22%	1 (0.05) 11 (0.00) 16 (0.10) 42 (0.85)

	Hospital	*Score*	*Benchmarks*
28	Hospital Leiria, EPE	95.91%	11 (0.44) 18 (0.06) 41 (0.12) 42 (0.38)
29	Hospital Montijo	70.02%	16 (0.33) 32 (0.02) 38 (0.65)
30	Hospital Ovar	70.11%	31 (0.17) 38 (0.64) 40 (0.19)
31	Hospital Peniche	100.00%	5
32	Hospital Pombal	100.00%	7
33	Hospital S. João da Madeira	100.00%	0
34	Hospital S. João, EPE	100.00%	0
35	Hospital S. Marcos Braga	100.00%	0
36	Hospital S. Sebastião, EPE	100.00%	1
37	Hospital Santarém, EPE	75.29%	11 (0.06) 18 (0.29) 41 (0.17) 42 (0.48)
38	Hospital Tondela	100.00%	9
39	Hospital Universitário Coimbra, EPE	81.61%	10 (0.24) 15 (0.76)
40	Hospital Valongo	100.00%	5
41	Hospital Vila Franca de Xira	100.00%	6
42	Hospital Viseu, EPE	100.00%	14
43	IPO Coimbra, EPE	100.00%	0
44	IPO Lisboa, EPE	52.87%	1 (0.27) 11 (0.10) 16 (0.18) 40 (0.45)
45	Unidade Local Saúde Baixo Alentejo, EPE	63.24%	32 (0.59) 42 (0.41)
46	Unidade Local Saúde da Guarda, EPE	100.00%	2
47	Unidade Local Saúde de Matosinhos, EPE	100.00%	0

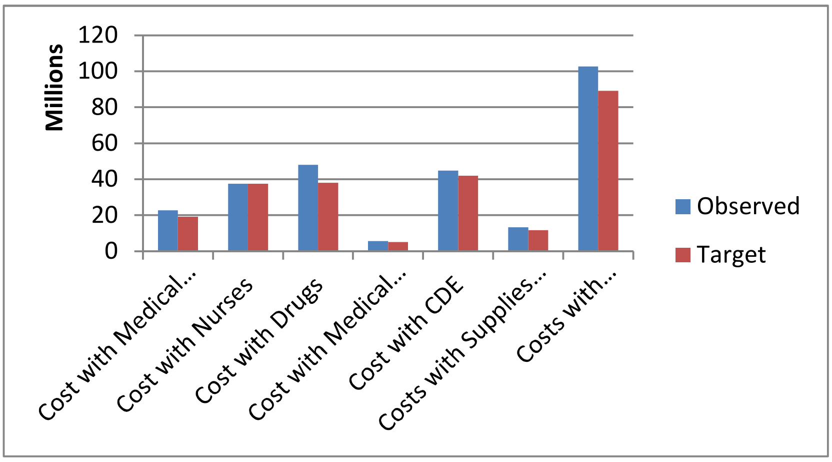

Figure 35 - Observed Costs and Target Savings for General Surgery

APPENDIX D: Service of Infectious Diseases

Table 21 - Efficiency Results for the Service of Infectious Diseases

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Coimbra, EPE	100.00%	0
2	Centro Hospitalar Cova da Beira, EPE	100.00%	1
3	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
4	Centro Hospitalar Setúbal, EPE	69.36%	8 (0.76) 9 (0.24)
5	Hospital Aveiro, EPE	82.28%	8 (0.92) 9 (0.08)
6	Hospital Curry Cabral	100.00%	1
7	Hospital Faro, EPE	100.00%	1
8	Hospital Garcia de Orta, EPE	100.00%	4
9	Hospital Joaquim Urbano	100.00%	3
10	Hospital S. João, EPE	76.92%	6 (0.49) 8 (0.15) 9 (0.35)
11	Hospital Santarém, EPE	24.32%	2 (0.33) 7 (0.52) 8 (0.15)
12	Hospital Universitário Coimbra, EPE	100.00%	0

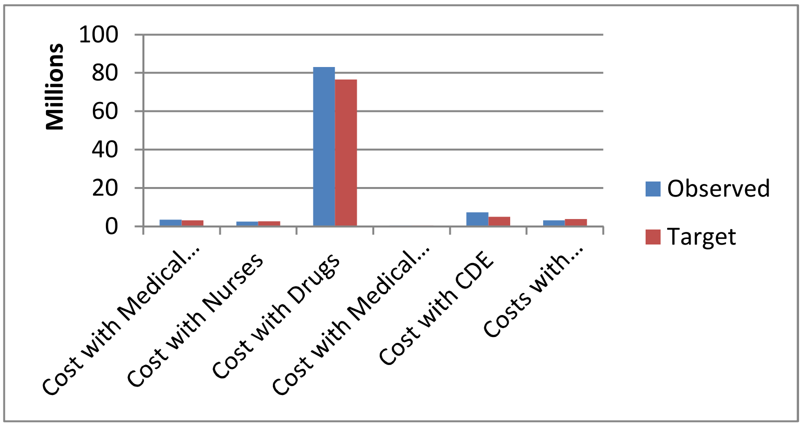

Figure 36 - Observed Costs and Target Savings for Infectious Diseases

APPENDIX E: Service of Gastroenterology

Table 22 - Efficiency Results for the Service of Gastroenterology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave. EPE	48.01%	14 (0.24) 16 (0.43) 18 (0.32)
2	Centro Hospitalar Barlavento Algarvio. EPE	63.70%	18 (0.88) 29 (0.12)
3	Centro Hospitalar Caldas da Rainha	40.67%	14 (0.14) 16 (0.51) 18 (0.35)
4	Centro Hospitalar Cascais	47.89%	16 (0.28) 18 (0.33) 29 (0.39)
5	Centro Hospitalar Coimbra. EPE	86.55%	13 (0.02) 18 (0.83) 24 (0.14)
6	Centro Hospitalar Cova da Beira. EPE	85.21%	8 (0.02) 13 (0.04) 18 (0.94)
7	Centro Hospitalar do Porto. EPE	60.66%	8 (0.02) 9 (0.14) 13 (0.84)
8	Centro Hospitalar Lisboa Central. EPE	100.00%	5
9	Centro Hospitalar Lisboa Norte. EPE	100.00%	1
10	Centro Hospitalar Médio Tejo. EPE	100.00%	0
11	Centro Hospitalar Setúbal. EPE	64.78%	8 (0.18) 13 (0.35) 18 (0.47)
12	Centro Hospitalar Trás-os-Montes e Alto Douro. EPE	100.00%	0
13	Centro Hospitalar V.N.Gaia/Espinho. EPE	100.00%	12
14	Hospital Aveiro. EPE	100.00%	4
15	Hospital Castelo Branco	68.73%	18 (0.62) 29 (0.38)
16	Hospital Évora. EPE	100.00%	6
17	Hospital Faro. EPE	65.43%	13 (0.35) 18 (0.51) 24 (0.13)
18	Hospital Garcia de Orta. EPE	100.00%	14
19	Hospital Leiria. EPE	53.33%	13 (0.00) 14 (0.07) 18 (0.93)
20	Hospital S. João. EPE	93.21%	8 (0.68) 13 (0.30) 18 (0.01)
21	Hospital S. Marcos Braga	25.76%	13 (0.30) 16 (0.24) 18 (0.10) 29 (0.36)
22	Hospital S. Sebastião. EPE	74.60%	13 (0.18) 16 (0.14) 25 (0.67)
23	Hospital Santarém. EPE	75.39%	16 (0.09) 25 (0.86) 29 (0.05)
24	Hospital Universitário Coimbra. EPE	100.00%	2
25	Hospital Vila Franca de Xira	100.00%	2
26	Hospital Viseu. EPE	73.92%	13 (0.38) 18 (0.55) 29 (0.07)
27	IPO Lisboa. EPE	57.29%	8 (0.45) 13 (0.35) 18 (0.19)
28	IPO Porto. EPE	44.04%	13 (0.13) 14 (0.87)
29	Unidade Local Saúde da Guarda. EPE	100.00%	6

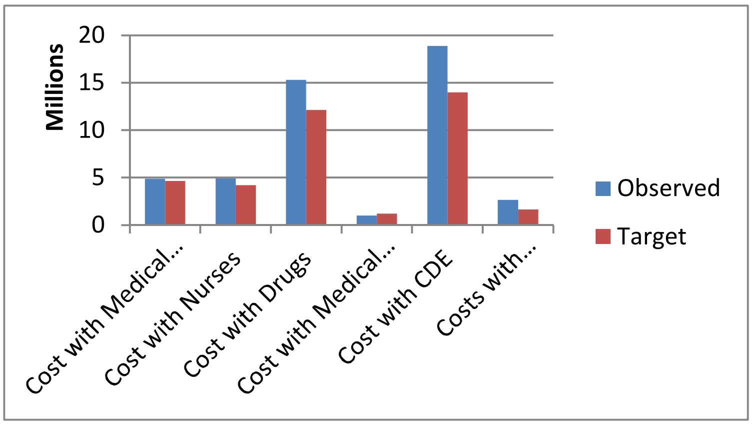

Figure 37 - Observed Costs and Target Savings for Gastroenterology

APPENDIX F: Service of Gynaecology/Obstetrics

Table 23 - Efficiency Results for the Service of Gynaecology/Obstetrics

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	100.00%	0
2	Centro Hospitalar Barlavento Algarvio, EPE	80.70%	11 (0.74) 16 (0.11) 19 (0.14)
3	Centro Hospitalar Caldas da Rainha	73.65%	13 (0.56) 16 (0.18) 24 (0.22) 27 (0.04)
4	Centro Hospitalar Cascais	72.55%	11 (0.26) 16 (0.43) 24 (0.31)
5	Centro Hospitalar Coimbra, EPE	100.00%	4
6	Centro Hospitalar Cova da Beira, EPE	86.87%	16 (0.34) 24 (0.26) 32 (0.40)
7	Centro Hospitalar do Nordeste, EPE	66.37%	11 (0.17) 16 (0.11) 18 (0.22) 24 (0.47) 27 (0.03)
8	Centro Hospitalar do Porto, EPE	100.00%	2
9	Centro Hospitalar Lisboa Central, EPE	37.61%	5 (0.06) 11 (0.24) 16 (0.50) 27 (0.20)
10	Centro Hospitalar Lisboa Norte, EPE	84.47%	8 (0.05) 16 (0.66) 31 (0.01) 35 (0.28)
11	Centro Hospitalar Médio Ave, EPE	100.00%	5
12	Centro Hospitalar Médio Tejo, EPE	46.15%	16 (0.17) 18 (0.06) 24 (0.54) 27 (0.21) 31 (0.02)
13	Centro Hospitalar Setúbal, EPE	100.00%	2
14	Centro Hospitalar Torres Vedras	80.66%	16 (0.38) 19 (0.28) 24 (0.24) 31 (0.10)
15	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	94.05%	5 (0.15) 11 (0.43) 16 (0.41) 32 (0.00)
16	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	18
17	Hospital Aveiro, EPE	73.71%	16 (0.10) 18 (0.13) 24 (0.25) 27 (0.29) 31 (0.23)
18	Hospital Barcelos, EPE	100.00%	6
19	Hospital Castelo Branco	100.00%	3
20	Hospital Évora, EPE	88.67%	18 (0.27) 24 (0.31) 27 (0.42) 31 (0.01)
21	Hospital Faro, EPE	59.83%	24 (0.09) 31 (0.91)
22	Hospital Garcia de Orta, EPE	70.92%	13 (0.62) 35 (0.38)
23	Hospital Leiria, EPE	82.07%	16 (0.62) 24 (0.03) 27 (0.33) 31 (0.02)
24	Hospital Oliveira de Azeméis	100.00%	15
25	Hospital S. João, EPE	95.54%	5 (0.40) 8 (0.12) 16 (0.21) 31 (0.27)
26	Hospital S. Marcos Braga	100.00%	0
27	Hospital S. Sebastião, EPE	100.00%	10

	Hospital	*Score*	*Benchmarks*
28	Hospital Santarém, EPE	75.37%	16 (0.15) 18 (0.18) 24 (0.08) 27 (0.58) 31 (0.01)
29	Hospital Universitário Coimbra, EPE	75.06%	31 (0.72) 35 (0.28)
30	Hospital Vila Franca de Xira	91.49%	16 (0.18) 18 (0.18) 24 (0.51) 31 (0.13)
31	Hospital Viseu, EPE	100.00%	14
32	IPO Coimbra, EPE	100.00%	4
33	IPO Lisboa, EPE	70.31%	16 (0.17) 19 (0.75) 31 (0.08)
34	IPO Porto, EPE	90.59%	16 (0.01) 24 (0.70) 27 (0.14) 32 (0.15)
35	Maternidade Alfredo da Costa	100.00%	3
36	Unidade Local Saúde Baixo Alentejo, EPE	47.89%	24 (0.72) 31 (0.28)
37	Unidade Local Saúde da Guarda, EPE	80.33%	24 (0.60) 31 (0.40)
38	Unidade Local Saúde de Matosinhos, EPE	82.65%	5 (0.07) 16 (0.07) 27 (0.75) 32 (0.11)

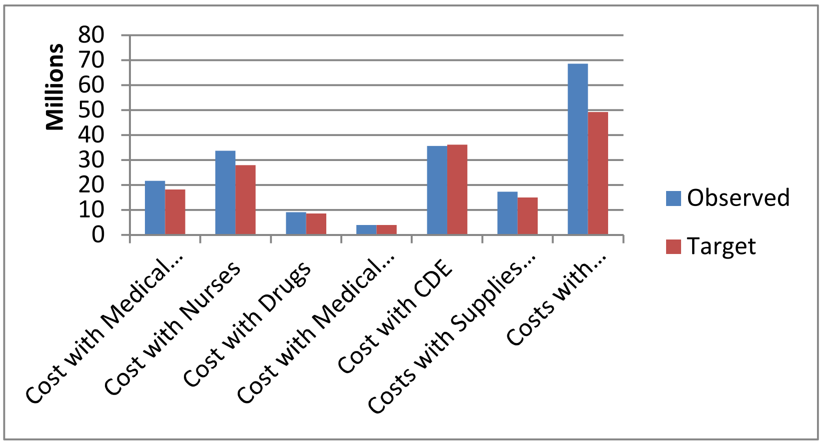

Figure 38 - Observed Costs and Target Savings for Gynaecology/Obstetrics

APPENDIX G: Service of Clinical Haematology

Table 24 - Efficiency Results for the Service of Clinical Haematology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Coimbra, EPE	100.00%	3
2	Centro Hospitalar do Porto, EPE	100.00%	2
3	Centro Hospitalar Lisboa Central, EPE	100.00%	0
4	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
5	Centro Hospitalar Setúbal, EPE	100.00%	2
6	Hospital Aveiro, EPE	57.01%	1 (0.10) 5 (0.24) 11 (0.66)
7	Hospital Évora, EPE	100.00%	1
8	Hospital Faro, EPE	9.13%	5 (0.06) 7 (0.33) 11 (0.61)
9	Hospital Garcia de Orta, EPE	71.33%	10 (0.36) 13 (0.64)
10	Hospital S. João, EPE	100.00%	3
11	Hospital Santarém, EPE	100.00%	2
12	Hospital Universitário Coimbra, EPE	51.99%	10 (1.00) 13 (0.00)
13	Hospital Viseu, EPE	100.00%	2
14	IPO Lisboa, EPE	51.34%	1 (0.00) 2 (0.12) 10 (0.88)
15	IPO Porto, EPE	75.39%	1 (0.88) 2 (0.12)

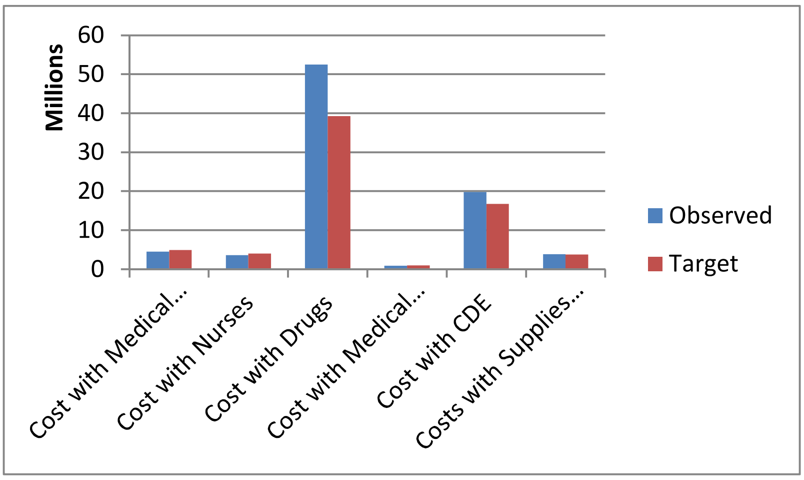

Figure 39 - Observed Costs and Target Savings for Clinical Haematology

APPENDIX H: Service of Imunohemoterapy

Table 25 - Efficiency Results for the Service of Imunohemoterapy

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	100.00%	6
2	Centro Hospitalar Barlavento Algarvio, EPE	35.14%	8 (0.16) 9 (0.01) 14 (0.01) 23 (0.82)
3	Centro Hospitalar Coimbra, EPE	26.44%	14 (0.09) 23 (0.91)
4	Centro Hospitalar Cova da Beira, EPE	70.24%	1 (0.19) 8 (0.27) 14 (0.01) 23 (0.53)
5	Centro Hospitalar do Porto, EPE	32.64%	1 (0.27) 8 (0.71) 9 (0.02)
6	Centro Hospitalar Lisboa Central, EPE	6.84%	8 (0.07) 9 (0.01) 14 (0.26) 23 (0.65)
7	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
8	Centro Hospitalar Médio Ave, EPE	100.00%	15
9	Centro Hospitalar Médio Tejo, EPE	100.00%	11
10	Centro Hospitalar Setúbal, EPE	45.11%	8 (0.17) 9 (0.05) 14 (0.01) 23 (0.77)
11	Centro Hospitalar Torres Vedras	82.42%	8 (0.01) 9 (0.00) 14 (0.14) 23 (0.84)
12	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	0
13	Hospital Aveiro, EPE	33.58%	1 (0.01) 8 (0.12) 14 (0.07) 23 (0.81)
14	Hospital Curry Cabral	100.00%	13
15	Hospital Évora, EPE	44.88%	8 (0.48) 9 (0.06) 23 (0.46)
16	Hospital Faro, EPE	22.71%	8 (0.01) 9 (0.02) 23 (0.97)
17	Hospital Leiria, EPE	33.27%	14 (0.02) 23 (0.98)
18	Hospital S. João, EPE	100.00%	0
19	Hospital S. Marcos Braga	57.00%	1 (0.58) 23 (0.42)
20	Hospital S. Sebastião, EPE	61.24%	1 (0.15) 8 (0.14) 23 (0.71)
21	Hospital Santarém, EPE	56.93%	8 (0.06) 9 (0.04) 14 (0.06) 23 (0.83)
22	Hospital Universitário Coimbra, EPE	12.64%	8 (0.36) 9 (0.06) 23 (0.58)
23	Hospital Vila Franca de Xira	100.00%	19
24	Hospital Viseu, EPE	21.65%	14 (0.02) 23 (0.98)
25	IPO Lisboa, EPE	18.84%	8 (0.05) 9 (0.14) 14 (0.16) 23 (0.66)
26	IPO Porto, EPE	24.78%	8 (0.55) 9 (0.40) 23 (0.04)
27	Unidade Local Saúde Baixo Alentejo, EPE	50.01%	14 (0.08) 23 (0.92)
28	Unidade Local Saúde de Matosinhos, EPE	94.80%	1 (0.37) 8 (0.09) 14 (0.01) 23 (0.54)

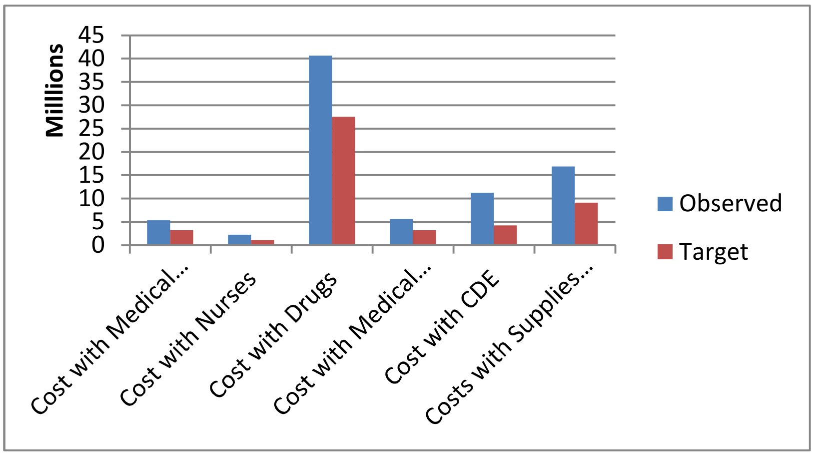

Figure 40 - Observed Costs and Target Savings for Imunohemotherapy

APPENDIX I: Service of Physical Medicine and Rehabilitation

Table 26 - Efficiency Results for the Service of Physical Medicine and Rehabilitation

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	40.39%	9 (0.11) 16 (0.89)
2	Centro Hospitalar Barlavento Algarvio, EPE	32.48%	19 (1.00)
3	Centro Hospitalar Caldas da Rainha	57.17%	17 (0.33) 28 (0.67)
4	Centro Hospitalar Cascais	46.25%	16 (0.06) 19 (0.94)
5	Centro Hospitalar Coimbra, EPE	45.45%	16 (0.04) 19 (0.96)
6	Centro Hospitalar Cova da Beira, EPE	21.66%	16 (0.81) 19 (0.19)
7	Centro Hospitalar do Nordeste, EPE	48.00%	16 (0.29) 19 (0.71)
8	Centro Hospitalar do Porto, EPE	36.44%	9 (0.03) 16 (0.19) 28 (0.78)
9	Centro Hospitalar Lisboa Central, EPE	100.00%	8
10	Centro Hospitalar Lisboa Norte, EPE	28.95%	9 (0.10) 16 (0.90)
11	Centro Hospitalar Médio Ave, EPE	20.08%	16 (0.51) 19 (0.49)
12	Centro Hospitalar Médio Tejo, EPE	68.68%	9 (0.41) 16 (0.59)
13	Centro Hospitalar Setúbal, EPE	41.32%	16 (0.83) 19 (0.17)
14	Centro Hospitalar Torres Vedras	18.37%	16 (0.09) 19 (0.91)
15	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	36.44%	9 (0.21) 16 (0.79)
16	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	25
17	Hospital Águeda	100.00%	2
18	Hospital Aveiro, EPE	28.12%	16 (0.02) 19 (0.98)
19	Hospital Castelo Branco	100.00%	22
20	Hospital Curry Cabral	100.00%	0
21	Hospital Évora, EPE	45.62%	16 (0.19) 19 (0.81)
22	Hospital Faro, EPE	10.41%	16 (0.17) 17 (0.73) 28 (0.10)
23	Hospital Garcia de Orta, EPE	26.36%	9 (0.04) 16 (0.96)
24	Hospital Leiria, EPE	23.18%	16 (0.88) 19 (0.12)
25	Hospital Peniche	52.76%	19 (1.00)
26	Hospital S. João da Madeira	40.78%	16 (0.22) 19 (0.78)
27	Hospital S. João, EPE	22.63%	9 (0.05) 16 (0.95)
28	Hospital S. Marcos Braga	100.00%	3
29	Hospital S. Sebastião, EPE	74.79%	9 (0.53) 16 (0.47)
30	Hospital Santarém, EPE	39.52%	19 (1.00)

	Hospital	*Score*	*Benchmarks*
31	Hospital Universitário Coimbra, EPE	10.11%	16 (0.27) 19 (0.73)
32	Hospital Vila Franca de Xira	39.88%	16 (0.04) 19 (0.96)
33	IPO Coimbra, EPE	91.08%	19 (1.00)
34	IPO Lisboa, EPE	38.60%	16 (0.48) 19 (0.52)
35	IPO Porto, EPE	74.33%	16 (0.62) 19 (0.38)
36	Unidade Local Saúde Baixo Alentejo, EPE	26.80%	19 (1.00)
37	Unidade Local Saúde da Guarda, EPE	72.30%	19 (1.00)
38	Unidade Local Saúde de Matosinhos, EPE	73.34%	16 (0.57) 19 (0.43)

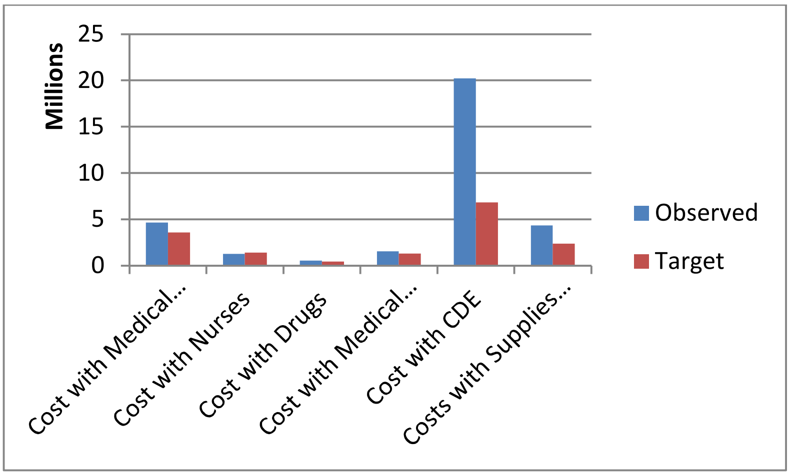

Figure 41 - Observed Costs and Target Savings for Physical Medicine and Rehabilitation

APPENDIX J: Service of Internal Medicine

Table 27 - Efficiency Results for the Service of Internal Medicine

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave. EPE	100.00%	0
2	Centro Hospitalar Barlavento Algarvio. EPE	43.12%	7 (0.13) 13 (0.79) 38 (0.09)
3	Centro Hospitalar Caldas da Rainha	31.96%	5 (0.16) 13 (0.36) 45 (0.47)
4	Centro Hospitalar Cascais	33.66%	13 (0.64) 41 (0.36)
5	Centro Hospitalar Coimbra. EPE	100.00%	8
6	Centro Hospitalar Cova da Beira. EPE	100.00%	2
7	Centro Hospitalar do Nordeste. EPE	100.00%	11
8	Centro Hospitalar do Porto. EPE	100.00%	0
9	Centro Hospitalar Lisboa Central. EPE	100.00%	0
10	Centro Hospitalar Lisboa Norte. EPE	100.00%	0
11	Centro Hospitalar Médio Ave. EPE	80.06%	7 (0.14) 13 (0.21) 29 (0.64)
12	Centro Hospitalar Médio Tejo. EPE	90.94%	7 (0.80) 15 (0.16) 29 (0.04)
13	Centro Hospitalar Setúbal. EPE	100.00%	26
14	Centro Hospitalar Torres Vedras	53.65%	13 (1.00) 41 (0.00)
15	Centro Hospitalar Trás-os-Montes e Alto Douro. EPE	100.00%	3
16	Centro Hospitalar V.N.Gaia/Espinho. EPE	59.85%	7 (0.08) 13 (0.59) 29 (0.33)
17	Hospital Águeda	51.57%	13 (0.11) 41 (0.89)
18	Hospital Alcobaça	56.15%	13 (0.16) 41 (0.84)
19	Hospital Anadia	46.69%	22 (0.20) 41 (0.80)
20	Hospital Aveiro. EPE	97.14%	7 (0.20) 13 (0.50) 38 (0.30)
21	Hospital Barcelos. EPE	54.58%	5 (0.02) 13 (0.61) 45 (0.37)
22	Hospital Cantanhede	100.00%	5
23	Hospital Castelo Branco	26.63%	13 (0.37) 41 (0.63)
24	Hospital Curry Cabral	67.70%	7 (0.48) 13 (0.32) 38 (0.20)
25	Hospital Estarreja	90.77%	22 (0.16) 41 (0.84)
26	Hospital Évora. EPE	48.20%	6 (0.38) 13 (0.62) 45 (0.00)
27	Hospital Faro. EPE	31.14%	13 (0.96) 38 (0.04)
28	Hospital Garcia de Orta. EPE	70.68%	5 (0.24) 13 (0.63) 29 (0.12)
29	Hospital Leiria. EPE	100.00%	7
30	Hospital Montijo	83.16%	5 (0.42) 13 (0.14) 45 (0.45)

	Hospital	*Score*	*Benchmarks*
31	Hospital Oliveira de Azeméis	38.78%	13 (0.34) 41 (0.66)
32	Hospital Ovar	51.54%	5 (0.07) 13 (0.16) 45 (0.78)
33	Hospital Peniche	61.66%	22 (0.32) 41 (0.68)
34	Hospital Pombal	71.80%	5 (0.03) 13 (0.36) 45 (0.60)
35	Hospital S. João. EPE	71.98%	7 (0.06) 15 (0.68) 38 (0.26)
36	Hospital S. Marcos Braga	38.52%	5 (0.11) 13 (0.16) 29 (0.73)
37	Hospital S. Sebastião. EPE	87.35%	5 (0.35) 29 (0.41) 45 (0.24)
38	Hospital Santarém. EPE	100.00%	8
39	Hospital Tondela	54.20%	22 (0.00) 41 (1.00)
40	Hospital Universitário Coimbra. EPE	42.07%	7 (0.16) 13 (0.52) 38 (0.33)
41	Hospital Valongo	100.00%	12
42	Hospital Vila Franca de Xira	76.00%	6 (0.16) 7 (0.15) 13 (0.69)
43	Hospital Viseu. EPE	91.32%	7 (0.54) 13 (0.24) 29 (0.21)
44	IPO Coimbra. EPE	88.09%	13 (0.06) 22 (0.85) 41 (0.02) 45 (0.07)
45	IPO Porto. EPE	100.00%	8
46	Unidade Local Saúde Baixo Alentejo. EPE	33.22%	13 (0.75) 41 (0.25)
47	Unidade Local Saúde da Guarda. EPE	48.11%	13 (0.87) 38 (0.13)
48	Unidade Local Saúde de Matosinhos. EPE	95.71%	7 (0.58) 15 (0.31) 38 (0.11)

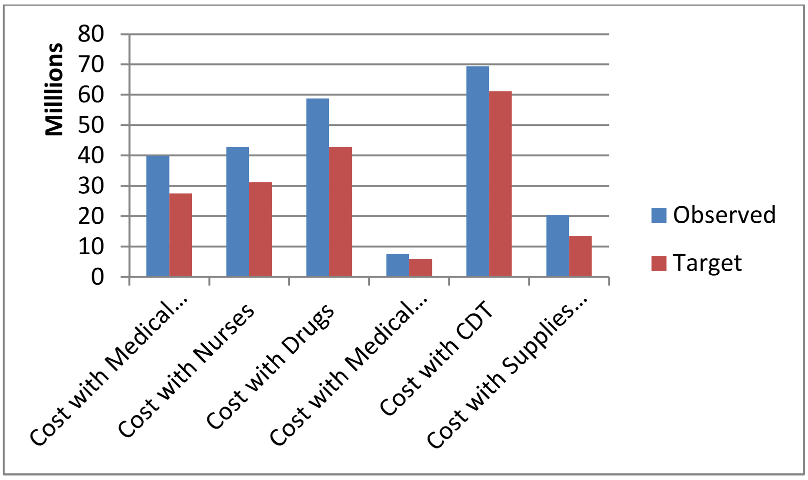

Figure 42 - Observed Costs and Target Savings for Internal Medicine

APPENDIX K: Service of Nephrology

Table 28 - Efficiency Results for the Service of Nephrology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Coimbra, EPE	100.00%	1
2	Centro Hospitalar do Nordeste, EPE	100.00%	1
3	Centro Hospitalar do Porto, EPE	100.00%	0
4	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
5	Centro Hospitalar Médio Tejo, EPE	100.00%	2
6	Centro Hospitalar Setúbal, EPE	93.33%	10 (0.32) 11 (0.59) 18 (0.09)
7	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	100.00%	1
8	Centro Hospitalar V.N.Gaia/Espinho, EPE	90.41%	5 (0.38) 9 (0.26) 10 (0.13) 18 (0.23)
9	Hospital Castelo Branco	100.00%	2
10	Hospital Curry Cabral	100.00%	4
11	Hospital Évora, EPE	100.00%	3
12	Hospital Faro, EPE	87.00%	1 (0.32) 5 (0.47) 9 (0.21)
13	Hospital Garcia de Orta, EPE	94.93%	7 (0.25) 10 (0.15) 11 (0.60)
14	Hospital S. João, EPE	100.00%	0
15	Hospital Santarém, EPE	100.00%	3
16	Hospital Universitário Coimbra, EPE	100.00%	0
17	Hospital Vila Franca de Xira	75.69%	15 (1.00)
18	Hospital Viseu, EPE	100.00%	2
19	IPO Porto, EPE	85.93%	2 (0.67) 11 (0.02) 15 (0.31)
20	Unidade Local Saúde de Matosinhos, EPE	15.36%	10 (0.11) 15 (0.89)

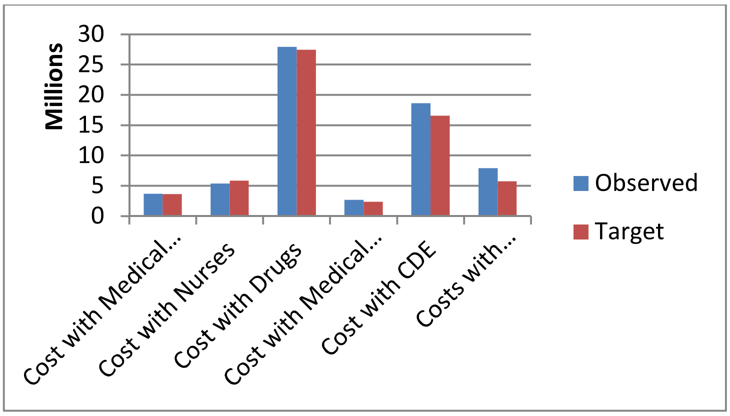

Figure 43 - Observed Costs and Target Savings for Nephrology

APPENDIX L: Service of Neurology

Table 29 - Efficiency Results for the Service of Neurology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	78.82%	3 (0.40) 5 (0.06) 9 (0.54)
2	Centro Hospitalar Barlavento Algarvio, EPE	85.32%	8 (0.09) 13 (0.15) 18 (0.76)
3	Centro Hospitalar do Nordeste, EPE	100.00%	5
4	Centro Hospitalar do Porto, EPE	100.00%	0
5	Centro Hospitalar Lisboa Central, EPE	100.00%	2
6	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
7	Centro Hospitalar Médio Tejo, EPE	100.00%	4
8	Centro Hospitalar Setúbal, EPE	100.00%	2
9	Hospital Aveiro, EPE	100.00%	2
10	Hospital Castelo Branco	59.06%	3 (0.46) 7 (0.24) 18 (0.30)
11	Hospital Évora, EPE	60.74%	3 (0.18) 7 (0.81) 13 (0.01)
12	Hospital Oliveira de Azeméis	63.43%	15 (1.00)
13	Hospital S. Sebastião, EPE	100.00%	3
14	Hospital Santarém, EPE	87.18%	7 (0.52) 8 (0.31) 13 (0.17)
15	Hospital Vila Franca de Xira	100.00%	1
16	IPO Coimbra, EPE	84.44%	3 (0.43) 7 (0.57)
17	IPO Lisboa, EPE	61.75%	3 (0.40) 5 (0.13) 9 (0.47)
18	Unidade Local Saúde da Guarda, EPE	100.00%	2

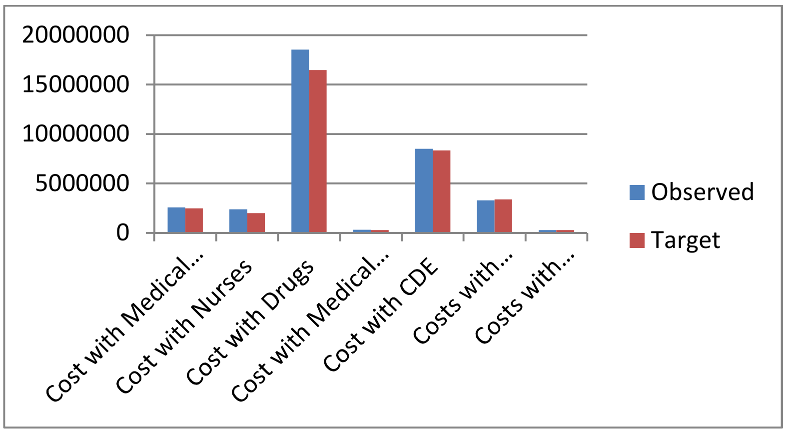

Figure 44 - Observed Costs and Target Savings for Neurology

APPENDIX M: Service of Ophthalmology

Table 30 - Efficiency Results for the Service of Ophthalmology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	38.75%	10 (0.74) 23 (0.02) 25 (0.24)
2	Centro Hospitalar Coimbra, EPE	100.00%	1
3	Centro Hospitalar Cova da Beira, EPE	75.97%	10 (0.76) 23 (0.05) 25 (0.20)
4	Centro Hospitalar do Nordeste, EPE	65.29%	5 (0.13) 10 (0.87)
5	Centro Hospitalar do Porto, EPE	100.00%	3
6	Centro Hospitalar Lisboa Central, EPE	100.00%	0
7	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
8	Centro Hospitalar Médio Tejo, EPE	13.23%	10 (0.62) 11 (0.11) 20 (0.09) 25 (0.18)
9	Centro Hospitalar Setúbal, EPE	54.62%	10 (0.05) 20 (0.65) 23 (0.29)
10	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	100.00%	11
11	Hospital Aveiro, EPE	100.00%	1
12	Hospital Castelo Branco	100.00%	3
13	Hospital Évora, EPE	79.92%	2 (0.00) 10 (0.17) 12 (0.00) 20 (0.41) 23 (0.41)
14	Hospital Faro, EPE	28.67%	10 (0.57) 25 (0.43)
15	Hospital Garcia de Orta, EPE	89.73%	10 (0.03) 12 (0.36) 20 (0.08) 23 (0.53)
16	Hospital Leiria, EPE	99.12%	5 (0.11) 20 (0.89)
17	Hospital S. João da Madeira	100.00%	0
18	Hospital S. João, EPE	100.00%	0
19	Hospital S. Marcos Braga	58.70%	20 (0.58) 23 (0.35) 25 (0.07)
20	Hospital S. Sebastião, EPE	100.00%	7
21	Hospital Santarém, EPE	47.62%	10 (0.26) 12 (0.05) 23 (0.11) 25 (0.58)
22	Hospital Universitário Coimbra, EPE	100.00%	0
23	Hospital Viseu, EPE	100.00%	10
24	Instituto Oftalmológico Dr. Gama Pinto	100.00%	0
25	IPO Porto, EPE	100.00%	8
26	Unidade Local Saúde Baixo Alentejo, EPE	10.39%	23 (0.07) 25 (0.93)
27	Unidade Local Saúde da Guarda, EPE	36.60%	10 (0.87) 23 (0.07) 25 (0.06)
28	Unidade Local Saúde de Matosinhos, EPE	35.08%	5 (0.03) 10 (0.35) 20 (0.48) 23 (0.14)

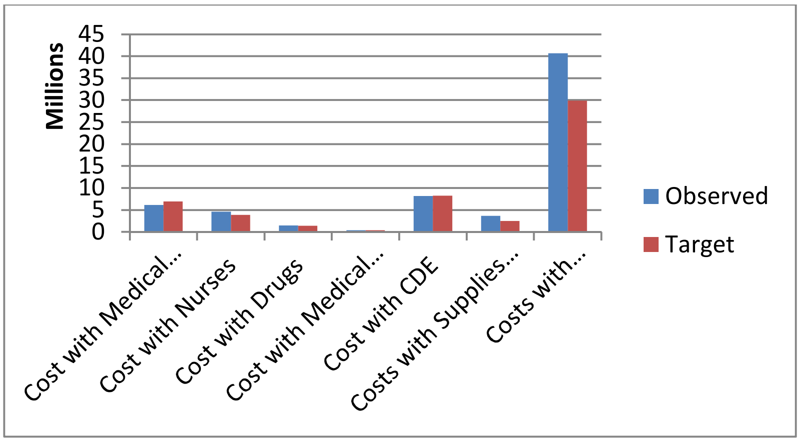

Figure 45 - Observed Costs and Target Savings for Ophthalmology

APPENDIX N: Service of Medical Oncology

Table 31 - Efficiency Results for the Service of Medical Oncology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	66.49%	2 (0.28) 7 (0.33) 20 (0.11) 25 (0.28)
2	Centro Hospitalar Barlavento Algarvio, EPE	100.00%	13
3	Centro Hospitalar Caldas da Rainha	73.51%	2 (0.05) 20 (0.65) 25 (0.30)
4	Centro Hospitalar Cascais	71.30%	6 (0.68) 22 (0.14) 25 (0.12) 26 (0.06)
5	Centro Hospitalar Coimbra, EPE	11.61%	2 (0.03) 20 (0.97)
6	Centro Hospitalar Cova da Beira, EPE	100.00%	4
7	Centro Hospitalar do Porto, EPE	100.00%	10
8	Centro Hospitalar Lisboa Central, EPE	61.33%	2 (0.39) 9 (0.33) 22 (0.27)
9	Centro Hospitalar Lisboa Norte, EPE	100.00%	4
10	Centro Hospitalar Médio Ave, EPE	82.06%	7 (0.06) 22 (0.11) 25 (0.83)
11	Centro Hospitalar Médio Tejo, EPE	49.31%	2 (0.47) 7 (0.03) 20 (0.32) 25 (0.18)
12	Centro Hospitalar Setúbal, EPE	73.72%	7 (0.50) 22 (0.27) 25 (0.09) 26 (0.14)
13	Centro Hospitalar Torres Vedras	85.13%	2 (0.27) 20 (0.73)
14	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	25.42%	2 (0.13) 6 (0.49) 20 (0.38)
15	Centro Hospitalar V.N.Gaia/Espinho, EPE	78.55%	2 (0.41) 7 (0.51) 9 (0.08)
16	Hospital Aveiro, EPE	69.30%	7 (0.03) 20 (0.05) 25 (0.92)
17	Hospital Barcelos, EPE	75.97%	20 (0.47) 25 (0.53)
18	Hospital Évora, EPE	70.74%	2 (0.18) 7 (0.58) 20 (0.12) 25 (0.12)
19	Hospital Faro, EPE	77.32%	2 (0.75) 9 (0.01) 22 (0.01) 27 (0.22)
20	Hospital Leiria, EPE	100.00%	12
21	Hospital S. João, EPE	38.62%	2 (0.58) 9 (0.11) 22 (0.31)
22	Hospital S. Sebastião, EPE	100.00%	7
23	Hospital Santarém, EPE	34.10%	2 (0.20) 6 (0.02) 20 (0.08) 25 (0.71)
24	Hospital Universitário Coimbra, EPE	36.30%	2 (0.90) 7 (0.02) 22 (0.05) 25 (0.03)

	Hospital	*Score*	*Benchmarks*
25	Hospital Vila Franca de Xira	100.00%	13
26	IPO Coimbra, EPE	100.00%	2
27	IPO Lisboa, EPE	100.00%	1
28	IPO Porto, EPE	100.00%	0
29	Unidade Local Saúde Baixo Alentejo, EPE	17.20%	7 (0.05) 20 (0.92) 25 (0.03)
30	Unidade Local Saúde da Guarda, EPE	98.88%	6 (0.23) 20 (0.77)
31	Unidade Local Saúde de Matosinhos, EPE	47.60%	7 (0.34) 25 (0.66)

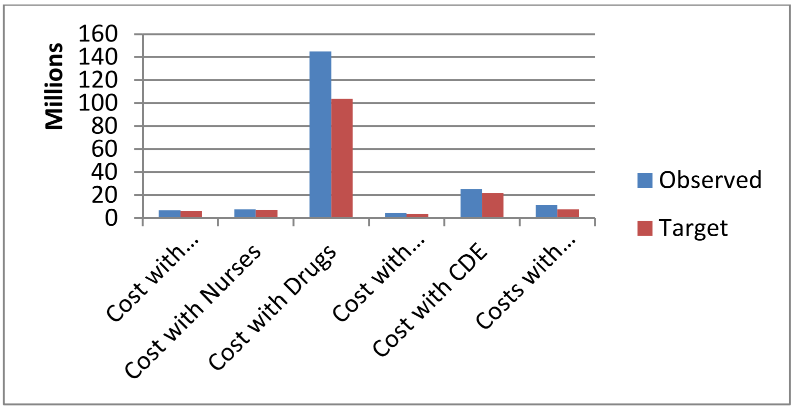

Figure 46 - Observed Costs and Target Savings for Medical Oncology

APPENDIX O: Service of Orthopaedics

Table 32 - Efficiency Results for the Service of Orthopaedics

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	95.92%	15 (0.17) 16 (0.33) 36 (0.50)
2	Centro Hospitalar Barlavento Algarvio, EPE	89.09%	11 (0.38) 20 (0.42) 36 (0.20)
3	Centro Hospitalar Caldas da Rainha	57.84%	16 (0.06) 20 (0.31) 22 (0.54) 28 (0.09)
4	Centro Hospitalar Cascais	58.01%	11 (0.23) 16 (0.55) 25 (0.06) 34 (0.16)
5	Centro Hospitalar Coimbra, EPE	93.91%	15 (0.49) 26 (0.22) 36 (0.29)
6	Centro Hospitalar Cova da Beira, EPE	94.86%	11 (0.36) 16 (0.08) 20 (0.13) 22 (0.42) 36 (0.01)
7	Centro Hospitalar do Nordeste, EPE	77.57%	16 (0.14) 20 (0.19) 22 (0.21) 28 (0.46)
8	Centro Hospitalar do Porto, EPE	100.00%	2
9	Centro Hospitalar Lisboa Central, EPE	93.82%	8 (0.31) 15 (0.08) 16 (0.04) 21 (0.15) 28 (0.43)
10	Centro Hospitalar Lisboa Norte, EPE	48.56%	11 (0.25) 20 (0.09) 32 (0.15) 36 (0.52)
11	Centro Hospitalar Médio Ave, EPE	100.00%	8
12	Centro Hospitalar Médio Tejo, EPE	82.38%	15 (0.50) 16 (0.05) 25 (0.24) 26 (0.21)
13	Centro Hospitalar Setúbal, EPE	80.97%	8 (0.01) 15 (0.38) 16 (0.22) 21 (0.39)
14	Centro Hospitalar Torres Vedras	75.66%	16 (0.63) 22 (0.12) 32 (0.24)
15	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	100.00%	5
16	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	15
17	Hospital Águeda	85.63%	11 (0.36) 16 (0.04) 25 (0.08) 34 (0.52)
18	Hospital Aveiro, EPE	72.45%	11 (0.49) 16 (0.33) 32 (0.12) 36 (0.06)
19	Hospital Barcelos, EPE	98.24%	16 (0.16) 22 (0.07) 32 (0.42) 34 (0.35)
20	Hospital Castelo Branco	100.00%	10
21	Hospital Curry Cabral	100.00%	2
22	Hospital Estarreja	100.00%	6
23	Hospital Évora, EPE	87.16%	20 (0.33) 32 (0.36) 36 (0.30)
24	Hospital Faro, EPE	57.75%	20 (0.28) 36 (0.72)
25	Hospital Garcia de Orta, EPE	100.00%	4
26	Hospital Leiria, EPE	100.00%	2
27	Hospital S. João da Madeira	100.00%	0
28	Hospital S. João, EPE	100.00%	5

	Hospital	*Score*	*Benchmarks*
29	Hospital S. Marcos Braga	72.23%	16 (0.39) 20 (0.23) 28 (0.12) 36 (0.25)
30	Hospital S. Sebastião, EPE	100.00%	0
31	Hospital Santarém, EPE	96.74%	11 (0.18) 25 (0.53) 36 (0.29)
32	Hospital Tondela	100.00%	6
33	Hospital Universitário Coimbra, EPE	100.00%	0
34	Hospital Valongo	100.00%	4
35	Hospital Vila Franca de Xira	86.41%	16 (0.15) 32 (0.62) 36 (0.23)
36	Hospital Viseu, EPE	100.00%	12
37	Unidade Local Saúde Baixo Alentejo, EPE	49.93%	11 (0.04) 20 (0.64) 22 (0.32)
38	Unidade Local Saúde da Guarda, EPE	69.67%	20 (0.88) 36 (0.12)
39	Unidade Local Saúde de Matosinhos, EPE	98.60%	16 (0.64) 28 (0.13) 34 (0.23)

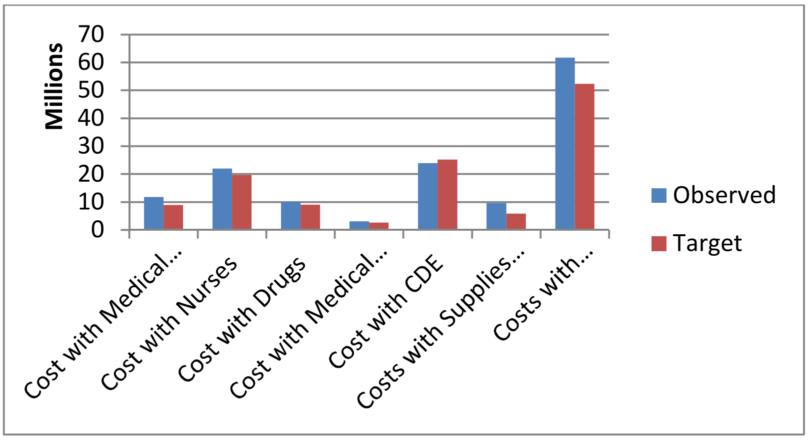

Figure 47 - Observed Costs and Target Savings for Orthopaedics

APPENDIX P: Service of Paediatrics

Table 33 - Efficiency Results for the Service of Paediatrics

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	100.00%	7
2	Centro Hospitalar Barlavento Algarvio, EPE	51.46%	15 (0.10) 29 (0.72) 30 (0.18)
3	Centro Hospitalar Caldas da Rainha	59.96%	9 (0.14) 19 (0.15) 24 (0.11) 29 (0.61)
4	Centro Hospitalar Cascais	90.78%	15 (0.04) 16 (0.08) 29 (0.87)
5	Centro Hospitalar Cova da Beira, EPE	92.47%	1 (0.16) 19 (0.59) 24 (0.23) 30 (0.02)
6	Centro Hospitalar do Nordeste, EPE	61.03%	1 (0.16) 15 (0.16) 20 (0.55) 24 (0.13)
7	Centro Hospitalar do Porto, EPE	100.00%	0
8	Centro Hospitalar Lisboa Central, EPE	100.00%	2
9	Centro Hospitalar Médio Ave, EPE	100.00%	3
10	Centro Hospitalar Médio Tejo, EPE	71.08%	1 (0.89) 14 (0.01) 24 (0.02) 36 (0.08)
11	Centro Hospitalar Setúbal, EPE	100.00%	0
12	Centro Hospitalar Torres Vedras	47.38%	17 (0.22) 20 (0.21) 29 (0.56)
13	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	100.00%	0
14	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	1
15	Hospital Águeda	100.00%	6
16	Hospital Alcobaça	100.00%	1
17	Hospital Anadia	100.00%	3
18	Hospital Aveiro, EPE	81.76%	9 (0.50) 23 (0.47) 36 (0.03)
19	Hospital Barcelos, EPE	100.00%	2
20	Hospital Castelo Branco	100.00%	5
21	Hospital Évora, EPE	100.00%	1
22	Hospital Faro, EPE	100.00%	0
23	Hospital Leiria, EPE	100.00%	3
24	Hospital Ovar	100.00%	5
25	Hospital Pombal	100.00%	0
26	Hospital S. Marcos Braga	90.41%	1 (0.27) 8 (0.04) 23 (0.46) 30 (0.05) 36 (0.17)
27	Hospital S. Sebastião, EPE	100.00%	0
28	Hospital Santarém, EPE	86.97%	1 (0.07) 9 (0.44) 23 (0.12) 29 (0.38)
29	Hospital Vila Franca de Xira	100.00%	7

	Hospital	*Score*	*Benchmarks*
30	Hospital Viseu, EPE	100.00%	5
31	IPO Lisboa, EPE	57.08%	1 (0.08) 15 (0.34) 30 (0.58)
32	IPO Porto, EPE	62.58%	1 (0.20) 8 (0.08) 20 (0.69) 21 (0.03)
33	Maternidade Alfredo da Costa	88.06%	15 (0.59) 24 (0.35) 30 (0.06)
34	Unidade Local Saúde Baixo Alentejo, EPE	48.16%	15 (0.05) 17 (0.22) 20 (0.36) 29 (0.37)
35	Unidade Local Saúde da Guarda, EPE	62.30%	17 (0.22) 20 (0.40) 29 (0.38)
36	Unidade Local Saúde de Matosinhos, EPE	100,00%	3

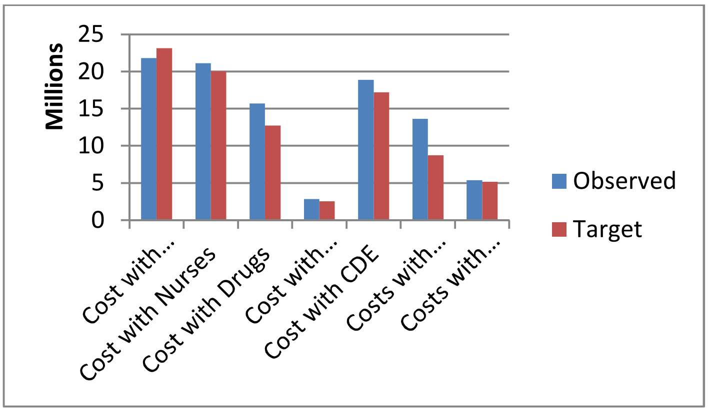

Figure 48 - Observed Costs and Target Savings for Paediatrics

APPENDIX Q: Service of Pulmonology

Table 34 - Efficiency Results for the Service of Pulmonology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	37.35%	15 (0.50) 20 (0.50)
2	Centro Hospitalar Barlavento Algarvio, EPE	29.60%	15 (0.71) 20 (0.29)
3	Centro Hospitalar Cascais	43.45%	9 (0.12) 15 (0.44) 20 (0.44)
4	Centro Hospitalar Coimbra, EPE	84.91%	8 (0.00) 11 (0.04) 13 (0.52) 24 (0.43)
5	Centro Hospitalar Cova da Beira, EPE	80.60%	13 (0.23) 21 (0.04) 24 (0.73)
6	Centro Hospitalar do Nordeste, EPE	26.99%	15 (0.94) 20 (0.06)
7	Centro Hospitalar Lisboa Central, EPE	52.67%	9 (0.29) 13 (0.22) 18 (0.28) 24 (0.22)
8	Centro Hospitalar Lisboa Norte, EPE	100.00%	2
9	Centro Hospitalar Médio Tejo, EPE	100.00%	10
10	Centro Hospitalar Setúbal, EPE	24.83%	9 (0.24) 13 (0.02) 21 (0.19) 24 (0.56)
11	Centro Hospitalar Torres Vedras	100.00%	5
12	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	51.66%	11 (0.18) 18 (0.18) 20 (0.08) 24 (0.55)
13	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	9
14	Hospital Aveiro, EPE	79.51%	9 (0.38) 20 (0.57) 24 (0.05)
15	Hospital Barcelos, EPE	100.00%	8
16	Hospital Évora, EPE	75.19%	9 (0.66) 15 (0.34)
17	Hospital Faro, EPE	92.00%	11 (0.10) 13 (0.37) 20 (0.52)
18	Hospital Garcia de Orta, EPE	100.00%	4
19	Hospital Joaquim Urbano	78.65%	9 (0.32) 13 (0.18) 18 (0.50)
20	Hospital Leiria, EPE	100.00%	9
21	Hospital Oliveira de Azeméis	100.00%	4
22	Hospital S. João, EPE	100.00%	0
23	Hospital S. Marcos Braga	93.78%	9 (0.32) 13 (0.17) 21 (0.23) 24 (0.28)
24	Hospital S. Sebastião, EPE	100.00%	8
25	Hospital Santarém, EPE	33.45%	9 (0.26) 20 (0.52) 21 (0.07) 24 (0.15)
26	Hospital Universitário Coimbra, EPE	58.96%	8 (0.01) 11 (0.83) 13 (0.15)

	Hospital	*Score*	*Benchmarks*
27	IPO Coimbra, EPE	70.73%	9 (0.38) 15 (0.62)
28	IPO Lisboa, EPE	39.49%	9 (0.69) 13 (0.15) 18 (0.16)
29	IPO Porto, EPE	4.67%	15 (1.00)
30	Unidade Local Saúde Baixo Alentejo, EPE	29.45%	15 (1.00)
31	Unidade Local Saúde da Guarda, EPE	63.88%	11 (0.37) 20 (0.63)

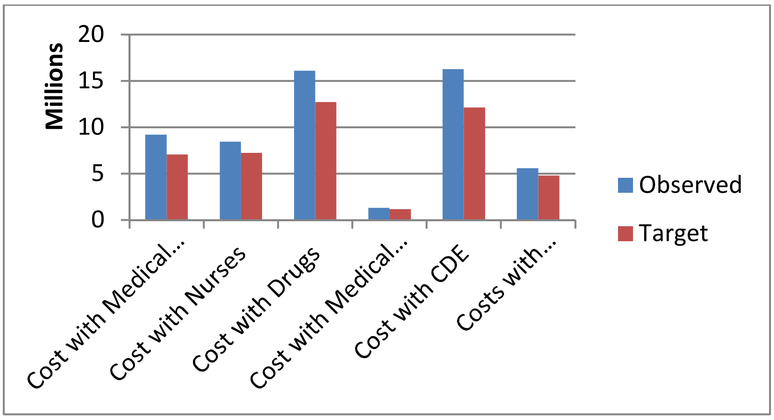

Figure 49 - Observed Costs and Target Savings for Pulmonology

APPENDIX R: Service of Psychiatry

Table 35 - Efficiency Results for the Service of Psychiatry

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Barlavento Algarvio, EPE	82.75%	2 (0.41) 19 (0.59)
2	Centro Hospitalar Cova da Beira, EPE	100.00%	13
3	Centro Hospitalar do Nordeste, EPE	74.95%	15 (0.10) 19 (0.90)
4	Centro Hospitalar Lisboa Norte, EPE	100.00%	0
5	Centro Hospitalar Médio Tejo, EPE	30.17%	2 (0.22) 15 (0.12) 19 (0.66)
6	Centro Hospitalar Psiquiátrico de Coimbra	16.30%	2 (0.95) 19 (0.05)
7	Centro Hospitalar Psiquiátrico de Lisboa	100.00%	0
8	Centro Hospitalar Setúbal, EPE	45.47%	2 (0.71) 15 (0.01) 19 (0.28)
9	Centro Hospitalar V.N.Gaia/Espinho, EPE	53.19%	2 (0.37) 15 (0.36) 19 (0.27)
10	Hospital Aveiro, EPE	70.14%	2 (0.26) 15 (0.33) 19 (0.41)
11	Hospital Évora, EPE	43.63%	2 (0.06) 19 (0.94)
12	Hospital Faro, EPE	35.27%	2 (0.43) 19 (0.57)
13	Hospital Garcia de Orta, EPE	71.55%	2 (0.74) 15 (0.06) 19 (0.20)
14	Hospital Psiquiátrico Magalhães Lemos	100.00%	0
15	Hospital S. João, EPE	100.00%	8
16	Hospital S. Marcos Braga	46.42%	2 (0.35) 15 (0.65)
17	Hospital Santarém, EPE	44.04%	2 (0.55) 19 (0.45)
18	Hospital Universitário Coimbra, EPE	21.94%	2 (0.39) 19 (0.61)
19	Hospital Valongo	100.00%	14
20	Hospital Viseu, EPE	36.27%	2 (0.00) 15 (0.31) 19 (0.69)
21	Unidade Local Saúde Baixo Alentejo, EPE	21.40%	19 (1.00)

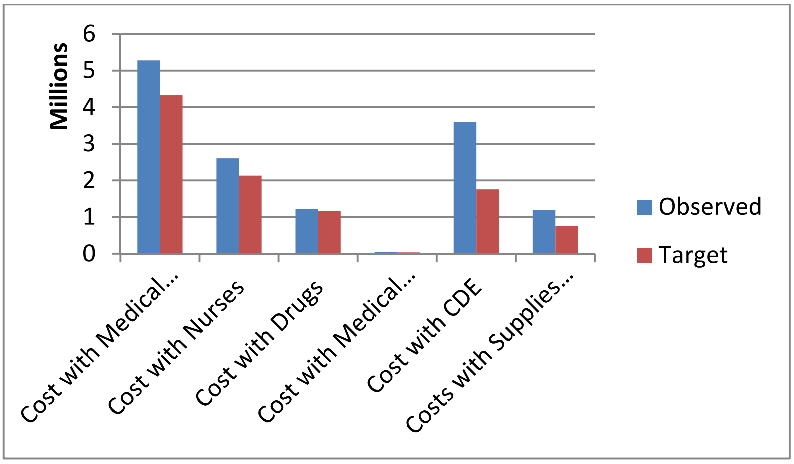

Figure 50 - Observed Costs and Target Savings for Psychiatry

APPENDIX S: Service of Urology

Table 36 - Efficiency Results for the Service of Urology

	Hospital	*Score*	*Benchmarks*
1	Centro Hospitalar Alto Ave, EPE	100.00%	7
2	Centro Hospitalar Barlavento Algarvio, EPE	57.30%	1 (0.35) 11 (0.59) 13 (0.05)
3	Centro Hospitalar Coimbra, EPE	77.79%	8 (0.11) 12 (0.13) 13 (0.37) 20 (0.20) 26 (0.20)
4	Centro Hospitalar Cova da Beira, EPE	65.54%	1 (0.48) 11 (0.20) 13 (0.26) 23 (0.06)
5	Centro Hospitalar do Nordeste, EPE	44.47%	11 (0.55) 13 (0.45)
6	Centro Hospitalar do Porto, EPE	100.00%	0
7	Centro Hospitalar Lisboa Central, EPE	100.00%	0
8	Centro Hospitalar Lisboa Norte, EPE	100.00%	2
9	Centro Hospitalar Médio Tejo, EPE	71.13%	8 (0.07) 12 (0.15) 13 (0.78)
10	Centro Hospitalar Setúbal, EPE	36.69%	11 (0.34) 13 (0.66)
11	Centro Hospitalar Torres Vedras	100.00%	13
12	Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	100.00%	3
13	Centro Hospitalar V.N.Gaia/Espinho, EPE	100.00%	15
14	Hospital Aveiro, EPE	59.25%	1 (0.11) 11 (0.21) 13 (0.56) 23 (0.12)
15	Hospital Castelo Branco	40.29%	1 (0.47) 11 (0.37) 13 (0.16)
16	Hospital Faro, EPE	54.89%	1 (0.52) 23 (0.40) 26 (0.07)
17	Hospital Garcia de Orta, EPE	99.00%	12 (0.13) 20 (0.12) 26 (0.75)
18	Hospital Leiria, EPE	40.22%	1 (0.20) 11 (0.30) 13 (0.50)
19	Hospital S. João da Madeira	85.26%	11 (0.75) 13 (0.25)
20	Hospital S. João, EPE	100.00%	2
21	Hospital S. Marcos Braga	100.00%	0
22	Hospital S. Sebastião, EPE	79.87%	11 (0.59) 13 (0.41)
23	Hospital Santarém, EPE	100.00%	3
24	Hospital Universitário Coimbra, EPE	100.00%	0
25	Hospital Vila Franca de Xira	49.18%	11 (0.63) 13 (0.37)
26	Hospital Viseu, EPE	100.00%	3
27	IPO Coimbra, EPE	41.58%	11 (0.07) 13 (0.93)
28	IPO Lisboa, EPE	100.00%	0

	Hospital	*Score*	*Benchmarks*
29	IPO Porto, EPE	23.68%	11 (0.40) 13 (0.60)
30	Unidade Local Saúde Baixo Alentejo, EPE	45.21%	1 (0.34) 11 (0.61) 13 (0.05)
31	Unidade Local Saúde de Matosinhos, EPE	100.00%	0

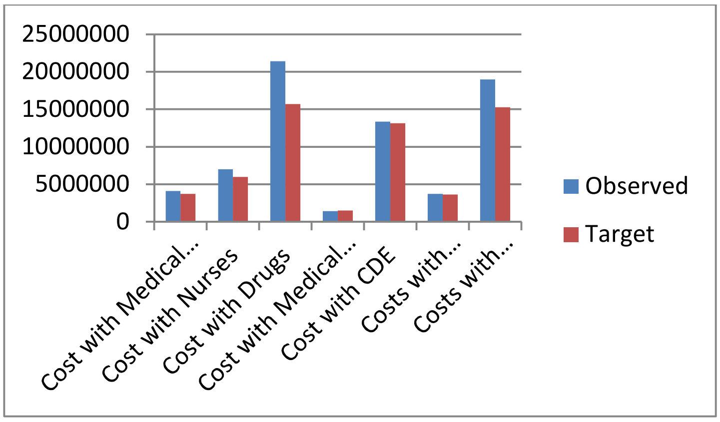

Figure 51 - Observed Costs and Target Savings for Urology

APPENDIX T: Overall Efficiency and Number of Services

Table 37 - Efficiency Results of the Hospitals and Number of Services

Hospital	*Efficiency*	*Number of Services Analysed*
Centro Hospitalar Alto Ave, EPE	94%	15
Centro Hospitalar Barlavento Algarvio, EPE	65%	15
Centro Hospitalar Caldas da Rainha	60%	8
Centro Hospitalar Cascais	68%	11
Centro Hospitalar Coimbra, EPE	94%	15
Centro Hospitalar Cova da Beira, EPE	87%	16
Centro Hospitalar do Nordeste, EPE	84%	14
Centro Hospitalar do Porto, EPE	93%	16
Centro Hospitalar Lisboa Central, EPE	94%	16
Centro Hospitalar Lisboa Norte, EPE	96%	18
Centro Hospitalar Médio Ave, EPE	95%	8
Centro Hospitalar Médio Tejo, EPE	76%	17
Centro Hospitalar Psiquiátrico de Coimbra	16%	1
Centro Hospitalar Psiquiátrico de Lisboa	100%	1
Centro Hospitalar Setúbal, EPE	77%	19
Centro Hospitalar Torres Vedras	72%	12
Centro Hospitalar Trás-os-Montes e Alto Douro, EPE	95%	13
Centro Hospitalar V.N.Gaia/Espinho, EPE	94%	15
Hospital Águeda	84%	7
Hospital Alcobaça	76%	4
Hospital Anadia	69%	3
Hospital Aveiro, EPE	79%	18
Hospital Barcelos, EPE	89%	9
Hospital Cantanhede	100%	1
Hospital Castelo Branco	83%	12
Hospital Curry Cabral	80%	9
Hospital Estarreja	96%	3
Hospital Évora, EPE	77%	17
Hospital Faro, EPE	64%	18
Hospital Garcia de Orta, EPE	87%	15

Hospital	*Efficiency*	*Number of Services Analysed*
Hospital Joaquim Urbano	98%	2
Hospital Leiria, EPE	91%	14
Hospital Montijo	77%	4
Hospital Oliveira de Azeméis	71%	5
Hospital Ovar	76%	4
Hospital Peniche	82%	3
Hospital Pombal	86%	3
Hospital Psiquiátrico Magalhães Lemos	100%	1
Hospital S. João da Madeira	96%	6
Hospital S. João, EPE	91%	16
Hospital S. Marcos Braga	75%	13
Hospital S. Sebastião, EPE	95%	15
Hospital Santarém, EPE	77%	19
Hospital Tondela	87%	3
Hospital Universitário Coimbra, EPE	79%	17
Hospital Valongo	100%	4
Hospital Vila Franca de Xira	90%	14
Hospital Viseu, EPE	96%	13
Instituto Oftalmológico Dr. Gama Pinto	100%	1
IPO Coimbra, EPE	92%	9
IPO Lisboa, EPE	73%	12
IPO Porto, EPE	80%	13
Maternidade Alfredo da Costa	99%	2
Unidade Local Saúde Baixo Alentejo, EPE	44%	14
Unidade Local Saúde da Guarda, EPE	71%	13
Unidade Local Saúde de Matosinhos, EPE	87%	12