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DOES THE TYPE OF HEALTHCARE MODEL AFFECT HOSPITAL PERFORMANCE? AN EFFICIENCY ASSESSMENT ACROSS OECD COUNTRIES

¿AFECTA EL TIPO DE MODELO SANITARIO AL RENDIMIENTO HOSPITALARIO? UN ANÁLISIS DE EFICIENCIA PARA PAÍSES DE LA OCDE

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ABSTRACT

During the last years, most of developed countries are facing budget cuts in health spending, which stresses the need of hospitals to use their resources efficiently, so the quality of the care provided to patients is not compromised. The need for efficient hospitals has grown in importance with the pandemics situation the world is involved in since March of 2020 due to covid-19. Within this framework, this paper assesses hospital efficiency across 19 OECD countries for the period 2005 – 2015, and then explores the determinants that affect hospitals' performance. A two-stage approach was followed in order to perform this efficiency analysis. In the first stage, we obtained efficiency scores for each country using data envelopment analysis (DEA). In the second stage, Panel Tobit Analysis was employed to spot the environment variables that affect the efficiency scores calculated previously.

Special attention was paid to the variable discerning if the country presents a Beveridge or Bismarck healthcare model. Based on the results from DEA, it was found that the efficiency levels followed an increasing overall trend during the period considered, excluding an important drop during the financial crisis, reaching its lowest levels in 2010. In the second stage, due to the censored nature of the dependent variable calculated previously through DEA, Panel Data Analysis was proposed in order to obtain unbiased and consistent estimators. The results of the estimation showed that the type of healthcare model was not statistically significant when explaining hospitals' efficiency, although the estimated effect might suggest that countries with Beveridge healthcare model would perform better than those with Bismarck model. Regarding the environment non-discretionary factors that secondarily affect hospital´s efficiency, the level of education was found to have a positive impact on the efficiency of hospitals, while life expectancy affects negatively healthcare performance.

RESUMEN

Durante los últimos años, la mayoría de los países desarrollados se están enfrentando a recortes en el gasto en sanidad, lo que enfatiza la necesidad de que los hospitales utilicen sus recursos eficientemente, de modo que la calidad de los cuidados proporcionados a los pacientes no se vea comprometida. La necesidad de hospitales eficientes ha adquirido mayor relevancia dada la actual situación de pandemia en la que el mundo está inmerso desde marzo de 2020 a causa del covid-19. En este contexto, el presente trabajo estudia la eficiencia de hospitales a lo largo de 19 países de la OCDE durante el periodo 2005 – 2015, para después determinar los factores que afectan el rendimiento de dichos hospitales. En la primera etapa del enfoque en dos etapas utilizado en el análisis de eficiencia, obtenemos las puntuaciones de eficiencia para cada país a través del método DEA (Data Envelopment Analysis). En la segunda etapa, se utiliza Panel Tobit Analysis para identificar las variables de entorno que afectan las puntuaciones de eficiencia calculadas en la primera etapa del análisis. Se le presta especial atención a la variable que determina si el país presenta un modelo sanitario Beveridge o Bismarck. Atendiendo a los resultados obtenidos a través del DEA, se observa que los niveles de eficiencia siguieron una tendencia general al alza durante el periodo considerado, a excepción de una importante caída de los mismos durante la crisis financiera, alcanzando sus niveles más bajos en 2010. En la segunda etapa, debido a la naturaleza censurada de la variable dependiente calculada previamente usando DEA, se propone Panel Tobit Analysis con el fin de obtener estimadores insesgados y consistentes. Los resultados de la estimación mostraron que el tipo de modelo sanitario no es estadísticamente significativo a la hora de explicar la eficiencia hospitalaria, aunque el efecto estimado podría sugerir que países con el modelo sanitario Beveridge funcionarían más eficientemente que aquellos con el modelo Bismarck. Respecto a los factores no discrecionales de entorno que afectan de manera indirecta el rendimiento de los sistemas sanitarios, se encontró que el nivel de educación de la población tiene un impacto positivo en la eficiencia de los hospitales, mientras que la esperanza de vida se relaciona negativamente con estos niveles de eficiencia.

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1. INTRODUCTION

One of the main goals pursued by a company or institution is to use resources in an efficient way. This is not different for hospitals which, aside of the public or private nature of its ownership, seek to maximize its outcomes using the health resources they got. Efficiency is the primary indicator of hospital performance (Ehreth, 1994) and it is a particularly important aspect of medical services nowadays, considering the pandemic situation we are suffering due to covid-19, which is stressing the need of efficient hospitals that are able to keep working normally and avoid the collapse of the healthcare system. Moreover, the actual health crisis and the restrictive measures applied by governments are also resulting in a severe economic crisis that will force countries to decrease their spending on healthcare. Under these conditions, healthcare systems need to use their resources in the most efficient way, so the quality of the service is not compromised.

Since the late 20th century, the health system of most countries has suffered deep reforms, fostered by the rising pressure to improve its efficiency. (Ancarani, Di Mauro and Giammanco 2009). Nevertheless, existing research on the topic suggested that significant inefficiencies are still at work for health expenditure in the Organization for Economic Co-operation and Development (OECD). (Evans et al., 2000). Considering the above-mentioned aspects, an assessment of healthcare performance by country at global scale, identifying its drawbacks to achieve higher levels of hospitals efficiency is of great relevance. Particularly, this work focuses on the difference between two main healthcare models (Beveridge and Bismarck) efficiency. For that purpose, a two-stage analysis is proposed in this paper to assess the performance of different healthcare systems. Data envelopment analysis is a technique used in many studies to calculate the relative efficiency of a decision-making unit (DMU). However, using this technique, only variables that directly affect hospitals performance can be considered and interpreted, while in the evaluation of the efficiency of a healthcare model, other variables particular to some specific countries might play an important role too. Consequently, in addition to DEA we use econometric models in the second stage of our analysis to examine the effect of environment variables on the efficiency levels obtained in the first stage. As the efficiency scores calculated through DEA have a censored structure, using ordinary least squares (OLS) regression would lead to biased and inconsistent estimations. For this reason, Panel Tobit Analysis is used in the second stage of the assessment, so we can obtain unbiased and consistent estimators.

Assessing the hospital efficiency of countries through a one-stage analysis would be insufficient, and addressing just 1 year, as previous studies examining healthcare efficiency have done, would limit our vision of the hospitals development evolution. The aim of this study in which 11 years of data (2005 – 2015) regarding 19 OECD countries have been used, is to investigate hospital efficiency and contrast the difference between two main healthcare models performance (Beveridge and Bismarck) using a two-stage performance analysis. In the first stage of the assessment, we use DEA to obtain the hospital efficiency scores of each country and year, assuming constant returns to scale (CRS). In the light of these results we can observe which countries and which model perform better. In the second stage, we use the efficiency scores as dependent variable in an econometric model where we include some environment variables that could explain the performance of countries and health models. These environment variables refer to social and economic factors specific to certain countries that affect their healthcare system functioning. As the dependent variable (efficiency scores) has a censored structure Panel Tobit Analysis will be used instead of traditional panel data analysis.

The main contribution of this work is the performance of a hospital efficiency analysis from the point of view of the two main healthcare models. Many papers have analysed the efficiency of healthcare systems across countries, but very limited work is done when trying to assess differences of performance depending on the health system model. For this reason, I found interesting to investigate if either Beveridge or Bismarck models perform better when delivering care.

The following sections of this work are organized as follows. Firstly, we will explain the main differences between the two considered models and how can these differences affect efficiency. In second term, we will review the existing literature about hospitals and healthcare performance. This section will be followed by the description of data sets and variables used in our study. Thereafter, the methods used in the efficiency analysis will be explained, focusing on each of the two stages of the process. Then the results of the analysis will be presented and, in the last section we will sum up the contributions, conclusions and limitations of the study.

2. TWO MAIN HEALTHCARE MODELS

The Beveridge Model was created in 1943 by William Beveridge, the daring social reformer who designed Britain´s National Health Service to help British people recover from war. In this system, health care is provided and financed by the government through tax payments. Many hospitals and clinics are owned by the government, and most of doctors and healthcare professionals are government employees. People living in countries with Beveridge Model can go to the doctor for free, not getting any bill. The main downsides of this model are long waiting lists and hospitals often suffering underfunding, which tend to push pressure on the quality of the care. These systems use to have low costs per capita, as the government controls what doctors can do and how much they can charge. (Physicians for National Health Program 2010). The Beveridge model is considered as a pay as you go system of pensions and was proposed in the "Beveridge Report" (1942). This report advocated the introduction of minimum system, as a way to fight poverty, which would provide with a flat welfare pension most of the workers. This model emphasized the redistributive aspect of the system. The Government role should be limited to redistribute in favour of poor people, while individuals are able to satisfy privately their own additional needs. (Conde-Ruiz and González 2018). In the Beveridge model, which is characterized by a centrally organized National Health Service, healthcare budgets compete with other spending priorities. (Lameire, Joffe and Wiedemann 1999).

The Bismarck Model was named after the Prussian Chancellor Otto von Bismarck, who invented the world's first welfare state as part of the unification of Germany in 1873. This healthcare system, also known as mutual insurance model, was mandatory for all and its main goal was to head off the upcoming socialists, who were organising themselves with all sorts of workers health plans. It consists on an insurance system where every working person contributes part of their income to a central fund and, when someone become sick, they are able to claim part of the cost back from these mutual insurance funds called sickness funds. Under this model, people are free to choose their doctor. Bismarck-type health insurance plans are obligated to cover everybody, and they do not make any profit. Doctors and hospitals tend to be private in countries with this type of healthcare system. Even though this is a model with several players, Germany, for instance, has about 240 different funds, tight regulation from the government allows to achieve a cost-control level similar to the provided by Beveridge Model. (Physicians for National Health Program 2010). These model, introduced due to the pressure of the "middle class", follows a pay as you go system with contributory pensions, which is, a system with a direct relation between workers contributions and their pensions. (Conde-Ruiz and González 2018). The Bismarck model is funded mainly through a premium-financed social/mandatory insurance and results in a mix of private and public providers, that allows more flexible spending on healthcare. (Lameire, Joffe and Wiedemann 1999).

Both models were designed to accomplish different purposes, since the political support was key for the creation of Beveridge and Bismarck models. (Conde-Ruiz and Profeta 2007).

Summing up, the main differences between both models are various. One of them is the original purpose of its creation. While the Beveridge model pursued a redistribution in favour of poor people, allowing individuals to satisfy privately their own additional needs, the Bismarck model was adopted under the pressure of unions and the "middle class". Both models also differ in the way they are funded. The Beveridge model is financed through tax payment collected by the government; therefore, healthcare budgets compete with other spending priorities for the administration. On the other hand, in the Bismarck model the funding comes from workers direct contributions to multiple premium-insurance funds and, since these funds are generally managed by private entities, healthcare spending does not have the burden of different public expenditures. Regarding to the ownership, while in the Beveridge model hospitals are public and doctors, government employees, in the Bismarck model they tend to be private. Another difference lies in the fact that the Beveridge healthcare model covers everybody with the same care services, while in the Bismarck model workers are able to choose among different insurances that provide individuals with different levels of care services.

According to these differences, we would expect Beveridge model to perform more efficiently than Bismarck, particularly due to lower costs per capita consequence of the government control commented previously.

This hypothesis is shared by other authors like Łyszczarz (2016), whose results confirmed the common opinion that the Bismarck-style systems perform worse in controlling the costs.

3. LITERATURE REVIEW

Achieving a high level of efficiency is, as we said before, one of the key objectives pursued by a company or, in our particular case, a hospital. Most of the works that have tried to assess this efficiency have done it through a one-stage analysis, using DEA. Sherman (1984), Puig-Junoy (1998), Mobley and Magnussen (1998), Alexander, Busch and Stringer(2003), Steinmann et al. (2004), Retzlaff-Roberts, Chang and Rubin (2004), Bhat(2005), Grosskopf, Self and Zaim (2006), Spinks and Hollingsworth (2009) and Hu, Qi and Yang (2012) are among such studies. Puig- Junoy (1998) and Retzlaff-Roberts, Chang and Rubin (2004) are specifically among the works that compare health care efficiency across OECD countries through DEA.

There are also a few authors who tried to evaluate the efficiency of healthcare systems through different methods to DEA. In a paper for the World Health Organization (WHO), for instance, Evans et al. (2000) assessed the efficiency of health care in different countries using free disposal hull (FDH) analysis, a non-parametric technique.

Several studies have employed DEA along with different parametric or non-parametric methods in the evaluation of hospital efficiency. One example is the work of Varabyova and Schreyögg (2013), who used DEA and stochastic frontier analysis to calculate hospital efficiency scores. Using three inputs and one output, their paper reviewed nine DEA models, six of them input oriented and the other three output oriented, and three SFA models, examining the correlation between the results of each different model. They perform this comparison using data from 2007, obtaining that closer results were found between output-oriented models and SFA models, than between input-oriented and SFA models. Weng et al. (2008) used DEA and Panel-based Benchmarking to analyse the efficiency of 65 hospitals in Iowa during a 5 year period. Afonso and Aubyn(2005) estimated hospital efficiency through two different non-parametric methods, free disposable hull(FDH) and data envelopment analysis (DEA). On the other hand, Hollingsworth and Wildman, (2003) came to the conclusion that estimating the performance of health care systems using only one method was a limited effort and revaluated the efficiency of 191 countries through panel data, DEA, Malmquist and SFA techniques. Alonso, Clifton and Díaz-Fuentes (2014) compared the efficiency of traditional managed hospitals and those operating through new management formulas. For this purpose, they used a sample of 25 hospitals of the community of Madrid, and obtained their technical efficiency using Data Envelopment Analysis (DEA). In order to compare the efficiency of these two types of hospital management, they performed a non-parametric Mann-Whitney U test and an analysis of bootstrapped average efficiency confidence intervals computed through DEA. They found that there is no statistically significant difference between traditionally managed hospitals and those using new management formulas.

Another way to perform efficiency measure is by using a two stage analysis. An example of this is the estimation of hospital efficiency carried out by Rosko and Chillingerian (1999) through a two stage approach in a stochastic frontier analysis. In the first stage, they used a trans log cost-function to estimate inefficiency scores and, in the second stage, these inefficiency scores are regressed against independent variables.

A most common way of performing a two stage analysis is obtaining the efficiency scores through DEA in the first stage, and then using this scores as dependent variable in an econometric model in the second stage. Some of the studies following this procedure have employed ordinary least squares regression (OLS) in the second stage of the two stage analysis. Medin et al. (2011), carried out an international comparison of the hospitals of four Nordic countries using DEA in the first stage, and OLS in the second. Another example of this type of analysis is the work of Pelone et al. (2012), where they obtain the technical efficiency of general practice across 20 Italian regions through DEA in the first stage, and then identified the environment variables that affected that efficiency using Ordinary Least Square regression. On a similar way, Gok and Sezen (2013) used DEA to compute the efficiency scores of a set of hospitals in Turkey in the first stage, and regressed the satisfaction of the patients on these efficiency scores to estimate the effects of such efficiency.

However, the dependent variables in these econometric models are the efficiency scores obtained through DEA, which have a censored nature and, thus, lead to biased and inconsistent OLS estimation. For this reason, it´s preferable to do the estimation using Tobit or truncated regression. Mitropoulos, Mitropoulos and Sissouras (2013) calculated the efficiency scores of hospitals in Greece using DEA in the first stage, and then analysed the effects of operational environment on this hospital efficiency through truncated regression in the second stage. In their assessment of cost-effectiveness, Nedelea and Fanin (2013), used DEA in the first stage, and truncated regression in the second stage, using environment variables as independent variables. Puig-Junoy(2000) used DEA in the first stage and log regression on the second stage of his analyse of the efficiency across 94 Catalan intensive care hospitals.

Moran and Jacobs (2013) compared the efficiency of mental healthcare provided in 32 OECD countries using a two-stage method. In the first stage, the efficiency of each country in 2010 was calcukated through DEA and, in the second stage, a tobit regression model was estimated to identify the environment variables related to the efficiency. Lee, Yang and Choi (2008) assessed the association between hospital ownership and technical efficiency for a set of hospitals in Florida, through a two-stage process. In the first stage, they used DEA to obtain the efficiency scores of each hospital and, in the second stage, they used these efficiency scores as a dependent variable in a Tobit regression, concluding non profit hospitals were more efficient than for profit hospitals for all of the four years examined in their study. Similarly, Ancarani, Di Mauro and Giammanco (2009) studied the effects of managerial perspectives on the efficiency of hospital wards in Italian hospitals. In their paper a two-stage approach was also used, consisting of DEA analysis in the first stage, and Tobit regression in the second stage. Dalmau-Atarrodona and Puig-Junoy (1998) examined the potential effect of market structure on the efficiency of Catalan hospitals using a DEA-Tobit two stage analysis. Hu, Qi and Yang (2012) investigated the effects of healthcare system reform in China on the efficiency of hospitals. They derived the efficiency scores by DEA in the first stage, and then regress these scores as dependent variable on some environment variables through Tobit model. Afonso and Aubyn (2005) studied the performance of health provision for a set of OECD countries through a two-stage approach, obtaining the efficiency scores in the first stage through DEA, and using a Tobit regression in the second stage to estimate the effect of non-discretionary inputs on hospital efficiency. Similarly, Samut and Cafri (2015), examined the efficiency of the healthcare system of 29 OECD countries, using a two-stage analysis. In the first stage, they employed DEA to obtain the efficiency scores and the regressed these scores on some environment variables through Tobit Regression. Following the same procedure, the same authors, Afonso and Aubyn (2011) investigated hospital efficiency across 21 OECD countries for 2005 using DEA in the first stage and then Tobit in the second stage so the environment variables affecting efficiency were identified. Chillingerian (1995) assessed the efficiency of 36 physicians from a single hospital through a DEA-Tobit two stage analysis. An example of an alternative application of these type of analysis is the study of efficiency differences among Finnish schools carried out by Kirjavainen and Loikkanen(1998). In their work, a two-stage approach was chosen to analyse the performance of schools, obtaining the efficiency scores through DEA in the first stage, and then explaining this efficiency using a Tobit estimation in the second stage. This is an example of how this procedure can be applied to different fields apart of the hospital and healthcare efficiency evaluation.

Another commonly used model in the second stage for the evaluation of the efficiency of healthcare systems along the time is panel data analysis. One of the studies following this method is Kjekshus and Hagen (2007), where the authors studied, through a two-stage approach, if the alignment of 17 Norwegian hospitals increased their efficiency. They obtained the hospitals efficiency for the period 1992-2000 using DEA, and then used panel data analysis in the second stage to test if the unification of hospitals had a relevant effect on efficiency. Furthermore, Biorn et al. (2003) analysed the effects of a cost-based accounting system on hospital efficiency from 1992 to 2000 through the use of DEA in the first stage and panel data regression in the second. In a similar way, Kittelsen et al. (2008) investigated if the centralization reform of hospitals in Norway had a positive effect on the efficiency of these hospitals using a two-stage analysis. DEA was employed to obtain the efficiency scores of each hospital and then a fixed effects model was used in the second stage to test the matter of study.

Nevertheless, due to the censored nature of the efficiency scores obtained through DEA, Tobit Panel Analysis will be necessary in the second stage instead of traditional panel data analysis so the estimation is unbiased and consistent. In this way, Chen, Hwang and Shao (2005) calculated the efficiency scores for a set of hospitals in California using DEA, and then transformed them into inefficiency scores subtracting them from 1. Tobit Panel Analysis was chosen in the second stage to study the connection between the inefficiency scores and some environment variables.

Focusing on our matter of interest, there are some works that have tried to compare the efficiency of different health care systems using alternative methods to DEA. Sherry (2008), using econometrics models and data from the OECD, stated that there is no relation between the type of financing of each health system and the efficiency of them. On the other hand, Mosidou(2017), evaluated the performance of various health care system models through an empirical analysis using statistical tools and came to the conclusion that Beveridge model is more efficient than Bismarck model.

None of the studies we have reviewed have attempted to assess the difference between healthcare system models efficiency using DEA. For this reason, I found interesting trying to examine this matter with a new perspective. In this study, we used a two-stage approach to compare the efficiency of Bismarck and Beveridge healthcare system models. In the first stage we employed DEA method to obtain the efficiency scores of hospitals of 19 OECD countries along 11 years. In the second stage of our study we used Tobit model to test if the type of healthcare system model is statistically relevant to explain the hospitals efficiency of each country, controlling for environment country-specific socio-economic variables. Considering the results of the few literature available on this topic, we would expect Beveridge model to be more efficient than Bismarck model.

4. DATA AND VARIABLES

In this paper, an available data set of 19 OECD countries for the period 2005 – 2015 was used. Using this data, a two-stage approach was deployed to analyse the efficiency of health system models. DEA and Panel Tobit were employed in the first and second stage, respectively. DEA method was performed on three inputs and one output. These inputs and output are variables that can directly affect the efficiency of health care services provided by a hospital. The output proposed for the analysis is hospital discharge rates. Increases in this variable would mean increases in health outcomes and at the same time, improvement on countries' health systems. Three variables measuring the level of heath care resources available for hospitals were used as inputs. These variables that provide more efficient health services can be divided in two groups, those who measure health care equipment (hospital beds) and those that accounts for the workforce employed in hospitals (doctors and nurses). At the second stage, for the Panel Data Tobit, we used environment variables that could affect indirectly health care performance as independent variables to explain the efficiency scores obtained through DEA. These environment variables include country specific factors that it is considered that could affect efficiency of health care systems. One of these variables is a dummy for the type of health system (Beveridge or Bismarck) of each country, that will allow us to infer the effect of having one of these two main healthcare system models. For the identification of these variables we reviewed the previously mentioned literature and choose those we found more interesting for our study. For the classification of countries in one of the two healthcare system models we considered in our study, we use information from the web of the "Physicians for a National Health Program" organization. All the variables used in the models are presented along with their definitions in *Table 3.1.*

The data used in this study was collected from the World Bank and OECD databases (The World Bank 2020, OECD 2020). Data for most variables were not available later than 2015 in the databases we consulted in 2020. Due to this limitation, the analysis could be carried out until 2015. Missing values for some countries during a few years were filled using linear interpolation. The rest of OECD countries not included in this study suffered a huge lack of data for the period considered. In the end, the sample size was limited to 19 OECD countries.

Table 4.1. - Model variables

	Definition	Measurement
Outputs		
Hospital Discharge Rates	Discharge rates from all hospitals Hospital discharge is defined as the number of patients who leave a hospital after receiving care. The rate includes the patients who have stayed at least one night in hospital and the deaths in hospital following inpatient care. (OECD 2020).	Per 100 000 patients
Inputs		
Hospital Beds	Total hospital beds “Hospital beds are the total number of beds that are available for inpatients in hospitals. They include beds in general hospitals, mental health hospitals, and other specialty hospitals.” (OECD 2020).	Per 1000 population
Doctors	Total practising doctors “Doctors are defined as “practising” doctors providing direct care to patients. They include generalists doctors and specialists doctors such as paediatricians, obstetricians/gynaecologists, psychiatrists, medical and surgical specialists.” (OECD 2020).	Per 1000 population
Nurses	Total practising nurses “Nurses are defined as all the “practising” nurses providing direct health services to patients, including self-employed nurses.” (OECD 2020).	Per 1000 population
Independent Variables		
GDP	Gross Domestic Product “GDP per capita is divided by country population.” (OECD 2020).	Per capita, PPP (constant 2015 US dollars)

Health expenditure	Health expenditure "Health expenditure includes public and private health expenditure. The first one includes recurrent and capital spending from government budgets, external borrowings and grants, and social health insurance funds. The second one consists of direct household spending, private insurance, charitable donations, and direct service payments by private corporations." (OECD 2020).	% GDP
Education	Adult population with tertiary education "Adult population with tertiary education is defined as those having complete the highest level of education in the age group 25 to 64 years. This includes both theoretical programmes leading to advanced research or high skill professions such as medicine and more vocational programmes leading to the labour market." (OECD 2020).	% of same age group population
Life expectancy	Life expectancy "Life expectancy at birth measures how long, on average, a new-born can be expected to live. The value is calculated using the unweighted average of life expectancy of men and women." (OECD 2020).	At birth, total (years)
Healthcare model	Type of healthcare system model Dummy which takes value 1 if the country presents a Beveridge healthcare model, and 0 if the country presents a Bismarck healthcare system model	

Source: own elaboration with data from OECD and The World Bank.

5. METHODOLOGY

5.1. DATA ENVELOPMENT ANALYSIS (DEA)

Farrell (1957) was the first author who proposed data envelopment analysis, a non-parametric method, for the measurement of productive efficiency. This method was named for the first time by Charnes, Cooper and Rhodes (1978), who popularized the use of DEA as a common technique to analyse efficiency. DEA is a mathematical programming method employed to measure the relative technical efficiency of decision-making units (DMUs) through the use of multiple inputs and outputs (Samut and Cafri 2015). When using DEA to analyse efficiency, we can assume there are constant returns to scale (CRS) or variables returns to scale (VRS). Each of these assumptions lead to two different models, CCR model (the standard DEA model with CRS) and BCC model (modified DEA model with VRS). These acronyms stand for the authors of each model, CCR for Charnes, Cooper and Rhodes (1978), and BCC for Banker, Charnes and Cooper (1984). In the studies on hospitals' performance, the CCR model is preferred as it gives better results (Samut and Cafri 2015). This is due to the absence of any scale or congestion effect on the relation of inputs and outputs (Gök and Sezen 2013). One common goal of healthcare entities is to provide the higher possible health outcomes using a given amount of resources (beds, MRI units, personnel, etc.). According to this, CCR output-oriented models are suitable to be used in the analysis of hospitals efficiency. An output-oriented DEA-CCR model that calculates the efficiency score for the DMU k, using m inputs and s outputs is presented below:

$$\text{Maximize} \quad h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad , \quad x_{ij} > 0 \, , \; y_{rj} > 0$$

$$\text{Subject to} \quad \frac{\sum_{r=1}^{s} u_r y_j}{\sum_{i=1}^{m} v_i x_j} \leq 1 \, , \quad j = 1,2,\ldots,j_k,\ldots,n$$

$$u_r \geq \varepsilon, \quad r = 1,2,\ldots,s$$

$$v_i \geq \varepsilon, \quad i = 1,2,\ldots,m$$

Where:

- x_{ij} is the observed magnitude of i-type input for DMU j;
- y_{rj} is the observed magnitude of r-type output for DMU j;
- v_i is the weights to be determined for input I;
- m is the number of inputs;

- u_r is the wights to be determined for output r;
- s is the number of ouputs;
- h_k is the relative efficiency of DMU_k;
- n is the number of DMUs;
- ε is a small positive value.

To calculate the technical efficiency scores for n DMU, the program would be run n times (Samut and Cafri 2015). The technical efficiency scores obtained through this method will take values between 0 and 1. If the technical efficiency score is equal to 1, it means the Decision Making Unit is technically efficient as it produces on the production frontier.

5.2. TOBIT PANEL ANALYSIS

In a regression model, those variables whose values are restricted to a certain range are known as "censored" or "truncated" data. If values outside this range are excluded from the sample, then they are considered as "truncated" data. On the other hand, if the observations do not provide any data about the dependent variable, but we can observe the explicative variables, then they are considered "censored" data (Davidson and MacKinnon 2003). If observations resulted from DEA analysis, which is, the efficiency scores, are higher than 1, then they would not be excluded from the sample as it would be in the case of the truncated data. Nevertheless, these observations can not take their own original values either and, for this reason, they are censored to 1 (Chilingerian 1995). In this situation, assuming that the dependent variable (efficiency scores from DEA) is limited to (0,1), it has a censored structure.

Using OLS to estimate a model with a censored dependent variable would lead to biased and inconsistent estimatiors (Greene 2003). Moreover, the fact that the scores obtained from DEA represent a relative efficiency index and the existing correlation between the efficiency scores would invalid the OLS regression (Atkinson and Wilson 1995). For the above-mentioned reasons, Tobit regression, one of the few regression models that consider a possible censored structure, was chosen for this study.

For the estimation of the parameters in the model, the Maximum Likelihood Estimation (MLE) is employed in the Tobit Regression. Due to the non-linearity of the parameters obtained using MLE, the estimations are performed by iterations. The Newton-Raphson

method has also been used for these purposes (Jamil 2013), as it requires less time and fewer iterations.

Panel data consists of the observation of N different entities at T different time periods, it can be interpreted as the combination of cross section data and temporal series. In this regard, the basic formula of Panel Tobit used in this work is expressed as follows:

$$y_{it}^{*} = \beta' X_{it} + \varepsilon_{it}$$

$$y_{it} = \begin{cases} y_{it}^{*}, & \text{if } y_{it}^{*} < 1 \\ 1, & \text{otherwise} \end{cases} \qquad \begin{aligned} i &= 1, \ldots, N \\ t &= 1, \ldots, T \end{aligned}$$

where subscript i defines the country and subscript t defines the time. X_{it} is the explanatory variable in the dimension of 1 x k and β is the parameter vector on the dimension of k x 1 (Baltagi 2008) (Samut and Cafri 2015).

The error term in panel data is generally defined in the following way:

$$\varepsilon_{it} = \alpha_i + u_{it}$$

Where α_i is the unobservable individual heterogeneity and u_{it} is the idiosyncratic error. The unobservable individual heterogeneity is addressed in the following two different ways:

If α_i is assumed fixed along the individuals, then it is known as the “Fixed Effect” estimator; if, in contrast, we assume it follows a random distribution, then we refer to it as the “Random Effect” estimator.

However, due to the non-linearity of the Panel Tobit model, using fixed effects in the analysis would increase the α_i as N increases, causing then incidental parameter problems that leads to biased estimations. (Fernandez-Val and Weidner 2013). Greene (2004), suggested the existence of an issue concerning the distribution of disturbance variance estimator with the fixed effect Tobit models aside from the incidental parameters problem previously mentioned. In the light of these aspects, using a Random Effect estimator would be more appropriate for Panel Tobit Regression Model.

The results of DEA in this paper were obtained using a DEA Solver Plugin for Excel and the results of Panel Tobit were obtained using Stata.

6. RESULTS AND DISCUSSION

This study analyses the efficiency of hospitals across European OECD countries, focusing on the difference in performance between two main healthcare models, Beveridge and Bismarck. The technical efficiency of hospitals was assessed for 19 OECD countries for the 2005-2015 period through a two-stage approach. Data Envelopment Analysis (DEA) was employed in the first stage of the study while, in the second stage, Panel Tobit Analysis was the chosen method. Efficiency scores were obtained through DEA and then, used as dependent variable in Tobit Regression Model.

6.1. RESULTS OF DEA MODEL

An output-oriented DEA analysis across 19 OECD countries was applied under CRS assumption. Using 3 inputs and 1 output, the hospital efficiency for our set of countries was obtained for the period 2005-2015. *Table 5.1* shows the technical efficiency scores for each country and year of study. *Table 5.2* shows the main descriptive statistics for these scores. When we consider the average efficiency scores of the countries along the years, it's observed an increase in the first years of the period, achieving a score of 0.892253 in 2008 and then a huge decrease in this efficiency, dropping to 0.798047 in 2010. This could be explained by the cuts in health spending adopted by several OECD countries during the financial crisis, particularly between 2009 and 2011 (OECD 2013). In the last years of the period the efficiency has been slightly increasing ageing, reaching a score of 0.884795 in 2015. Focusing on the efficiency distribution across our set of countries along the years, we can observe that only 3 countries out of the 19 we analyse were considered as fully efficient (efficiency score equals to one), at the beginning of our period (2005) being this number the highest for the period, showed also for 2010, probably due to the above mentioned financial crisis. Excluding 2010, the number of fully efficient countries has followed a positive trend, reaching 7 for 2011, 2012 and 2014, and stabilizing at 6 the last year of the period.

Greece is the only country been fully efficient during this whole 11-year period. Although Great Britain has not showed a maximum efficiency score for every year, this country has achieved a fully efficiency score for 8 out of 11 years, which place it as one of the countries with a better performance of its healthcare system. In their study on hospitals efficiency for OECD countries, Samut and Cafri (2015) also reached the conclusion that United Kingdom was one of the countries with better hospitals performance, obtaining a result of fully efficiency for the whole period 2000 – 2010 for this country. Reviewing the inputs and outputs, we found that these high efficiency levels could be consequence of a lack of nurses in the Greek healthcare system, which provokes and increase in its efficiency scores. In the case of Great Britain, these large scores might be related to the fact that this country has some of the lower levels of beds and doctors at hospitals comparing with the rest of countries considered in our study. Spain, France, Portugal and The Netherlands have scores under the average for all the years.

Table 6.1. – Efficiency scores from DEA

Country/Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Austria	0.9686	1	1	1	1	0.8267	1	1	1	1	1
Czech Republic	0.8419	0.86	0.8785	0.8855	0.864	0.8065	0.8545	0.8709	0.8874	0.9074	0.8918
Estonia	0.8724	0.9099	0.9191	0.8906	0.8822	0.7772	0.8946	0.8899	0.937	0.9276	0.9251
Finland	0.8748	0.9112	0.9501	0.9833	0.8955	0.8589	0.8623	0.8743	0.8513	0.8815	0.8972
France	0.6908	0.7258	0.7387	0.7584	0.7527	0.7294	0.7604	0.7695	0.7352	0.8573	0.7347
Germany	0.7708	0.8307	0.8869	0.9361	0.8966	0.9045	0.8983	0.9197	0.8861	0.9064	0.9144
Greece	1	1	1	1	1	1	1	1	1	1	1
Hungary	1	1	1	1	1	0.643	1	1	0.9718	0.9706	0.9829
Iceland	1	0.9787	0.8795	0.9245	0.8268	0.8311	0.8101	0.7481	0.7315	0.7123	0.745
Ireland	0.6729	0.7636	0.7632	1	1	1	1	1	1	1	0.97
Italy	0.889	1	0.961	0.9462	0.9215	0.8394	0.8533	0.8423	0.834	0.8128	0.9009
Luxembourg	0.8947	0.8927	0.9089	0.9109	0.8867	0.6847	0.8634	0.8647	0.8109	0.8062	0.7948
Netherlands	0.5903	0.663	0.6252	0.6427	0.6227	0.6318	0.6883	0.643	0.5273	0.5198	0.583
Poland	0.7331	0.8491	0.8903	0.9943	1	1	1	1	1	1	1
Portugal	0.5887	0.6808	0.6643	0.6526	0.619	0.5778	0.5702	0.5551	0.5725	0.5407	0.6174
Slovak Republic	0.7958	0.8325	0.83	0.8635	0.8744	0.7918	0.9016	0.96	0.984	1	1
Slovenia	0.9213	1	1	1	1	0.8364	1	1	1	1	1
Spain	0.7587	0.8176	0.8096	0.801	0.7706	0.7197	0.7281	0.7249	0.77	0.7419	0.8539
Great Britain	0.881	1	1	1	0.9753	0.704	1	1	1	1	1

Source: own elaboration with data from OECD and The World Bank

Table 6.2. - Main Statistics

Statistic/Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Degree of efficiency =1	3	6	5	5	6	3	7	7	6	7	6
Mean	0.828674	0.879695	0.879247	0.892253	0.883579	0.798047	0.878163	0.876968	0.868368	0.872868	0.884795
Minimum	0.8557	0.663	0.6252	0.5427	0.619	0.5778	0.5702	0.5551	0.5273	0.5198	0.583
Maximum	1	1	1	1	1	1	1	1	1	1	1
Standard Deviation	0.127179	0.110627	0.112016	0.113892	0.117684	0.120473	0.120000	0.130961	0.142939	0.147666	0.128388

Source: own elaboration with data from OECD and The World Bank

6.2. RESULT OF PANEL TOBIT

Considering the efficiency scores obtained through DEA as dependent variables, Panel Tobit Analysis was employed in the second stage of the healthcare performance assessment to investigate the socio-economic environment variables that could affect the efficiency of hospitals for each country, emphasizing the impact of having a particular healthcare system model (Beveridge or Bismarck). For the implementation of the Tobit regression estimation, the dependent variable was considered censored to 1 and, for a more accurate estimation of the effect of the environment variables, we introduce them in their logarithmic form in the model. The results of Panel Tobit model estimation are shown in *Table 5.3.*

Table 6.3 – Tobit Regression Results

Variables	Coefficients	Standard Errors	t statistic	
Healthcare model	-0.0266325	0.0288503	-0.92	
Education	0.0840973***	0.0408957	2.06	
Life expectancy	-1.703495***	0.7127306	-2.39	
GDP	-0.0383343	0.0488388	-0.78	
Health expenditure	0.0068336	0.0808696	0.08	
Intercept	8.489594	2.720985	3.12	
Observations				209
Pseudo R Squared				1.0928
Right censored observations				64
Uncensored observations				145

Source: own elaboration with data from OECD and The World Bank

Focusing on the variable of interest, the dummy for the type of healthcare system seems to be not significant in the Tobit Model. Although we cannot assure there is a causal effect of the dummy on the efficiency scores, the estimated parameter is negative, which might suggest that countries with a Bismarckian healthcare system model might perform worse in terms of hospitals efficiency than those following the Beveridge model.

The results for the rest of environment variables shows that only two of them were statistically significant when explaining the efficiency scores used as dependent variable. These variables are the human capital (education), measured as the percentage of adult population that has achieved tertiary education level, and life expectancy, measured as the average life expectancy of a new-born. The effect of human capital on efficiency is positive, which means that an increase on the levels of human capital will raise the efficiency. On the other hand, life expectancy shows a negative effect on the performance of hospitals, in other words, an ageing population will lead to lower levels of efficiency in its healthcare system.

In respect to the rest of variables, both GDP per capita and health expenditure are not statistically significant.

7. CONCLUSIONS

This study applied a two-stage performance assessment across 19 OECD countries for the period 2005 – 2015. In the first stage of the study, hospital efficiency scores were calculated through DEA for each year and country. Then, in the second stage of this approach, environment non-discretionary factors affecting the efficiency levels obtained in the first stage were identified. Particularly, we focus on the possible effect the type of healthcare system model might have on the hospital performance.

In the first stage, using a three inputs-one output DEA method, under Constant Returns to Scale presumption (CRS), the efficiency scores for each year along the period were obtained. It was found that the efficiency scores have been increasing along the period.

Excluding a important drop of this efficiency during the financial crisis, falling to 0.798047 in 2010, due to the cuts in health spending countries had to make, the overall trend followed showed an increment in hospital performance over time, reaching a score of 0.884795 in 2015.

Greece and Great Britain were the countries with most efficiency healthcare systems, while the countries whose hospitals performed worse were Spain, France, Portugal and The Netherlands.

In the second stage of the study, the environment variables that affect the efficiency scores obtained through DEA were identified using Panel Tobit Analysis. These variables include social-economic factors specific for each country. Panel Tobit Analysis was proposed instead of Ordinary Least Squares (OLS) due to the censored nature of the dependent variable obtained in the first stage, which would lead to bias and inconsistent OLS estimators. Using Tobit this problem is solved and we are able to obtain an unbiased and consistent estimation.

Looking at the results of the estimation, as the coefficient obtained is not statistically significant, we cannot conclude one of Beveridge or Bismarck models performs in a more efficient way than the other one. A feasible reason for these findings is the fact that most of modern healthcare systems shows hybrid models which share features from both models. The resulting healthcare system is a mixed model including the best characteristics from each of the two main ones.

Regarding to the environment factors, a positive and statistically significant relation between human capital(education) and efficiency was found. In addition, there was obtained a negative and statistically significant relation effect of life expectancy on hospital performance. In the light of these findings, we can conclude that countries with higher levels of education and shorter life expectancy have more efficient health systems.

The main limitations of this study are, on one hand, the exclusion of some countries from the final sample due to lack of data and, on the other hand, the fact that the effect of some environment variables of the efficiency were not statistically significant, specially the effect of the type of healthcare system model. This second limitation is probably a consequence of the limited number of countries included in the analysis, as we commented before.

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