ASSESSMENT OF DIFFERENT PRODUCTION FUNCTIONS OF 10 HOSPITALS FROM AN EUROPEAN REGION FOR 2012-2018.

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Abstract

The subject of discussion is the health care production function. Similarly, waiting time for elective surgery is an important problem in today's medical world. The objective is to evaluate the most appropriate econometric model for the study of hospital production functions. To analyse the existence of growth or decrease of scale for the different hospitals. The data used refer to public hospitals in Galicia for the period 2012-2018, including the number of beds, the number of physicians, and the number of discharges per Diagnosis Related Group (DRG). The method used are econometric models with panel data to estimate Cobb-Douglas functions, Translog, and Leontief model. The results show that the Translog model is more adequate than the Cobb-Douglas or the Leontief model to evaluate the hospital production function, for public hospitals located in Galicia, for the study period. The elasticity of the labour factor is positive while that of the capital factor is negative. The capital factor is complementary to the labour factor, which can be a substitute for the former. The best model for assessing the hospitalisation production function in the sample hospitals is the Translog, followed by the Cobb-Douglas. In this model, the labour factor shows increasing returns to scale as opposed to the capital factor. The results show that the labour factor seems to be complementary to the capital factor.

Key Words: Production functions of hospitals, Econometric Model, Efficiency, Region

JEL Classification: C23, E23, I11

1. Introduction

Hospitals, whether public or private, are complex institutions to manage. The constant evaluation of their available resources and their productivity in a rigorous and objective manner is a fundamental action in the running of a hospital.

The raison d'être of a modern hospital is the effective coordination of its structural resources with the quality of the care processes and their productivity, which must be oriented towards its end products: the user, the health services and, above all, the community they serve.

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Hospitals play a crucial role in health and treatment economics, as they are the main organisations providing health services and are the largest and most costly operational units in the health system (Reza Pour & Asefzade, 2006).

The characterisation of hospital production has been a major challenge for health administrators and managers for decades. In other industries, the production apparatus concentrates its efforts on solving the equation of "input" and "output", taking into account at most a few dozen variables related to the production processes involved and the products or services generated in the output. In the case of hospitals, patients, depending on their causes of admission and their personal characteristics, may produce different output variables. In turn, within hospitals, they may also undergo hundreds of other procedures and combinations of these, to finally deliver a product (output) that will correspond to a combination of hundreds of possibilities.

The essence of production functions in economics concerns the productive capacity and efficiency of the factors of production. If capacity and efficiency are related to several factors of production, we are evaluating a production function of several variables or, especially, we could analyse a function related to a single factor of production, i.e. a production function of one variable.

The term production function refers to the physical relationship between the organisation of productive resources and the output in the form of goods or services per unit of time. Two models are commonly used in hospital production function estimation (Rosko & Broyles, 1988): The Cobb-Douglas model and the Transcendental Logarithmic model (Translog model). Cobb-Douglas has been very popular among economists due to its simplicity of calculation. However, theoretical and empirical work has frequently questioned the validity of the parametric Cobb-Douglas model as a representation of the production of health care services (López Casasnovas & Wagstaff, 1988). Compared to the Cobb-Douglas model, the Translog model has the advantage of adding to the function the effects of the interaction between inputs, while the former omits these effects. Therefore, many studies on production functions have employed the Translog function (Rosko & Broyes, 1988; McGuire, 1987).

The basic assumption of the fixed rate production function under the Leontief model is that there is no substitution between production factors. Looking at the hospital sector as a whole, it becomes clear that this assumption is not correct from a descriptive point of view. The reason for this is that some substitution of medical services is to be expected, e.g. an increase in the number of doctors may reduce bed occupancy. Some substitution between doctors and nurses and between nurses and hospital administrative staff is also to be expected. Therefore, the fixed ratio model, which assumes that there is no possibility of substitution between health resources, is (over)simplified (Yfantopoulos, 1980).

OBJECTIVES: The main objective of this study is to estimate a production function for hospitals and hospital clinical and surgical services, using econometric models with panel data. Secondly, the main strengths and weaknesses of the different functional forms used in this study, the Cobb-Douglas, the Translog and the Leontief to estimate the production functions of clinical services (medical and surgical) are examined.

2. Health resources and scores in Spain and other European countries

2.1. A comparison of Spain with 5 European countries, the USA and World average.

It is important to present some comparisons of Spain with other European countries in order to analyse the relationship between resources and scores of Health services.

For that purpose we analyse several indicators in year 2019, taken from the study by Guisan(2023) and the statistical sources there cited, that include World Bank Indicators, OECD Health statistics, the European Consumer Index and other ones.

Table 1 includes a comparison of Health resources and outputs in 6 European countries, the United States and the World average around year 2019: rates of Doctors, Nurses and Hospiltal Beds per thousand people and the value of Health Expenditure per capita, expressed in Dollars at 2019 prices and Purchasing Power Parities. The comparison also includes the rates of the United States and the World averages.

Table 1. Health services rate per 1000 people (Doctors, Nurses, Beds and Discharges), Expenditure per capita, and European Global Score (points and ranking position), in 5 European countries, the USA and World average, year 2019

Country	Doctors rate 2019	Nurses rate 2019	Beds	Expen diture 2019	Global Score 2018	Global Ranking position	Dischar ges 2019	Discharges /Beds
France	3.3	11.8	5.9	5452	796	11	182.6	31
Germany	4.4	14.2	8.0	6515	785	12	253.0	32
Italy	4.0	6.4	3.1	3853	687	20	113.0	36
Spain	4.4	6.1	3.0	3600	698	19	103.4	34
Switzerland	4.3	18.3	4.6	7138	893	1	168.8	37
UK	2.9	8.9	3.0	4500	728	16	128.7	43
USA	2.6	15.7	2.9	10948	-	-	125.5	43
World	1.6	4	2.9	1427	-	-	-	-

Source: Elaborated by Guisan(2023) from World Bank, EHCI(2018), and OECD statistics. Notes: World average data corresponds to 2018 instead of 2019. Data lf Beds rate in Italy of year 2014. Data of Dicharges rate in the United States of year 2012. Expenditure elaborated from OECD data, Health at a Glance, in Dollars at 2019 prices and Purchasing Power Parities.

The first position in the European Health Consumption Index corresponds to Switzerland with 893 points. In comparison with Switzerland Spain represents only a 42% of real Gross Domestic Product per capita and a 50.43% of Health Expenditure per capita at PPPs, but gets a similar rate of Doctors, a 61.26% of the rateo of Hospital Discharges,a 65,22% of Hospital Beds and a 89.13% of Global Score, but Spain only has a 33.33% of the Nurses rate of Switzerland, what implies a lose of quality of services for patients and a loss of quality of working conditions for Doctors and Nurses, particularly those with more patients, which have more work and a lot of stress due to the low of enough Nurses.

2.2. A Comparison of Galicia with other Spanish and European regions

Accordingly to the regional data presented by Guisan(2023) from the National Institute of Statitics (INE), Spanish regions present a number of Doctors per thousand people in central positions of the European regions, mosto of them between 3 and 5. Among 216 European regions the Eurostat results present a great variability, with many regions in the central positions, but some below 3 and other ones over 5.

The rates of Doctors per thousand people varied, in year 2020, between a minimum of 2.7 in Castilla-La Mancha and 6.4 in Navarra. Galicia had aa value of 4.6 like the non weighted average of 17 Spanish regions.

The rates of Nurses per thousand people in year 2017 in the Spanish regions presente dan average of 5.9, with great variability between a minimum of 2.7 in Cantabria and a maximum of 8.7 in the Pais Vasco. Galicia presented a value of 6.5 slightly over Spanish average.

The rates of Hospital Beds per thousand people in year 2020 varied between a minimun of 2.19 in Andalucia and a maximum of 3.83 in Catalunya. Galicia presented a value of 3.30, slightly over the regional average of 3.13

The rate of Hospital Discharges per thousand people varied in year 2014 between a minimum of 8.16 in Andalucia and a maximum of 11.60 in La Rioja. The vaule of Galicia was 10.68 slightly over the national average of 10.09.

The econometric models estimated by Guisan(2023) with data of 6 European countries show the positive impacto of the rates of Doctors and Nurses on the Accessability Scote, and the postive impacto of Accessability on the Global Score. Regarding the rate of Discharges per thousand people the rate of beds is the explanatory variable which gets a higher goodness of fit. Quantity depends at a great extent of infrastructures but quality depends mainly of human resources.

3. Methodology

3.1.- Input and Output of hospital production.

The variables used in the study are the inputs, understood as capital and labour, and the outputs of hospital production.

Hospitals are multi-product production centres, where a variety of patients are treated with a variety of inputs. There is no consensus on the best measure of the outputs of hospital production Q, so researchers have used different indicators to measure hospital output including the number of discharges, the number of admissions or the number of stays. However, these measures fail to adequately capture the healthcare provided by hospitals to patients.

In this research we have used as a measure of hospital output the number of admissions standardised by complexity or case-mix, obtaining a homogeneous unit of output called the Hospital Output Unit (HPU), whose calculation is obtained by multiplying the number of admissions by their complexity obtained from the DRG weights (López Casasnovas et al., 1988), thus addressing the need to take into account the complexity of different hospitals and further adjusting the output of each hospital's production.

Following Ferrier and Valmanis (2004) and Yin et al. (2021) the inputs of hospitals can be measured as: for the capital input the number of beds for each hospital and each year is used, obtaining these data from official hospital statistics. The labour input is measured as the number of hospital specialists in the workforce of each hospital on 31 December of each year.

3.2.- Data.

The data have been collected and organised from the Servizo Galego da Saúde information system panel and completed with statistics from the reports of the sample of 10 hospitals of the Servizo Galego da Saúde:

In order to give an impression of the size of the Galician hospital sector, some quantitative characteristics shows that of public hospitals comprise about 7.764 beds, what means 90% of hospital supply beds in the Region accompanied by 4.159 physician full-time equivalents. In 2018 the number of inpatients treated in hospitals was 243.515 facing 1.889.676 inpatient days, what was accompanied at the same time by 1.216.109 first-time visits and 1.021.849 emergencies produced.

In Galicia, hospitals have been classified within three clusters by Reyes (2009). This classification indicates the number of specialities which a given hospital is equipped to treat, reflecting the type of services it may offer.

For example, Cluster 2 hospitals only provide internal medicine, surgery and a few basic specialities whereas Cluster 3 hospitals provide a considerable range of specialized services. By contrast, Cluster 1 hospitals provide specialized services with advanced technology and highly qualified human resources. In this context, hospitals with the fewest number of specialities treat simpler cases, and if we compare them with Cluster 2 and 1 they are less equipped with advanced medical technology such as the computerised axial tomography scanners.

The hospital data collected for the period 2014-2018 were:

- Number of beds for each hospital (BED)

- Number of specialist doctors for each hospital (FAC)

- Number of patients admissions and discharges, weighted by complexity (HPU)

Number of DRG (Diagnosis Relaged Group) admissions and discharges for each hospital (HPU) which are calculated by multiplying the number of admissions by the complexity (weight) obtained from the DRGs, standardizing admissions by means of complexity, obtaining homogenous units of production (Lopez Rois et al., 1996). Data for the variable are annual.

The variable Year, as a proxy for changes in production technology shows no statistical significance for the overall model, which would indicate that technological changes are neutral in relation to output. The use of the time variable as a proxy for technological change has been used in many studies, but following Blank and Van Hulst (2009), innovations diffuse at a slow pace until they reach all hospitals and therefore, we can find different hospitals working with different technologies in the same period of time.

In the Annex we include three tables with data of the evolution, for the period 2014-2018, in 3 groups of hospitals of this study.

3.3. Econometric models

In this work, three alternative models are used to study the Hospital Production Units.

a) Model based on the Cobb-Douglas function, as this is the most generalised for production models, since it allows us to obtain the estimated elasticities, these being constant (as they coincide with the estimators of the parameters that accompany the regressors).

The Cobb-Douglas function, which was estimated by Charles W. Cobb and Paul H. Douglas (1928), although it was already anticipated by Wicksell (1901, 1934) and, according to some authors (Von Thünen, 1863) has the following form:

$$Q = \alpha L^{\beta_1} K^{\beta_2}$$

where Q, L and K represent output, labour and capital respectively, and α, β1 and β2 are constants.

One problem with this function is the omission of the change in production technology. The need to account for this technological change was identified by Handsaker and Douglas (1937). A standard procedure for introducing technological change into the function is to include the time series. This allows the function to capture changes in technology, although this is assumed to be exogenous to the specification of the function.

$$Q = \alpha(T) L^{\beta_1} K^{\beta_2} \text{ y } \alpha(T) = \alpha e^{\varphi T}$$

where, α and φ are constants. φ is a measure of the proportion of change in output per time period holding input levels constant. This implies that technological change is exogenous.

The above equation is usually estimated as:

$$lnQ = \varphi T + ln(\alpha) + \beta_1 ln(L) + \beta_2 ln(K) + \varepsilon$$

where ε is the random disturbance term following a normal distribution. The log-linear specification assumes that the estimates of β1 and β2 give us the elasticities and, therefore, these will be constant.

b) Translog model.

Although the Cobb-Douglas function is the most widely used to estimate production functions, there are authors (López Casanovas et al., 1988) who have questioned its validity for the study of the production function in the case of hospital services, opting for the Translog model (Christensen et al., 1973). As in the Cobb-Douglas equation, if the effects of technological progress are assumed to be neutral, the form of the translog production function is simplified as follows:

$$lnQ = \beta_0 + \beta_1 ln(L) + \beta_2 ln(K) + \beta_3 ln(L) ln(K) + \beta_4 T + \varepsilon$$

where Q represents aggregate output, T is time, K is fixed capital and L is labour and the. β represent the parameters of the function.

c) Leontief model

This methodology refers to the production function of fixed proportions or coefficients introduced by W. Leontief (1941), according to which productive activities are reviewed where there is a "single" technique, since the inputs are used in fixed or constant proportions. Therefore, there is no possibility of substitution between inputs, and the respective elasticity $\sigma = 0$.

This function is represented by: x = min (l1/v, l2/u), with v, u > 0, such that to produce one unit of x requires v units of input 1 and u units of input 2. If, for example, I1/v <l2/u, then x = l1/v since l1 is the binding constraint in this production process. It follows that l1 = vx are the requirements of input 1 and l2 = ux are the requirements of input 2. The only technique is the constant ratio (I1/I2) = v/u, which is a particular fixed proportion of the required inputs (1 and 2) to produce x efficiently. The use of an input beyond this ratio would be inefficient and superfluous (waste of a positively priced input), since it will not increase x, its marginal product being zero.

A characteristic of this production function is that it exhibits constant returns to scale.

$$Q = \beta_0 + \beta_1\sqrt{K} + \beta_2\sqrt{L} + \beta_3\sqrt{K * L} + \varepsilon$$

The Cobb-Douglas, Translog and Leontief models that have been estimated in this study would be represented as follows:

1.Cobb-Douglas model:

$$\ln(HPU) = \beta_0 + \beta_1 \ln(FTE) + \beta_2 \ln(BEDS) + \varepsilon$$

2.Translog model:

$$\log(HPU) = \beta_0 + \beta_3 \log(BEDS) + \beta_2 \log(FTE) + \\ + \beta_3\, log(BEDS)^2 + \beta_4\, log(FTE)^2 + \beta_5 \log(BEDS)\, x \log(FTE) + \varepsilon$$

3. Leontief model

$$HPU_{it} = \beta_0 + \beta_1\sqrt{FTE_{it}} + \beta_2\sqrt{BEDS_{it}} + \beta_3\sqrt{FTE_{it}BEDS_{it}} + \varepsilon_{it}$$

Following De la Fuente (2008), the elasticity of marginal product (MPE) of each factor with respect to the endowments of the same factor and other inputs can be found:

$$EMP_{ii} = \beta_i - 1 + \frac{\beta_{ii}}{\beta_i}$$

Where βi is the estimated coefficient of the translog function referring to factor i, and βii, the estimated coefficient of the square of that same factor.

Likewise, the elasticity of the marginal product of factor i with respect to another factor j (EMPij) is equal to:

$$EMP_{ij} = \beta_j - 1 + \frac{\beta_{ij}}{\beta_i}$$

The sofware used was the Econometric Views.

4. Results and estimation of the models

The availability of statistical data for a short period of time (5 years) and a larger number of economic units (10 hospitals), has led us to consider the estimation of an econometric model with panel data (micro-panel) which has the following advantages: it allows us to work with a larger number of observations (50), it allows us to capture the heterogeneity that occurs in the data (between the different hospitals) and it reduces the problems of multicollinearity in the models (when, as in this case, the correlations between the explanatory variables are very high).

For any of the production functions defined above, the general specification of the model may not capture possible unobservable heterogeneity (between economic units or between time units, depending on whether the differences occur between hospitals or between years). Two estimation methods can be used to capture the existence of such heterogeneity: fixed effects (FE) and random effects (RE).

Fixed effects assume that there may be unobservable differences between the different hospitals in the sample and that these differences are constant over time (or conversely). It assumes the same as including dummy variables for the different units. The estimation of this model allows for unbiased and consistent estimates, even if the individual effects are correlated with the explanatory variables.

The random effects model considers unobservable differences as part of the random disturbance term. In this case, to obtain consistent estimators the disturbance must be uncorrelated with the explanatory variables in the model.

If there is no correlation between the FEs and the explanatory variables, the RE model is more consistent (the model with FEs is consistent even in the presence of such correlation). To select the most appropriate model, the Hausman test is often used which indicates that, in the absence of such correlation, the estimated values for the parameters will be very similar whereas, they will be different when the individual effects and the explanatory variables are correlated.

When the test result suggests not rejecting the null hypothesis, the estimators hardly differ, and it follows that the random disturbance and the explanatory variables are not correlated and the most appropriate model is the RE model (we estimate a smaller number of dummies so the model is more efficient).

Thus, this section contains the results of the estimations made for the three models proposed by Ordinary Least Squares (LS) or by Generalised Least Squares (GLS) if the tests previously carried out recommend this method of estimation on detecting any non-compliance with the starting hypotheses of the MRLC, considering Fixed Effects (FE) and Random Effects (RE), in addition to the results of the Hausman test, which allows us to select whether the model should be estimated considering FE or RE, under the null hypothesis of the existence of random effects. Finally, the results obtained in the three proposals will be compared in order to select the most appropriate one and interpret the results obtained.

Table 1.- Results Model 1. Cobb Douglas. Estimation LOG(HPU)

	Estimation 1: GLS	Estimation 2: Panel LS	Estimation 3: Panel RE/ EGLS
C	3.962606*	7.139194*	3.955358*
LOG(BED)	0.782594*	0.337766***	0.716047*
LOG(FTE)	0.263172	0.174490	0.340098*
AR(1)	0.724033*		
R^2	0.990984	0.996494	0.909358
Adjusted R^2	0.990232	0.995478	0.905501
Akaike info criteria	-1.579615	-2.237694	
DW	2.187789	2.551078	2.042326
Hausman Test			8.256901**

*p inferior at 1% **p inferior at 5% ***p inferior at 10%

The results of the Durbin-Watson test in the LS estimation of the model have led us to carry out the estimation considering the existence of first-order autocorrelation. These results are shown in the first column (Estimation 1. GLS).

The fit in the three estimations of model 1 is clearly high in the three alternatives carried out, obtaining values of the coefficient of determination (R2) above 0.90 and very close to 1 in the case of estimation 1, by GLS, and in estimation 2 in which we consider the existence of cross-section Fixed Effects.

The variable that includes the number of beds, in logarithms, turns out to be statistically significant in all three estimations (although it is only significant at 10% in estimation 2), and its influence is positive. However, the variable that includes the number of doctors is only statistically significant in the estimation considering the existence of Random Effects, which is the one that presents the least adjustment of the three (it was not significant in the estimation of the Ordinary Least Squares model either).

With regard to the choice between the existence of FE or RE, the Hausman test indicates the rejection of the null hypothesis, i.e. the existence of EA, so that the RE model would be discarded.

In any of the estimates made, the elasticity corresponding to the number of beds is higher than that of the number of doctors, making it the variable with the greatest influence on the number of hospital production units (HPU).

If we look at the adjustment, we would choose the estimation considering Fixed Effects, as it presents a higher adjusted coefficient of determination than that resulting from estimating the panel by Generalised Least Squares.

Table 2.- Results Model 2. Trans-Log Function. Estimation LOG(HPU)

	Estimation 1: GLS	Estimation 2: Panel LS	Estimation 3: Panel RE/ EGLS
C	15.14519*	9.206322	12.17498*
LOG(BED)	-8.154770*	-2.845944	-4.924296**
LOG(FTE)	6.279923*	2.868957	3.662087**
(LOG(BED))^2	1.906995*	0.640341	1.002379***
(LOG(FTE))^2	1.026943*	0.251566	0.406583
LOG(BED)*LOG(FTE)	-2.737876*	-0.860648	-1.245348
R^2	0.991684	0.996828	0.958328
Ajusted R^2	0.990739	0.995559	0.953593
Akaike info criteria	-1.614152	-2.217849	
DW	1.652430	2.699864	2.379025
Hausman Test			4.281939

*p inferior at 1% **p inferior at 5% ***p inferior at 10%

The OLS estimation of the model with panel data (estimation 1) provides significant parameter estimators at a significance level of 1% and a very high goodness of fit (R2 of 0.99).

The estimation considering the possible existence of Fixed and Random Effects, in both cases, also presents a high fit, but the estimators of the parameters in the first case (EF) do not turn out to be statistically significant. In any case, the Hausman test indicates that the estimation that considers random effects would be accepted, so that the model with FE would be discarded.

In terms of fit, and the significance of the estimators, we would select estimate 1 (Panel LS) as the most appropriate estimate, which, moreover, does not present any problems in relation to other tests carried out.

Table 3.- Result model 3. Leontief Model. Estimation HPU

	Estimation 1: GLS	Estimation 2: Panel LS	Estimation 3: Panel RE/ EGLS
C	-985.8509	-40280.90	2718.270
$\sqrt{BED}$	3431.929**	4095.807	2484.843***
$\sqrt{FTE}$	-5957.824*	2536.386	-5266.220**
$\sqrt{BED * FTE}$	121.6477**	-132.1999	139.6856**
AR(1)	0.389334		0.683002
R^2	0.942076	0.972173	0.662328
Adjusted R^2	0.935456	0.963148	0.662328
Akaike info criteria	20.98790	20.58822	
DW	1.476288	2.781525	2.361750
Hausman Test			3.705500

*p inferior at 1% **p inferior at 5% ***p inferior at 10%

With regard to the results obtained in the estimation of Model 3, the estimators are all statistically significant at a significance level of 5% in the case of estimation 1 of the panel model, MCG (to correct for the existence of first-order autocorrelation). This model also shows a high fit, with a coefficient of determination value of 0.94.

Although the fit is greater if we consider the existence of Fixed Effects, the Hausman test advises against this estimate, favouring the model with Random Effects. Moreover, in the FE model the estimators of the model parameters are not statistically significant. The model with RE, on the other hand, has a much lower fit than the model estimated by GLS.

Comparison of the three models

Next, we analyse the value of the Akaike Information Criterion, which measures the goodness of fit based on the maximum likelihood of the model and the complexity based on the number of parameters, and which allows us to select which of the three models presented has the best fit, the better the better the lower the value of this indicator. We use this statistic instead of the coefficient of determination, since we are comparing models with different functional forms.

Table 4. Akaike info Criteria

	Model 1. Estimation 1	Model 2. Estimation 1	Model 3. Estimation 1
Akaike Info criteria	-1,579615	-1,614152	20,98790

According to the Akaike criterion, the best model of the three is Model 2, in which we estimate by OLS the panel data model of the translog function, and whose results we now interpret.

For beds we obtain the following value of the elasticity: EMPk = -8.154770 - 1 + 1.906995/-8.154770 = -8.920920

For the Optional we get the following value of the elasticity: EMPl = 6.279923 - 1 + 1.026943/6.279923 = 5.11639504

The calculation of the elasticity of the marginal product of one factor with respect to the other, for the factor beds is: EMPlk = -8.154770 + -2.737876/6.279923 = -8.154770

And for physicians: EMPkl = 6.279923 + -2.737876/-8.154770 = 6.61566221

The negative sign of the elasticity of the capital factor with respect to itself reflects that, ceteris paribus, the marginal product of this factor is decreasing with respect to its endowment. The opposite happens with the elasticity of the labour factor, which is positive, allowing us to conjecture that we are dealing with increasing returns to scale for this factor. The explanation would be that human capital would generate positive externalities on human capital itself, in the sense that professionals with higher qualifications and experience would interact with each other, generating even greater knowledge that can be exploited and favour productivity growth.

The signs of the elasticities of the marginal product of one factor with respect to a different factor reflect the type of relationship that exists between the two factors. Thus, if these elasticities have a positive sign, they show complementarity relationships between the two factors, and if they have a negative sign, they show substitution relationships.

Thus, it is observed that the capital factor (beds) can be substituted by the labour factor (doctors) who could apply their clinical knowledge through physical examination and/or anamnesis, while the capital factor (beds) requires the complementary factor labour (doctors); thus indicating that an increase in the productive factor labour generates an increase in the marginal productivity of the capital factor.

The positive and significant coefficients of the squares of both factors show that the estimation of a Cobb-Douglas function is not the most adequate and that having a negative sign, they reflect diminishing returns to scale.

The factor product parameter is significant and has a negative sign, suggesting factor substitution.

5. Discussion

Following McKee et al. (1999) to understand the components of the health production function allows a coherent cost management strategy. The problem is that the data on which these analyses are based are at least one-year-old. The resource capacities (room size, equipment and staffing) identified in these analyses are based on events that occurred one or more years ago. The healthcare production function is a dynamic process, not a static one. That is why we have chosen 6 years to avoid this inconvenience in our study.

In the present work, the variable Year, as a representation of the changes in production technology, does not show any statistical significance for the global model, which would indicate that technological changes are neutral in relation to output. The use of the variable time as an approach to technological change has been used in multiple studies, but following Blank and Van Hulst (2009), innovations are disseminated slowly to reach all hospitals and, therefore, we can find different hospitals working with different technologies in the same period of time.

An example of the above is the work of Meyer et al. (2007) on the application of an economic function of production in hospitals with different levels of integration in their information systems. The study included 17 public hospitals of the Public Assistance of the Paris Region that were followed up in the period 1998–2005. Using an extended Cobb–Douglas production function, the annual output was correlated with three inputs: the capital factor, the labour factor, and information technology.

The calculations done for two subgroups of hospitals, divided according to the level of integration of information technologies, indicate that the higher the level of integration of the information system, the greater is its positive influence on the level of hospital production.

The results related to the work factor present different tendencies according to the hospital clusters, and the services should be analyzed in relation to other studies that address this issue. In this respect, the increase in income, surgical interventions and consultations in the period 1995–1999 in a regional hospital was compared with the increase in the number of hospital professionals during the same period of time. The data show that, for each category of health professionals, there are global decreases in productivity, defined as per capita consultations. However, several services show a different behaviour, with increases in productivity (Bratlid, 2000). The latter is the case in our study where the labour factor shows increasing returns to scale as opposed to the capital factor represented by the variable number of beds.

In a now classic article on the impact of the labour factor and, in particular, physicians on hospital production functions, Jensen and Morrisey (1986) analyzes the role of medical staff characteristics in determining the different dimensions of hospital production. Employing a set of production functions with a flexible functional form, and adjusting for the complexity of the hospital, the authors examine the contribution to the hospital's production of the physicians and other factors, as well as the influence that the physicians of the different clinical services have on the productivity of the remaining physicians, and other factors of work and capital. The study also examines the possibilities of substitution between the factors of hospital production. The authors have identified that physicians are an important production factor that should be taken into account in studies of the cost and production functions of hospitals. Similarly, in our study, the labour factor, represented by the number of hospital doctors, is complementary to the capital factor, whereas the capital factor can be substituted by the labour factor.

A specific production function can be used to study the existence and, where appropriate, the magnitude of the scale effects for each service or process. If the economies of scale and the optimal configuration of the production of the hospital clinical services exist, this may be due to the existence of learning curves. Giancotti et al. (2017) in their study on the production of hospital services, in an individualized way, identify a common limitation to all of them: they assume that the production of a hospital is divisible and, therefore, that hospitals do not organize their productive factors to obtain a global product.

Following Rezapoor et al (2014), some results of their study were that of the variables influencing the sector's output, medical expenditure, active beds and other staff expenditure have a positive effect, while nursing expenditure has a negative effect. Of these inputs, the capital factor or active beds has the largest positive impact, while the smallest impact is associated with doctors. According to the results of the study, the output elasticity of physicians was estimated at 0.017, which means that a 1% increase in the number of physicians in the area under study can lead to a 0.017% increase in hospital admissions. According to the most recent survey, the elasticity of production of active beds was estimated at 1.02, meaning that a 1% increase in the number of active beds in the industry could lead to an increase in hospital admissions of more than 1%. The results also showed that the coefficient of the Cobb-Douglas production function for the examined sector was estimated at 1.143, indicating that increasing returns to scale can be achieved in this sector as a whole.

In relation to this, our study presents a higher elasticity of 5.11 and a much lower elasticity of -8.9 for the capital factor.

Attending the results of the study by Mohammadi and Meskarpour-Amiri (2016), it is revealed that in Iranian public hospitals, the elasticity of service level for inpatients with respect to skilled human resources (0.88) is higher than that of beds (0.18).

Therefore, the performance of individual public hospitals is more affected by skilled human resources and is more sensitive to a decrease or increase in skilled human resources than to the number of beds. A net increase in the number of hours worked by qualified staff (doctors and nurses) by 10% would increase the performance of public hospitals by 9%. Similarly, in our study, physicians also show, as we have indicated, a greater impact on the productivity of the system but with higher figures than the Iranian study.

6. Conclusions

Based on the value of the Akaike Information Criterion, which measures goodness of fit from the maximum likelihood of the model and complexity from the number of parameters, the best model for assessing the hospitalisation production function in the sample hospitals is the Translog, followed by the Cobb-Douglas.

The positive sign of the parameter indicating the elasticity of the labour factor suggests that we are dealing with increasing returns to scale for this factor as opposed to the capital factor represented by the variable number of beds. In this sense, human capital would generate positive externalities on human capital itself.

The results of this study show that the capital factor (beds) can be substituted by the labour factor (doctors) who could apply their clinical knowledge through physical examination and/or anamnesis, while the capital factor (beds) requires the complementary labour factor (doctors).

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Annex. Tables elaborated by authors from Galician Health Services (SERGAS) data

Table A1. Number of Hospital Beds in Hospitals of groups 1, 2 and 3, years 2014-2018

BEDS	**2014**	**2015**	**2016**	**2017**	**2018**
Group 1	3559	3543	3647	3601	3754
Group 2	2429	2301	2458	2511	2469
Sum G1+G2	5988	5924	6105	6112	6223
3. Group 3	380	366	352	382	373
Total	6368	6290	6457	6494	6596

Table A2: Number of Doctors (FAC)

FAC	**2014**	**2015**	**2016**	**2017**	**2018**
Group 1	1598	1551	1576	1647	1563
Group 2	1019	1075	1118	1165	1238
Sum G1+G2	2617	2626	2694	2812	2801
3. Group 3	127	131	140	138	143
Total	2744	2757	2834	2950	2944

Table A3: Hospital Patients Units, number of patients weighted by complexity

HPU	**2014**	**2015**	**2016**	**2017**	**2018**
Group 1	199850	201425	205136	204990	206121
Group 2	127388	128475	134668	138499	139236
Sum G1+G2	327238	329900	339804	343489	345357
3. Group 3	17957	17546	17559	18559	18755
Total	345195	347446	357363	362048	364112

Groupo 1: 3 Hospital with more than 1000 beds (A Coruña, Santiago, Vigo)
Group 2: 4 Hospitals with 300 to 900 beds (Ferrol, Lugo, Ourense, Pontevedra
Grouo 3: Hospitals with less than 300 beds (Burela (Coast Hospital), Monforte, Valdeorras)