Mehdi Farsi, Massimo Filippini

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EFFECTS OF OWNERSHIP, SUBSIDIZATION AND TEACHING ACTIVITIES ON HOSPITAL COSTS IN SWITZERLAND

Mehdi Farsi [†,‡]   Massimo Filippini [†,‡]

[†] Department of Management, Technology and Economics,
ETH Zurich, Zurichbergstr. 18, Zurich 8032, Switzerland

[‡] Department of Economics, University of Lugano, 6900 Lugano, Switzerland

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ABSTRACT

This paper explores the cost structure of Swiss hospitals, focusing on differences due to teaching activities and those across different ownership and subsidization types. A stochastic total cost frontier with a Cobb-Douglas functional form has been estimated for a panel of 150 general hospitals over the six-year period from 1998 and 2003. Inpatient cases adjusted by DRG cost weights and ambulatory revenues are considered as two separate outputs. The adopted econometric specification allows for unobserved heterogeneity across hospitals. The results indicate that the time-invariant unobserved factors could account for considerable cost differences that could be only partly due to inefficiency. The results suggest that teaching activities are an important cost driving factor and hospitals that have a broader range of specialization are relatively more costly. The excess costs of university hospitals can be explained by more extensive teaching activities as well as the relatively high quality of medical units. However, even after controlling for such differences university hospitals have shown a relatively low cost-efficiency especially in the first two or three years of the sample period. The analysis does not provide any evidence of significant efficiency differences across ownership and subsidization categories.

Keywords: general hospitals, teaching hospitals, stochastic frontier, cost efficiency

1. Introduction

The increasing growth of health care costs in Switzerland has raised the public interest in identifying the possibilities of improvement in productive efficiency. General hospitals (specialized clinics excluded) that account for about a quarter of national health expenditures have been subject of much debate and a few studies. The previous empirical studies [1,2] have found significant differences in productivity and/or cost-efficiency among hospitals. Identifying the sources of such differences is an important policy issue that has not been explored sufficiently in the Swiss context.

Ownership and subsidization as well as research and teaching activities have been considered as important cost-driving factors among Swiss hospitals. University hospitals have been often criticized for being excessively costly. Many policy-makers believe that public and subsidized hospitals are not as efficient as private facilities. However these policy debates remain qualitative and lack sufficient empirical evidence.

The present study addresses the above issues using data form a national sample of 150 general hospitals over a 6-year period from 1998 to 2003. Compared to the previous research on Swiss hospitals this paper benefits from a larger data set and several additional variables especially those related to teaching activities. Moreover, the adopted methodology is based on some of the recent developments in stochastic frontier panel data models. A total cost frontier with the Cobb-Douglas functional form has been estimated.

The analysis indicates that teaching activities can explain part of cost differences among hospitals. The results suggest that university hospitals while showing the highest average inefficiency scores, have improved over the sample period. There is no evidence of statistically significant efficiency differences among hospitals with different ownership/subsidy types. The estimation results also point to unexploited economies of scale in a majority of the studied hospitals.

The rest of the paper is organized as follows. Section 2 provides a general description of the adopted methodology with discussions of the functional form and econometric models. Section 3 describes the model specification. The data and descriptive statistics are given in Section 4. The estimation results along with a are presented and discussed in Section 5. Section 6 concludes the paper.

2. Methodology

Though many authors [3-5] have used cost frontier models to evaluate hospitals' efficiency, the application of such models in the health-care sector has been criticized [6,7]. The main arguments against these models are related to the unobserved heterogeneity due to differences in case-mix and quality of care as well as the errors incurred by aggregation of outputs. Admitting the sensitivity of individual efficiency estimates other studies show the practical use of stochastic frontier analysis for comparing the performance across groups of providers [8-10]. Following this thread of literature, we adopt a stochastic cost frontier approach to estimate the efficiency differences across hospital types. A complementary analysis with GLS estimation has been used to confirm the results. In this section, the adopted functional form and the econometric specification are discussed.

Functional form

Griffin et al. [12] provide a comprehensive list of alternative functional forms and proposed a series of criteria for model selection in cost and production analyses. In this study the most important restrictions are related to the sample size and the estimation method. As the number of variables increase, most functional forms require a geometrically increasing number of parameters to be estimated, thus necessitate much larger samples. The best choice is therefore a functional form that can be estimated with available estimation procedures and limits the number of parameters while using as many relevant variables as possible. One of the most commonly used functional forms is the Cobb-Douglas (log-linear) model. Using this form the cost function with M outputs, N input factors and K output characteristics can be written as:

$$\ln TC = \beta_0 + \sum_{m=1}^{M} \beta_m \ln Y_m + \sum_{n=1}^{N} \gamma_n \ln P_n + \sum_{k=1}^{K} \omega_k Z_k \qquad (1)$$

where TC is the total costs; Y_m (m=1, … , M) are the outputs; P_n (n=1, …, N) are the input factor prices; and Z_k (k=1, ... , K) are output characteristics and other exogenous factors that may affect costs.

Thanks to its limited number of variables the Cobb-Douglas form has a practical advantage in regards to estimation and interpretation, over more complicated forms. Because of its simplicity, this functional form is commonly used in recent papers on cost-efficiency measurements [1,4,13,14]. The main shortcoming of this model is the assumption of constant scale elasticity, which implies a constant rate of scale economies. This is considered as restrictive because by using the same proportional increase in output, small companies usually gain more than large firms. On the other hand, in many cases, the scale elasticity could be more or less constant in the range of observed data.

The potential changes in scale elasticity with output can be analyzed using flexible functional forms such as translog. However, a translog model requires the estimation of a large number of parameters. As we will see later there are at least 15 important variables that are essential for our cost models and the number of parameters in more general functional forms can be excessively high compared to our limited sample size. Furthermore, the included interaction terms could cause multicollinearity, which can affect the model's statistical performance. Our preliminary analyses showed that a numerically feasible estimation of a translog cost frontier with non-degenerate stochastic components was only possible with simplified specifications that excluded some of the important output characteristics. We therefore decided to focus on the Cobb-Douglas functional form. Nevertheless our main results especially those related to scale economies are also confirmed by an additional analysis with a parsimonious translog model with homothetic cost function.

Resulting from a minimization problem given input prices and output, cost functions must be non-decreasing, concave, linearly homogeneous in input prices and non-decreasing in output [15]. The linear homogeneity constraint is usually imposed by dividing total costs and input prices by one of the factor prices. However, as we see later, we do not impose this restriction because our models do not include all input factors. Other theoretical restrictions are usually verified after the estimation. In particular, the concavity of the estimated cost function reflects the fact that the cost function is a result of cost minimization.

Cost frontier models also allow an estimation of scale efficiency. Scale efficiency indicates the degree to which a company is producing at optimal scale, namely, the output level that minimizes the average cost. The optimal scale is defined as the level of operation where the scale elasticity is equal to one [16]. The degree of returns to scale (RS) is defined as the proportional increase in output (Y) resulting from a proportional increase in all input factors, holding all input prices and output characteristic variables fixed [17]. The *RS* degree may also be defined in terms of the effects on total costs resulting from a proportional increase in output [18]. This is equivalent to the inverse of the elasticity of total cost with respect to the output, which can be obtained from: $RS = 1 \Big/ \left(\frac{\partial \ln TC}{\partial \ln Y} \right)$. *TC* and *Y* represent the hospital's total cost and output respectively. The firm operates at increasing returns to scale if *RS* is greater than 1, indicating unexploited scale economies, in which case the average costs can be reduced by increasing the output. The company's optimal size (output) can be obtained when scale economies are fully exploited that is, *RS* = 1.

Econometric models

There are a number of econometric approaches to estimate stochastic cost frontier models [19]. The original cost frontier model [20] applied to panel data can be written as:

$$\ln TC_{it} = f(Y_{1it}, \ldots, Y_{Mit}; P_{1it}, \ldots, P_{Nit}; Z_{1it}, \ldots, Z_{Kit}) + u_{it} + v_{it} \quad (2)$$

where subscripts i and t represent the firm and year respectively; u_{it} is a positive stochastic term representing inefficiency of firm i in year t; v_{it} is the random noise or unobserved heterogeneity; and other variables are similar to those in Equation (1). Typically, it is assumed that the heterogeneity term v_{it} is normally distributed and that the inefficiency term u_{it} has a half-normal distribution that is, a normal distribution truncated at zero:

$$u_{it} \sim \left| N(0, \sigma_u^2) \right|, \quad v_{it} \sim N(0, \sigma_v^2). \quad (3)$$

The firm's inefficiency is estimated using the conditional mean of the inefficiency term as proposed by Jondrow et al. [21] that is: $\mathrm{E}\left[u_{it} \left| \hat{\varepsilon}_{it} \right.\right]$, where $\varepsilon_{it} = u_{it} + v_{it}$.

Assuming a time-invariant inefficiency term u_{it}=u_i, this term can be identified by panels' individual fixed or random effects [22,23]. The resulting specifications relax the distribution assumptions on stochastic terms, in particular in the fixed effect specification the individual firm effects (u_i) do not need to be uncorrelated with explanatory variables. Several authors have extended the above panel data models to include time-variant inefficiency [24-26]. Others [13,27-31] have adopted another approach in which a stochastic firm-specific term (fixed or random effect) is added into the original stochastic frontier model presented in Equation (2). This approach allows a distinction of unobserved time-invariant heterogeneity across firms from the time-variant differences that are interpreted as inefficiency. Such a distinction is particularly important in hospital cost functions which are characterized by strong unobserved heterogeneity associated with case mix and quality differences, many of which are hospital-specific and would not change considerably over time. Failure to account for such differences could result in overstating inefficiencies.

In particular the random intercept frontier model ('true' random effects frontier model) proposed by Greene [13,31] has been successfully used in other sectors like nursing homes [10] and public transport [11]. This model can be written by adding an firm-specific stochastic term $\alpha_\mathrm{i} \sim N(0,\sigma_\alpha^2)$, on the right-hand-side of Equation (2). As opposed to alternatives with fixed effects, this model does not have the incidental parameters problem. The main difficulty of this model is in its numerically cumbersome estimation method. As the likelihood function does not have a closed from, this model is estimated using Simulated Maximum Likelihood (SML) estimation method, in which the random effects (α_i) are simulated by random draws. Because of non-linearity of errors in the number of simulations, the SML estimators require a large number of simulations or might show sensitivity to the draws [32].

In this paper, we use the Greene's true random effect frontier model that we label as TRE. We use pseudo-random Halton draws to minimize the potential sensitivity of the results to simulation process. Number of draws has been fixed to 1000. Our sensitivity analysis using several options suggested that the estimations are not sensitive when the number of draws is higher than a few hundred. The inefficiency is estimated using the (simulated) conditional mean of the inefficiency term (u_{it}) given by $\mathrm{E}\left[u_{it} \,|\, \hat{\omega}_{it}\right]$, where $\omega_{it} = \alpha_i + u_{it} + v_{it}$ [33]. In addition to the true random effects (TRE) model, we estimated the original pooled frontier model as shown in Equation (2). The inefficiency estimates obtained from these two models complement each other. Namely, TRE estimates are expected to be at the lower bound of inefficiencies as unlike the pooled model's estimates, they are abstracted from potential persistent inefficiencies that remain more or less constant over time.

Differences across ownership/subsidization types

Although, economic theory predicts lower costs for organizations with relatively high-powered financial incentives such as for-profit and non-subsidized firms, the empirical literature does not provide a strong evidence of such differences in hospitals. While many authors [2,34] conclude no significant differences, a few studies [35,36] report evidence of slightly lower costs in for-profit hospitals compared to non-profit ones. In this paper, the effects of ownership/subsidization status on efficiency are studied using a two-stage method. This method is based on testing the significance of efficiency differences across hospital groups. We use the Kruskal-Wallis (KW) rank test [37] as well as the t-test with unequal variances. The KW test is a non-parametric test that has been often used in frontier analysis [38,39]. The two-stage approach has a disadvantage in that the first-stage estimation errors may affect the results of the test in the second-stage. These errors may lead to an under-rejection of the null hypothesis postulating similar cost-efficiencies across different categories [39]. On the other hand, the two-stage approach allows the use of non-parametric statistical tests that do not impose any distribution assumption on the efficiency scores. The KW test has an additional advantage in that it relies on efficiency ranks rather than efficiency magnitudes that are subject to relatively large estimation errors and sensitive to outlier values.

An alternative approach is to include type indicators in the regressions and test the significance of the corresponding coefficients. We performed a GLS estimation of this alternative specification to confirm the KW results. Given that the hospital types are more or less constant over the sample period, the tests could also be performed on the hospital average values over the sample period. Our data show that the subsidization status has not changed over the sample period and out of the 150 hospitals in the sample there are only 9 hospitals whose ownership status has changed from one year to another. However, our analysis shows that the results of the tests would not change significantly, should the tests be performed on hospital average values over the sample period.

3. Model specification

The specification used in this study is based on two main outputs: hospitalizations and outpatient (ambulatory) care. In line with many other papers in the literature [4,5,40] the main measure of hospitalization output is taken as a DRG weighted number of hospitalizations. We prefer this approach over the alternative in which the hospitalizations are classified into a few output categories based on their DRG weights [41], mainly because such categories might be arbitrary as the DRG weights define the cost intensity of the cases rather than different service categories.

Since the number of outpatient cases is not available in the data, the ambulatory output is approximated by the corresponding revenues adjusted for inflation. This approximation is based on the assumption that the average unit price of ambulatory care is similar across hospitals. The reported zero values for ambulatory revenues (2 hospitals) have been substituted by the nominal value of 1 Franc. Given the negligible number of the zero values, we preferred this approach [42,43] over more elaborate solutions such as Box-Cox or hybrid functional forms [44]. Three input factors are considered: capital, physicians' input and all other employees' labor. Similar to several other studies [5,45-46], capital prices are approximated by the hospital's total capital expenditure divided by the number of available beds in the hospital.

In line with many authors [2,8,34,47,48] who have considered labor inputs in two or more categories, physicians and non-physicians are considered as two separate labor inputs. In fact physicians' services constitute of interventions for medical treatments while other employees' services are more continuous and aimed at nursing care, administration and maintenance. Furthermore, wages are considerably higher and more variable among physicians than other employees. Labor prices are calculated by dividing total salaries by the number of remunerated days. Only employed physicians are considered. The physicians' fees accounting on average for about 5% of the hospital's total costs, might also include payments to physicians who are not employed by the hospital, thus are not included. Both labor prices are proportionally adjusted for social benefits, accounting on average, for about 9% of total costs. These charges are proportionally distributed to each one of the two groups (physicians, non-physicians), the proportions being the respective shares of each group's salaries. This adjustment captures the potential variation in social benefits across hospitals due to differences in pension funds as well as the age and seniority of the employees mix.

The three input factor prices considered in the model correspond to about 70 percent of a hospital's total cost on average. The available data do not allow an appropriate calculation of the prices of remaining inputs such as medical materials, food, cleaning, water and power as well as physicians' fees and other personnel charges. Given that the model specification does not include all input prices, the linear homogeneity cannot be imposed. The excluded prices are obviously not constant and neglecting their variation could affect the estimation results. However, some of these variations are probably captured by the three included factor prices. For instance, physicians' fees are likely to be correlated with physicians' salaries. Another concern is the accuracy of the price data that may create bias in the price coefficients. However, other coefficients are not affected if these measurement errors and the unobserved factor prices are uncorrelated with explanatory variables.

Similar to previous studies [36,47,48] the average length of hospitalization has been included in the model. In addition to representing hospital's 'hotel services' like nursing care and accommodation [49], this variable provides an additional measure of severity of the case mix. It should be noted that the DRG adjustment is only an approximate way to control for severity variations. In fact, there are considerable variations among patients within a DRG, as indicated by the wide range of acceptable hospital stays provided by the Swiss AP-DRG [50]. Other characteristics in the model include the number of medical service centers, and the number of medicotechnical, therapeutic and infrastructure units. These variables represent the range of specializations offered in the hospital. The share of outpatient clinics (over all medical service centers) operated by the hospital is also included as a complementary measure of ambulatory output in the model. The level of hospital's teaching activities is measured by the total number of postgraduate medical training positions offered in the hospital and the share of the positions that are recognized by the Swiss Medical Association (FMH) in specialized categories. Moreover, the model includes the percentage of medical service centers that are accredited by FMH for specialized medical training.

Hospitals' costs can also be affected by quality of care. The evidence on the effect of quality measures on hospital costs is rather mixed. Some studies conclude that quality indicators do not have significant cost effects [3,5,51], whereas others suggest a significant effect for structural quality measures such as bed availability and the share of board-certified physicians [8]. This may be explained by the fact that the structural quality is usually easier to measure whereas other quality indicators especially outcome measures are prone to measurement errors and outside factors. In this paper we focus on structural measures of quality. In addition to the share of FMH-recognized medical units and training positions, we included the hospital's nurse per bed ratio to represent the quality of nursing care.

We also included two binary indicators for emergency room (ER) and geriatrics department. While emergency services are usually involved with relatively severe cases, geriatrics cases are less intensive in medical care thus less costly. Year dummies are included to capture the overall technological progress and the variation in unobserved variables such as potential differences in reporting procedures and data collection from one year to another.

The specification of the true random effects model can therefore be written as:

$$
\begin{aligned}
\ln TC_{it} = {} & \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln AMB_{it} + \gamma_1 \ln PK_{it} + \gamma_2 \ln PL_{1it} + \gamma_3 \ln PL_{2it} \\
& + \omega_1 \ln LOS_{it} + \omega_2 \ln NB_{it} + \omega_3 \ln MU_{it} + \omega_4 \ln TU_{it} + \omega_5 \ln NP_{it} \\
& + \rho_1 AMBC_{it} + \rho_2 FMH_{it} + \rho_3 AB_{it} + \delta_1 ER_{it} + \delta_2 GER_{it} \\
& + \delta_{99} Y99_t + \delta_{00} Y00_t + \delta_{01} Y01_t + \delta_{02} Y02_t + \delta_{03} Y03_t + \alpha_i + u_{it} + v_{it}
\end{aligned}
\tag{4}
$$

Subscripts i and t represent the hospital and year respectively. The stochastic components α_i, u_{it} and v_{it} respectively represent the hospital-specific random effect, inefficiency term and random noise: $\alpha_i \sim N(0,\sigma_\alpha^2)$, $v_{it} \sim N(0,\sigma_v^2)$ and $u_{it} \sim N^+(0,\sigma_u^2)$, as described in the previous section. Y is the DRG-adjusted number of hospitalizations; *AMB* the ambulatory revenue; *PK*, PL_1 and PL_2 are respective factor prices for capital, physicians and other employees; *LOS* is the average length of hospitalization; *NB* is the nurse per bed ratio; *MU* the number of medical units; *TU* the number of techno-medical, therapeutic and infrastructure units; *NP* the number of medical training positions; *AMBC* is the fraction of ambulatory clinics over all medical units; *FMH* is the fraction of medical units recognized by FMH; *AB* is the fraction of medical training positions recognized by FMH in the two highest categories; and *ER* and *GER* are dummy variables for emergency room and geriatrics department respectively. Finally, *Y*99 through *Y*03 are year dummies for 1999 through 2003, with 1998 being the omitted year. The pooled model is a special case of Equation (4), in which the stochastic component α_i is set equal to zero.

4. Data

The data used in this paper are extracted from the annual financial and administrative data reported by general hospitals to the Federal Statistical Office [52] from 1998 to 2003. These data have been merged with another data set consisting of an aggregate extraction of the medical data of the Swiss hospitals with records for individual hospitalizations [53]. The extracted medical data consist of the number of cases by AP-DRG in each hospital-year, including about a million observations. Using the cost weights from Swiss AP-DRG version 4.0 [50], we calculated an average cost weight (AP-DRG adjustment ratio) for each hospital-year. The adjusted number of admissions is then calculated by multiplying these average cost weights by the number of admissions recorded in the administrative data.

After excluding the observations with missing and invalid values from an unbalanced panel with 1082 observations from 221 general hospitals, the final sample was created with 632 observations from 150 hospitals operating from 1998 through 2003. The excluded observations are mainly those with missing DRG data or erroneous values for outpatient revenues. We also excluded three hospitals with fewer than 20 beds. In general, the excluded observations with missing or suspicious values include higher proportion of small-size hospitals. Statistical tests (t-test) suggest that the excluded observations are from hospitals with significantly lower number of beds (an average of 110 beds against 211 beds for the hospitals included in the sample). However, similar tests suggest that there is no significant difference regarding average cost of a hospitalization across the two groups. Therefore, we assert that the resulting sample remains more or less representative of the Swiss general hospital sector. The sample also includes all the five university hospitals in Switzerland.

A descriptive summary of the variables used in the analysis is given in Table 1. As this table shows there is a considerable variation among hospitals in most variables. While hospital capacity varies from 20 to about 1200 beds, the average cost of a hospitalization varies from 4,500 to 54,000 Francs. The average length of hospitalization also varies considerably across hospitals ranging from 4 to about 50 days.

The number of general hospitals in the sample and their average capacity by ownership/subsidy types are listed in Table 2. All public hospitals and most private non-profit hospitals are subsidized, whereas in the private for-profit sector, a large fraction of hospitals are not. Table 2 also lists the average hospital size measured by the number of beds for each ownership/subsidy type. Public hospitals with an average of 258 beds are by far the largest providers of health care in the sample. Subsidized hospitals are also considerably larger than non-subsidized ones.

Table 1: Descriptive statistics

	Mean	Std. Dev.	Min.	Max.
Hospital's total costs (CHF '000)	85'720	138'909	5'036	884'764
Number of hospitalizations	7'467	7'784	367	50'774
Number of hospitalizations (AP-DRG adjusted)	6'486	7'791	208	49'251
Average total cost per hospitalization (CHF '000)	10.15	4.51	4.39	53.78
Average AP-DRG cost weight	0.8213	0.1124	0.5204	1.4735
Number of patient-days	62'682	62'975	4'997	410'140
Average length of hospitalizations (days)	10.1	5.2	3.9	49.1
Average length of full hospitalizations (days) [a]	11.1	5.1	4.5	49.1
Hospiatl's outpatient revenues (CHF '000)	12'759	21'725	0	144'802
Hospital capacity (number of beds)	211.5	219.1	20	1277
P_K *(capital price) CHF '000 per bed*	24.75	23.58	3.08	242.57
P_L *- physicians* [b] *(CHF per day)*	345.93	134.59	93.22	1'044.49
P_L *- other employees* [c] *(CHF per day)*	177.42	32.86	76.82	320.02
Nurse per bed ratio	1.357	0.505	0.474	4.410
Number of hospital's medical service centers	31.6	16.9	4	81
Number of hospital's non-medical units [d]	31.7	7.3	9	48
Number of postgraduate medical training position	45.0	94.9	1	583
Fraction of ambulatory clinics in medical units	0.1204	0.0825	0	0.4286
Fraction of medical units recognized by FMH	0.2338	0.1910	0	0.8571
Fraction of accredited training positions (FMH types A and B)	0.6050	0.3579	0	1

- The sample includes 632 observations from 150 general hospitals (1998-2003).
- All monetary values are adjusted by the global consumer price index relative to 2003 prices.
- Semi-hospitalizations (shorter than 24 hours) are considered as one-day hospitalizations.

[a] Excludes semi-hospitalizations (over-night hospital stays shorter than 24 hours).
[b] Employed physicians' average salary, adjusted for social benefits and excludes fees.
[c] Average salary (adjusted for social benefits) of all hospital employees except physicians.
[d] Includes medicotechnical, therapeutic and infrastructure units.

Table 1: Descriptive statistics (continued)

	Mean	Std. Dev.	Min.	Max.
Emergency Room	0.9177	0.2750	0	1
Geriatrics	0.5285	0.4996	0	1
Year 1998	0.1108	0.3141	0	1
Year 1999	0.1566	0.3638	0	1
Year 2000	0.1851	0.3887	0	1
Year 2001	0.1867	0.3900	0	1
Year 2002	0.1883	0.3913	0	1
Year 2003	0.1725	0.3781	0	1
Private for-profit Hospital	0.0965	0.2955	0	1
Private non-profit hospital	0.3307	0.4708	0	1
Public hospital	0.5728	0.4951	0	1
Subsidized hospital	0.9098	0.2867	0	1
University hospital	0.0380	0.1913	0	1

- The sample includes 632 observations from 150 general hospitals (1998-2003).

Table 2: Number of hospitals and average size by ownership/subsidy (1998-2003)

		PUBLIC	PRIVATE NON-PROFIT	PRIVATE FOR-PROFIT	TOTAL
SUBSIDIZED	Hospitals	362	175	38	575
	Hospital size (beds)	*258*	*155*	*194*	*222*
NON SUBSIDIZED	Hospitals	-	34	23	57
	Hospital size (beds)		*80*	*133*	*101*
TOTAL	Hospitals	362	209	61	632
	Hospital size (beds)	*258*	*143*	*171*	*211*

5. Results

Table 3 lists the regression results of the cost frontier analysis as presented in Equation (4). The estimated coefficients generally have the expected signs and mostly statistically significant. Overall, the differences across the two models, while being statistically significant, are not much considerable for practical purposes. According to the TRE model the main output's coefficient is 0.64, that is, 1% increase in the adjusted number of hospitalization will result in about 0.64% increase in total costs. As expected, the coefficient of ambulatory output is much smaller (.10), suggesting a 0.1% rise in total costs as a result of 1% increase in outpatient revenues, *ceteris paribus*. The estimated coefficient of LOS (.4) suggests that this variable is an important predictor of hospital costs. For instance, a 1% increase in the average length of hospitalization results in a 0.4% increase in total costs. Given that hospital stays are on average about 10 days, this implies that a difference of one day in the hospital's average LOS is approximately equivalent to 4% of total costs. In the pooled model, LOS shows a greater effect (.53). This could suggest that this variable may also capture some of the unobserved severity differences among hospitals.

Table 3: Estimation results

	Pooled Model	True RE Model
Number of hospitalizations (AP-DRG adjusted)	0.7447 *	0.6373 *
	(0.016)	(0.0049)
Average length of all hospitalizations	0.5293 *	0.3968 *
	(0.021)	(0.0062)
Outpatient revenues	0.0652 *	0.0998 *
	(0.0067)	(0.0018)
P_K *(capital price)*	0.1452 *	0.1174 *
	(0.010)	(0.0031)
P_L *- physicians*	0.1022 *	0.0335 *
	(0.019)	(0.0059)
P_L *- others*	0.2471 *	0.1537
	(0.045)	(0.013)
Nurse per bed	0.2730 *	0.1405 *
	(0.028)	(0.0083)
Number of medical units	0.0746 *	0.0797 *
	(0.016)	(0.0048)
Number of non-medical units	-0.0141	0.0878 *
	(0.040)	(0.012)
Number of training positions	0.1109 *	0.0921 *
	(0.012)	(0.0034)
Fraction of ambulatory clinics	-0.2685 *	-0.3520 *
	(0.076)	(0.023)
Fraction of medical units recognized by FMH	0.0433	0.0695 *
	(0.040)	(0.012)
Fraction of training positions A and B	0.0483	0.0147
	(0.026)	(0.0078)
Emergency Room	-0.0277	0.0467 *
	(0.024)	(0.0076)
Geriatrics	-0.0375 *	-0.0263 *
	(0.014)	(0.0041)
Year 1999	-0.0166	-0.0065
	(0.022)	(0.0070)
Year 2000	0.0175	0.0182 *
	(0.022)	(0.0065)
Year 2001	0.0335	0.0459 *
	(0.022)	(0.0065)
Year 2002	0.0485 *	0.0658 *
	(0.022)	(0.0064)
Year 2003	0.0560 *	0.0710 *
	(0.022)	(0.0066)
Constant (α)	-0.1378	1.4234 *
	(0.27)	(0.078)
σ_α	-	0.1703 *
		(0.0023)
σ [where: $\sigma^2=\sigma_u^2+\sigma_v^2$]	0.1902 *	0.0890 *
	(0.00024)	(0.0018)
$\lambda=\sigma_u/\sigma_v$	1.4544 *	1.7992 *
	(0.13)	(0.10)
Log Likelihood	336.08	598.03

* Significant at 5%; Standard errors are given in parentheses; Dependent variable is hospital's total costs in logs; All variables except dummies and the three fractions are in logarithms.

As expected, the price coefficients are positive and significant. However, these estimates significantly differ from the average actual share of the corresponding input factors (about 7, 11 and 53 percent for capital, physician services and other employees). This result can be related to the fact that because of labor contracts and other institutional restrictions hospitals are not fully responsive to changes in labor prices. As for quasi-fixed factors like capital stock, hospitals cannot change their allocations quickly. This might imply that hospitals do not completely minimize their total costs. However, as all hospitals face more or less similar constraints, we can assume that their cost frontiers follow a similar form. It should also be noted that hospitals might have other objectives in addition to cost minimization, in which case functions based on cost optimization can still be used as a "behavioral" cost functions and can be helpful in studying the firms' behavior rather than their production technological characteristics [49,55].

As seen in Table 3, the number of hospital units has a significant effect on total costs. The numbers suggest that increasing the number of medical centers by 10 percent would result in only about 0.8% increase in total costs. The marginal cost of training positions is also low but statistically significant. The results predict an average increase of 0.9% in total costs for 10% increase in the number of positions. The share of ambulatory clinics has a negative and significant effect, consistent with the fact that ambulatory visits are usually less costly than inpatient care. The TRE model suggests that for instance, an increase of 10 percentage points in the share of ambulatory clinics thus 10 points decrease in the share of inpatient units, results in a decrease of about 3.5% in the hospital's total costs. The share of specialized training positions has a positive effect on hospital's costs, but this effect is only significant at 10% level. However, the fraction of medical centers with FMH recognition has a significant effect on total costs. According to TRE model's estimates, the marginal cost of 10 percentage point increase in this fraction is about 0.7% of the hospital's total costs.

The nurse per bed ratio has a relatively high and significant effect, indicating that the cost of nursing care is quite considerable. As expected, the ER dummy has a positive coefficient and the geriatrics dummy has a negative effect. The coefficients of the year dummies suggest a positive growth in hospital costs starting from 2000, with an average annual rate of 1 to 3 percent.

Regarding scale economies, the results listed in Table 3 indicate a main output coefficient of 0.64 to 0.74, suggesting that the returns to scale are on average significantly higher than 1 (from 1.3 to 1.6 depending on the model). This suggests that the majority of general hospitals in Switzerland do not fully exploit the potential scale economies. However, it should be noted that these economies are likely to be marginal for large hospitals with more than 130 to 200 beds [47,56-58].

Overall cost-efficiency

Table 4 provides a descriptive summary of the inefficiency scores estimated by the two models. The pooled model's estimates are (12% inefficiency on average) higher than those of the TRE model (6% on average). Taken literally, these results suggest that on average, one can reduce the hospital costs by 6 or 12 percent. These results are in general lower than the inefficiency estimates reported in previous studies for the Swiss hospitals [1,2,59]. However, the differences can be explained by several additional characteristics included in this paper, such as teaching and specialization variables, and/or a different methodology in separating random noise from inefficiency differences.

Table 4: Descriptive summary of inefficiency estimates

Model	**Mean**	**Std. Dev.**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Pooled	0.1242	0.0661	0.0323	0.0792	0.1100	0.1513	0.5239
True RE	0.0601	0.0332	0.0149	0.0389	0.0521	0.0723	0.2880

The inefficiency estimates are in general comparable to similar estimates reported in the literature for the US hospitals, ranging from 5 to 15 percent [3,8,34], but differ from other studies particularly those on European samples, which estimate generally higher levels of inefficiency amounting to 20 to 30 percent [4,45,46,59,60]. It should be noted that even the seemingly low values estimated from the TRE model are equivalent to considerable excess costs amounting, for instance in 2003, to about 630 million Francs out of the actual total costs of 11 billion Francs for the 150 hospitals in the sample. The 6 percent average inefficiency is also equivalent to 2 or 3 years efficiency lag according to the efficiency targets set by the UK health care authorities, based on an annual efficiency gain of about 2 to 3 percent [61].

The inefficiency scores obtained from the two models are significantly correlated with a correlation coefficient of 0.50. As expected the TRE model that accounts for hospital-specific unobserved factors, produces a lower level of inefficiency. This suggests that these factors could account on average, for about 6 percent of the hospital's total costs. The inefficiency estimates based on the TRE model are valid if all the hospital-specific (time-invariant) effects are due to external factors beyond the hospital's control. In this case, the inefficiency is limited to 6% on average. On the other hand, if time-variant differences and hospital-specific effects are not separated, as in the pooled model, the average inefficiency amounts to 12%. According to this model, a quarter of the studied hospitals show 15% or more excess costs. However, the inefficiency is less than 11 percent for half of the sample and the excess costs are rarely more than 20 percent.

The TRE model's estimates do not include the persistent inefficiencies that might stay constant over time. In fact in this model the persistent excess costs are assumed to be related to external factors rather than inefficiency. This model assumes that, with managers constantly facing new market conditions and technologies, inefficiencies vary with time, whereas some of the external factors that are beyond the management's control such as hospital location and case mix remain more or less constant. It is difficult to assess the validity of this assumption in the context of Swiss hospitals, in which certain inefficiencies may persist because of institutional restrictions and strong regulation. Therefore, we cannot favor any model over the other. We contend that the two estimates (6% and 12%) could represent reasonable lower and upper bounds for the average inefficiency in Swiss hospitals.

Cost-efficiency in university hospitals

The estimation results suggest that university hospitals are on average less efficient than other hospitals. However, this difference is not statistically significant in the TRE model. Excepting the university hospitals the average efficiency estimates do not show any significant changes over time. University hospitals however show a different pattern with a relatively high inefficiency in the first years (1998 to 2000) and a decreasing trend over the sample period (Figure 1).

Several t-tests on the university hospitals' efficiency scores across different years suggest that the efficiency improvement in university hospitals is statistically significant. According to these estimates, from 1998 to 2003, university hospitals have considerably reduced their excessive costs. The estimated decrease in inefficiency score is 10 percentage points (from 24% to 14%) in the pooled model and about 4 points (from 10% to 5.5%) in the TRE model. Part of these changes could be explained by the variation of case mix severity. In fact, the trends in AP-DRG cost weights suggest that the severity of the patient mix has grown relatively more in university hospitals (Figure 2). Over the sample period the average cost weight for university hospitals has increased from 0.99 to 1.17 whereas the corresponding change in other hospitals is from 0.78 to 0.84. Given that in Switzerland, DRG coding has been introduced in 1998, some of such increases might be related to changes in the quality of DRG coding especially in university hospitals that, having relatively severe cases, require a more elaborate coding practice. In this case the observed changes in efficiency of university hospitals could be an artifact of a different DRG coding.

In order to explore the relationship between changes in severity and inefficiency, we estimated another model similar to Equation (4), with the only difference that the number of admissions is not adjusted for AP-DRG cost weights. The inefficiency estimates of this analysis still show a slight but significant improvement (about 2 or 3 percentage points) in university hospitals over the sample period. These results indicate that part of efficiency gains in university hospitals could be related to the fact that these hospitals increasingly treat more severe cases. However, even if we assume that the observed severity trends are entirely related to gradual effect of better coding practices, the results still indicate that on average university hospitals have improved.

Figure 1: Efficiency trend in university hospitals

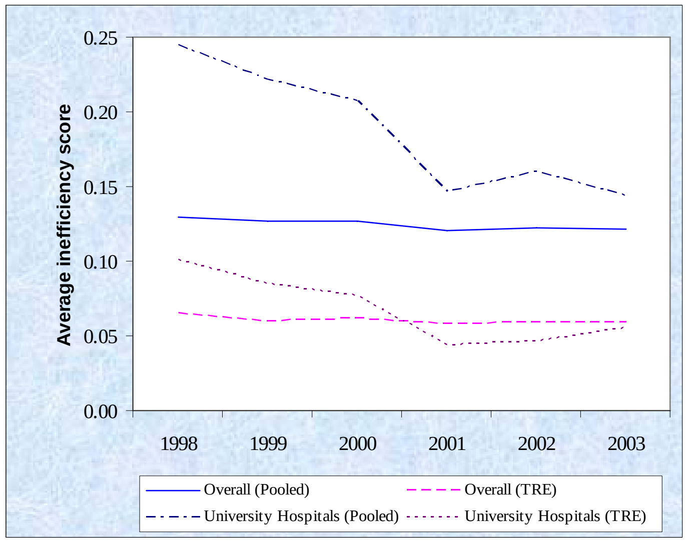
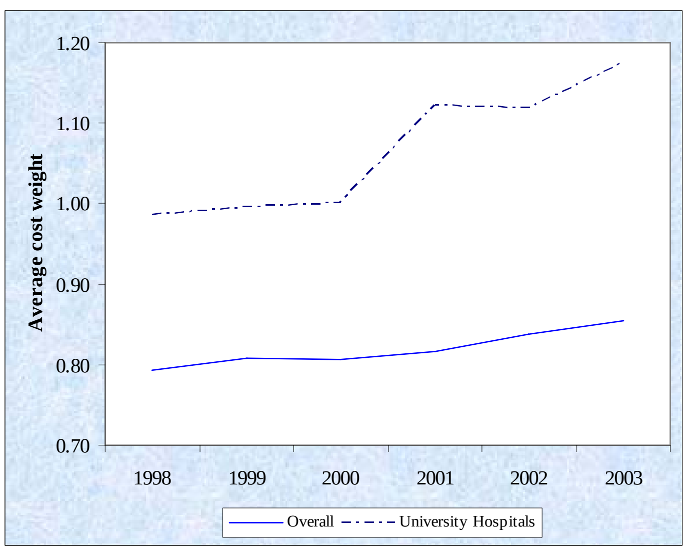


Figure 2: Average AP-DRG cost weight



Effects of ownership/subsidy types

The average inefficiency estimates are listed by ownership and subsidization categories in Table 5 and Table 6 respectively for the pooled and TRE models. These results point to some differences among various hospital types. The main observed difference is between subsidized and non-subsidized hospitals, suggesting a higher level of efficiency for the former group. We explored the significance of these differences with several Kruskal-Wallis and t-tests. Several possible groupings have been considered. In summary, the TRE model's inefficiency estimates do not show any statistically significant difference across hospital types. The estimates obtained from the pooled model are significant at 10% level only for two cases, suggesting respectively a higher efficiency in favor of subsidized versus non-subsidized hospitals and non-profit versus for-profit hospitals. Overall, the results do not provide any conclusive evidence of significant difference across ownership/subsidy types.

Given that these tests are performed on the efficiency estimates, there is a possibility that estimation errors of the efficiency scores mask the differences across hospital types, resulting in under-rejection of the null hypothesis. Therefore, in a complementary analysis, we estimated a GLS random-effect model based on the specification given in Equation (4), with three additional dummies respectively for subsidized, for-profit and non-profit hospitals. The results of this regression are listed in the appendix (Table A.1). All three dummies proved to be insignificant, suggesting that after controlling for other factors, subsidization and ownership do not have any significant effect on hospital costs. This conclusion is consistent with the results reported in previous studies [1,2].

It should be noted that the above results are based on the assumption that input prices especially capital prices are exogenous. One of the main differences across different ownership/subsidy types is related to their access to capital resulting in relatively high capital prices for non-subsidized and for-profit hospitals. Our additional analyses indicate that if capital prices are not included in the model, the inefficiency estimates could be significantly higher in non-subsidized and for-profit hospitals.

Table 5: Average inefficiency by ownership/subsidy type (pooled model)

	PUBLIC	PRIVATE NON-PROFIT	PRIVATE FOR-PROFIT	TOTAL
SUBSIDIZED	0.1241	0.1212	0.1130	0.1225
NON SUBSIDIZED	-	0.1559	0.1207	0.1417
TOTAL	0.1241	0.1268	0.1159	0.1242

Table 6: Average inefficiency by ownership/subsidy type (TRE model)

	PUBLIC	PRIVATE NON-PROFIT	PRIVATE FOR-PROFIT	TOTAL
SUBSIDIZED	0.0589	0.0607	0.0627	0.0597
NON SUBSIDIZED	-	0.0623	0.0665	0.0640
TOTAL	0.0589	0.0610	0.0641	0.0601

6. Conclusions

A stochastic total cost frontier has been estimated for an unbalanced panel of 150 Swiss general hospitals over the six-year period from 1998 and 2003, including 632 observations. The adopted specification is based on the Cobb-Douglas functional form with the hospital output considered in two groups: inpatient cases adjusted by the average AP-DRG cost weights and ambulatory output measured by corresponding revenues. A number of output characteristics such as average length of stay and the number of ambulatory clinics as well as teaching characteristics are included in the model.

The regression results point to considerable unexploited scale economies in a majority of the studied hospitals. The results also confirm several findings reported in previous studies. Namely, the length of hospital stays has an important marginal cost suggesting that hospitals with long hospitalizations can achieve considerable savings by curtailing lengthy hospital stays. The marginal cost of ambulatory care is about less than a tenth of that of inpatient care. Moreover, costs also depend on the type of care provided. For instance, hospitals with emergency care have higher costs and those with a geriatrics department have lower costs than comparable facilities.

The results also indicate that hospitals with a greater number of medical units are relatively more costly. This implies that hospitals with a wide range of specialization are more costly than those that specialize in fewer services. However, the cost differences resulting from specialization are limited to a few percentage points for a relatively large change in the number of services. Hospitals with more ambulatory clinics are significantly less costly than similar hospitals. The results suggest a considerable marginal cost for graduate medical training positions, which is more or less comparable to that of ambulatory output. As expected, the quality of medical units for teaching purposes has a positive effect on hospital costs.

The observed trends in the data indicate that over the study period, the average AP-DRG cost weight of Swiss hospitals has consistently grown at a rate of about 1 percentage point per year, suggesting that the patient case mix treated in hospitals has become more severe. The estimations suggest that after accounting for these changes in average severity, the total costs still show an increase of about 1.5 percent per year in a typical general hospital. Overall, we can conclude that over time, the Swiss general hospitals have increasingly treated more severe cases with disproportionately higher costs. This can be partly explained by technological progress, which enables the hospitals to provide more complex thus more costly medical interventions. Such changes are only partially captured by variation of cost weights between different AP-DRG categories. Another explanation could be because of the commonly observed growth in costs of labor-intensive services due to increasing wages and social benefits which is not fully captured by labor prices in two labor categories included in the model.

The results suggest that the considerable excess costs of university hospitals, estimated in previous studies, can be explained by more extensive teaching activities in those hospitals as well as the relatively high quality of their medical units for teaching purposes. However, our analysis indicates that even after controlling for such differences university hospitals have shown a relatively poor cost-efficiency in the first two or three years of the sample period. The results also point to a statistically significant improvement of efficiency of university hospitals over the sample period such that the average efficiency difference with other hospitals has been negligible since 2001.

Our analysis indicates that the inefficiency estimates could significantly change depending upon whether the unobserved hospital-specific heterogeneity is considered as inefficiency or as external factors beyond hospital’s control. A typical hospital’s average excessive costs due to productive inefficiencies are estimated about 6 or 12 percent depending on the adopted assumption about hospital-specific persistent stochastic factors. While these factors are separated from inefficiency in the lower estimate (6 percent), the higher estimate (12 percent) does not exclude all these factors. Lacking any evidence in favor of either of these assumptions, we contend that the two estimates provide a reasonable lower and upper bounds for the average inefficiency score.

Finally, the effect of different regulatory systems on the hospital efficiency has been studied. The statistical tests do not provide any evidence of statistically significant efficiency differences across ownership and subsidization categories. This result has been confirmed by a panel data model that integrates the ownership/subsidy indicators. Lack of evidence for significant efficiency advantage of one type over another might be restricted to our data, thus should not be generalized. In fact, the potential correlation between hospital types and other cost driving factors might mask their actual ownership/subsidy effects.

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Appendix

Table A.1: Total cost function with a GLS model with random effects

	Model I	Model II
Private For-Profit	-	0.0144 (0.017)
Private Non-Profit	-	-0.0067 (0.018)
Subsidized	-	0.0626 (0.041)
Number of admissions (AP-DRG adjusted)	0.6313 * (0.017)	0.6293 * (0.017)
Average length of all hospitalizations	0.4001 * (0.020)	0.4020 * (0.020)
Outpatient revenues	0.1043 * (0.0079)	0.1042 * (0.0080)
P_K *(capital price)*	0.1195 * (0.0090)	0.1203 * (0.0092)
P_L *- physicians*	0.0342 * (0.013)	0.0334 * (0.013)
P_L *- others*	0.1828 * (0.030)	0.1831 * (0.030)
Nurse per bed	0.1515 * (0.020)	0.1510 * (0.020)
Number of medical units	0.0799 * (0.016)	0.0825 * (0.016)
Number of non-medical units	0.0948 * (0.037)	0.0921 * (0.037)
Number of training positions	0.0878 * (0.011)	0.0858 * (0.011)
Fraction of ambulatory clinics	-0.3276 * (0.072)	-0.3351 * (0.072)
Fraction of medical units recognized by FMH	0.0687 * (0.030)	0.0646 * (0.030)
Fraction of training positions A and B	0.0163 (0.016)	0.0136 (0.016)
Emergency Room	0.0472 (0.026)	0.0402 (0.027)
Geriatrics	-0.0300 * (0.013)	-0.0325 * (0.013)
Year 1999	-0.0111 (0.0086)	-0.0106 (0.0086)
Year 2000	0.0142 (0.0091)	0.0144 (0.0091)
Year 2001	0.0391 * (0.0087)	0.0396 * (0.0087)
Year 2002	0.0601 * (0.0091)	0.0592 * (0.0092)
Year 2003	0.0647 * (0.0097)	0.0639 * (0.0097)
Constant	1.3167 * (0.22)	1.2935 * (0.22)

* Significant at 5% or less.
Standard errors are given in parentheses; Dependent variable is hospital's total costs;
All variables except fractions and dummies are in logarithms.

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