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**AN ANALYSIS OF
EFFICIENCY AND PRODUCTIVITY
IN SWISS HOSPITALS ***

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ABSTRACT

This paper examines the productive efficiency of the hospital sector in Switzerland. A panel data of 214 general hospitals over the four-year period between 1998 and 2001 has been analyzed. A descriptive analysis of the data casts some light on differences across hospital types especially regarding case mix severity and length of hospitalizations. The final sample used for the cost frontier analysis consists of 459 observations from 156 hospitals that is, an unbalanced panel with an average length of three years. The adopted methodology is based on a stochastic total cost frontier with a Cobb-Douglas functional form. Given the limited number of periods and the sample's low within variation, a pooled cross-sectional model has been used. Several specifications have been considered. The main outputs are measured by the DRG-adjusted number of hospitalizations and the hospital's outpatient revenues. Services of capital, physicians and other employees are considered as input factors. The cost frontier analysis suggests a significant potential for improving efficiency. The results also point to unexploited scale economies in the majority of the sample. An analysis of inefficiency estimates indicates that the differences among various ownership-subsidization types are not statistically significant.

JEL classification: I180; I120; L330; L250

Keywords: Stochastic Frontier; Cost Efficiency; General Hospitals

1 Introduction

The health care expenditure is growing rapidly in Switzerland. During the five-year period between 1997 and 2002, the national level of health care costs has grown with an average annual rate of about 4.5% attaining about 48 billion Francs in 2002. General hospitals¹ incur a considerable part of health costs. In 2002, general hospitals (about 12.4 billion Francs) and specialized clinics (4.0 billion Francs) respectively accounted for about 25.8 and 8.3 percent of the total health care expenditures in Switzerland. In particular, the general hospitals sector shows an increasing growth rate rising from about 3.9 percent per year between 1997 and 1999 to an average of about 6.5 percent per year between 2000 and 2002. This increasing growth has raised the public interest in improving the performance of hospitals and determining the extent and identifying the sources of possible inefficiencies in this sector.

This paper studies the productive efficiency of the Swiss general hospitals. The financial data of 214 general hospitals over the four-year period between 1998 and 2001 are used. Specialized clinics are excluded from this study. After excluding the hospitals with less than twenty beds and the observations with missing and suspicious values, the final regression sample includes 459 observations of 156 general hospitals. The cost efficiency of hospitals is studied using stochastic cost frontier analysis.² Several specifications are considered and the results are compared. The efficiency estimates of individual hospitals are also analyzed to test whether hospitals with different ownership and subsidization types are significantly different regarding efficiency. The results suggest considerable savings could be achieved through improvement of hospitals' efficiency. On average, university hospitals and large regional facilities are the most costly providers. However, part of these cost differences could be due to higher expenses resulting from teaching and research activities. In small hospitals, one of the main sources of excessive costs is related to lengthy hospital stays. The inefficiency estimates do not provide any evidence of significant differences among hospitals with different ownership/subsidy types. The results also point to unexploited economies of scale.

The rest of the paper is organized as follows. Section 2 provides a general description of the cost frontier approach followed by a discussion of the adopted functional form and econometric specification. A descriptive analysis of the data is given in Section 3. Section 4 describes the model specification. The estimation results along with a discussion of cost and scale efficiency and the effects of ownership/subsidy types are presented in Section 5. Section 6 concludes the paper with a summary of the main results.

2 Methodology

There are several methods to estimate the cost efficiency of individual firms. Two main categories are non-parametric methods originated from operations research,

¹ In Switzerland hospitals are divided into two categories: general hospitals and specialized clinics. While general hospitals provide short-term medical care in any field, specialized clinics are restricted to one of the following care categories: psychiatrics, rehabilitation, surgeries, gynecology/neonatology, pediatrics, geriatrics, and other specialties. See SFSO (2001) for more details.

² The research project also includes estimation of simple indicators of efficiency and productivity. These results are not reported in this paper. See Filippini and Farsi (2004) for more details on these results as well as additional analyses of total factor productivity growth and short-term variable costs.

and econometric approaches namely stochastic cost frontier models.³ In non-parametric approaches like Data Envelopment Analysis, the cost frontier is considered as a deterministic function of the observed variables but no specific functional form is imposed.⁴ Moreover, non-parametric approaches are generally easier to estimate. Parametric methods on the other hand, allow for a random unobserved heterogeneity among different firms but need to specify a functional form for the cost function. The main advantage of such methods over non-parametric approaches is the separation of the inefficiency effect from the statistical noise due to data errors, omitted variables etc. Another advantage of parametric methods is that these methods allow statistical inference on the significance of the variables included in the model, using standard statistical tests. In non-parametric methods on the other hand, statistical inference requires elaborate and sensitive re-sampling methods like bootstrap techniques.⁵ Given the above discussion we decided to focus on the stochastic cost frontier models.

Many authors have used cost frontier models to evaluate hospitals' efficiency. Zuckerman et al. (1994), Linna (1998) are two examples. The former paper used a translog functional form while the latter used a Cobb-Douglas cost function. Rosko (2001) has also used the frontier approach with a translog cost function and with instrumental variables to account for the potential endogeneity of capital and labor prices. The use of cost frontier models to evaluate efficiency in the health-care sector has been criticized by Newhouse (1994) and Skinner (1994). The main arguments against these models are related to the unobserved heterogeneity due to differences in case-mix and quality and the errors committed by aggregation of outputs as well as non-testable assumptions on the distribution of efficiency.

Folland and Hofler (2001) provide a discussion on the reliability of hospital efficiency estimates obtained from stochastic cost frontier models. These authors show that the individual efficiency estimates are rather sensitive to the adopted model specification and functional form. However, the results are robust when the comparisons are performed between hospital group mean inefficiencies. This finding is consistent with the results reported by Hadley and Zuckerman (1994) suggesting that the stochastic frontier analysis of hospitals efficiency is of practical use when applied for comparing group means. Farsi, Filippini and Kuenzle (2003) reached a similar conclusion in their study of the Swiss nursing homes.

A frontier cost function defines minimum costs given output level, input factor prices and the existing production technology. Theoretically, the perfectly efficient production units are located at the frontier. In stochastic frontier approach it is assumed that the cost frontier can differ across production units. The difference between a firm's observed costs and its corresponding frontier costs is decomposed into two parts: The first part is a symmetric random error due to the unobserved differences between firms and the second component is related to the inefficiency of the firm. With certain assumptions on the distribution of these stochastic terms, individual inefficiencies can be estimated.

³ See Kumbhakar and Lovell (2000) for an extensive survey of parametric methods and Coelli et al. (1998), chapter 6, and Simar (1992) for an overview of non-parametric approaches.

⁴ See Coelli et al. (2003) for more details on DEA. See also Steinmann and Zweifel (2003) for an application of DEA to estimate the efficiency of Swiss hospitals.

⁵ These methods are available for rather special cases and have not yet been established as standard tests. See Simar and Wilson (2000) for an overview of statistical inference methods in non-parametric models.

Cost frontier models also allow an estimation of scale efficiency. Scale efficiency indicates the degree to which a company is producing at optimal scale. The optimal size of a firm is defined as the amount of output that minimizes the average cost of producing one unit of output. Frisch (1965) defines the optimal scale as the level of operation where the scale elasticity is equal to one. 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 (Caves et al., 1981). The *RS* degree may also be defined in terms of the effects on total costs resulting from a proportional increase in output (Silk and Berndt, 2003). This is equivalent to the inverse of the elasticity of total cost with respect to the output.⁶

Functional form

The cost frontier is a function of output and input factor prices. Other hospital and output characteristics like quality indicators can also be included as independent variables. Griffin et al. (1987) provide a comprehensive list of alternative functional forms. These authors have also proposed a series of criteria for selecting the functional form in cost and production analyses. These criteria can be grouped in four categories corresponding to hypotheses, estimation methods, data and application. The first category concerns the restrictions imposed by the maintained hypotheses. In the absence of such hypotheses the unrestrictive forms are more appropriate. Second, the availability of data may restrict the choice of statistical estimation procedures. 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 third criterion concerns the conformity of the functional form to the data. Finally, in some applications, some properties are desired in the functional form, because for instance they might be used in simulations.

In this study the most important restrictions are related to the sample size and the estimation method. 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. A Cobb-Douglas cost function with *M* outputs, *N* input factors and *K* output characteristics can be written as:

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

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.

The main advantage of this model is its simplicity. Thanks to its limited number of variables the Cobb-Douglas form has a practical advantage in statistical estimations over more complicated forms. The interpretation of the results is also easier because it

⁶ The inverse of cost elasticity of output is referred to by Chambers (1988), as the “economies of size” rather than economies of scale, which are defined in regards to production function. Scale and size economies are equivalent if and only if the production function is homothetic (see Chambers, 1988, page 72). However, as for the purpose of this study we are more interested in the cost effects of output, we define the returns to scale in terms of cost elasticity.

does not include any interaction term. Another interesting characteristic of this function is self-duality. Namely, the corresponding production function of a Cobb-Douglas cost function is also log-linear. The main shortcoming of this model is that the output elasticities, thus the scale economies are assumed to be constant. One can expect that the scale economies change with the output level. Using the same proportional increase in output, small companies usually gain more than large firms, by saving in their fixed costs. However, in some industries, it might be the case that the scale economies do not vary much in the range of observed data.

The potential changes in scale economies with output can be analyzed using flexible functional forms. One of the main flexible forms is transcendental logarithmic (translog) model. This model is a second-order Taylor approximation of any arbitrary function. However, a translog model requires the estimation of a large number of parameters. Furthermore, the included interaction terms could cause multicollinearity. These problems can substantially affect the model's statistical performance. As we will see later there are at least 15 important variables that are essential for our cost models. Compared to the sample size that is limited to about 500 observations, the number of parameters in more general functional forms can be excessively high. For instance the adopted specification with a general (non-homothetic) translog model could easily have more than 30 parameters. Moreover, the primary purpose of this study is hospitals' cost efficiency and the scale economies come only as secondary results. We therefore decided to focus on the Cobb-Douglas functional form.⁷ Because of its simplicity, this functional form is commonly used in recent papers on cost-efficiency measurements such as Greene (2003, 2004) and Linna (1998).

It is generally assumed that the cost function is the result of cost minimization given input prices and output. Cost functions should therefore satisfy certain properties.⁸ Mainly, the cost function must be non-decreasing, concave, linearly homogeneous in input prices and non-decreasing in output. The linear homogeneity constraint⁹ 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. The 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. This latter condition is automatically satisfied in Cobb-Douglas functional form.

Econometric specification

There are a number of econometric approaches to estimate stochastic cost frontier models. Kumbhakar and Lovell (2000) provide an extensive survey of these methods. A general form of a stochastic cost frontier can be written as:

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

⁷ We estimated several specifications with translog form. The results (not reported here) indicate that when applied to our data, these models tend to converge to solutions in which one of the stochastic components degenerates to zero.

⁸ For more details on the functional form of the cost function see Cornes (1992), p.106.

⁹ Linear homogeneity in prices means that if all input prices increase proportionally, the costs will increase with the same proportion. This condition implies that the coefficients of factor prices add to one.

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:

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

This model is based on the original cost frontier model proposed by Aigner et al. (1977). The firm's inefficiency is estimated using the conditional mean of the inefficiency term $E[u_{it} | u_{it} + v_{it}]$, proposed by Jondrow et al. (1982).

An important variation of this model is Pitt and Lee (1981)'s model in which the inefficiency term u_{it} is assumed to be constant over time, that is: $u_i \sim |N(0, \sigma_u^2)|$. There is also another version of this model (proposed by Schmidt and Sickles (1984)), that relaxes the distribution assumptions on both u_i and v_{it} , and estimates the model using Generalized Least Squares (GLS) method. The advantage of these models is that they use the panel aspect of the data to estimate the parameters. In cases where the individual firm effects (u_i) are correlated with the explanatory variables, the estimated parameters may be biased. Schmidt and Sickles (1984) proposed a fixed-effects approach to avoid such biases. In this model the inefficiency term is not random and is estimated as an intercept for each company.

There is however, an important practical problem with the fixed-effect model in that it requires the estimation of a large number of parameters, which limits its application to reasonably long panels with sufficient within-firm variation. Generally, in short panels the fixed effects are subject to considerable estimation biases, which directly reflect in the inefficiency scores.¹⁰ Given that our data is a rather short panel of four years, the fixed effects model is not a quite feasible approach. Moreover, our preliminary analysis shows that in virtually all the main variables, the between variations are dominant and the within variations are comparatively insignificant.¹¹

Another important issue is that in both fixed and random effects models discussed above, the inefficiencies are assumed to be constant over time. This is an unrealistic assumption in most practical cases, where the driving forces of cost-inefficiency are not generally persistent. In fact firms constantly face new problems¹² and revise their strategies. Moreover, there exist incentive mechanisms (either through regulation and monitoring or through profit and career incentives) that induce managers to correct their past suboptimal decisions.

Greene (2004, 2002b) proposes a new approach that integrates the random and fixed effects approaches into the original Aigner et al. (1977)'s model. These models are labeled as "true" random effects and "true" fixed effects models.¹³ These models can be written by adding a firm-specific stochastic term (α_i) in the right-hand-side of Equation 2. This term is an *i.i.d.* random component in random-effects framework, or a

¹⁰ See Greene (2004, 2002b) for more details. This author considers a panel of 5 years as a short panel.

¹¹ In contrast with "between" variations that are related to the differences across companies, "within" variations correspond to the changes in a given company over time.

¹² These problems may emerge from the implementation of new techniques, or from dealing with new regulation systems, or other external constraints.

¹³ See Farsi, Filippini and Kuenzle (2003) for an application in Switzerland's nursing homes.

constant parameter in fixed-effects approach. Such models have an important advantage in that they allow for time-variant inefficiency while controlling for firm-level unobserved heterogeneity through fixed or random effects. The main difficulty of these models is that they are numerically cumbersome. In particular, our experience suggests that in cases where the within variation in the data is low, these methods are numerically unstable. Our preliminary analyses show that with the available data, these models were not numerically feasible. This can be explained by the small number of periods in our sample and its relatively low within variations. As we see later in Section 3, our sample is an unbalanced data with maximum 4 periods but on average it has about three periods.

The data constraints and also the numerical restrictions bring us back to the original pooled frontier model in line with Aigner et al. (1977). However, we also estimated Pitt and Lee (1981)'s model and checked if the results are consistent. Our analysis (not reported here) indicates that in terms of scale economies the two models provide comparable results. In terms of efficiency estimates the results show a quite high correlation. However, the results estimated from Pitt and Lee's model were systematically higher than those of the pooled model. This difference can be explained by the fact that the inefficiency estimates from Pitt and Lee's model capture other sources of heterogeneity across hospitals that are not necessarily related to inefficiency. In fact our analysis suggests that the firm-specific effects capture a significant part of between variations in costs and reflect them as inefficiency. Given that there may be a great amount of unobserved heterogeneity among hospitals, we contend that these estimates are likely to be exaggerated. Therefore, we restricted our analysis to the pooled model as shown in Equation 2.

3 Data

The data used in this study are extracted from the annual data reported by Swiss general hospitals to the Federal Statistical Office from 1998 to 2001. The sample consists of an unbalanced panel with 747 observations from 1998 through 2001. According to these data, overall 214 general hospitals have operated in Switzerland during this period. In Switzerland, general hospitals are classified into five typologies based on size, number of departments and level of specialization. The details of this classification are given in SFSO (2001). A brief description of each hospital type is given in Table 1. Typology 1 includes only the five largest hospitals, which are affiliated to universities and provide a wide variety of services in a large number of specializations. At the other extreme, Typology 5 includes small general hospitals (mostly less than 100 beds), which provide basic medical care with few specializations. Accounting for more than 40 percent of Switzerland's hospitals, this category has the highest number of hospitals in the sample. Table 2 lists the number of general hospitals available in the data by year and hospital typology.

Table 1: General hospitals classification

Type	Code	Description	Hospitalization cases per year (F)
1	K111	University hospital	$F \geq 30,000$
2	K112	Large general hospital	$30,000 > F \geq 9,000$
3	K121	Large basic-care hospital	$9,000 > F \geq 6,000$
4	K122	Medium basic-care hospital	$6,000 > F \geq 3,000$
5	K123	Small basic-care hospital	$3,000 > F \geq 0$

Table 2: Number of general hospitals in Switzerland (1998-2001)

Type	Code	Year				Total
		1998	1999	2000	2001	
1	K111	5	5	5	5	20
2	K112	20	20	21	21	82
3	K121	27	28	29	30	114
4	K122	53	53	56	53	215
5	K123	86	89	73	68	316
Total		191	195	184	177	747

These data (administrative data) include variables such as total costs, total salaries and labor charges, hospital operating costs, capital expenditure, number of employees and paid hours, and number of hospitalizations. Capital costs are considered as the sum of the maintenance and repair costs for buildings and equipment, interest charges and all other investment charges and amortizations. Costs related to nursing staff's salaries and physicians salaries and fees are also given separately. These variables allow that salaries for physicians, nursing staff and other employees be calculated separately. Among other variables are the total hospital revenue from medical services and its outpatient-related part.

Another data set used in this study is an aggregate extraction of the medical data of the Swiss hospitals from 1998 to 2001 with records for each individual admission.¹⁴ The extracted data used in this study consists of the number of cases by AP-DRG¹⁵ in each hospital. These data were merged with the cost weights from Swiss APDRG version 4.0 developed by *Institut de Santé et d'Economie* (2003).¹⁶ These cost weights are used as an official reference for cost reimbursement in several Swiss cantons that have adopted a DRG-based reimbursement system. These data have been used to calculate an average cost weight (AP-DRG adjustment ratio) for each hospital-year. The adjusted number of admissions is then calculated by multiplying these adjustment ratios by the number of admissions recorded in the administrative data.¹⁷

The main trends in the number of hospitalizations are given in Table 3. This table shows that during the study period, while the number of hospitalizations has slightly increased (about 4%), the total number of semi-hospitalizations has significantly increased. Particularly, the semi-hospitalization cases have increased by about 35% from 1998 to 1999. Given that the distinction between full and semi-hospitalizations is not fully clear, more representative trend patterns can be seen through the numbers of admissions and patient-days.¹⁸ These numbers show that while the aggregate output of Swiss general hospitals have increased by about 10% in terms of admissions from 1998 to 2001, the number of patient-days has rather fluctuated around 9 million, suggesting shorter hospital stays over time. This pattern is confirmed by a continuous decrease in the average length of hospitalization from more than 12 days in 1998 to 10.7 days in 2001. The main observation here is the presence of a growing demand of hospital care shown by an overall increase in number of admissions. These numbers also point to a general trend in Switzerland's hospitals to limit the hospital stays and to favor the short-term treatments like one-day surgeries and other semi-hospitalizations, over long-term hospitalizations.

Table 3 also lists the total hospital costs in the general hospitals. These numbers point to a significantly increasing trend of 3 to 6 percent per year. The ambulatory revenues account for a considerable portion (about 13%) of total costs. The aggregate numbers do not show any significant in the share of ambulatory revenue over the study period. The average AP-DRG adjustment ratios are also given. These numbers do not change considerably over time. Finally, Table 4 indicates that the average size of general hospitals has slightly increased over the study period. This change can be explained by the decrease in the number of small hospitals (Typology 5) as shown in Table 2.

¹⁴ See SFSO (1997b) for more details on these data.

¹⁵ APR-DRG (All-Patients-Refined Diagnostic Related Groups) is a system of classification of diseases patented by 3M Health Information Systems www.3Mhis.com.

¹⁶ These cost weights were estimated based on a sample of about 200,000 acute short-term hospitalizations in 12 Swiss hospitals (including 3 university hospitals) during 1999-2001.

¹⁷ We observed some differences between the number of DRG records from the medical data and the number of hospitalizations from the administrative data, suggesting that some of the cases were not coded. Our method is based on the assumption that non-coded patients are not systematically different from the coded cases.

¹⁸ Usually, the planned hospitalizations of less than 24 hours such as one-day surgeries are referred to as semi-hospitalizations. See S.F.S.O. (1997) for more details. However, reporting an admission as semi- or full hospitalization is rather discretionary.

Table 3: Main trends in hospitalizations in Swiss general hospitals

	Year			
	1998	1999	2000	2001
Total number of full hospitalizations	918'972	938'525	972'244	955'729
Total number of semi-hospitalizations	114'309	158'604	179'870	186'064
Total number of hospitalizations	1'033'281	1'097'129	1'152'114	1'141'793
Total number of patient-days	8'977'192	9'180'478	9'000'636	8'733'425
Total hospital costs*	10'334	10'719	11'353	11'851
Total ambulatory revenues*	1'351	1'340	1'590	1'530
Average length of hospitalization	12.40	12.92	11.45	10.74
Average AP-DRG adjustment ratio	0.786	0.797	0.798	0.804
Average hospital capacity (beds)	163	162	166	172

* In million Swiss Francs deflated to May 2000 prices.

The general trend in decreasing hospital stays is also confirmed when different types of general hospitals are considered separately. The variation of the average length-of-stay in 5 hospital categories is depicted in Figure 1. As shown in the figure, the average length of hospitalization is significantly higher in small basic-care hospitals (Type 5). These hospitals have an average LOS of 16 days compared to an average of about 9 days for other hospital types. Our analysis indicates the presence of a large number of patients with excessively long stays for small hospitals of Type 5. In fact the average LOS in these hospitals can reach 90 days (with the 95 percentile of 33 days). These numbers are in great contrast with the highest average LOS values for other hospital types (11, 13, 18 and 21 days respectively for Typologies 1 through 4). Figure 2 also shows a significant decrease in hospital stays in all hospital types. This decrease for all hospital types except the basic-care small hospitals (Typology 5) is on average, about 3 to 7 percent from 1998 to 2001. With an average decrease of 15% in the same period, the small hospitals of Type 5 appeared to decrease their average LOS more aggressively.

Figure 2 illustrates the variation of AP-DRG adjustment ratios by hospital typology. This ratio can be considered as a measure of average severity of hospital's case mix. As expected, the university hospitals have the highest average adjustment ratio, indicating that these hospitals treat the most severe cases. In fact the adjustment ratio for the university hospitals (1.03) is about 20% higher than the overall average value of 0.80, suggesting that on average each patient of a university hospital costs as much as 1.2 patients in other hospitals. Among other hospitals larger hospitals appear to have more costly cases on average. Again Typology 5 stands out as an exception. The

adjustment ratios show that the patients of these hospitals are on average more costly than those hospitalized in medium-size basic-care hospitals of Type 4.

Figure 1: Average length-of-stay in Switzerland's general hospitals

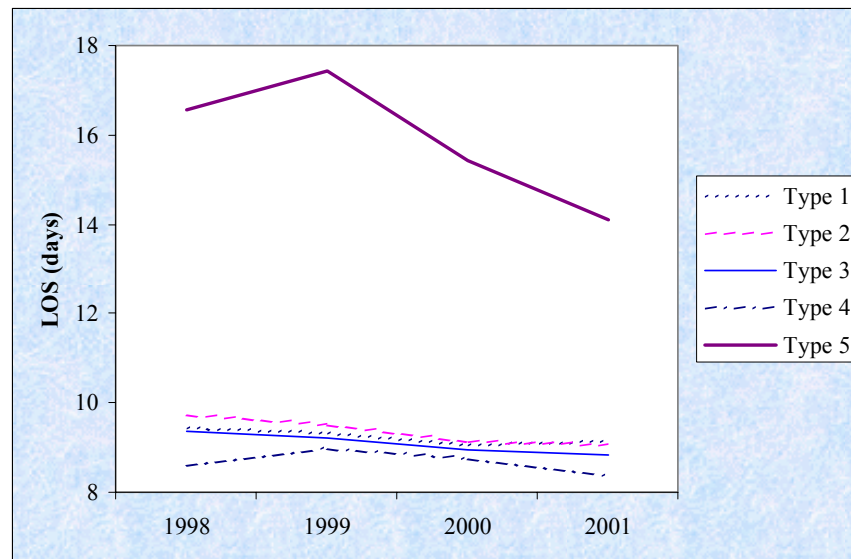
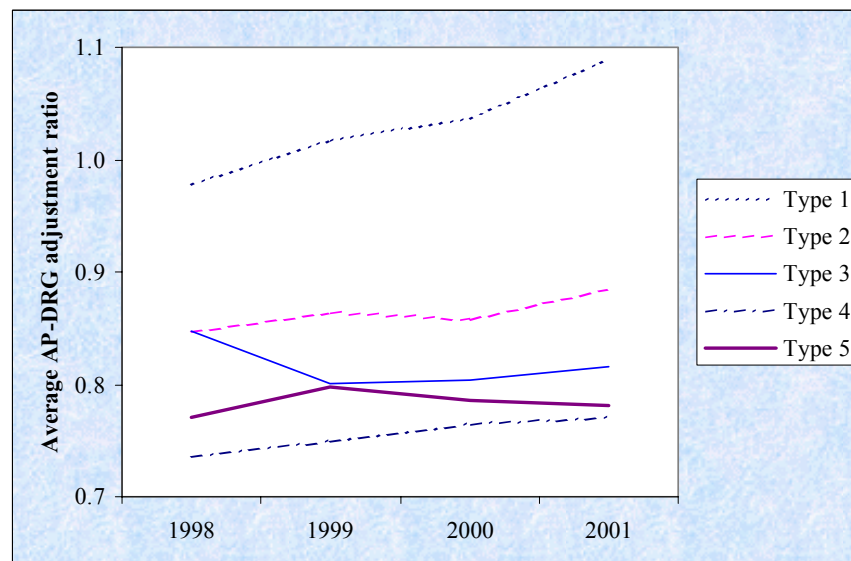


Figure 2: Average AP-DRG adjustment ratio

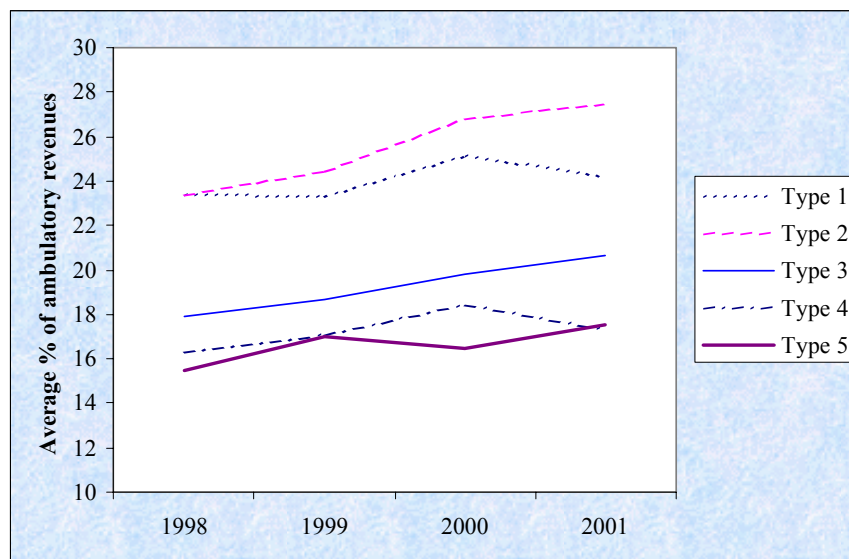


All hospital types except large basic-care hospitals (Typology 3) show an increase in average severity of their patients. Especially university hospitals (Type 1) indicate a continuous increase from an average of 0.98 in 1998 to 1.09 in 2001. On the

other hand in small basic-care hospitals (Type 5) the average adjustment ratio has only increased by 1%. Hospital Types 2 and 4 show an increase of .03 to .04 in the study period. Typology 3 is an exception that shows a decrease of .03 in the average adjustment ratio. Given that the quality of DRG coding has improved over time, these observations do not seem to be a conclusive evidence of any general change in severity of patients over time. The relatively strong rate of increase in university hospitals is the only pattern that may be distinguished from small changes in other typologies that might simply reflect the changes in coding procedures. Therefore, according to these data, the university hospitals have admitted more and more severe patients.

The time trends of the shares of ambulatory revenues are depicted in Figure 3.¹⁹ The first observation is that the general hospitals (Types 1 and 2) have generally higher ambulatory share than basic-care hospitals (Types 3, 4 and 5). This difference is on average between 5 to 8 percentage points. This figure also shows that over the study period the ambulatory share has increased in all hospital types. This increase is exceptionally low (about 0.7% from 1998 to 2001) for university hospitals.²⁰ The increase in ambulatory share is the highest for large general hospitals (Typology 2) that show a significant growth from about 23.4% in 1998 to 27.5% in 2001. The basic-care hospitals (Typologies 3 to 5) show an average increase of 1 to 3 percentage points from 1998 to 2001.

Figure 3: Average percentage of ambulatory revenues



¹⁹ The ambulatory share is calculated by dividing the ambulatory revenues by the hospital's total revenues from all medical services.

²⁰ Given the limited number of university hospitals and since one of these hospitals has not reported its ambulatory revenues for 2001, we checked two other alternatives by replacing the non-reported value by the value reported in year 2000 or by the hospital's average. The rate of increase changes slightly but still remains below 1 percent.

The hospital sector in Switzerland is characterized by a variety of subsidy systems and ownership forms. The main ownership categories are public, private non-profit (NP) and private for-profit (FP) hospitals. Public hospitals include hospitals owned by governments (federal, cantonal and communal) or other public corporations. A majority of these hospitals are run directly by a cantonal or communal government, thus included in the public administration. Private non-profit hospitals are owned and operated by non-profit foundations, associations or cooperatives. These institutions function for public interest set by their mission, and cannot distribute any monetary profit to their members. For-profit hospitals are owned by individuals, partnerships or corporations, which in principle are the residual claimants of their profit/loss. Only a limited number of FP hospitals benefit from government subsidies. However, all public hospitals and most NP hospitals are subsidized.

The number of general hospitals and their average capacity for six groups (by regulation /ownership) are listed in Table 4. According to these data, out of 177 general hospitals that operated in Switzerland in 2001, 88 hospitals (63.4 percent of hospital beds) were public (owned by government), 53 (23.5 percent of beds) were private non-profit, and 36 (13% of beds) were for-profit hospitals. All public hospitals and most private non-profit hospitals (about 80% of these hospital beds) are subsidized, whereas in the private for-profit sector, only 36% of the hospital beds are operated in subsidized hospitals. In fact only 8 for-profit hospitals benefited from government subsidies in 2001. We also studied the distribution of hospital regulation/ownership types across different typologies. It turns out that all university hospitals (Typology 1) and almost all regional hospitals (Typology 2) benefit from government subsidies.²¹ The distribution of different regulation/ownership types in the basic-care hospitals (Typologies 3 to 5) is not much different from the overall distribution shown in Table 4.

Table 4 also lists the average hospital size measured by the number of beds for each ownership/subsidy type. Public hospitals with 221 beds on average are by far the largest providers of health care, followed by private non-profit facilities with 135 beds and for-profit hospitals with 111 beds on average. This table also shows that the subsidized hospitals are considerably larger (an average capacity of 200 beds) than non-subsidized ones (average of 90 beds). Finally, the for-profit hospitals that benefit from subsidies (178 beds on average) are likely to be larger than the subsidized non-profit hospitals (156 beds on average).

Table 4: Distribution of hospitals and average hospital size by ownership/subsidy type (2001)

		PUBLIC	PRIVATE NON-PROFIT	PRIVATE FOR PROFIT	TOTAL
SUBSIDIZED	Hospitals	88	37	8	133
	<i>Hospital size (beds)</i>	221	156	178	200
NON SUBSIDIZED	Hospitals	-	16	28	44
	<i>Hospital size (beds)</i>	-	86	92	90
TOTAL	Hospitals	88	53	36	177
	<i>Hospital size (beds)</i>	221	135	111	172

²¹ According to our data for 2001, only one out of 21 regional hospitals was not subsidized.

The above descriptive analyses were based on the entire sample of general hospitals with 747 observations. Given that a number of variables used in the cost frontier analysis have missing values, this sample could not be entirely used for the regressions.²² The final sample used for the regression analysis consists of all the observations that have non-missing values for all the variables used in the specification of cost frontier models. We also excluded eight hospitals (27 observations) with less than 20 beds. This sample includes 459 observations related to 156 general hospitals. In this sample, there are only 69 hospitals that have non-missing values for all the four years. There are 24 hospitals that have information only for one year. In addition, there are respectively 30 and 33 other hospitals with non-missing values for 2 and 3 years. The regression sample is therefore an unbalanced panel with an average of 3 periods. This sample on average includes about 61 percent of all the general hospitals that operated in Switzerland from 1998 to 2001. A simple analysis (not reported here) using t-test, shows that the excluded 258 observations and the regression sample (with 459 observations) are not significantly different regarding the hospital's total costs, labor costs, and the number of beds. Therefore, with a relatively high representation rate in all groups, the regression sample can be considered as a representative sample of all Swiss general hospitals in the study period. A descriptive summary of this sample is given in the next section (see Table 5).

4 Model specification

The efficiency of hospitals is studied using a total cost function²³ with Cobb-Douglas functional form. Four different model specifications are considered. The cost functions used in this study are based on two outputs: hospitalizations and outpatient (ambulatory) care. Many authors such as Linna (1998), Rosko (2001) and Heshmati (2002) used the DRG-weighted number of admissions as the hospital's main output.²⁴ Here, the main measure of hospitalization output is taken as the AP-DRG adjusted number of hospitalizations including both full and semi-hospitalizations. However, the unadjusted number of hospitalizations and the number of patient-days are also considered as alternatives.²⁵ Other authors like Vita (1990), Eakin (1991) and Steinmann and Zweifel (2003) have considered unadjusted number of cases in several departments as multiple outputs. Given that certain hospitals in our data the number of zero cases

Since the number of outpatient cases is not available in the data, the ambulatory output is approximated by the corresponding revenues in real monetary terms (with May 2000 prices). This approximation is based on the assumption that the average unit price of ambulatory care is similar across hospitals. The ambulatory revenues are reported zero for about 5 percent of the observations. Since our econometric models are based on a logarithmic form, the zero values are replaced by a negligible value. This

²² We also observed unreasonable and suspicious values in a small number of observations, which were changed to missing. See Filippini and Farsi (2004), Section 3.1, for more details.

²³ A complementary analysis variable costs is provided in Filippini and Farsi (2004).

²⁴ Rosko (2001) also controls for several case-mix adjusters such as the percentage of ER visits and outpatient surgeries out of all outpatient visits. Other authors like Vita (1990), Eakin (1991) and Steinmann and Zweifel (2003) have considered unadjusted number of cases in several departments as multiple outputs. Brown (2003) considers cases with DRG weight of lower than 1, between 1 and 2, and higher than 2 as three output categories.

²⁵ The number of patient-days does not include the negligible share of semi-hospitalizations. In fact, they account only for about 1% of patient-days even if they are considered as one-day hospitalizations.

method has been used by Kim (1987) and Gilligan and Smirlock (1984).²⁶ As the minimum non-zero value in the regression sample is about 120 (that is 120,000 Francs), we replace the zero values by one²⁷ (less than .001 of the mean value) making the log values equal to zero.

Three input factors are considered: capital, physician labor services and all other employees' labor services.²⁸ Capital price is approximated by the hospital's total capital expenditure divided by the number of available beds in the hospital. Therefore, similar to Wagstaff (1989) and Rosko (2001) among others, the capital stock is proxied by the hospital capacity in terms of beds.²⁹ Many authors have considered labor inputs in multiple categories.³⁰ In this paper, similar to Eakin (1991), physicians and non-physicians are considered as two labor categories. Physicians' services constitute of interventions for medical treatments while other employees' services are more continuous and aimed at nursing care, administration and maintenance. Furthermore, physicians' wage rates are considerably higher and more variable than other employees.

Labor prices are calculated for employed physicians and other employees as the corresponding salaries. The physicians' fees (*honoraires*) are not included.³¹ In fact, since these fees may also include payments to physicians who are not employed by the hospital, the regular salaries represent a more accurate measure of labor price. Labor prices are proportionally adjusted for social charges, which on average, account for about 8 percent of total costs. Namely, these charges are proportionally distributed to each one of the two groups (physicians, non-physicians), the proportions being the shares of each group's salaries.

The three input factors considered in the models do not include all the hospital's costs. In fact, capital and labor costs on average account for about 76 percent of a hospital's total cost. Other expenses such as medical materials, food, cleaning, water and power etc. are on average, about 24 percent of total costs. Furthermore, the labor prices do not account for physicians' fees and other personnel charges, which together, account for about 6.7 % of the total costs. This means that about 31 percent of the total costs are related to input factors whose prices are not considered in the model. In fact, the available data do not allow an appropriate calculation of these prices.³² The excluded prices are obviously not constant and neglecting their variation may 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

²⁶ It should be noted that there exist other solutions (such as Box-Cox or hybrid functional forms) for the problem of zero values for one or several outputs in a cost function. See Weninger (2003) for a recent review. Given that in our sample the zero values are quite limited, we adopted the simplest method.

²⁷ Different values (from .001 to 10) have also been tried. Our regressions (not reported here) indicate that the results are not sensitive to this choice.

²⁸ Our preliminary regressions include another alternative with nursing staff as a separate input factor. However, we found out that the labor price for nursing staff and other employees are highly correlated. Moreover including this additional variable does not change our main results. We therefore decided to retain the model with two labor factors.

²⁹ A more accurate measure of capital stock (cf. Christensen and Jorgenson, 1969) would require inventory data, which is not available to us.

³⁰ For instance Eakin (1991) considers physicians and other staff and Folland and Hofler (2001) consider nursing staff and other employees in separate categories. Others like Steinmann and Zweifel (2003), Scuffham et al. (1996) and Vita (1990) used 3 or 4 labor categories.

³¹ Physicians' fees, reported under account K-38 on hospitals' accounting sheet, account on average, for about 5.8% of total costs.

³² Though the expenditures on these input factors are available in the data the quantities are not. Moreover, these expenditures correspond to diverse items that could not be measured with similar units.

physicians' salaries. Moreover, insofar as these unobserved factor prices are randomly distributed across hospitals and over time, the estimation results are not affected by any bias. Given that the input factors do not include all hospital's inputs, the linear homogeneity cannot be imposed.

In addition to outputs and input prices, a series of hospital characteristics are included in the model. We included the year dummies to capture the technological progress and the variation in unobserved variables such as potential differences in reporting procedures and data collection from one year to another. For instance, some of the observed patterns in the data suggest that AP-DRG coding has improved over the years. The typology indicators are also included. The provided medical services vary across hospital types. In particular, university and large general hospitals provide a wide variety of services while other types provide basic medical care and do not have many specializations. Another difference is in teaching and research activities that are generally much less significant in basic-care hospitals. We considered three indicators for hospital typologies. Since there are too few university hospitals in the sample for having a meaningful separate indicator for these hospitals, a single indicator is considered for Typologies 1 and 2.

After a careful study of all other available characteristics, we concluded that as long as hospital typology is included in the model, additional variables can be limited to a few indicators representing important aspects of hospital output. The most important output characteristic is the average length of hospitalization. Many authors such as Vita (1990), Scuffham et al. (1996) and Carey (1997) have included this variable as an output characteristic.³³ As we see later, variation in the length of stay is one of the main sources of cost differences between hospitals. One may argue that the DRG adjustment already controls for any justifiable variation in the length of stay. In this case, including the average length-of-stay in the model results in an underestimation of inefficiency in hospitals with lengthy stays. However, DRG adjustment is only an approximate way to control for severity variations. In fact, there are considerable cost variations among patients with the same DRG. For instance, the acceptable range of variation of hospital stays provided by the Swiss APDRG version 4.0 (I.S.E, 2003) is quite wide within a given DRG. Thus, considering a fixed LOS for all patients with the same DRG is at best a great approximation. Moreover, given that the length of hospital stays also represents hospital's *hotel services* like nursing care and accommodation rather than medical treatment, the LOS can be regarded as a separate output.³⁴

Hospitals' costs can also be affected by quality of care. The evidence on the effect of quality measures on hospital costs is rather mixed. Referring to his previous empirical literature, Rosko (2001) conclude that the omission of quality indicators may not be as serious as commonly thought. For instance, Zuckerman et al. (1994) controlled for several outcome measures of quality such as 30-day post-admission mortality rates. Their analysis suggests that none of those measures have significant effects. Similarly Vitaliano and Toren (1996) report that most of their 12 quality measures showed insignificant effects on hospital costs. On the other hand, Folland and Hofler (2001) have considered two measures of structural quality (percentage of board-certified physicians and a measure of bed availability), both of which showed significant effects on total costs. In general the available evidence often points to a significant effect by structural quality measures, while outcome and process measures

³³ Others like Folland and Holfer (2001) have considered the LOS through the number of patient days.

³⁴ See Breyer (1987) for a discussion.

are more likely to appear unimportant.³⁵ 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. Given the data availability and measurement problems, we focused on one structural measure of quality, defined as the hospital's nurse per bed ratio. We also included two binary indicators for ER and geriatrics departments. Emergency services are usually costly and involve relatively severe cases, while geriatrics cases are less intensive in medical care.

It is assumed that all hospitals have similar cost functions and the hospital typology can only shift the costs without affecting the function's shape and parameters. To study the validity of this assumption we used several tests of structural break.³⁶ First, we considered the hypothesis that hospitals with different typologies have different cost function parameters. Four hospital groups have been considered, with the university hospitals and large general hospitals considered in a single group. Secondly, we grouped the hospitals in two groups: general hospitals (Types 1 and 2) and basic-care hospitals (Types 3, 4 and 5). The third test is based on a break between small basic-care hospitals (Type 5) and other hospitals. The model specification includes the number of DRG-adjusted admissions and ambulatory revenues as output; capital price and a single labor price as input prices; LOS as output characteristics; and year dummies. None of the three tests can reject the hypothesis of no-structural break, suggesting that the cost function parameters are overall similar across different typologies.

Four specifications labeled as models *I* to *IV*, have been considered. The general model can be written as:

$$\begin{aligned} \ln TC_{it} = & \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln AMB_{it} + \gamma_1 \ln PK_{it} + \gamma_2 \ln PL_{1it} + \gamma_3 \ln PL_{2it} \\ & + \omega_1 \ln LOS_{it} + \omega_2 \ln NB_{it} + \omega_3 ER_{it} + \omega_4 GER_{it} + \delta_{12} D_{12i} + \delta_3 D_{3i} + \delta_4 D_{4i} \\ & + \delta_{99} Y99_t + \delta_{00} Y00_t + \delta_{01} Y01_t + u_{it} + v_{it} \end{aligned} \quad (4)$$

Subscripts *i* and *t* represent the hospital and year respectively. The stochastic components u_{it} and v_{it} respectively represent inefficiency and random noise as described in Equation 2. *Y* is the hospitalization output, which is taken as unadjusted number of hospitalizations in Model *I*, number of patient-days in Model *III*, and DRG-adjusted number of hospitalizations in Models *II* and *IV*. *AMB* is the ambulatory revenue; *PK*, *PL₁* and *PL₂* are respective factor prices for capital, physicians and other employees; *LOS* is the average length of hospitalization (not included in Model *III*); *NB* the nurse per bed ratio; *ER* and *GER* are dummy variables for emergency room and geriatrics department respectively. *D₁₂* is a dummy for Typologies 1 and 2; and *D₃* and *D₄* are dummies for hospitals in Typologies 3 and 4. The small basic-care hospitals (Type 5) are the omitted typology. Finally, *Y99*, *Y00* and *Y01* are the year dummies for 1999, 2000 and 2001 respectively, 1998 being the omitted year.

³⁵ Structural measures represent the quality of the provider in terms of physical amenities, administrative organization and staff qualification. Process measures are based on the evaluation of the medical procedures and practices against professional standards, while outcome measures are associated with the patients' health outcomes resulted from medical care. Process and outcome measures usually require data from expert reviews or health outcomes. See Donabedian (1980) for an extensive discussion.

³⁶ These tests are based on Chow test. The null hypothesis is that the regression coefficients are identical across different groups.

The specification given in (4) summarizes Models *I* to *III*. Descriptive statistics of the main variables used in these models are given in Table 5. Model *IV* is similar to Model *II* with the difference that 13 additional binary indicators are also included for 14 cantonal groups.³⁷ The idea here is to control for part of the unobserved heterogeneity that is specific to location. Populations in different cantons may differ in health and socio-economic status. Moreover, the hospitals are subject to different cantonal regulations that may affect their efficiency. Comparing this model with other models without canton dummies can indicate to what extent the inefficiency variations can be explained by differences in cantonal regulations.

The effects of ownership/regulation types on efficiency are studied using a two-stage method. This method is based on a non-parametric rank test on the efficiency estimates. The inefficiency scores for each hospital are considered as the average inefficiency values over the sample period. The hospitals that have apparently changed ownership status from one year to another are excluded from the analysis.³⁸

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 that cost-efficiencies are similar across different types.³⁹ An alternative approach is to include ownership/subsidy indicators in the regressions and test the significance of the corresponding coefficients. However, this method would imply that ownership/subsidy type affects the hospital's production function. This assumption is not consistent with our contention that hospitals use a similar technology and only their productive efficiency is influenced by regulation. Moreover, the two-stage approach allows the use of non-parametric statistical tests like Kruskal-Wallis rank test.⁴⁰ Such tests 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.

5 Results

Table 6 lists the regression results of the cost frontier analysis, with four different specifications. Some descriptive statistics of inefficiency estimates are also given at the bottom of the table. Most of the coefficients are statistically significant. Overall, the coefficients are generally reasonable and have the expected signs. The first two models (*I* and *II*) are based on the number of hospitalizations. In Model *I* the hospitalizations are not adjusted, whereas in Model *II* the hospitalization numbers are adjusted with AP-DRG cost weights. The first observation is that ignoring DRG adjustment slightly biases the coefficients. For instance, the output coefficient increases by about .03 and the first typology dummy by .04 when the number of hospitalizations

³⁷ There are 23 cantons in the regression sample. Most of the cantons with less than 5% share in the sample are grouped with the neighboring cantons. Only two groups have less than 5% share in the sample (see Appendix).

³⁸ According to our data out of 159 hospitals in the regression sample, there are 13 hospitals whose ownership has changed from one year to another. From these hospitals, 5 have changed status between public and FP, 5 between public and private NP and 3 between FP and private NP status.

³⁹ For a more detailed discussion of this point see Farsi and Filippini (2004).

⁴⁰ This test is due to Kruskal and Wallis (1952). See Singh and Coelli (2001) and Farsi and Filippini (2004) for examples of application of this test to compare the efficiency across groups of firms.

Table 5: Descriptive statistics of the regression sample

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
<i>Hospital's total costs (SFr '000)</i>	57'267	101'240	14'170	27'253	57'845
<i>Number of admissions</i>	5'692	6'399	1'571	3'761	7'779
<i>Number of admissions (AP-DRG adjusted)</i>	4'792	6'148	1'238	2'946	6'118
<i>Number of patient-days</i>	48'801	53'241	18'917	32'186	56'685
<i>Hospital's outpatient revenues (SFr '000)</i>	7'958	13'920	1'296	3'635	8'007
<i>P_K (capital price) SFr '000 per bed</i>	23.60	20.15	10.41	16.21	27.73
<i>P_L - physicians (SFr per day)*</i>	368.10	499.67	244.14	307.75	387.51
<i>P_L - others (SFr per day)**</i>	181.74	137.28	153.14	169.49	194.03
<i>Nurse per bed</i>	0.882	0.354	0.633	0.839	1.067
<i>Average length of hospitalization (days)***</i>	12.06	6.78	8.22	9.31	13.80
<i>Emergency Room</i>	0.847	0.360	1	1	1
<i>Geriatrics</i>	0.429	0.496	0	0	1
<i>Typology 1/2</i>	0.155	0.362	0	0	0
<i>Typology 3</i>	0.148	0.356	0	0	0
<i>Typology 4</i>	0.264	0.441	0	0	1
<i>Year 1999</i>	0.266	0.442	0	0	1
<i>Year 2000</i>	0.255	0.436	0	0	1
<i>Year 2001</i>	0.264	0.441	0	0	1

The sample includes 459 observations from 156 general hospitals (1998-2001).

All monetary values are deflated to May 2000 prices. Labor prices include charges.

* calculated for physicians employed by the hospital.

** includes all hospital employees except physicians.

*** calculated for hospitalizations of longer than 24 hours.

is not adjusted. However, these biases appear to be insignificant for practical purposes. This can be explained by the fact that adjusted and unadjusted numbers of hospitalizations are highly correlated, with a correlation coefficient of about 0.99.

We consider Model *II* as our benchmark model because it is a complete model with DRG-adjusted output and all the relevant factors. According to this model the main output's coefficient is 0.82, that is, a 1% increase in the adjusted number of hospitalization will result in about 0.82% increase in total costs. As expected, the coefficient of ambulatory output is much smaller (.036), suggesting a .036% rise in total costs as a result of 1% increase in outpatient visits, all other factors being constant. This implies that the marginal cost of a 1% increase in hospitalizations is on average 20 times higher than a similar increase in outpatient visits.

The coefficient of LOS is about 0.45, suggesting that for instance, a 1% increase in the average length of hospitalization results in a .45% increase in total costs. Given that hospital stays are on average about 12 days, this result implies that a difference of one day in the hospital's average LOS is approximately equivalent to 4% of total costs. The length of hospitalization is therefore an important predictor of hospital costs. Comparing the LOS coefficient between models *I* and *II* shows that if hospital output is not adjusted for severity, the effect of LOS is considerably higher (coefficient of 0.53). This result suggests that the average LOS captures part of the variations in severity.

In Model *III* the number of patient-days is considered as the hospital's main output. The output coefficient in this model (0.81) is very close to the corresponding coefficient in Model *II* confirming the existence of unexploited scale economies. As expected the ambulatory output's coefficient is higher in this model, because a patient-day is on average less costly than one case. According to this model the marginal cost of a relative increase in patient-day is on average about 11 times higher than that of a similar increase in outpatient visits.

As expected, the price coefficients are positive and significant. Since the three factor prices do not include all hospital inputs, the price coefficients do not add to one. The nurse per bed ratio has a positive and significant effect, indicating that quality of care is costly. As expected, the ER dummy has a positive coefficient, but its effect is statistically insignificant in most models. Similarly, the geriatrics dummy has expectedly a negative but insignificant coefficient in most models. As explained earlier, the effects of these indicators are partly captured by typology dummies.

All three typology dummies are positive, indicating that all other factors held constant, small basic-care hospitals are less costly than other hospitals. However, their difference with other basic-care hospitals (types 3 and 4) is significant only if the average LOS is not controlled for. This implies that the systematic cost differences between these hospital types are mainly due to their different hospitalization lengths. University and large general hospitals (typologies 1 and 2) are significantly more costly than basic-care hospitals. According to Model *II* compared to small basic-care hospitals the difference is strikingly high amounting to 35% in total costs. This difference can be partly explained by the additional expenses on medical equipment and also research and teaching activities. This result is in general consistent with the results documented in I.S.E. (2003) suggesting that the AP-DRG cost weights are on average 24% higher in university hospitals.

Table 6: Estimation results

	Model I	Model II	Model III	Model IV
<i>Number of admissions</i>	0.8532 * (0.029)	-	-	-
<i>Number of admissions (AP-DRG adjusted)</i>	-	0.8180 * (0.028)	-	0.7916 * (0.026)
<i>Number of patient-days</i>	-	-	0.8140 * (0.030)	-
<i>Outpatient revenues</i>	0.0321 * (0.0071)	0.0357 * (0.0059)	0.0724 * (0.0063)	0.0363 * (0.0070)
<i>P_K (capital price)</i>	0.1434 * (0.018)	0.1552 * (0.018)	0.1676 * (0.019)	0.1866 * (0.018)
<i>P_L - physicians</i>	0.0746 * (0.016)	0.0764 * (0.017)	0.0387 (0.023)	0.0507 * (0.020)
<i>P_L - others</i>	0.2142 * (0.039)	0.1981 * (0.041)	0.2599 * (0.061)	0.1445 * (0.044)
<i>Nurse per bed</i>	0.1875 * (0.028)	0.1617 * (0.030)	0.2236 * (0.032)	0.1093 * (0.028)
<i>Average length of hospitalization</i>	0.5346 * (0.036)	0.4451 * (0.036)	-	0.4759 * (0.042)
<i>Emergency Room</i>	0.0369 (0.037)	0.0400 (0.038)	-0.0209 (0.036)	0.0953 * (0.039)
<i>Geriatrics</i>	-0.0591 * (0.029)	-0.0423 (0.028)	-0.0395 (0.032)	-0.0767 * (0.034)
<i>Typology 1/2</i>	0.3915 * (0.075)	0.3499 * (0.079)	0.3766 * (0.096)	0.3888 * (0.077)
<i>Typology 3</i>	0.0974 (0.056)	0.0701 (0.058)	0.2801 * (0.076)	0.1176 * (0.052)
<i>Typology 4</i>	0.0135 (0.041)	0.0312 (0.043)	0.1316 * (0.050)	0.0625 (0.042)
<i>1999</i>	0.0349 (0.030)	0.0377 (0.030)	0.0447 (0.035)	0.0225 (0.029)
<i>2000</i>	0.0884 * (0.031)	0.0722 * (0.031)	0.1222 * (0.037)	0.0617 * (0.029)
<i>2001</i>	0.1426 * (0.031)	0.1314 * (0.032)	0.1830 * (0.035)	0.1140 * (0.030)
<i>Constant</i>	-0.4354 (0.26)	0.2632 (0.27)	-1.1268 * (0.35)	0.6754 * (0.27)
<i>Inefficiency scores</i>				
<i>U_{mean}</i>	0.2261	0.2194	0.2164	0.1774
<i>U_{median}</i>	0.1879	0.1912	0.1930	0.1557
<i>U_{95 perc}</i>	0.4355	0.4474	0.4190	0.3369
<i>U_{max}</i>	1.2845	1.1520	1.0849	0.8434

Standard errors are given in parentheses. * significant at .05
Model IV includes canton dummies, which are not shown in the table.

The year dummies indicate that over the study period the total hospital costs have grown about 4 percent by year. However, it should be noted that these dummies might capture other year-specific effects such as changes in quality of reporting DRG cases. Most probably, such changes in quality of data are not significant between 2000 and 2001. Therefore the difference between the coefficients of these two dummies is more representative of the annual growth in total costs. Interestingly, the growth in total costs from 2000 to 2001 is about 6% in all four models, while the differences with previous years vary considerably across different specifications. The robustness of this result to model specification confirms that the estimated growth after 2000 is not affected by changes in data quality. It should be noted that the year dummies should generally represent the technical change. Technical progress should in principle result in lower costs in usual production units that produce a similar output. However, an increasing growth in hospital costs and in the health-care sector in general is a common observation that is not contradictory to technical progress. In fact, with progress in medical technology, hospitals use increasingly more advanced methods and the quality of medical care constantly increases.⁴¹ All these changes result in higher costs. Many of these cost-increasing factors are not directly taken into account, thus are captured by the year dummies. Therefore, the estimated growth in costs should not be interpreted as a decline in technology.

Table 6 also provides the estimation results obtained from Model *IV*. This model is similar to Model *II* with the sole difference that 13 canton dummies are also included as explanatory variables.⁴² Comparing the results of Model *IV* with those of Model *II* indicates that the two models give quite similar results for the output coefficients and also the effect of LOS. In general the coefficients corresponding to time-variant factors (including year dummies) are not sensitive to whether or not the cantonal effects are controlled for. However, the coefficients of time-invariant factors, namely typology dummies and ER and geriatrics indicators, have considerably changed. In particular both ER and geriatrics dummies are significant when the canton dummies are included. As for inefficiency estimates, controlling for canton dummies decreases the inefficiency scores by about .04 (compare .22 in Model *II* with .18 in Model *IV*).

Scale economies and cost efficiency

The results listed in Table 6 indicate that the main coefficients are more or less similar across different specifications. In particular the coefficient of the hospital's main output is about 0.8 in all specifications. This result implies that the returns to scale are on average significantly higher than 1 ($RS=1.2$), suggesting that the majority of general hospitals in Switzerland do not fully exploit the potential scale economies.⁴³ This implies that most of the hospitals in the sample do not reach the optimal size. This result is consistent with the empirical evidence in previous literature. In particular, Crivelli et

⁴¹ See Dranove (2000) for an extensive study of such evolutions in the US health sector. In particular, this author studies how non-price competition between health care providers has resulted in higher quality and costs.

⁴² The coefficients of canton dummies are listed in the appendix. Among these 13 indicators, 7 have significant effects (at .05 level). Canton Geneva has the most costly general hospitals while the least expensive general hospitals are located in canton Ticino. Compared to Bern (the omitted canton), Geneva's hospitals are on average 29% more costly, and Ticino's hospitals are on average 18% more economical.

⁴³ The returns to scale parameter is given by: $RS = 1 / \left(\frac{\partial \ln TC}{\partial \ln Y} \right)$.

al. (2001) who used a translog cost frontier model for Swiss hospitals between 1989 and 1991, suggest an optimal size of 300 beds, but conclude that the unexploited scale economies are relatively low for hospitals with more than 135 beds. Other empirical results in the literature suggest an optimal size of about 200 beds.⁴⁴

Some statistics of the inefficiency estimates are given in the lower panel of Table 6. These results suggest that the average inefficiency score is not much sensitive to DRG-adjustment (22.6% in Model *I* and 21.9% in Model *II*). However, the maximum inefficiency score is significantly lower with DRG adjustment. This result suggests that the individual efficiency estimates especially the outliers can be biased if the output is not adjusted for case mix severity. In Model *III* in which the hospital output is measured as the number of patient-days, the average inefficiency score is quite similar to Model *II*, where the output is the number of hospitalizations. However, the maximum inefficiency estimate is about 7 percentage points lower in Model *III*, suggesting that part of the cost inefficiency in certain hospitals is due to the outlier cases that have longer than usual hospitalizations. The inefficiency estimates of Model *IV* are on average about 4 percentage points lower than those of Model *II*. The difference between the two models is more considerable at the tails with about 30 percentage points at the maximum. This result suggests that controlling for certain unobserved differences through canton dummies can considerably attenuate the estimates of individual hospitals' inefficiencies.

The close similarity among average inefficiency estimates and the strong correlation between the individual scores obtained from different models suggest that the results are in general robust to specification.⁴⁵ Given that the inefficiency results are more or less similar across different models, we choose a single model to highlight some of the patterns in cost-efficiency. We consider Model *II* to present the results regarding the cost-efficiency, because this model controls for DRG variation. The variations in inefficiency scores by year and hospital typology are depicted in Figure 4. The first observation is that the inefficiency scores are different across hospital typologies. In particular, the university hospitals (Type 1) have the highest scores with average values of 36% to 44%. However, these estimates should be considered with caution. University hospitals have the highest levels of research and teaching activities and provide a relatively wide range of medical services including the most complex interventions. Given that there are only three university hospitals in our regression sample a separate dummy could not be included for these hospitals. Therefore, the inefficiency estimates inevitably capture some of these unobserved differences. A better estimation of cost inefficiency in university hospitals requires more information about the incurred costs of research and teaching activities and other medical interventions that are exclusively carried out in these hospitals.

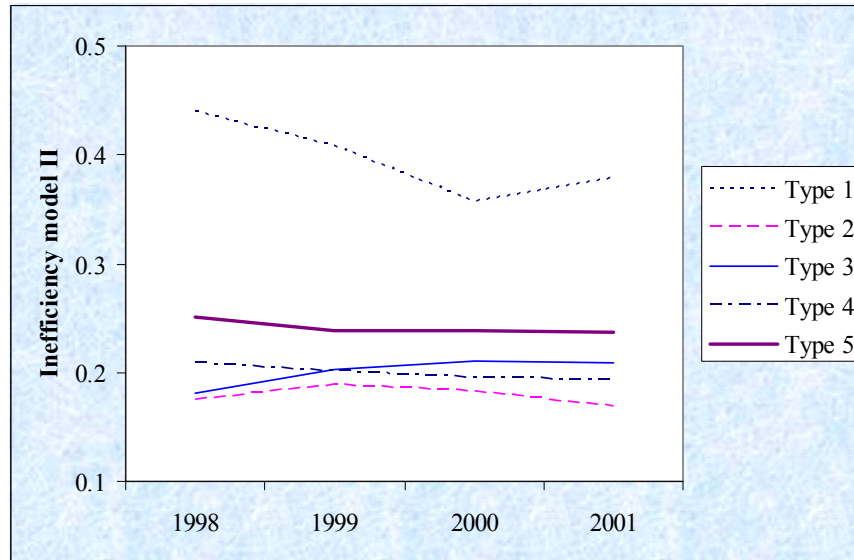
Small basic-care hospitals (Type 5) with an average inefficiency of 24 to 25 percent have the second highest inefficiency scores. Other hospital types (Typologies 2, 3 and 4) show a rather similar average inefficiency score of 18 to 20 percent. It should be noted that these inefficiency estimates are obtained after accounting for a potential shift of cost frontiers across hospital types. The second result from this figure is that the inefficiency has decreased over the sample period in all hospital types except large basic-care hospitals (Typology 3). The decrease of inefficiency is quite considerable in

⁴⁴ See for instance Aletras (1999), Dranove (1998) and Scuffham et al. (1996).

⁴⁵ All the pair-wise correlation coefficients between efficiency estimates from Models *I*, *II* and *IV* are higher than 85%. The estimates of Model *III* show a correlation of 68 to 80 percent with those of the other three models.

university hospitals (about 6 to 7 percentage points) but rather insignificant in small basic-care hospitals (typology 5). These results also suggest that the inefficiency has slightly decreased in hospitals of Typologies 2 and 4 but slightly increased in type-3 hospitals.

Figure 4: Inefficiency by typology and year (based on Model II)



Effects of ownership/subsidy types

The inefficiency estimates obtained from different models do not show much difference insofar as the differences between ownership/regulation types are concerned. In order to avoid repetition the results are only reported for Model II, which we considered as the most realistic specification. The inefficiency estimates from Model II are given in Table 7. The numbers in this table point to slight efficiency differences among hospitals with different ownership or subsidies. For instance it appears that private NP hospitals are on average slightly more costly than FP and public hospitals, or subsidized hospitals are on average more cost-efficient than non-subsidized facilities. Particularly, this table suggests that among non-subsidized providers, the private NP hospitals are on average more costly than the FP ones. Whether these differences are statistically significant remains to be seen.

We used the Kruskal-Wallis test for several alternative sets of subgroups to test if the differences shown in Table 7 imply that different subgroups belong to different populations of hospitals in terms of their cost-efficiency. The first grouping is based on five ownership/subsidy subgroups as shown in Table 7, that is public, subsidized private NP, non-subsidized private NP, subsidized private FP, and non-subsidized private FP). The second grouping is related to ownership (public, private NP and FP) and the third is related to subsidies (subsidized versus non-subsidized). Finally the last set consists of three subgroups: public, private subsidized and private non-subsidized. In all cases, we also performed the test for all the possible pair-wise comparisons such as public vs.

private, private NP vs. private FP etc. In order to see if the results are sensitive to the presence of university and regional hospitals (Typologies 1 and 2), similar tests were also performed on a sample excluding these hospitals.

The results indicate that in all the groupings and all pair-wise comparisons the Chi-squared test statistic is statistically insignificant even at 10% significance level.⁴⁶ In the case of pair-wise comparisons, the results of the KW tests are confirmed with a simple t-test with equal variances. These results suggest that there is no statistically significant difference in efficiency among hospitals with different ownership or regulation types. These results are in general consistent with those reported by Steinmann and Zweifel (2003) who did not find any significant difference between private and public hospitals.

Table 7: Average inefficiency estimates by ownership/subsidy type

	PUBLIC	PRIVATE NON-PROFIT	PRIVATE FOR-PROFIT	OVERALL
SUBSIDIZED	0.214	0.213	0.203	0.213
NON SUBSIDIZED	-	0.239	0.215	0.227
OVERALL	0.214	0.220	0.212	0.216

Notes: The inefficiency estimates are based on the results obtained from Model II (see Table 6). The inefficiency scores for each hospital are calculated as the average inefficiency values over the sample period (1998 to 2001). The results are based on 146 hospitals that have a constant ownership/regulation status over the sample period.

6 Conclusions

A panel data of all Swiss general hospitals over the four-year period between 1998 and 2001, including 747 observations of a total of 214 facilities, has been analyzed. These data show a significant increase in the total number of hospitalizations amounting to about 10 percent growth over the study period. In the same period, the total expenditures of Swiss general hospitals have increased by about 15 percent in real terms. Our descriptive analysis of the data shows that most hospitals while decreasing their average length of stay, have considerably increased the share of their ambulatory revenues. The observed patterns in the data indicate that the small basic-care hospitals have the longest hospitalizations (on average about seven days longer than other hospitals) while university hospitals treat the most severe cases shown by the highest average AP-DRG cost weight (20% higher than the overall average).

A sample of 459 observations corresponding to a total of 156 hospitals has been used for the econometric analysis of efficiency. A stochastic total cost frontier has been estimated using Cobb-Douglas functional form and several specifications. The main results of this analysis can be listed as follows:

⁴⁶ Only in one case the differences were significant at 10% but not significant at 5%. This was related to the comparison of public versus private hospitals using Model III. Note that this model does not adjust the output for AP-DRG (see Table 6).

- There are unexploited scale economies in the majority of Swiss general hospitals. Although we cannot clearly identify the optimal hospital size, our results along with the empirical evidence reported in the previous literature suggest that the scale economies are significant in hospitals with less than 200 beds.
- Ignoring the severity adjustment by AP-DRG cost weights slightly biases the main coefficients. However, these differences are not significant for practical purposes, suggesting that most of the variation in DRGs among hospitals is random.
- There are systematic cost differences among different typologies with larger hospital types being generally more costly. These differences remain considerable after controlling for severity through AP-DRG cost weights. In particular, the university and regional hospitals are the most costly hospitals (about 35% more costly than the small basic-care hospitals). This difference can be explained by the relatively wide range of medical specializations as well as research and teaching activities in those hospitals.
- A one-day decrease in the average length of hospitalization can lower the hospital's total costs by about 4 percent. Given that the small basic-care hospitals have extremely long hospitalizations, considerable savings might be achieved by curtailing lengthy hospital stays.
- Ambulatory care is much less costly than inpatient care. On average, each patient-day costs as much as 11 times more than an outpatient visit. To the extent that the insurers have more accommodating reimbursement plans for outpatient services, this result might partly explain the motivation behind the growing share of ambulatory care in most hospitals.
- Although our quality measures are limited the results suggest that the quality of medical services is an important factor in cost determination. Thus, some of the estimated cost differences could be due to unobserved variations in quality.
- There exists a considerable cost variation among hospitals operating in different cantons. Part of these differences may be related to different regulatory systems implemented in different regions.
- On average, the total costs of a typical general hospital have grown by about 4 percent per year. This can be explained by technological progress in medical care, which enables the hospitals to provide more advanced services to more severe cases resulting in higher costs.

The cost-efficiency analysis using several models indicates that the inefficiency scores are not sensitive to the adopted model specification. The resulting mean inefficiency score of about 20 percent suggests that there is a potential for cost saving in Switzerland's general hospitals. However, it should be noted that part of these inefficiency estimates might be driven by unobserved factors. A better account of such factors would require a longer panel that is, more observations over time. The estimations also suggest that the cost-inefficiency has slightly but consistently decreased over the study period. Certain typologies show significantly different

inefficiency estimates. In particular, the university hospitals the highest inefficiency estimates. However, these estimates are partly because of the special activities like advanced medical research and complex medical interventions in these hospitals. The inefficiency estimates are also relatively high in small basic-care hospitals, which is probably related to extremely long hospitalizations in these hospitals. Given the methodological and data limitations of this study, the individual hospitals' efficiency scores should be considered with caution. In particular, these estimates should not be directly used as a basis for rewarding or punishing specific hospitals. Rather, the present analysis provides an overall picture of inefficiency situation in Switzerland's general hospitals.

Finally, the effect of different regulatory systems and ownership types on the hospital efficiency has been studied. The general hospitals are divided into five groups based on their ownership (public, private non-profit and for-profit) and subsidy status (subsidized, not subsidized). A large majority of Switzerland's hospitals are owned by the State or benefit from government subsidies. Our data show that in 2001, 63 percent of general hospital beds were owned by the State, which together with the subsidized hospitals owned by the private sector, account for about 87 percent of the total general hospital beds in Switzerland. Our analysis of inefficiency estimates obtained from the stochastic frontier analysis suggests that the efficiency differences across different ownership/subsidy types are not statistically significant. This result indicates that our data do not provide any evidence of a significant efficiency advantage of one type over another. However, it should be noted that this result is restricted to our specific data and cannot be generalized. Moreover, because of the potential correlation between ownership/subsidy types and other hospital characteristics such as typology and size, disentangling the actual effects of ownership/regulation may be difficult. Therefore, the presented results cannot be considered as conclusive evidence that different subsidy rules and ownerships induce similar cost efficiency.

In general the quality of the available data is acceptable for an econometric analysis of cost-efficiency. However, because of the limited number of available years with non-missing data (three in most hospitals), some of the advanced panel data models could not be used. We contend that the data can be generally improved by minimizing the missing values and reporting errors and including more years. Such improvements can be helpful from a methodological standpoint in that they allow the application of more accurate econometric models and functional forms. In particular, potential data improvements can be considered in accounting capital investments and amortization, reporting average wage rates for hospital employees as well as coding DRGs and admission types. Furthermore, additional information on the resources allocated to research and teaching activities and hospital quality can be useful for an accurate analysis of costs.

7 References

- Aigner, D., C. A. K. Lovell and P. Schmidt (1977). "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, 6, 21-37.

- Aletras, V. H. (1999). "A comparison of hospital scale effects in short-run and long-run cost functions", *Health Economics*, 8: 521-530.
- Breyer, Friedrich (1987). "The specification of a hospital cost function: A comment on the recent literature", *Journal of Health Economics*, 6 (1987): 147-157.
- Brown, H. Shelton (2003). "Managed care and technical efficiency", *Health Economics*, 12 (2): 149-158.
- Carey, Kathleen (1997). "A panel data design for estimation of hospital cost functions", *The Review of Economics and Statistics*, 79 (2): 443-453.
- Caves, W. C., L. R. Christensen and J. A. Swanson (1981). "Productivity growth, scale economies, and capacity utilization in U.S. railroads, 1955-74", *American Economic Review*, 71 (5): 994-1002.
- Chambers, Robert G. (1988). *Applied Production Analysis: A Dual Approach*, Cambridge University Press.
- Christensen, L. R. and D. Jorgenson (1969). "The measurement of US real capital input, 1929-1967", *Review of Income and Wealth*, 15: 293-320.
- Coelli, Tim, A. Estache, S. Perelman and L. Trujillo (2003). *A Primer on Efficiency Measurement for Utilities and Transport Regulators*, World Bank Institute Development studies, The World Bank, Washington DC.
- Coelli, Tim, D. S. Prasada Rao, and George E. Battese (1998). *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers.
- Cornes, R. (1992). *Duality and Modern Economics*, Cambridge University Press.
- Crivelli, L., M. Filippini and D. Lunati (2001). "Dimensione ottima degli ospedali in uno Stato federale" (in Italian), *Economia Pubblica*, 5: 97-119.
- Donabedian, A. (1980). *The definition of quality and approaches to its assessment, Vol. I: Explorations in quality assessment and monitoring*, Health Administration Press, Ann Arbor, Michigan.
- Dranove, David (2000). *The Economic Evolution of American Health Care*, Princeton University Press.
- Dranove, David (1998). "Economies of scale in non-revenue producing cost centers: implications for hospital mergers", *Journal of Health Economics*, 17 (1998): 69-83.
- Eakin, B. Kelly (1991). "Allocative inefficiency in the production of hospital services", *Southern Economic Journal*, July 1991, 58 (1): 240-248.
- Farsi, Mehdi and Massimo Filippini (2004). 'An Empirical Analysis of Cost Efficiency in Non-profit and Public Nursing Homes', *Annals of Public and Cooperative Economics*, 75 (3): 339-365.
- Farsi, Mehdi, Massimo Filippini and Michael Kuenzle (2003). "Unobserved heterogeneity in stochastic cost frontier models: a comparative analysis", [Working Paper No. 03-11](#), Department of Economics, University of Lugano, Switzerland.
- Filippini, Massimo and Mehdi Farsi (2004). *An analysis of efficiency and productivity in Swiss hospitals*, Final Report, Swiss Federal Statistical Office, Neuchâtel, Switzerland, June 2004.

- Folland, Sherman T. and R. A. Hofer (2001). "How reliable are hospital efficiency estimates? Exploiting the dual to homothetic production", *Health Economics*, 10: 683-698.
- Frisch, R. (1965). *Theory of Production*, Dordrecht, 1965.
- Gilligan, T. and M. Smirlock (1984). "An empirical study of joint production and scale economies in commercial banking", *Journal of Banking and Finance*, 8 (1): 67-76.
- Greene, William (2004). "Reconsidering Heterogeneity in Panel Data Estimators of the Stochastic Frontier Model", *Journal of Econometrics*, forthcoming.
- Greene, William (2003). "Simulated Likelihood Estimation of the Normal-Gamma Stochastic Frontier Function", *Journal of Productivity Analysis*, 19, (2/3): 179-190.
- Greene, William (2002b). "Alternative panel data estimators for stochastic frontier models", Working paper, Stern School of Business, New York University (September 2002).
- Griffin, Ronald C., J. M. Montgomery and M. E. Rister (1987). "Selecting Functional Form in Production Function Analysis", *Western Journal of Agricultural Economics*, December 1987, pp. 216-227.
- Hadley, Jack and Stephen Zuckerman (1994). "The role of efficiency measurement in hospital rate setting", *Journal of Health Economics*, 13: 335-340.
- Heshmati, Almas (2002). "Productivity measurement in Swedish departments of gynecology and obstetrics", *Structural Change and Dynamics*, 13: 315-336.
- Institut de Santé et d'Economie (2003). *APDRG Suisse - Cost Weights version 4.0*, Prilly, Switzerland, available in French and German at: www.hospvd.ch/ise/apdrg.
- Jondrow, J., I. Materov, K. Lovell, and P. Schmidt (1982) 'On the estimation of technical inefficiency in the stochastic frontier production function model' *Journal of Econometrics*, 19, 2/3 (August), 233-238.
- Kim, H. Y. (1987). "Economies of scale in multi-product firms: an empirical analysis", *Economica*, 54 (214): 185-206.
- Kruskal, W. H. and W. A. Wallis (1952). "Use of ranks in one-criterion variance analysis", *Journal of the American Statistical Association*, 47: 583-621.
- Kumbhakar, Subal C. and C. A. Knox Lovell (2000). *Stochastic Frontier Analysis*, Cambridge University Press, Cambridge.
- Linna, Miika (1998). "Measuring hospital cost efficiency with panel data models", *Health Economics*, 7: 415-427.
- Newhouse, Joseph P. (1994). "Frontier Estimation: How Useful a Tool for Health Economics", *Journal of Health Economics*, 13: 317-322.
- Pitt, M. and L. Lee (1981). "The measurement and sources of technical inefficiency in Indonesian weaving industry", *Journal of Development Economics*, 9: 43-64.
- Rosko, Michael D. (2001). "Cost efficiency of US hospitals: A stochastic frontier approach", *Health Economics*, 10: 539-551.
- S.F.S.O.: Swiss Federal Statistical Office (2001). *Statistiques des établissements de santé (soins intra-muros), Typologie des hôpitaux*, Office fédéral de la statistique,

- Section de la santé, Neuchâtel, Switzerland (available in French and German at www.statistik.admin.ch).
- S.F.S.O. (1997). *Statistiques des établissements de santé (soins intra-muros), Statistique des hôpitaux, Conception détaillée - Déc. 1997*, Office fédéral de la statistique, Section de la santé, Neuchâtel, Switzerland (available in French and German at www.statistik.admin.ch).
- S.F.S.O. (1997b). *Statistiques des établissements de santé (soins intra-muros), Statistique médicale des hôpitaux, Conception détaillée 1997*, Office fédéral de la statistique, Section de la santé, Neuchâtel, Switzerland (available in French and German at www.statistik.admin.ch).
- Schmidt, P. and R. E. Sickles, (1984). Production Frontiers and Panel Data, *Journal of Business and Economic Statistics*, 2, 367-374.
- Scuffham, Paul A., N. J. Devlin and M. Jaforullah (1996). "The structure of costs and production in New Zealand public hospitals: an application of the transcendental logarithmic variable cost function", *Applied Economics*, 28, 75-85.
- Silk, Alvin J. and Ernst R. Berndt (2003). "Scale and scope economies in the global advertising and marketing services business", *NBER Working Paper 9965*, National Bureau of Economic Research, Cambridge, MA.
- Simar, Leopold and P. W. Wilson (2000). "Statistical Inference in Nonparametric Frontier Models: The State of the Art", *Journal of Productivity Analysis*, 13: 49-78.
- Simar, Leopold (1992). "Estimating Efficiencies from Frontier Models with Panel Data: A Comparison of Parametric, Non-parametric and Semi-parametric Methods with Bootstrapping", *The Journal of Productivity Analysis*, 3, 171-203.
- Singh, Satbir and Tim Coelli (2001). "Performance of dairy plants in the cooperative and private sectors in India", *Annals of Public and Cooperative Economics*, 72 (4): 453-479.
- Skinner, Jonathan (1994). "What do stochastic frontier cost functions tell us about inefficiency?", *Journal of Health Economics*, 13: 323-328.
- Steinmann, L. and P. Zweifel (2003). "On the (in)efficiency of Swiss hospitals", *Applied Economics*, 35: 361-370.
- Vita, Michael G. (1990). "Exploring hospital production relationships with flexible functional forms", *Journal of Health Economics*, 9 (1990): 1-21.
- Vitaliano, D. and M. Toren (1996). "Hospital cost and efficiency in a regime of stringent regulation", *Eastern Economic Journal*, 22:161-184.
- Wagstaff, A. (1989). "Estimating Efficiency in the Hospital Sector: a Comparison of Three Statistical Cost Frontier Models", *Applied Economics*, 21, 659-672.
- Weninger, Quinn (2003). "Estimating multiproduct costs when some outputs are not produced", *Empirical Economics*, 28: 753-765.
- Zuckerman, Stephen, Jack Hadley and Lisa Iezzoni (1994). "Measuring hospital efficiency with frontier cost functions", *Journal of Health Economics*, 13 (1994): 255-280.

Appendix

Regression coefficients for canton dummies (Model *IV*)

	Coefficient	Std. Err.	Sample Mean
AG	0.1599 *	0.0718	0.0501
BL / BS / JU / SO	0.1368 *	0.0573	0.1111
FR	0.0682	0.0832	0.0610
GE	0.2902 *	0.0735	0.0196
GR	0.0599	0.0591	0.0479
LU / NW / OW / UR	0.1590 *	0.0793	0.0283
NE	-0.0106	0.1024	0.0523
SG / AI / AR / SH	-0.0090	0.0496	0.0588
TI	-0.1800 *	0.0542	0.1198
VD	0.0076	0.0461	0.1285
VS	-0.0089	0.0849	0.0523
ZG / GL / SZ	0.2322 *	0.0603	0.0523
ZH	0.1285 *	0.0557	0.0850
BE	0	-	0.1329

- The omitted canton is Bern (BE).

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Quaderno n. 04-10

A.S. Bergantino, S. Bolis, *An adaptive conjoint analysis of freight service alternatives : evaluating the maritime option*

Quaderno n. 05-01

M. Farsi, M. Filippini, *An analysis of efficiency and productivity in Swiss hospitals*