Mehdi Farsi

The temporal variation of cost-efficiency in Switzerland's hospitals : an application of mixed models

Quaderno N. 07-04

Decanato della Facoltà di Scienze economiche
Via G. Buffi, 13 CH-6900 Lugano

The Temporal Variation of Cost-efficiency in Switzerland's Hospitals: An Application of Mixed Models

Mehdi Farsi

Department of Management, Technology and Economics,
ETH Zurich, Zürichbergstr. 18, Zurich 8032, Switzerland
and
Department of Economics, University of Lugano, 6900 Lugano, Switzerland

November 2007

ABSTRACT

This paper examines the temporal variation of cost efficiency in Switzerland's general hospitals. The variation of total costs and the number of empty beds has been analyzed using a sample of 168 hospitals operating from 1998 to 2003. In addition more than 100,000 observations form the inpatient data disaggregated to DRG categories have been used to analyze the variations in the length of hospital stays across hospitals and over time. The adopted econometric specification is based on a mixed effects model, including individual fixed effects to account for the time-invariant unobserved heterogeneity and random coefficients representing different patterns of temporal variations across hospitals and DRG categories. The analyses aim at identifying different trends of efficiency changes across various types of hospitals regarding ownership and subsidization status and among different regions. The results of this paper indicate that hospitals have adopted measures to curtail hospitalizations and reduce empty beds, but the extent and effectiveness of these measures vary significantly across individual hospitals. While pointing to certain differences among cantons, the results do not provide any evidence in favor of a particular ownership type or subsidization regime. Moreover, while generally supporting the fact that decreasing empty beds has been used as an effective cost-cutting strategy, the data do not provide any conclusive evidence for the cost-savings expected from shortening hospitalizations.

Keywords: general hospitals, stochastic frontier, cost efficiency, mixed models, random coefficients

1. Introduction

Switzerland's health care expenditures and particularly the operating costs of Swiss general hospitals has been subject of much policy debate. The increasing growth of health care costs has raised public concern for containing the hospitalization costs. Starting from 1994, together with the introduction of the mandatory federal insurance law and its implementation in 1996, the Swiss legislators have introduced several measures in order to give discretionary power to cantonal authorities for controlling the hospitals' expenses. Among the main measures was the optional implementation of a prospective reimbursement system at the discretion of cantons. Along with these legislation reforms, the mandatory Diagnosis Related Group (DRG) coding system has been implemented in 1998 across all cantons.

Although the implementation of the prospective payment system has so far taken various forms across cantons and mostly been limited to specific services such as ambulatory visits, hospital managers throughout the country are increasingly aware of the public concerns and the pressure exerted by health care authorities. This awareness is reflected in increasingly economical planning of hospitalizations, careful DRG coding and recording the data for an eventual justification of the costs. While one can reasonably assume that all Swiss hospitals have committed themselves to containing health care costs, most policy debates reflect a common perception that certain types of hospitals do not have strong incentive for a substantial improvement in their efficiency. Small local hospitals, non-profit providers and university hospitals are among the types that have often been singled out as inefficient providers. Several studies have tried to detect the efficiency differences across different ownership and organization types (*cf*. Farsi and Filippini, 2006, 2007; Steinmann and Zweifel, 2003). However, while finding significant differences in productivity and cost-efficiency among hospitals, none of the available empirical studies have so far provided any conclusive evidence of any association of these differences with specific hospital types. Identifying the sources of efficiency differences remains an open question that needs further exploration.

The main methodological problem in such statistical analyses is the fact of the cost differences among hospitals might be attributed to unobserved factors such as quality of service and case-mix severity factors. Assuming that the hospitals have undertaken measures to control their costs, this paper adopts a different approach from the previous studies, in that it focuses on the variation of hospitals' efficiency over time. The working hypothesis is that parallel with policy reforms whose implementation dates back to 1998, the Swiss hospitals have adopted cost-reduction measures such as curbing the length of hospitalizations and reducing the excess capacity. The main purpose of this study is to explore the differences across hospital types regarding the extent and effectiveness of these cost-saving measures. Rather than searching for a reliable estimate of a specific hospital's efficiency at a given period, this paper aims at identifying the hospital-specific rates of change in cost-efficiency.

Using a relatively rich panel data set including 168 general hospitals operating from 1998 to 2003 and using about 130,000 observations on the average length of hospitalization of patients with similar DRG's, this paper attempts to study the evolution of efficiency in Swiss general hospitals during the recent period starting from the main policy reforms. In addition to the cost analysis, the variation of hospitals' excess capacity and their average lengths of stays have been analyzed. Similarly these analyses aim at identifying the patterns of variations across different types of hospitals and those across various regions.

The econometric specification is based on a mixed panel data model that combines individual hospital and DRG fixed effects with random coefficients of the time variables. The frontier approach is based on a special version of the general parametric framework proposed by Sickles (2005), or the mixed effects model proposed by Kneip et al. (2003). The adopted model can be considered as an extension of the random effects model proposed by Cornwell et al. (1990).

Overall the results suggest a considerable overall growth in hospital costs over the sample period. The results point to significant efficiency differences among hospitals regarding their cost-reduction efforts. While the efficiency differences across cantons could be significant, the findings generally do not provide any evidence in favor of a particular hospital ownership type or subsidization status. The analysis in general indicates that hospitals that had relatively important cuts in their empty beds are likely to have relatively good efficiency gains. The evidence regarding the hospitalization length is nor conclusive. In most cases, the cost reductions that are often expected from shortening hospital stays do not appear to be significant. However, the results suggest that at least in certain hospitals that have not had relative efficiency gain, the length of hospitalization might be an important factor for consideration.

The rest of the paper is organized as follows. Section 2 provides a critical discussion of the methods of efficiency estimation and justifies the adopted methodology used in this paper. The econometric specification and the explanatory variables are described in Section 3. Section 4 summarizes the data and provides the descriptive statistics of the main variables included in the models. Section 5 presents and analyzes the estimation results and Section 6 concludes the paper with summary of main results and policy implications.

2. Methods

The estimation of firm-specific efficiency is a contentious topic that has been subject of a great body of literature that has developed a variety of econometric models commonly referred to as Stochastic Frontier Analysis. The application of these models to health care providers such as hospitals has been questioned by several authors (Newhouse, 1994; Skinner, 1994; Street, 2003; Folland and Hofler, 2001). The main criticism against these models is based on the fact that a hospital provides a myriad of various services that cannot be aggregated in a few output measures. In fact the number of hospital services is so large that cannot be summarized in a practically manageable multi-output cost or production function. In other words, such aggregation could leave out important factors that distinguish individual hospitals.

Despite these general criticisms the efficiency analysis in health care sector remains commonplace (Hollingsworth and Street, 2006; Worthington, 2004; Rowenta *et al*., 2006). While admitting the limitations of their approach many authors have adopted various measures for accounting for output characteristics such as case mix severity indexes and other distinctive hospital characteristics (Zuckerman *et al.*, 1994; Linna, 1998; Rosko, 2001; Deily and McKay, 2006; Brown, 2003). Other studies have used econometric modeling strategies that have proved more robust in presence of such heterogeneities (Liu *et al*., 2007; Bradford *et al*., 2001) or panel data models that account for unobserved factors through hospital-specific stochastic terms (Farsi and Filippini, 2007). The latter models usually labeled as 'true' frontier models have been proposed by Greene (2005a,b) and has been applied in several studies on different health-care related contexts (Greene, 2004; Farsi *et al.*, 2005). The basic underlying assumption in these models is that hospital characteristics that are beyond the management control like severity of illness, are more or less constant over time, while (in)efficiency is a time-variant stochastic component.

This is a practical and realistic assumption that allows a distinction between the time-variant efficiency differences and the hospital-specific unobserved heterogeneity that is unrelated to inefficiency (hereafter, simply referred to as "heterogeneity"). Such models have also certain appealing feature for the regulators and policy makers in that in addition to providing efficiency estimates for a given company in a specific year they allow an identification of those companies that might be inefficient in a persistent way. The efficiency estimation remains however a challenge to the researchers in this field, mainly because of a general shortcoming in most frontier models namely, the excessively large prediction (estimation) errors entailed in the estimation of efficiency based on a single observation point. Studies such as Horrace and Schmidt (1996) and Jensen (2000) have pointed out the fact that the differences between estimates of efficiency across individual companies might be entirely due to statistical sampling errors. It should be noted that such discrepancies are not limited to cross-sectional data or parametric approaches (*cf*. Hawdon, 2003; Farsi *et al*., 2006). The main problem is that if one assumes a stochastic variation of inefficiency over time, there will be only one sample point for the estimation of efficiency of a given firm in a given period, hence large estimation errors. On the other hand, if one assumes that inefficiency is constant, panel data provide several observations thus decreases the estimation errors. However the criticism shifts to the validity of the estimates as they might be biased by the firm-specific omitted factors that are not related to inefficiency. This is especially important in health care applications in which many unobserved factors might remain stable for a given provider. For instance severity might depend on the location of the hospital (more or less similar mix of patients from a given neighborhood) or quality of care and the offered specializations that are long-term determinants that could not change over a short period of time.

The frontier literature is rich in the modeling approaches that provide a compromise solution between models with stochastically time-variant inefficiency and those with time-invariant efficiency terms. The first generation of these models such as Kumbhakar (1990) and Battese and Coelli (1992), extend the random effects model proposed by Pitt and Lee (1981) to include a uniform time-variation of efficiency for all the firms. The extensions of these models starting from Cornwell et al. (1990) and developing into mixed effects models with Kneip et al. (2003) and semi-parametric models with Sickles (2005), have considered functional forms of temporal variation that vary across individual companies.

Sickles (2005) provides a general framework for the treatment of time-varying efficiency. He recognizes the vulnerability of efficiency and productivity measures as estimation residuals and 'reduced from' concepts that are inevitably based on ad hoc econometric specifications. With a series of Monte Carlo simulations and applying several alternative specifications, the author highlights the difficulties in identifying firm-specific and time-varying efficiency. Sickles (2005) asserts that the robustness, flexibility and precision are the most 'important distinguishing features' that should be considered in model specification strategies.

From an econometric point of view the robustness can be achieved by relaxing the assumptions on the distribution and the correlation structure. For instance, considering freely distributed fixed effects instead of random effects with specific distributions is a solution that has been most commonly used, dating back to Schmidt and Sickles (1984). The fixed effects are particularly interesting as they allow a more realistic assumption about the potential correlation between the individual effects and the explanatory variables. However, the first generation of these models have not shown much success mainly because the firm-specific inefficiency can be over-estimated to implausible levels (Farsi et al., 2005; Farsi and Filippini, 2004). In fact the firm's fixed effect that is interpreted as inefficiency captures much of the unobserved time-invariant factors that might be unrelated to inefficiency. More recent models such as the fixed effects frontier models proposed by Polachek and Yoon (1996) and Greene's (2005a,b)[1] include an additional time-varying skewed stochastic component in the fixed effects model for representing inefficiency. While being attractive in theory, this model is numerically cumbersome in practice. Although authors like Greene (2005b) provide powerful numerical algorithms for solving the frontier specification with fixed effects, according to this author's experience, the available algorithms for the estimation of this model could lead to unreliable estimates that can perhaps be explained by the incidental parameters problem in non-linear models.

Farsi *et al*. (2005) have proposed a specification based on Greene's (2005a,b) 'true' random effects model, that reconciles the flexibility of fixed effects estimation with the precision and efficiency of random effects model. The proposed modification is based on Mundlak's (1978) specification of fixed effects estimator through incorporating the individual sample means in the random effects model, thus allowing correlation between the individual effects with the explanatory variables.

In any case, regardless of whether the individual effects are fixed or random, a rich error structure such as that in Greene's (2005a,b) 'true' frontier models or those proposed by Polachek and Yoon (1996) or earlier by Kumbhakar (1991) exacerbates

[1] This model is named 'true fixed effects model' by Greene (2005a,b).

the sensitivity of frontier models to the skewness of the residuals. In fact, these models like the original frontier approach in cross-sectional data (Aigner *et al*., 1977; Meeusen *et al*., 1977) rely on the skewness of the regression residuals to produce any meaningful values for efficiency estimates. When the residuals are decomposed into three components instead of two (as in the original cross-sectional models) respectively for random noise and efficiency term, the skewness of the latter term can be sensitive to slight changes in the observations or the included explanatory variables. In many cases, such changes might easily cause one of the stochastic components degenerate to zero.

While recognizing that the firm's efficiency can vary from one year to another, one could argue that a fully stochastic variation over time implies an idiosyncratic nature for the temporal changes in the firm's productive efficiency. This is probably a too flexible assumption that ignores the fact that these changes originate from an underlying learning process that is specific to the firm's management and their efforts in improving productivity. In other words, even assuming that firms constantly face new technology shocks and market developments that make their resulting productive efficiency look like a stochastic variable, it is unrealistic to assume that such variable is independently distributed over time. As Alvarez and Schmidt (2006) point out, even though the randomness appears to be quite important, 'over longer periods of time, skill persists while luck averages away.'

Furthermore, even if the nature of shocks is such that the independence assumption simulates the real situation, these models remain heavily dependent on the distribution assumptions. In fact the only way to distinguish random noise from the efficiency term is through a non-testable distribution assumption that assigns for instance a half-normal distribution to efficiency and a normal distribution to random noise.

As Sickles (2005) has pointed out, in many cases the parametric assumptions help to have a better interpretation of the results. Therefore, a reasonable assumption would be to assign a deterministic functional form for the temporal variation of firm's efficiency while allowing for changes in the values of the parameters across different companies. This is the approach adopted by Cornwell et al. (1990) through a quadratic function and Lee and Schmidt (1993) with a linear function both with random coefficients that vary across firms. The functional form and the variation of the individual effects have been later extended to mixed effects models and semi-parametric models respectively by Kneip et al. (2003) and Sickles (2005).

Sickles (2005) presents the general framework of these models. While the general framework can be applied with random or fixed effects, the latter approach requires a long panel data in order to avoid the problems related to incidental parameters. For instance a quadratic form for temporal variations requires the estimation of 3 fixed parameters for each company, which creates a considerable plausibility problem for short and medium panels. In order to avoid such problems, in this paper a mixed effects version has been adopted, in which the companies individual intercepts are specified as fixed effects while the coefficients of the time variables are considered as random effects. A formal description of this specification will be presented in the next section.

Another important issue in the estimation of productive efficiency is the study of the sources of inefficiency. The reduced form of the frontier model does not allow in itself an understanding of the inefficiency sources. As Sickles (2005) elegantly points out, a 'strong institutional understanding of the industry under study' is required to choose an adequate estimator among the available alternatives that satisfy the generic properties. Given the existing discrepancy and sensitivity issues in the frontier methodology (as discussed earlier), most studies face a recurrent question regarding the validity and reliability of efficiency estimates, namely, whether these estimates are artifact of sampling variations. An appropriate way to explore the question is to study the potential sources of inefficiency.

For instance, in the case of hospitals, unnecessarily long hospitalizations might be a source of excess costs. This is surely a debatable issue that has been subject of a number of papers. For instance Carey (2000) provides evidence that the US hospitals, facing the policy concerns about rising costs, have reduced the lengths of hospitalizations. Her findings suggest however, that the extent of cost savings has been commonly overstated. Other studies suggested that curtailing the hospital stays has led to a deterioration of quality of care and might have a counter-productive effect in the long run. In Switzerland, as shown by Farsi and Filippini (2005), there is a considerable variation in the average length of stay among hospitals and the small local hospitals have on average significantly longer hospitalizations. As shown in that study, the marginal cost of one day hospital stay is considerable. Therefore, it is helpful to see if the changes in average length of hospitalization have any relationship with the observed cost savings. Another potential source of inefficiency in hospitals could be related to excess capacity. For instance Gaynor and Anderson (1995) estimate that in the US, the costs of empty hospital beds could amount to 9.5% of the total costs.

Partial efficiency measures based on length of hospital stays and the number of empty beds, could be helpful in understanding at least how the hospitals deal with these sources of inefficiency and to what extent they could reduce the hospital's overall costs. In particular, the length of stay is an interesting measure that can be analyzed at micro level. Unlike the cost data that are not usually available in disaggregate form, the records of hospital stays are generally available for individual patients. Such micro-level analyses can be helpful in understanding the temporal variation in hospitals' strategies for reducing costs. In this paper, in addition to hospital cots, the variation of the average number of hospital's empty beds and the average length of hospital stays at the DRG level have been analyzed.

3. Model specification

The main measure of hospital's inefficiency used in this paper is based on a total cost function with a Cobb-Douglas functional form. The second measure is based on a measure of excess capacity represented by the hospital's average number of empty beds. Finally, the third measure of efficiency is based on the average length of hospitalization. In all three analyses, the working hypothesis is that hospitals have adopted measures to contain their operating costs by improving their overall productive efficiency (cost-efficiency), by reducing their excess capacity, or by curtailing the hospital stays. Including individual fixed effects allows a straightforward identification of the temporal variation of each of the three variables without worrying about the unobserved hospital-specific characteristics and their potential correlation with the observed explanatory variables. However, the downside is that the efficiency variations across hospitals that are stable over time, cannot be identified as they are captured along other external heterogeneities, by the fixed effects. Therefore, any assessment of hospitals' performances based on the results of this study is valid only to the extent that the hospitals do not differ significantly with respect to their initial efficiency before the reforms say in 1998.

The explanatory variables for the cost function include two outputs namely, the severity adjusted number of hospitalizations, a measure of ambulatory services offered by the hospital, and three input factor prices *i.e.*, labor price in two categories, non-physician employees and employed physicians, and capital price. The average length of hospitalization and the number of medical training positions (interns and medical students) have also been included as output characteristics. The above explanatory variables for the cost function are similar to the specification used in Farsi and Filippini (2007). The reader will be referred to that paper for a justification for including each of these variables and also the choice of the adopted functional form. It should be noted that because of the presence of hospitals' individual fixed effects, a number of variables that are time-invariant or practically stable over time have been excluded from the model.

For the excess capacity the explanatory variables are specified as follows: the number of hospitalizations and the share of patients with private health insurance. The idea here is that hospitals should adjust the number of available beds according to the changes and fluctuations in the demand and also to accommodate their private-insurance patients who are entitled to rooms that are not shared by several patients. The working hypothesis is that if a hospital has a higher share of private-insurance patients, it is likely to have a higher excess capacity to accommodate those patients.

As for the length of hospitalization, the analysis has been conducted at the DRG level. Namely, the dependent variable is the average length of stay for the patients within a given DRG, hospitalized in a given hospital during a given year. Individual fixed effects are considered for each hospital-DRG group. In addition to time variables, the total number of training positions has been included as explanatory variable. The findings in previous studies such as Rogowski and Newhouse (1992) and Simmer *et al*. (1991) suggest that hospitals with more teaching activities are likely to have longer hospitalizations. In line with the Rogowski and Newhouse, here it is assumed that this potential effect is a result of 'indirect' costs of training medical students and not due to hospital's inefficiency as Simmer *et al*. suggest.

As shown by Martin and Smith (1996), the length of stay could depend on several patient characteristics that cannot be summarized in the DRG categories, thus remain among unobserved variables in the present analysis. Part of such variations should be captured by the hospital-DRG fixed effects. In order to have unbiased results it is required to assume that the remaining variation is uncorrelated with the hospital type.

The definition and the summary statistics of all the variables included in the models will be provided in the data section. Now we turn to the adopted econometric specification. The cost model used in this study is based on a mixed effects model written as:

$$\ln C_{it} = \boldsymbol{\beta} \ln \mathbf{X}_{it} + \boldsymbol{\gamma} \mathbf{Z}_i + \rho t + \varphi t^2 + \alpha_i + u_{it} + \varepsilon_{it}, \qquad (1)$$

where i and t represent the hospital and year respectively with t=0 representing the first year covered in the sample; C is the total costs; $\ln\mathbf{X}_{it}$ is the vector of time-varying explanatory variables expressed in logarithm; $\mathbf{Z}_i$ is a vector including all the hospital-specific characteristics that do not vary with time; and $[\boldsymbol{\beta}, \boldsymbol{\gamma}, \rho, \varphi]$ is the vector of regression coefficients. The stochastic terms α_i and ε_{it} respectively represent the hospital's individual effect and the random noise. Finally u_{it} is the inefficiency (here cost-inefficiency) of hospital i at year t, specified as a quadratic function of time:

$$u_{it} = u_{i0} + \delta_i t + \theta_i t^2, \qquad (2)$$

with u_{i0} representing hospital i's initial inefficiency at year t=0, δ_i and θ_i are random coefficients with a multivariate normal distribution, specified as:

$$\begin{pmatrix}\delta_i \\ \theta_i\end{pmatrix} \sim N(\mathbf{0}, \mathbf{\Sigma});\ \text{with}\ \mathbf{\Sigma} = \begin{pmatrix}\sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2\end{pmatrix}, \tag{3}$$

where $(\sigma_1, \sigma_2, \sigma_{12})$ are the parameters to be estimated. The residual term ε_{it} is assumed to be normally distributed with zero mean: $N(0, \sigma_\varepsilon^2)$ and the individual effects α_i are assumed to be constant fixed effects.

The mean values of the random coefficients (δ_i, θ_i) have been set to zero. This is a simplifying assumption that allows the parameters (ρ, φ) to be identified, while recognizing that the hospital costs might follow a growth pattern that is not related to hospitals' efficiency, but due to external factors, such as the general progress in medical treatments and pharmaceuticals that are increasingly more costly. Such temporal variations that are not captured by the explanatory variables included in the model, are assumed to be more or less similar for all hospitals, thus represented by the average growth in costs captured by parameter pair (ρ, φ).

The model in Equation (1) is a mixed effects model with both random and fixed effects. It should be noted that because of the presence of the fixed effects the coefficient vector $\boldsymbol{\gamma}$ cannot be identified in this model. This model can be easily transformed to a random-coefficient model on the deviations from hospital means. Using Equation (2), and denoting the "within-demeaning" operator for hospital i, by Δ_i. the model can be re-written as:

$$\Delta_i \ln C_{it} = \boldsymbol{\beta}.\Delta_i \ln \mathbf{X}_{it} + \rho.\Delta_i t + \varphi.\Delta_i t^2 + \delta_i.\Delta_i t + \theta_i.\Delta_i t^2 + \varepsilon_{it}, \tag{4}$$

where $\Delta_i x_{it}$ for a generic variable x_{it} is defined as the deviation of the variable from its mean value ($\bar{x}_i$) within hospital *i*:

$$\Delta_i x_{it} = x_{it} - \bar{x}_i \; ; \text{ with } \bar{x}_i = \frac{1}{T_i}\sum_{t=0}^{T_i} x_{it} \; , \tag{5}$$

where T_i is the number of periods for hospital *i*.

As it can be seen the above specification does not allow a separate identification of the unobserved heterogeneity represented by fixed effects α_i and the initial inefficiencies denoted by u_{i0}. Both of these terms along with the time-invariant variables $\mathbf{Z}_i$ (including the model's intercept) are canceled out in the above within transformation. The random-coefficient models described in Equation (4) can be estimated using the EM algorithm. This model is the basis of the econometric estimations in this paper. The parameters to be estimated are $\{\boldsymbol{\beta}, \rho, \varphi, \sigma_\varepsilon, \sigma_1, \sigma_2, \sigma_{12}\}$. The hospital specific parameters (δ_i, θ_i) can be estimated by a conditional Bayesian predictor, based on the estimated parameters and the obtained residuals for each hospital.

The model used for the analysis of the hospitals' excess capacity is similar to that described in Equation (4) with the difference that the dependent variable is the number of hospital's empty beds (instead of total costs) and includes its own the explanatory variables **X**. Another difference is that unlike costs, there is no reason other than efficiency improvement that the excess capacity should uniformly grow or decrease among all hospitals. Therefore it is reasonable to relax the zero-mean assumption for the individual random coefficients. Thus, the resulting specification can be written as:

$$\Delta_i \ln E_{it} = \boldsymbol{\beta}^e . \Delta_i \ln \mathbf{X}_{it} + \delta_i^e . \Delta_i t + \theta_i^e . \Delta_i t^2 + \varepsilon_{it}^e \; , \tag{6}$$

where E is the number of empty beds and superscript e denotes parameters related to excess capacity; and the random coefficients are specified as:

$$\begin{pmatrix} \delta_i^e \\ \theta_i^e \end{pmatrix} \sim N(\boldsymbol{\mu}^e, \boldsymbol{\Sigma}^e); \text{ with } \boldsymbol{\mu}^e = \begin{pmatrix} \rho^e \\ \varphi^e \end{pmatrix}, \ \boldsymbol{\Sigma}^e = \begin{pmatrix} (\sigma_1^e)^2 & \sigma_{12}^e \\ \sigma_{12}^e & (\sigma_2^e)^2 \end{pmatrix}. \quad (7)$$

The analysis of hospitals' average length of stay (LOS) has been conducted at DRG level observations. Denoting DRG group by subscript j, the model specification for this analysis can be formulated as:

$$\Delta_{ij} \ln L_{ijt} = \boldsymbol{\beta}^l .\Delta_{ij} \ln \mathbf{X}_{ijt} + \delta_{ij}^l .\Delta_{ij} t + \theta_{ij}^l .\Delta_{ij} t^2 + \varepsilon_{ijt}^l , \quad (8)$$

where L_{ijt} is the average LOS for DRG group j hospitalized in hospital i during period t; superscript l denotes parameters related to LOS equation; and the random coefficients and the within operator are respectively defined as:

$$\begin{pmatrix} \delta_{ij}^l \\ \theta_{ij}^l \end{pmatrix} \sim N(\boldsymbol{\mu}^l, \boldsymbol{\Sigma}^l); \text{ with } \boldsymbol{\mu}^l = \begin{pmatrix} \rho^l \\ \varphi^l \end{pmatrix}, \ \boldsymbol{\Sigma}^l = \begin{pmatrix} (\sigma_1^l)^2 & \sigma_{12}^l \\ \sigma_{12}^l & (\sigma_2^l)^2 \end{pmatrix}, \quad (9)$$

$$\Delta_{ij} x_{ijt} = x_{ijt} - \bar{x}_{ij} ; \ \text{ with } \bar{x}_{ij} = \frac{1}{T_{ij}} \sum_{t=0}^{T_{ij}} x_{ijt} , \quad (10)$$

where T_{ij} is the number of periods for patients with DRG j treated in hospital i.

The random-coefficient models described in Equations (4), (6) and (8) have been estimated using the EM algorithm and the hospital specific parameters have been using a conditional Bayesian predictor. As the main objective of this paper is to compare the efficiency trends across various hospital types such as ownership, or different regions, the estimated random coefficients have been grouped for different hospital categories. In order to test the statistical significance of the differences across various categories the Kruskal-Wallis (1952) rank test as well as the t-test with unequal variances has been considered. The Kruskal-Wallis test is a non-parametric test that has been often used in frontier analysis (Singh and Coelli, 2001; Grosskopf *et al*., 2001).[2]

4. Data

The data used in this paper consists of two samples. The first data set is hospital-level sample that is extracted from the annual financial and administrative data reported by general hospitals[3] to the Federal Statistical Office (SFSO, 1997a) from 1998 to 2003. These data have been merged with another data set consisting of an aggregate extraction of the medical data of the Swiss hospitals with records for individual hospitalizations (SFSO, 1997b). The extracted medical data consist of the number of cases by AP-DRG in each hospital-year, including information about the average length of hospitalization for each group and admission type.

This data set that includes about a million observations has been used to extract data on the average length of stay by hospital, year and DRG categories. Moreover, these data have been used to estimate an average cost weight calculated for each hospital-year. This average value is obtained by dividing the weighted sum of the number of admissions recorded in the medical data with weights being the cost weights from Swiss AP-DRG version 4.0 (APDRG Suisse, 2003) for each DRG category, by the total number of cases recorded in the medical data. The adjusted number of admissions for a given hospital-year is then calculated by multiplying these average cost weights by the number of admissions recorded in the administrative data, which had generally fewer missing values than the medical data (second data set).

[2] An alternative approach would be to include type indicators as interaction terms in the regression models and test the significance of the corresponding coefficients. I preferred the non-parametric test based on hospitals' ranks. Some of the advantages of this approach have been outlined in Farsi and Filippini (2004, 2007).

[3] Specialized clinics, rehabilitation centers and other long-term facilities have been excluded.

Since one of the main purposes of this study is to identify potential differences across different ownership types, ten hospitals that have changed ownership status over the sample period have been excluded. These hospitals might have undergone under efficiency changes prior to conversion, therefore might bias the results (*cf.* Farsi, 2004). In order to have a sufficient number of sample points over time, about 36 hospitals that have been covered for less than three years have also been excluded. In addition a few hospitals with less than ten beds were excluded, as they might belong to a special outlier category. After dropping the observations with missing values and invalid data, the final hospital-level sample includes 863 observations from 168 general hospitals.

As for the DRG-level data, the adopted sample has been restricted to the hospitals that have been included in the hospital-level data set and also the categories included in Swiss AP-DRG version 4.0. The analysis is also limited to the full hospitalizations that are by definition longer than 24 hours and the AP-DRG categories that have a clear definition. Namely, the DRG categories that are described by ambiguous terms like 'other' or 'non-specified' have been excluded. In order to avoid the outlier value problem that might arise when the number of cases is limited, all the observations that are based on fewer than three cases were excluded. Moreover, about 1600 observations that could be considered as severe outliers based on 3 times the inter-quartile range (equivalent to average LOS of 36.4 days) have been excluded. The final sample includes 108,227 observations from 162 general hospitals, 492 AP-DRG categories, 826 hospital-year groups and 23,281 hospital-DRG groups. From the 492 DRG's included in the sample, 223 are classified as surgical procedures. In terms of the number of hospitals and the composition of hospital types regarding ownership, university hospitals and also the distribution across different regions, this sample is very similar to the hospital-level sample used for the analyses of cost and excess capacity. A descriptive summary of the main variables included in the models is provided in Table 1. In the rest of this section these variables will be described.

Insert Table 1

The main measure of hospital output is taken as a DRG weighted number of hospitalizations (*cf*. Linna, 1998; Rosko, 2001; Heshmati, 2002). This approach was preferred over the alternative based on multiple output categories based on DRG weights (Brown, 2003), mainly because such categories might be arbitrary as the DRG weights define the cost intensity of the cases rather than different outputs. Since the number of outpatient cases is not available in the data, the ambulatory output is approximated by the corresponding revenues adjusted for inflation. This approximation is based on the assumption that the average unit price of ambulatory care is similar across hospitals.

Three input factors are considered: capital, physicians' input and all other employees' labor. Similar to Wagstaff and Lopez (1995) and Rosko (2001), capital prices, are approximated by the hospital's total capital expenditure divided by the number of available beds in the hospital. Labor prices are calculated by dividing total salaries by the number of remunerated days. Physicians and non-physicians are considered as two separate labor inputs similar (*cf*. Folland and Hofler, 2001; Scuffham *et al.*, 1996). The physicians' labor price represents the average salary of those employed by the hospital and exclude honoraries and fees, accounting on average for about 5% of the hospital's total costs, usually paid to both employed and unemployed physicians. Both labor prices are proportionally adjusted for social benefits, accounting on average, for about 9% of total costs with the proportions being the respective shares of each group's salaries. This adjustment captures the potential variation in social benefits due to differences in pension funds as well as the age and seniority of the employees mix.

The three input factor prices considered in the model correspond to about 70 percent of a hospital's total cost on average. The available data do not allow an appropriate calculation of the prices of remaining inputs such as medical materials, food, water and power as well as physicians' fees and other personnel charges. The excluded prices are obviously not constant and neglecting their variation over time could affect the estimation results. We assume that these variations are more or less uniform for all hospitals, thus captured by the time variables included in the cost model.

The average length of hospitalization has been included in the model (Vita, 1990; Scuffham *et al.*, 1996; Carey, 1997). In addition to representing hospital's 'hotel services' like nursing care and accommodation (Breyer, 1987), this variable provides a measure of severity of the case mix within each DRG. In fact, there is a considerable variation among patients within a DRG, as indicated by the wide range of acceptable hospital stays provided by the Swiss DRG Association (APDRG Suisse, 2003).

Hospitals' costs can also be affected by the number of specializations and services offered in a hospital. Here we assume that these factors are time-invariant, thus captured by the fixed effects. The shortcoming of the analysis is mainly related to the quality of care. In fact, it is reasonable to consider that by improving cost-efficiency, certain quality aspects of health care might be compromised. We do not have any reliable data on any measure of quality in Swiss hospitals that show a reasonable variation over the sample period. It should be however noted that the evidence on the effect of quality measures on hospital costs is not conclusive. Zuckermann et al (1994), Rosko (2001) and Vitaliano and Toren (1996) conclude that quality indicators do not have significant cost effects, whereas others such as Folland and Hofler (2001) suggest a significant effect for structural quality measures such as bed availability and the share of board-certified physicians.

The measure of excess capacity is based on the average number of empty beds in a given hospital-year. This is obtained by subtracting the number of available beds by the total number of patient days divided by 365. The semi-hospitalizations (inpatient hospital stays shorter than 24 hours) have been considered as one-day stays. The data show some discrepancy in this measure particularly several negative values. These values have been re-calculated using an alternative measure of hospital's available beds namely, the number of hospital's bed-days.

Hospital types have been considered in several aspects. The ownership status and subsidization form have been considered in four categories: public hospitals (which are also subsidized), private subsidized hospitals (mainly non-profit), non-subsidized private non-profit hospitals, and finally non-subsidized for-profit hospitals. The hospital categories regarding the size and specialization are based on the Swiss Federal Statistical Office's classification that groups general hospitals into five *typologies*. The details of this classification are given in SFSO (2001). Typology 1 includes only the five university hospitals, which provide a wide variety of services in a large number of specializations. At the other extreme, basic-care hospitals of level 3 are local small general hospitals (mostly less than 100 beds) that provide basic medical care with few specializations. Because of certain autonomy of cantons in the regulation of hospitals and the implementation of health policy reforms, one can expect differences across cantons. The number of observations within cantons is however small. In order to avoid the small-sample problem, five regional categories have been defined. These categories are mainly based on the observed patterns in the cooperation and policy coordination among the neighboring cantons as reflected by the inter-cantonal health policy conferences and meetings. In certain cases a more refined grouping has been considered based on the extent of the canton's main hospitals' health service area and the flow of patients across cantons. The distributions of hospitals included in the sample, among the three classifications are given in Table 2.

Insert Table 2

5. Results

Table 3 lists the regression results of the hospital-level analysis based on Equations (4) and (6), respectively for total costs and excess capacity. The estimation results for a similar model for the length of stay are also reported in the table. The results of the cost model point to considerable effects of hospital stays on costs. The variation of other factors such as ambulatory services and the training positions though being statistically significant are practically limited to a few percentage points in terms of elasticity. As expected, the price coefficients are positive and mostly significant. The estimated coefficients are mostly significant and generally have the expected signs. In the interpretation of the cost function's coefficients here, one should note that the hospitals' individual fixed effects are also included in the model. Although being useful for an effective estimation of the temporal variations free from time-invariant heterogeneity, the fixed effects capture all the 'between' variation, namely the long-term stabilized differences across hospitals. Therefore, the estimated marginal effects and elasticities will be based on within-hospital variations that are generally more limited and could be of a transient short-term effect. The implication is that the estimated results can only be used to predict quantities or behaviors that entail a limited range of variation that is reasonably comparable to the within hospital variations in the sample. Moreover, the presence of fixed effects can partly explain the relative weakness of the statistical significance in some of the included variables, compared to a pooled or a random-effects model.[4]

Insert Table 3

The estimation results of the cost analysis (Table 3) point to a pattern of increasing growth in hospital' operating costs, as suggested by the positive coefficients of the time variables included in the model. The numbers indicate an average growth rate of about 1.6 percent per year. The results also suggest that the temporal changes are significantly different from one hospital top another, as shown by the statistically significant values for the variance of the random effects. This implies that hospitals differ in their performance regarding cost-efficiency. The negative covariance between the two random coefficients is consistent with the fact that any growth (decline) is likely to slow down with time. The negative correlation implies for instance, that hospitals that start to cut the costs earlier and more aggressively, will have a relatively lower success later.

The estimation results from the analysis of excess capacity (Table 3, middle column) indicate that hospitals have decreased their empty beds with a substantial rate of about 8.6% per year on average. The effect of number of admissions is against our expectation. This can be explained by the mechanical negative relationship between admissions and the number of empty beds. Such a relationship might create endogeneity bias in the hospital-specific estimates of growth in excess capacity.

[4] Compare for instance with the estimation results reported in Farsi and Filippini (2007).

However, a preliminary analysis showed that an alternative model excluding the number of admissions would produce more or less similar results. As expected the share of private-insurance patients shows a positive effect on excess capacity, however, the coefficient is not statistically significant. Similarly the results indicate significant variation across hospitals regarding the empty beds.

Finally the results of hospital-level analysis of LOS are reported in the last column of the table. These results suggest an average decrease of about 3.3% per year in the length of hospitalizations. As expected the AP-DRG cost weight and the number of training positions have positive effects on length-of-stay, but the latter effect is not statistically significant. This aggregate analysis of LOS will only by used for comparison purposes. Table 4 provides the results of the main DRG-level analysis of the length of hospitalizations. As seen in the table, the results are somewhat different from those of the aggregate analysis in the previous table. In fact the estimated annual rate of decrease is about 2% on average. This might suggest that aggregating at the hospital level might bias the results. In fact, disaggregated data are less sensitive to outliers whose presence in one hospital-year group might distort the temporal patterns in that hospital. It should also be noted that in the DRG-level analysis, each of the hospital-DRG groups have their own fixed effect in the model. Therefore, the results might be more representative of the real situation, because in fact each specific DRG could have different potentials regarding the length of hospitalization.

Insert Table 4

The results listed in Table 4 indicate a significant variation in changes in LOS, across the included hospitals and also among the AP-DRG groups. Similar to Table 3, these results suggest that the study of the variations across hospital types and also across individual hospitals could be used to test hypotheses regarding the efficiency patterns in the hospital sector. Before turning to the results of these statistical tests, it is worthwhile to summarize the overall efficiency trends of the Swiss hospital sector. The average estimated time effects form the above tables are illustrated in Figure 1. This graph is drawn on the basis of the initial values associated with 1998. The variation of LOS is based on the DRG-level analysis (Table 4).

Insert Figure 1

As can be seen in the figure, over the five-year span in the sample period (1998-2003) a typical hospital's costs have grown about 14 percent. This is while the length of hospital stays and the number of empty beds have decreased by about 10 and 18 percent respectively. As shown here and in previous literature, hospital costs are growing throughout many countries. This growth has been often associated with new medical procedures and pharmaceuticals as well as the extension of life expectancy. These are obviously external factors that are modeled by average trends in the model specification used here. The hospital-specific inefficiency is roughly speaking, the hospital's excess costs as compared to the average increasing trend shown in Figure 1. The substantial rate of decline in LOS and hospital empty beds shown in the figure is an indicative that hospitals have made considerable efforts to contain the costs. The efficiency gain (loss) based on Equation (2) is a hospital-specific measure of these efforts as reflected in costs. Similar measures are obtained for the length-of-stay and empty beds.

With a series of statistical tests the differences between the three hospital groupings listed in Table 2, have been analyzed. The results generally suggest that the differences of across the ownership/subsidy types and hospital typologies are due to sampling error, not a systematic difference in the underlying distribution or type. The observed significance level was rather high in most cases (always higher than 10%) and the results were confirmed using only the linear trends or the resulting change over the five-year span of the sample. This result is valid for all three measures namely, changes in cost-efficiency, excess capacity and LOS.

The only statistically significant difference was found to be among the cost-efficiency changes across the regions. Here again, there is no significant difference regarding excess capacity and LOS. Further exploration using pair-wise tests indicate that the efficiency improvement in the South region (the Italian-speaking canton Ticino) is significantly higher than all other regions. This difference is statistically significant at less than 5% significance level. Table 5 provides the temporal changes of efficiency by region. As seen in this table, the hospitals in Southern Switzerland (TI) have improved their cost-efficiency by about 8.4 percentage point over the sample period. The table also indicates that this region heads the list in curtailing hospital stays by an average rate of 9.7%, and cutting the empty beds by 28% on average, over the sample period. The numbers listed for other regions have however only an indicative value, because they do not show any statistically significant difference among them.

Insert Table 5

In order to further explore the differences between regions and cantons, a series of statistical tests between pairs of cantons have been conducted. These tests have been limited to cantons that have at least three hospitals in the sample. These tests show that there are only six cantons that have a cost-efficiency performance that is similar to that of Ticino. Using the significance level of 10%, the following cantons have been singled out: BS, BL, FR, GE, NE and VS. Looking at the hospital-specific random coefficients suggest that the variation among individual hospitals often dominates the variations between regions and hospital types.

Noting the important variation among individual hospitals, an important question is whether improvement in cost-efficiency are positively correlated with other measures like limiting the empty beds and shortening hospitalizations that are presumably aimed at cost reductions. In order to see an overall picture, the correlation matrix between these measures has been estimated. These coefficients listed in Table 6, are based on the resulting changes in costs, excess capacity and LOS, over the five-year span, and according to the predicted hospital-specific random coefficient. As expected the positive and significant correlation between efficiency measures related to cost and excess capacity indicates that hospitals that have been able to decrease the empty beds are also successful in cutting costs.

Insert Table 6

The striking result is that the same statement does not apply to hospital stays. While the hospital-level and DRG-level measures of changes in LOS are strongly correlated, both of them have a negative correlation with changes in cost-inefficiency. Only the hospital-level measure having significant correlation, this implies that a hospital's efforts in curtailing hospital stays have no statistically significant on cost reduction. In order to explore this rather surprising result, a series of correlation analyses within various groups of hospitals has been performed. While detecting some significant correlations in a few groups, most of them tend to be negative. Therefore, according to the available data and based on the adopted measures in this paper, there is no conclusive evidence of significant correlation between changes in costs and those of hospitalization length.

Comparing the changes within hospital groups can however be insightful. For instance, Figure 2 illustrates the temporal changes for the five university hospitals in the sample. This figure shows about 13 percent increase in total costs, while a rather stagnating inefficiency. This implies that these hospitals on average are more or less like the average hospital in the sample (shown in Figure 1). A careful look into each one of these hospitals (not shown here) indicates however, that these hospitals differ from each other in all three measures.

Insert Figure 2

Finally, another way of investigation the relationships between costs and other measures, is by dividing the sample into two groups: A first group including hospitals that have contained their costs during the sample period namely, their improvement in cost efficiency were such that they could counter the growth in costs by external factors and thus overall shown non-increasing costs at the end of the period. The second group includes the rest of the hospitals that have a higher-than-average growth in their costs. Figure 3 and Figure 4 depict the temporal variation of efficiency in these groups respectively. Figure 3 shows that the 81 hospitals that had an efficiency improvement (in costs) have also considerably cut their hospital stays and empty beds. But comparing this figure with the average patterns in Figure 1, suggests that these hospitals while having a relatively high reduction in excess capacity, are not much different from average in terms of LOS. Another interesting point in Figure 3 is that the pattern of changes in cost-efficiency is very similar to that of length of stay. However, the correlation coefficient between the two measures is insignificant and negative, suggesting that even if the two curves are on average very close the individual hospitals do not follow this pattern.

Insert Figure 3

Insert Figure 4

Figure 4 shows a similar graph for 87 hospitals that have declined in cost efficiency over the sample period. Similarly, these hospitals show a change of LOS that is totally comparable to the averages shown in Figure 1. However, the excess capacity takes a somewhat milder reduction here. Another interesting result is that among these hospitals that had an increase in inefficiency, there is a positive and significant (less than 5% level) correlation between the changes in LOS and cost-inefficiency. Could this mean that although curtailing hospital stays might not be effective for hospitals that have no excessive long hospitalizations, it could be quite useful for those hospital managers that perhaps have had a more relaxed way of considering the issue?!

Figure 3 and Figure 4 also show that both groups of hospitals on average have changed their cost-efficiency by about 8 percentage points over the five-year span of the sample. This might suggest a good targeting benchmarking that is more or less comparable to the 2 to 3 percent annual efficiency gains targets set by the UK health care authorities (Jacobs and Dawson, 2003).

6. Conclusions

Using a panel data mixed effects model including fixed effects for unobserved time-invariant related to individual hospitals and DRG categories, and random coefficients representing the effects of time variables, this paper proposed an econometric specification inspired by Sickles' (2005) general models. Recognizing the difficulties in identifying the hospitals' time-invariant inefficiencies this paper focuses on the temporal variations in efficiency. The measures of interest are the hospitals' gains in cost-efficiency, the realized cuts in empty beds and the shortening of hospitalizations, over the period immediately after the beginning of the gradual implementation of the health policy reforms particularly the prospective payment system in Switzerland.

The results indicate that after adjusting for the changes in outputs, labor prices and other characteristics such as teaching activities, hospital costs have risen considerably and increasingly over the six-year period from 1998 to 2003, amounting to an average increase of 14 percent in total costs for a typical hospital. It is assumed that this overall increase on average reflects the external factors such as progress in medical treatments and extension of life expectancy, and the remaining hospital-specific changes in costs are assumed to be associated with efficiency gains or losses. The data also indicate that on average the length of hospitalization and the number of empty beds in a hospital have decreased by about 10 and 18 percent respectively.

The results indicate a considerable variation among individual hospitals concerning cost efficiency gains and also the efforts in cutting the excess capacity and hospitalizations. In general hospitals that showed a relatively important decrease in excess capacity are likely to show a relative gain in cost-efficiency and *vice versa*. However, the results do not provide any conclusive evidence that gains in cost efficiency be associated with shortening hospital stays. Interestingly, only among hospitals that experienced an efficiency loss over the sample period, relatively low cuts in hospitalization length are likely to be associated with the hospitals with low efficiency gains. This result can be interpreted as suggestive evidence that hospitals that have a good performance in containing costs are not concerned about their hospitalization length which is probably far from excessive. Whereas among those hospitals that could not contain their costs, the length of stay could be an important parameter to consider.

While confirming the strong heterogeneity across hospitals regarding efficiency gains, the findings do not provide any evidence in favor of a particular ownership/subsidization type. Moreover, the efficiency differences across various hospital typologies (based on size and specialization) are not statistically significant. This result similarly applies to the measures of LOS and excess capacity. The only case of statistically significant differences was regarding gains in cost efficiency across cantons. Certain cantons have been singled out. In any case, the variations among individual hospitals appear to dominate all the studied hospital groupings.

The adopted methodology is readily applicable to other cases and the assumptions are easy to understand and interpret. In addition, in line with several models in this field (probably starting from Cornwell, Schmidt and Sickles, 1990) the efficiency estimates do not rely on the skewness of the residuals in certain direction. The combination of fixed effects with random effects, allows a complete abstraction from the unobserved variables whose effects are not primordial for the analysis (through fixed effects) while at the same time providing an 'statistically' efficient estimation basis (random-effects) for the parameters that have certain importance for the study. In the estimation of efficiencies, the time-invariant component is difficult if at all possible to identify in a reliable manner. Therefore models that can provide reliable estimates of efficiency gains over time can be helpful in regulation and policy applications.

Acknowledgements

The author is grateful to the Swiss Federal Statistical Office for providing the data, especially André Meister for his support. He also wishes to thank Martin Jakob, Massimo Filippini and William Greene for many helpful discussions. Part of this research has been financed by the Swiss National Science Foundation through research grant 100012-108288, which is gratefully acknowledged. The views expressed in this paper as well as possible errors and omissions are from the author and do not necessarily reflect the position of any organization.

References

Aigner D, Lovell CAK, Schmidt P. 1977. Formulation and Estimation of Stochastic Frontier Production Function Models. *J Econom* **6**: 21-37.

Alvarez, Antonio M. and Peter Schmidt (2006). Is skill more important than luck in explaining fish catches? *J Prod Anal* **26** (1):15–25.

APDRG Suisse. 2003. *Cost Weights version 4.1.* Institut de Santé et d'Economie Prilly, Switzerland, available at: www.apdrgsuisse.ch.

Battese GE, Coelli T. 1992. Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India. *Journal of Productivity Analysis* **3**: 153-169.

Bradford, W.D. et al. (2001): 'Stochastic Frontier Estimation of Cost Models Within the Hospital', *Review of Economics and Statistics*, 83 (2): 302-309.

Breyer F. 1987. The specification of a hospital cost function: A comment on the recent literature. *J Health Econ* **6**: 147-157.

Brown HS. 2003. Managed care and technical efficiency. *Health Econ* **12** (2): 149-158.

Carey K. 2000. Hospital Cost Containment and Length of Stay: An Econometric Analysis. Southern Economic Journal, Vol. 67, No. 2 (Oct., 2000), pp. 363-380.

Carey K. 1997. A panel data design for estimation of hospital cost functions. *Rev Econ Stat* **79** (2): 443-453.

Cornwell Ch, Schmidt P, Sickles RC. 1990. Production frontiers with cross-sectional and time-series variation in efficiency levels. *J Econom* **46**: 185-200.

Deily, Mary E. and Niccie L. McKay (2006): 'Cost inefficiency and mortality rates in Florida hospitals', *Health Economics*, 15 (4): 419-431.

Farsi, Mehdi (2004). 'Changes in Hospital Quality after Conversion in Ownership Status', *International Journal of Health Care Finance and Economics*, 4 (3): 211-230.

Farsi, Mehdi, Massimo Filippini, and William Greene (2006). 'Application of Panel Data Models in Benchmarking Analysis of the Electricity Distribution Sector', *Annals of Public and Cooperative Economics*, 77 (3): 271-290.

Farsi M, Filippini M, Kuenzle M. 2005. Unobserved Heterogeneity in Stochastic Cost Frontier Models: An Application to Swiss Nursing Homes. *Appl Econ* **37**: 2127-2141.

Farsi, M. and Filippini M., (2004), Regulation and Measuring Cost Efficiency with Panel Data Models Application to Electricity Distribution Utilities, *The Review of Industrial Organization*, 25 (1): 1-19.

Farsi, Mehdi and Massimo Filippini (2007). Effects of Subsidization and Teaching Activities on Hospital Costs in Switzerland. *Health Economics*, forthcoming (available on line in articles in press).

Farsi M, Filippini M. 2006. An analysis of efficiency and productivity in Swiss hospitals. *Schweiz Z Volkswirtsch Stat* **142** (1): 1-37.

Farsi M, Filippini M. 2004. An Empirical Analysis of Cost Efficiency in Non-profit and Public Nursing Homes. *Annals of Public and Cooperative Economics* **75** (3): 339-365.

Folland ST, Hofler RA. 2001. How reliable are hospital efficiency estimates? Exploiting the dual to homothetic production. *Health Econ* **10**: 683-698.

Gaynor, M. and G. F. Anderson (1995). "Uncertain demand, the structure of hospital costs, and the cost of empty hospital beds", *Journal of Health Economics*, 14 (1995): 291-317.

Greene W. 2004. Distinguishing between heterogeneity and inefficiency: Stochastic frontier analysis of the World Health Organization's panel data on national health care systems. *Health Econ* **13**: 959-980

Greene W. 2005a. Reconsidering Heterogeneity in Panel Data Estimators of the Stochastic Frontier Model. *J Econom* **126** (2): 269-303.

Greene, William (2005b). "Fixed and Random Effects in Stochastic Frontier Models", *Journal of Productivity Analysis*, 23 (1): 7-32.

Grosskopf, S., D. Margaritis and V. valdmanis (2001). Comparing Teaching and Non-teaching Hospitals: A Frontier Approach (Teaching vs. Non-teaching Hospitals). *Health Care management Science*, **4**: 83-90.

Hawdon, David (2003). Efficiency, performance and regulation of the international gas industry--a bootstrap DEA approach, *Energy Policy* 31 (2003) 1167–1178.

Heshmati A. 2002. Productivity measurement in Swedish departments of gynecology and obstetrics. *Structural Change and Dynamics* **13**: 315-336.

Hollingsworth, Bruce and Andrew Street (2006): 'The market for efficiency analysis of health care organisations' (editorial), *Health Economics*, 15 (11): 1055-1059.

Horrace WC, Schmidt P 1996. Confidence Statements for Efficiency Estimates from Stochastic Frontier Models. *Journal of Productivity Analysis* **7**: 257–82.

Jacobs, Rowenta, Peter C. Smith and Andrew Street (2006): *Measuring Efficiency in Health Care: Analytic Techniques and Health Policy*, Cambridge University Press.

Jacobs R, Dawson D. 2003. Hospital efficiency targets. *Health Econ* **12** (8): 669-684.

Jensen U 2000. Is it Efficient to Analyse Efficiency Rankings? *Empir Econ* **25**: 189–208.

Kneip, A., Sickles, R.C., Song, W.H., 2003. On estimating a mixed effects model with applications to the US banking industry. Rice University, Mimeo.

Kumbhakar, S. C. (1990). 'Production frontiers and panel data, and time varying technical inefficiency'. *Journal of Econometrics*, 46(1990): 201-211.

Kruskal WH, Wallis WA. 1952. Use of ranks in one-criterion variance analysis. *J Am Stat Assoc* **47**: 583-621.

Kumbhakar, S. C. (1991). "Estimation of technical inefficiency in panel data models with firm- and time-specific effects". *Economics Letters*, 36 (1991): 43-48.

Kumbhakar SC. 1991. Estimation of technical inefficiency in panel data models with firm- and time-specific effects. *Econ Lett* **36**: 43-48.

Lee, Y, and P. Schmidt (1993), "A production frontier model; with flexible temporal variation in technical efficiency," in *The measurement of productive efficiency*, Fried, H., K. Lovell and S. Schmidt, eds. (Oxford University Press, New York).

Linna M. 1998. Measuring hospital cost efficiency with panel data models. *Health Econ* **7**: 415-427.

Liu, Chunping, Audrey Laporte and Brian Ferguson (2007). The Quantile Regression Approach to Efficiency Measurement: Insights from Monte Carlo Simulations, HEDG Working Paper 07/14, Department of Economics, University of York.

Martin, S. and P. Smith (1996). Explaining variations in inpatient length of stay in the National Health Service. *Journal of Health Economics*, **15**: 279-304.

Meeusen, Wim, and Julien van den Broeck (1977). 'Efficiency Estimation From Cobb-Douglas Production Functions With Composed Error', *International Economic Review*, **18** (2), 435-444

Mundlak, Yair (1978). "On the pooling of time series and cross section data" *Econometrica*, 64 (1): 69-85.

Newhouse JP. 1994. Frontier Estimation: How Useful a Tool for Health Economics. *J Health Econ* **13**: 317-322.

Pitt M, Lee L. 1981. The measurement and sources of technical inefficiency in Indonesian weaving industry. *J Dev Econ* **9**: 43-64.

Polachek S, Yoon B. 1996. Panel estimates of a two-tiered earnings frontier. *Journal of Applied Econometrics* **11**: 169-178.

Rosko MD. 2001. Cost efficiency of US hospitals: A stochastic frontier approach. *Health Econ* **10**: 539-551.

Rogowski, JA and Newhouse, JP. 1992. Estimating the indirect costs of teaching. *J Health Econ* **11**: 153-171.

Schmidt P, Sickles RC. 1984. Production Frontiers and Panel Data. *Journal of Business and Economic Statistics* **2**: 367-374.

Scuffham PA, Devlin NJ, Jaforullah M. 1996. The structure of costs and production in New Zealand public hospitals: an application of the transcendental logarithmic variable cost function. *Appl Econ* **28**: 75-85.

SFSO. 1997a. *Statistiques des établissements de santé (soins intra-muros), Statistique des hôpitaux, Conception détaillée, Déc. 1997*. (in French) Swiss Federal Statistical Office, Neuchâtel, Switzerland, www.statistik.admin.ch.

SFSO. 1997b. *Statistiques des établissements de santé (soins intra-muros), Statistique médicale des hôpitaux, Conception détaillée 1997*. (in French) Swiss Federal Statistical Office, Neuchâtel, Switzerland, www.statistik.admin.ch.

SFSO. 2001. *Statistiques des établissements de santé (soins intra-muros), Typologie des hôpitaux.* (in French) Swiss Federal Statistical Office, Neuchâtel, Switzerland, www.statistik.admin.ch.

Sickles RC. 2005. Panel estimators and the identification of firm-specific efficiency levels in parametric, semiparametric and nonparametric settings. *J Econom* **126** (2): 305-334.

Simmer, T, D. Nerenz, W. Rutt, C. Newcomb and C. Benfer (1991). A randomized, controlled trial of an attending staff servicei n general internal medicine. *Medical Care*, **29** (7): 31-40.

Singh S, Coelli T. 2001. Performance of dairy plants in the cooperative and private sectors in India. *Annals of Public and Cooperative Economics* **72** (4): 453-479.

Skinner J 1994. What do stochastic frontier cost functions tell us about inefficiency? *J Health Econ* **13**: 323-328.

Steinmann L, Zweifel P. 2003. On the (in)efficiency of Swiss hospitals. *Appl Econ* **35**: 361-370.

Street A 2003. How Much Confidence Should We Place in Efficiency Estimates? *Health Econ* **12**: 895–907.

Vita MG. 1990. Exploring hospital production relationships with flexible functional forms. *J Health Econ* **9**: 1-21.

Vitaliano D, Toren M. 1996. Hospital cost and efficiency in a regime of stringent regulation. *East Econ J* **22**:161-184.

Wagstaff A, Lopez G. 1995. Hospital costs in Catalonia: a stochastic frontier analysis. *Appl Econ Lett* **3**: 471-474.

Worthington, Andrew C. (2004). 'Frontier Efficiency Measurement in Health Care: A Review of Empirical Techniques and Selected Applications', *Medical Care Research and Review*, Vol. 61, No. 2, 135-170.

Zuckerman S, Hadley J, Iezzoni L. 1994. Measuring hospital efficiency with frontier cost functions. *J Health Econ* **13**: 255-280.

Figure 1: Temporal variation of costs, excess capacity and LOS (168 hospitals)

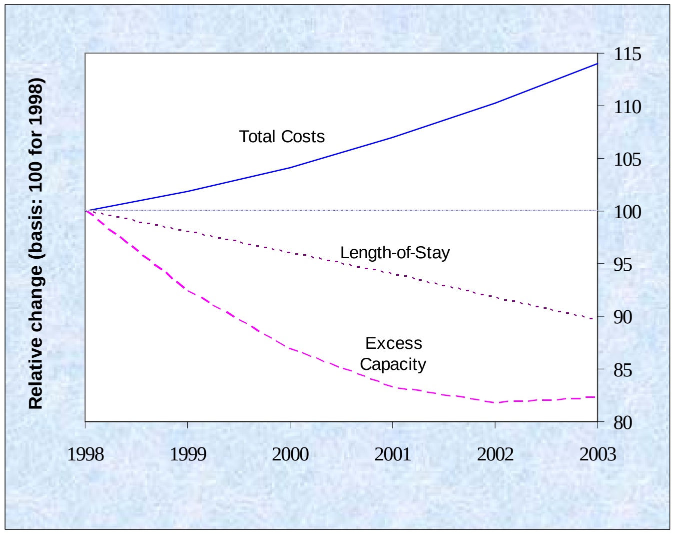

Figure 2: Temporal variations of inefficiency for five university hospitals

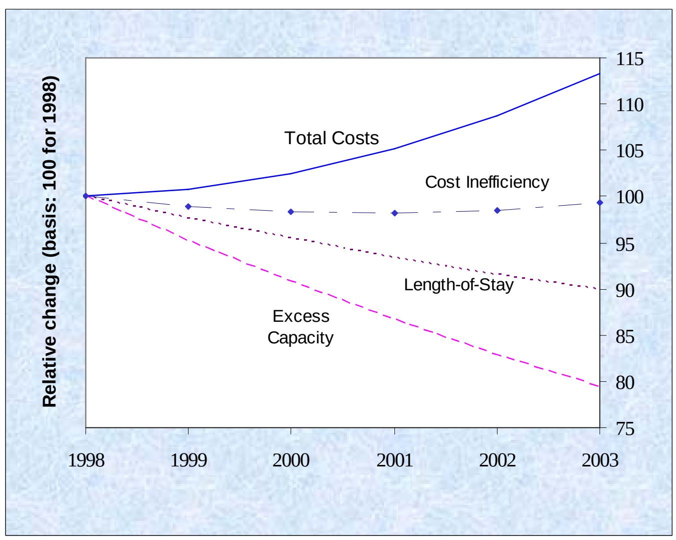

Figure 3: Variations in hospitals that improved in cost-efficiency (81 hospitals)

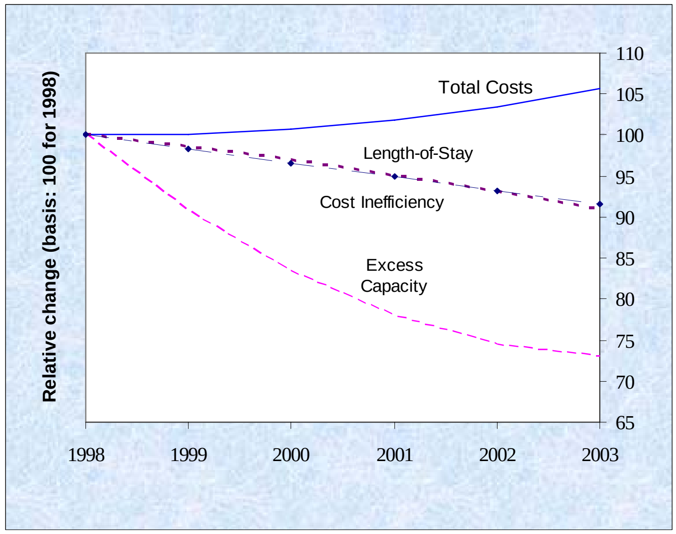

Figure 4: Variations in hospitals that declined in cost-efficiency (87 hospitals)

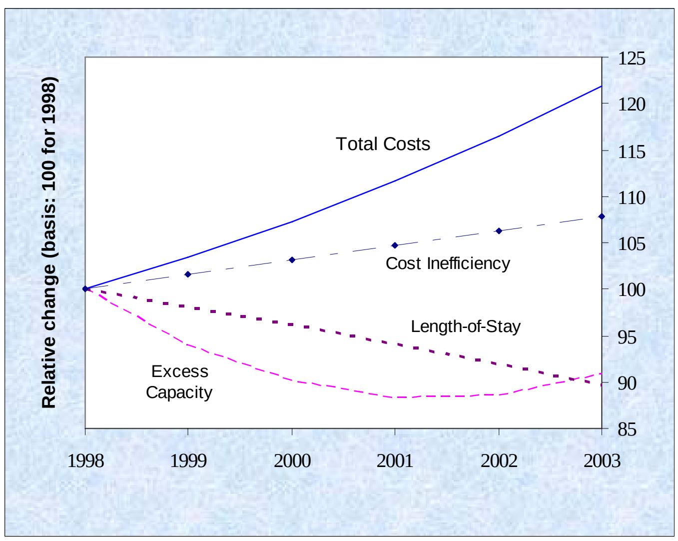

Table 1: Descriptive statistics

	Mean	Std. Dev.	Min.	1st Quartile	Median	3rd Quartile	Max.
Hospital's total costs (CHF '000)	69'655	124'286	924	15'657	32'592	65'129	884'764
Number of hospitalizations	6'306	7'128	116	1'845	4'096	7'871	50'774
Number of hospitalizations (AP-DRG adjusted)	5'400	7'065	76	1'370	3'123	6'568	49'251
Average total cost per hospitalization (CHF '000)	10.02	6.38	1.76	7.04	8.74	11.21	90.13
Number of patient-days	51'619	58'348	1'068	19'570	32'470	57'419	410'140
Average length of hospitalizations (days) [a]	10.4	6.6	2.0	6.6	8.4	11.5	57.6
Hospiatl's outpatient revenues (CHF '000)	10'752	20'458	0	1'301	4'118	10'281	144'802
Hospital capacity (number of beds)	175.2	202.0	12	63	104	210	1277
Excess capacity (average # of empty beds)	35.1	52.3	1	10	20	40	523
P_K *(capital price) CHF '000 per bed*	28.04	26.68	1.46	11.05	17.19	36.28	242.57
P_L *- physicians* [b] *(CHF per day)*	334.51	114.22	66.80	263.03	321.15	393.43	781.63
P_L *- other employees* [c] *(CHF per day)*	178.11	33.09	69.43	158.91	176.98	196.85	302.01
Number of medical training position	41.6	91.3	1	6	14	31	583
Share of private-insurance admissions [d]	0.28	0.22	0.00	0.15	0.22	0.31	1
Average length of full hospitalizations excluding semi-hospitalizations (days):							
Hospital-level sample	11.3	6.4	3.7	7.8	9.0	12.3	57.6
DRG-level sample	9.7	6.1	1.0	5.2	8.0	12.6	36.3
Average AP-DRG cost weight:							
Hospital-level sample	0.806	0.110	0.520	0.740	0.789	0.854	1.334
DRG-level sample	1.008	0.783	0.112	0.582	0.795	1.161	21.597

- Unless stated otherwise, the numbers are based on the hospital-level sample
- The hospital-level sample includes 863 observations from 168 hospitals (1998-2003).
- The DRG-level sample includes 108,227 observations from 492 AP-DRG categories.
- All monetary values are adjusted by the global consumer price index relative to 2003 prices.

[a] Semi-hospitalizations (shorter than 24 hours) are considered as one-day hospitalizations.
[b] Employed physicians' average salary, adjusted for social benefits and excludes fees.
[c] Average salary (adjusted for social benefits) of all hospital employees except physicians.
[d] Based on hospital discharges; includes cases with private and semi-private insurance.

Table 2: Number of hospitals by category (1998-2003)

Ownership/Subsidy status	Frequency	Percent
Non-subsidized For-Profit (FP)	27	16.07
Non-subsidized Non-Profit (NP)	16	9.52
Public (PUB)	81	48.21
Private subsidized (SUB)	44	26.19
Total	168	100

Hospital typology	Frequency	Percent
University hospitals (centralized care)	5	2.98
Regional hospitals (centralized care)	18	10.71
Basic-care level 1 (relatively large)	26	15.48
Basic-care level 2 (moderate size)	52	30.95
Basic-care level 3 (local and small)	67	39.88
Total	168	100

Region (Cantons)	Frequency	Percent
Central (LU SZ NW OW UR ZG)	13	7.74
East (ZH GR GL SG AI AR TG SH)	49	29.17
Mid-West (BE AG BL BS SO)	44	26.19
South (TI)	18	10.71
West (FR GE JU NE VD VS)	44	26.19
Total	168	100

Table 3: Estimation results (hospital-level analysis)

	Total Costs	Excess Capacity	Length-of-Stay
Number of hospitalizations (AP-DRG adjusted)	0.300*		
	(.018)		
Outpatient revenues	0.025*		
	(.008)		
Average length of hospitalizations	0.228*		
	(.022)		
P_K (capital price)	0.124*		
	(.008)		
P_L - physicians	0.008		
	(.013)		
P_L - others	0.050*		
	(.021)		
Number of training positions	0.021*		0.003
	(.010)		(.014)
Time (linear trend)	0.016*	-0.086*	-0.033*
	(.006)	(.035)	(.013)
Time (squared)	0.002*	0.010	0.003
	(.001)	(.006	(.002)
Number of hospitalizations		-0.447*	
		(.112)	
Share of private-insurance admissions		0.147	
		(.208)	
Average AP-DRG cost weight			0.374*
			(.068)
σ_1	0.062*	0.317*	0.153*
	(.006)	(.036)	(.011)
σ_2	0.011*	0.053*	0.023*
	(.001)	(.007)	(.002)
σ_{12}	-0.894*	-0.915*	-0.939*
	(.027)	(.024)	(.012)
σ_ε	0.040*	0.287*	0.052*
	(.001)	(.009)	(.002)
Log Likelihood (restricted)	1288.16	-305.90	964.25

* Significant at 5%; Standard errors are given in parentheses; All variables except AP-DRG cost weight and share of private insurance patients are in logarithms; The sample includes 863 observations from 168 hospitals (1998-2003).

Table 4: Estimation results (DRG-level analysis)

	Length-of-Stay
Number of training positions	0.0046 (.0046)
Time (linear trend)	-0.019* (.0022)
Time (squared)	-0.00034 (.00039)
σ_1	0.187* (.0027)
σ_2	0.032* (.00051)
σ_{12}	-0.936* (.0023)
σ_ε	0.220* (.00061)
Log Likelihood (restricted)	-1958.14

* Significant at 5%; Standard errors are given in parentheses; All variables except the time variables are in logarithms; The sample includes 108,227 observations from 492 AP-DRG categories from 162 hospitals (1998-2003).

Table 5: Temporal changes in inefficiency by region

Hospital's Total Costs	Linear Trend	T-Squared	Total change (1998-2003)
Central (LU SZ NW OW UR ZG)	-0.003	0.0011	0.014
East (ZH GR GL SG AI AR TG SH)	0.008	-0.0004	0.029
Mid-West (BE AG BL BS SO)	-0.004	0.0013	0.011
South (TI)	-0.022	0.0010	-0.084
West (FR GE JU NE VD VS)	0.005	-0.0016	-0.013

Hospital's Excess Capacity	Linear Trend	T-Squared	Total change (1998-2003)
Central (LU SZ NW OW UR ZG)	-0.045	0.0083	-0.016
East (ZH GR GL SG AI AR TG SH)	-0.061	0.0071	-0.129
Mid-West (BE AG BL BS SO)	-0.055	0.0055	-0.139
South (TI)	-0.043	-0.0026	-0.281
West (FR GE JU NE VD VS)	-0.174	0.0238	-0.275
Overall Average	-0.086	0.0101	-0.177

Length of Stay (DRG-level)	Linear Trend	T-Squared	Total change (1998-2003)
Central (LU SZ NW OW UR ZG)	-0.021	-0.0005	-0.119
East (ZH GR GL SG AI AR TG SH)	-0.018	-0.0005	-0.102
Mid-West (BE AG BL BS SO)	-0.016	-0.0004	-0.088
South (TI)	-0.019	-0.0001	-0.097
West (FR GE JU NE VD VS)	-0.011	-0.0016	-0.096
Overall Average	-0.016	-0.0007	-0.097

Table 6: Correlation between various measures (across 168 hospitals)

	Excess Capacity	Length-of-Stay (hospital-level)	Length-of-Stay (DRG-level))
Total Costs	0.162*	-0.208**	-0.091
Ex. Capacity	1	-0.109	-0.193*
LOS (hospital-level)		1	0.464**

** Significant at 1%;   * Significant at 5%;
The sample includes 863 observations from 168 hospitals (1998-2003).

QUADERNI DELLA FACOLTÀ

I quaderni sono richiedibili (nell'edizione a stampa) alla Biblioteca universitaria di Lugano
via G. Buffi 13 CH 6900 Lugano
e-mail: biblioteca@lu.unisi.ch

The working papers (printed version) may be obtained by contacting the Biblioteca universitaria di Lugano
via G. Buffi 13 CH 6900 Lugano
e-mail: biblioteca@lu.unisi.ch

Quaderno n. 98-01
P. Balestra, *Efficient (and parsimonious) estimation of structural dynamic error component models*

Quaderno n. 99-01
M. Filippini, *Cost and scale efficiency in the nursing home sector : evidence from Switzerland*

Quaderno n. 99-02
L. Bernardi, *I sistemi tributari di oggi : da dove vengono e dove vanno*

Quaderno n. 99-03
L.L. Pasinetti, *Economic theory and technical progress*

Quaderno n. 99-04
G. Barone-Adesi, K. Giannopoulos, L. Vosper, *VaR without correlations for portfolios of derivative securities*

Quaderno n. 99-05
G. Barone-Adesi, Y. Kim, *Incomplete information and the closed-end fund discount*

Quaderno n. 99-06
G. Barone-Adesi, W. Allegretto, E. Dinenis, G. Sorwar, *Valuation of derivatives based on CKLS interest rate models*

Quaderno n. 99-07
M. Filippini, R. Maggi, J. Mägerle, *Skalenerträge und optimale Betriebsgrösse bei den schweizerische Privatbahnen*

Quaderno n. 99-08
E. Ronchetti, F. Trojani, *Robust inference with GMM estimators*

Quaderno n. 99-09
G.P. Torricelli, *I cambiamenti strutturali dello sviluppo urbano e regionale in Svizzera e nel Ticino sulla base dei dati dei censimenti federali delle aziende 1985, 1991 e 1995*

Quaderno n. 00-01
E. Barone, G. Barone-Adesi, R. Masera, *Requisiti patrimoniali, adeguatezza del capitale e gestione del rischio*

Quaderno n. 00-02
G. Barone-Adesi, *Does volatility pay?*

Quaderno n. 00-03
G. Barone-Adesi, Y. Kim, *Incomplete information and the closed-end fund discount*

Quaderno n. 00-04
R. Ineichen, *Dadi, astragali e gli inizi del calcolo delle probabilità*

Quaderno n. 00-05
W. Allegretto, G. Barone-Adesi, E. Dinenis, Y. Lin, G. Sorwar, *A new approach to check the free boundary of single factor interest rate put option*

Quaderno n. 00-06
G.D.Marangoni, *The Leontief Model and Economic Theory*

Quaderno n. 00-07
B. Antonioli, R, Fazioli, M. Filippini, *Il servizio di igiene urbana italiano tra concorrenza e monopolio*

Quaderno n. 00-08
L. Crivelli, M. Filippini, D. Lunati. *Dimensione ottima degli ospedali in uno Stato federale*

Quaderno n. 00-09
L. Buchli, M. Filippini, *Estimating the benefits of low flow alleviation in rivers: the case of the Ticino River*

Quaderno n. 00-10
L. Bernardi, *Fiscalità pubblica centralizzata e federale: aspetti generali e il caso italiano attuale*

Quaderno n. 00-11
M. Alderighi, R. Maggi, *Adoption and use of new information technology*

Quaderno n. 00-12
F. Rossera, *The use of log-linear models in transport economics: the problem of commuters' choice of mode*

Quaderno n. 01-01
M. Filippini, P. Prioni, *The influence of ownership on the cost of bus service provision in Switzerland. An empirical illustration*

Quaderno n. 01-02
B. Antonioli, M. Filippini, *Optimal size in the waste collection sector*

Quaderno n. 01-03
B. Schmitt, *La double charge du service de la dette extérieure*

Quaderno n. 01-04
L. Crivelli, M. Filippini, D. Lunati, *Regulation, ownership and efficiency in the Swiss nursing home industry*

Quaderno n. 01-05
S. Banfi, L. Buchli, M. Filippini, *Il valore ricreativo del fiume Ticino per i pescatori*

Quaderno n. 01-06
L. Crivelli, M. Filippini, D. Lunati, *Effizienz der Pflegeheime in der Schweiz*

Quaderno n. 02-01
B. Antonioli, M. Filippini, *The use of a variable cost function in the regulation of the Italian water industry*

Quaderno n. 02-02
B. Antonioli, S. Banfi, M. Filippini, *La deregolamentazione del mercato elettrico svizzero e implicazioni a breve termine per l'industria idroelettrica*

Quaderno n. 02-03
M. Filippini, J. Wild, M. Kuenzle, *Using stochastic frontier analysis for the access price regulation of electricity networks*

Quaderno n. 02-04
G. Cassese, *On the structure of finitely additive martingales*

Quaderno n. 03-01
M. Filippini, M. Kuenzle, *Analisi dell'efficienza di costo delle compagnie di bus italiane e svizzere*

Quaderno n. 03-02
C. Cambini, M. Filippini, *Competitive tendering and optimal size in the regional bus transportation industry*

Quaderno n. 03-03
L. Crivelli, M. Filippini, *Federalismo e sistema sanitario svizzero*

Quaderno n. 03-04
L. Crivelli, M. Filippini, I. Mosca, *Federalismo e spesa sanitaria regionale : analisi empirica per i Cantoni svizzeri*

Quaderno n. 03-05
M. Farsi, M. Filippini, *Regulation and measuring cost efficiency with panel data models : application to electricity distribution utilities*

Quaderno n. 03-06
M. Farsi, M. Filippini, *An empirical analysis of cost efficiency in non-profit and public nursing homes*

Quaderno n. 03-07
F. Rossera, *La distribuzione dei redditi e la loro imposizione fiscale : analisi dei dati fiscali svizzeri*

Quaderno n. 03-08

L. Crivelli, G. Domenighetti, M. Filippini, *Federalism versus social citizenship : investigating the preference for equity in health care*

Quaderno n. 03-09

M. Farsi, *Changes in hospital quality after conversion in ownership status*

Quaderno n. 03-10

G. Cozzi, O. Tarola, *Mergers, innovations, and inequality*

Quaderno n. 03-11

M. Farsi, M. Filippini, M. Kuenzle, *Unobserved heterogeneity in stochastic cost frontier models : a comparative analysis*

Quaderno n. 04-01

G. Cassese, *An extension of conditional expectation to finitely additive measures*

Quaderno n. 04-02

S. Demichelis, O. Tarola, *The plant size problem and monopoly pricing*

Quaderno n. 04-03

F. Rossera, *Struttura dei salari 2000 : valutazioni in base all'inchiesta dell'Ufficio federale di statistica in Ticino*

Quaderno n. 04-04

M. Filippini, M. Zola, *Economies of scale and cost efficiency in the postal services : empirical evidence from Switzerland*

Quaderno n. 04-05

F. Degeorge, F. Derrien, K.L. Womack, *Quid pro quo in IPOs : why book-building is dominating auctions*

Quaderno n. 04-06

M. Farsi, M. Filippini, W. Greene, *Efficiency measurement in network industries : application to the Swiss railway companies*

Quaderno n. 04-07

L. Crivelli, M. Filippini, I. Mosca, *Federalism and regional health care expenditures : an empirical analysis for the Swiss cantons*

Quaderno n. 04-08

S. Alberton, O. Gonzalez, *Monitoring a trans-border labour market in view of liberalization : the case of Ticino*

Quaderno n. 04-09

M. Filippini, G. Masiero, K. Moschetti, *Regional differences in outpatient antibiotic consumption in Switzerland*

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*

Quaderno n. 05-02
M. Filippini, G. Masiero, K. Moschetti, *Socioeconomic determinants of regional differences in outpatient antibiotic consumption : evidence from Switzerland*

Quaderno n. 06-01
M. Farsi, L. Gitto, *A statistical analysis of pain relief surgical operations*

Quaderno n. 06-02
M. Farsi, G. Ridder, *Estimating the out-of-hospital mortality rate using patient discharge data*

Quaderno n. 06-03
S. Banfi, M. Farsi, M. Filippini, *An empirical analysis of child care demand in Switzerland*

Quaderno n. 06-04
L. Crivelli, M. Filippini, *Regional public health care spending in Switzerland : an empirical analysis*

Quaderno n. 06-05
M. Filippini, B. Lepori, *Cost structure, economies of capacity utilization and scope in Swiss higher education institutions*

Quaderno n. 06-06
M. Farsi, M. Filippini, *Effects of ownership, subsidization and teaching activities on hospital costs in Switzerland*

Quaderno n. 06-07
M. Filippini, G. Masiero, K. Moschetti, *Small area variations and welfare loss in the use of antibiotics in the community*

Quaderno n. 06-08
A. Tchipev, *Intermediate products, specialization and the dynamics of wage inequality in the US*

Quaderno n. 06-09
A. Tchipev, *Technological change and outsourcing : competing or complementary explanations for the rising demand for skills during the 1980s?*

Quaderno n. 07-01
M. Filippini, G. Masiero, K. Moschetti, *Characteristics of demand for antibiotics in primary care : an almost ideal demand system approach*

Quaderno n. 07-02
G. Masiero, M. Filippini, M. Ferech, H. Goossens, *Determinants of outpatient antibiotic consumption in Europe : bacterial resistance and drug prescribers*

Quaderno n. 07-03
R. Levaggi, F. Menoncin, *Fiscal federalism, patient mobility and the soft budget constraint : a theoretical approach*

Quaderno n. 07-04

M. Farsi, *The temporal variation of cost-efficiency in Switzerland's hospitals : an application of mixed models*