Ruhr Economic Papers

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# Does Higher Cost Inefficiency Imply Higher Profit Inefficiency?

## Evidence on Inefficiency and Ownership of German Hospitals

#132

Ruhr Graduate School in Economics
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# Ruhr Economic Papers

Published by

Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

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Hohenzollernstr. 1/3, 45128 Essen, Germany



# Ruhr Economic Papers #132

Responsible Editor: Christoph M. Schmidt

ISSN 1864-4872 (online) – ISBN 978-3-86788-146-3

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**Bibliografische Information der Deutschen Nationalbibliothek**
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

ISSN 1864-4872 (online)
ISBN 978-3-86788-146-3

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# Does Higher Cost Inefficiency Imply Higher Profit Inefficiency? – Evidence on Inefficiency and Ownership of German Hospitals

Abstract

This paper investigates cost and profit efficiency of German hospitals. More specifically, it deals with the question how hospital efficiency varies with ownership, patient structure, and other exogenous factors, which are neither inputs nor outputs of the production process. We conduct a Stochastic Frontier Analysis (SFA) on a multifaceted administrative German dataset combined with the balance sheets of 374 hospitals for the years 2002 to 2005. The results indicate that private (for-profit) and (private) non-profit hospitals are on average less cost efficient but more profit efficient than publicly owned hospitals.

JEL Classification: C13, I11, L33

Keywords: Hospital efficiency, ownership, stochastic frontier analysis, profit function

August 2009

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# 1 Introduction

Rising health care expenditures have been a concern to policy-makers in almost all industrialised countries for the past decades. Two of the main driving forces of exploding health care expenditures are technological progress and demographic change. Both factors, however, are difficult to control by policy-makers. They can address a third factor contributing to high costs: Inefficiencies in the health production process. Since the inpatient sector usually accounts for the major part of health care expenditures, analysing hospital efficiency has become an important issue of the health economics literature (compare the discussion of the literature below).

This paper gives a comprehensive evaluation of hospital inefficiency by focusing on costs and profits. Based on a unique data set, we perform both cost and profit efficiency analyses within the framework of stochastic frontier analysis. For the analysis, we combine the Hospital Statistics administered by the Statistical Offices of the German Federal States with the Hospital Database of the RWI Essen for the years 2002 to 2005. The data include detailed information on costs per hospital, the number as well as the demographics of the patients, and information on revenues and profits. The goal is to explain differences in inefficiencies across hospital ownership types. The main contribution of this study is twofold. First, it is the first study that analyses profit efficiency of German hospitals. Second, it is, to the best of our knowledge, the first paper that conducts a cost- and profit-efficiency analysis of hospitals with the same data set, giving us the opportunity to directly compare the results and interpret the differences between both types of efficiency analyses.

Theory clearly suggests that in competitive markets private organisations work more efficiently than public ones (Villalonga, 2000). Consequently, one solution to address inefficiencies in the hospital sector is to introduce more competition and subsequently reduce regulation, opening the doors for privatisation of public hospitals. Indeed, a large number of public hospitals have been privatised over the past ten years.[1] From 1991 to 2007, the share of all public hospitals has decreased from 46% to 32% whereas the share of all private hospitals has increased from 15% to 30%. The share of non-profit hospitals has remained relatively constant at 38–39% over the same period of time

[1]The German hospital industry is characterised by the simultaneous existence of various ownership types. Following the definition of the Statistical Offices of the Länder, three hospital types are distinguished: public, non-profit, and private hospitals. Non-profit hospitals are also private, i.e. non-public, but, in contrast to private hospitals, they are run by non-profit organisations mainly by churches, some by miners' associations. Thus, in this paper the term 'private' is used synonymously for 'private for-profit'.

(Statistisches Bundesamt, 2007).[2]

Whether privatisation of public hospitals leads to better health outcomes and better use of scarce resources is a yet insufficiently answered question. Most empirical studies concerning US hospital efficiency find that private hospitals are *less* cost efficient than the respective base groups (e.g. Zuckerman, Hadley and Iezzoni, 1994; Rosko, 2001; Rosko, 2004; Ozcan, Luke and Haksever, 1992).[3] Based on a stochastic frontier analysis, Herr (2008) confirms this result for German hospitals.[4] Hence, this result seems to be robust to the different health care systems schemes in the US and Germany.

The difference between the theoretical prediction and the empirical evidence on efficiency seems to be puzzling. One explanation may be that theoretical models assume cost minimising behaviour equally for all hospitals, regardless of the ownership type. This assumption may be true for non-profit hospitals, but private hospitals rather seek maximise profits to satisfy the private investors, for example. Maximising profits involves a simultaneous choice over the optimal input and output mix such that costs are minimised and revenues are maximised.[5] Berger and Mester (1997) argue that maximised profits are achieved by raising revenues at the expense of higher costs. In fact, our data and Augurzky et al. (2008) show that in Germany private hospitals have substantially higher profit margins than non-profit hospitals while they have higher costs per bed and per treated case.

Profit efficiency has been analysed first and foremost in the US banking industry (Akhavein, Berger and Humphrey, 1997; Berger and Mester, 1997; Kumbhakar, 2006) or in agriculture (Kumbhakar, 2001; Ali and Flinn, 1994; Ali, Parikh and Shah, 1994). Even though there is a large literature on cost efficiency, there are only two profit efficiency studies focusing on the health care market. For instance, Bradford and Craycraft (1996) estimate the effects of the Medicare reforms in 1983 on the level of inefficiency of capital expenditures using a stochastic profit frontier. Their study, however, does not distinguish between different ownership types. Knox, Blankmeyer and Stutzman (1981) analyse economic efficiency of nursing homes in Texas and find private providers to be more allocative and technical efficient than public nursing homes using OLS techniques.

[2]However, German private general hospitals still only supply 16% of the beds compared to 35% of the beds provided by non-profit and 49% by public general hospitals in 2007.

[3]Hollingsworth (2008, 2003) provides an extensive overview on international cost and technical efficiency studies of the health care market.

[4]Using DEA, Tiemann and Schreyögg (2008) come to the same conclusion regarding the efficiency of private hospitals in Germany in a later study.

[5]Hoerger (1991) shows that indeed non-profit and private hospitals responded differently to changes in the health care system in the US in the years 1983 to 1988.

Similar to most hospital markets, the German market is regulated in several different aspects and leaves, at first sight, little room for profit maximising behaviour. The new prospective payment system introduced in 2004 fixes prices for medical services based on the patients' diagnosis related group (DRG). Hospitals have nevertheless avenues to increase their revenues, either by attracting and treating more patients with complex needs and – to a certain extent – by offering additional services. They may also treat more patients with complex diagnoses to exploit cost reducing economies of scale. In the DRG system a higher level of complexity measured by the case-mix index (CMI) increases both remuneration and costs. Thus, in a cost-efficiency analysis hospitals with a large amount of complex diagnoses might be considered less cost-efficient. In fact, in Germany, private hospitals have a higher CMI than public hospitals (compare our data discussed below or Augurzky, Budde, Krolop, Schmidt, Schmidt, Schmitz, Schwierz and Terkatz (2008)).

The next section outlines the estimation strategy and describes the data. Results and robustness checks are presented in Section 3. Section 4 concludes.

# 2 Estimation Strategy and Data

## 2.1 Estimation Strategy

Inefficiency is defined as the hospital's deviation from the estimated or constructed cost or profit frontier. In the case of cost inefficiency, a hospital does not choose a cost-minimising input mix given input prices (input-allocative inefficiency) even though it may be technically efficient and produce on the technical frontier. In the case of revenue inefficiency, a hospital fails to maximise revenues because of either or both of two sources: output-oriented technical inefficiency (less than possible output produced given input use) and production of an inappropriate output mix in light of a prevailing output price vector. Finally, profit efficiency is the product of technical and both allocative efficiencies as well as a certain type of scale efficiency.

As explained in greater detail in Herr (2008),when measuring cost efficiency it is assumed that all hospitals seek to minimise costs (Coelli, Rao and Battese, 2005; Kumbhakar and Lovell, 2000).[6] Analogously to Herr (2008), we specify a log-linear single-output cost frontier assuming a Cobb-Douglas production function as follows

$$\ln \frac{C_i}{w_{ki}} = \beta_0 + \sum_{n \neq k} \beta_n \ln \frac{w_{ni}}{w_{ki}} + \beta_y \ln y_i + v_i + u_i. \qquad (1)$$

[6]Kumbhakar and Lovell (2000) provide a complete summary of both the theory and techniques used in Stochastic Frontier Production, Cost, and Profit Analysis.

$C_i$ are the observed total adjusted costs of hospital $i$, $y_i$ is the output and $\beta_n$ and $\beta_y$ are the vectors of the respective coefficients to be estimated. The $K$ input prices $w_i = [w_{1i}, ..., w_{Ki}]$ of inputs $x_i = [x_{1i}, ..., x_{Ki}]$ are calculated by dividing the costs for each input by its quantities used (e.g. number of doctors). Since a cost frontier must be linearly homogeneous in input prices, one input price $w_{ki}$ is chosen to normalise total costs and the other input prices $w_{ni}$. Estimation results do not depend on this choice. We further assume that the environment is characterised by standard normally distributed random noise $v_i$ and systematic hospital specific inefficiency $u_i$. The inefficiency term $u_i$ is assumed to be non-negative. The distribution of the two error terms is characterised below.

When estimating profit efficiency, hospitals are assumed to seek to maximise profits. The analysis of profit efficiency focuses on the short-run where hospitals face input rigidities. In the long-run, inefficient hospitals would exit competitive markets with marginal cost pricing and variable inputs.[7] Following Kumbhakar and Lovell (2000), the profit frontier maps maximum profits possible given exogenously fixed output prices, prices of variable inputs (labour), and quantities of quasi-fixed inputs such as the number of installed beds. The assumption that hospitals behave as price takers is plausible for a fixed price DRG market as the German one. Output prices are exogenously fixed and probably do not correspond with marginal costs.

As Coelli et al. (2005) note, no particular profit efficiency methodology has become widely used to date. The reasons are two-fold: Firstly, maximising profits means simultaneously to minimise costs and maximise revenues which makes the empirical identification of inefficiency more difficult than in the case of simple cost minimisation or revenue maximisation. Secondly, only few datasets provide information on input and output prices, profits, and the utilisation of inputs.

In the stochastic frontier framework, we differentiate between two profit frontiers explained in detail below. The first one is constructed analogously to the cost frontier above. Variation in inefficiency is in this case solely due to output allocative and technical inefficiency (model (i)). The second profit frontier additionally accounts for input allocative inefficiency by weighting the normalised prices with the returns to scale of production. Furthermore, in the second case, the output price, as opposed to one input price, is used for the normalisation (model (ii)).

In the first case, the profit frontier of a single-equation model without input

[7]In competitive markets, duality between cost and profit efficiency holds given prices (Mas-Colell, Whinston and Green, 1995) which probably does not hold for the German hospital industry.

allocative inefficiency is given as

$$\text{model (i):} \quad \ln \frac{\pi_i}{w_{ki}} = \beta_0 + \sum_{n \neq k} \beta_n \ln \frac{w_{ni}}{w_{ki}} + \beta_p \ln \frac{p}{w_{ki}} + \beta_q \ln q_i + v_i - u_i, \quad (2)$$

where $\pi_i$ is the observed profit of hospital $i$, $q_i$ is a quasi-fixed input, $v_i$ is random noise and the profit decreasing inefficiency is captured by a non-negative systematic error term $u_i$. Again, the frontier must be linearly homogeneous in prices, that is why the same input price $w_{ki}$ is chosen to normalise the profits and the other prices. In this case, the parameters of the profit frontier can be estimated consistently if input allocative efficiency is assumed, which means that the inputs are used in an optimal combination to each other given input prices and technology.[8] Thus, we estimate the effect of technical and output allocative inefficiency on profits assuming that output prices are fixed.

In the second case, we first need to calculate the returns to scale of production. Let $r = \sum_n \beta_n < 1$ measure the degree of homogeneity of the production function $y = f(x, q; \beta) \exp(-u)$ in $x$, i.e. we estimate the production frontier and sum across the coefficients on the inputs $x$. Since we assume the production function to be of a Cobb-Douglas type with a single output $y$, we can estimate profit efficiency in a single-equation model consistently if the normalised variable profit frontier is written as (Kumbhakar and Lovell, 2000, p.195)

$$\text{model (ii):} \qquad \ln \frac{\pi_i}{p} = \delta_0 + \sum_n \delta_n \ln \frac{w_{ni}}{p} + \delta_q \ln q_i + v_{\pi_i} - u_{\pi_i}, \qquad (3)$$

where $\pi_i$ are actually observed profits, $p$ is the exogenous output price, $q_i$ are quantities of the quasi-fixed input and $w_{ni}$ are the variable input prices. Furthermore, $\delta_0$ is a constant, $\delta_n = -1/(1-r)\beta_n \ \forall n$, $\delta_q = (1/1-r)\beta_q$, $v_{\pi_i} = 1/(1-r)v_i$ and $u_{\pi_i}$ is the overall normalised variable profit efficiency, where the inefficiency term $u_{\pi_i}$ contains both, allocative and technical inefficiency, which cannot be identified separately.

The literature offers several approaches to model the non-negative systematic inefficiency component $u_i$. For the three models described above, this study follows the approach first suggested by Deprins and Simar (1989) assuming that hospital-specific factors $z_i = [z_{1i}, ..., z_{Li}]$ directly influence inefficiency. Formally, $u_i \sim \mathcal{N}^+(z_i'\delta, \sigma_u^2)$, i.e. $u_i$ has a normal distribution truncated at zero with mode $z_i'\delta$ varying over the hospitals and constant variance $\sigma_u^2$. Note that

[8] Specifically, a firm is input allocative efficient if the ratio of the partial derivatives of the production function in $f(x_1, x_2)$ with respect to the respective inputs corresponds to the input price ratio: $\frac{\partial f(x_1,x_2)/\partial x_1}{\partial f(x_1,x_2)/\partial x_2} = \frac{w_1}{w_2}$.

$z_i$ does not influence the deterministic part of the cost or profit frontier. These models are called 'normal truncated normal' models because one component of the composite error is normally distributed while the other is truncated normally distributed. In order to estimate our model, we use the *one*-step procedure by Huang and Liu (1994) where we pool the years of observation and cluster the standard deviations on hospital level. Due to the assumption that the variance $\sigma_u^2$ is constant, the signs of the coefficients $\delta_j$ correspond to the signs of their marginal effects on the unconditional expected inefficiency (Wang, 2002).

To derive the log likelihood function, it is necessary to assume that $u_i$ and $v_i$ are distributed independently of each other and of the regressors. Furthermore, the estimates allow us to compute hospital-specific cost efficiency scores as $CE_i = \mathbb{E}[\exp(-u_i)|v_i + u_i]$ or profit efficiency scores as $PE_i = \mathbb{E}[\exp(-u_i)|v_i - u_i]$, respectively. The estimated cost efficiency scores are consistent in a panel data setting that allows for asymptotics along the time dimension (Kumbhakar and Lovell, 2000). In Section 3.4, we discuss two other approaches conducted as robustness checks.

## 2.2 Data

The data used in this study are extracted from the annual hospital and patient statistics, which are collected and administered by the Statistical Offices of the German Federal States for the years 2002 to 2005 (Forschungsdatenzentrum der Statistischen Landesämter, 2002-2005). They include detailed information on costs, number of doctors, nurses, beds, and patients characteristics. We merge our data with information on profits, sales, depreciations and costs extracted from the hospital database of the RWI Essen which contains balance sheet information of 374 hospitals. In particular we know the hospitals' EBITDA (Earnings before Interest, Taxes, Depreciation, and Amortization), EBIT (Earnings before Interest and Taxes), and EAT (Earnings After Taxes). EBITDA subsumes earnings before interests and tax payments, depreciation, and amortisation and represents the result of the operative business. EBIT denotes earnings before interest and tax payments. EAT is defined as earnings after taxes which thus captures the final result after subtracting all types of expenses. We construct a fourth measure from the balance sheets by subtracting total costs from total sales (before any reductions). In the following, we will call this measure "economic profits" (EP). It is independent of different profit reporting conventions across hospital types. As profits may be negative, we add a constant to each profit variable for all observations in the sample (compare e.g. Berger and Mester, 1997). The constant is the minimum value of the respective profit measure (that is, the highest loss in absolute terms) and leads to non-negative adjusted profits in the entire sample. Finally, we add the hospital-specific base rates (Basisfallwert)[9] of the years 2003 to 2005, the hospital-specific case-mix index (CMI) of the year 2004, and information on the regional structure (urban or rural) on postal code level from publicly available sources.[10]

The sample used in the analysis contains 1,026 observations from 374 hospitals excluding hospitals not receiving any public subsidies[11], university hospitals, and those with less than 100 beds (32 observations in total). Monetary variables are deflated to 2000 prices. The unit of analysis is either a single hospital or a small chain of hospitals (with up to 12 hospitals). Some small chains do not publish balance sheets for each single member but consolidated balance sheets. In this case we cannot decompose the different profits for the single hospitals within the chain and, therefore, we treat the small chain as one (large) hospital with average case-mix index and base rate. Since usually small chains encompass hospitals within a specific region which work closely together, this procedure is justified.

Table 1 reports summary statistics of the variables used in the analysis presented separately by ownership type. In general, big hospitals are overrepresented in this sample compared to the whole population of German general hospitals because they are more likely to publish their balance sheets than small hospitals. For a better comparability across hospitals, we choose *total adjusted costs* as the main cost variable. They are adjusted by subtracting costs for research and ambulatory care from total hospital costs. Input prices for labour such as *doctors*, *nursing services*, and *other staff* are calculated by dividing the costs incurred per group by its number of full-time equivalent employees. We distinguish three different generated capital prices in the cost frontier.[12] The first capital price, *medical requirements per case*, includes material costs for all medical requirements (pharmaceuticals, medical instruments, transplants, etc.) and is divided by the number of cases. The second and the third capital prices are generated by dividing *administrative costs* and

[9] The hospital-specific base rate and the potential number of cases weighted by their case-mix determine a hospital's budget. The revenues the hospital finally receives for a certain case are the product of the cost weight of a case (depending on the severity of the case and equal for all hospitals) and the base rate.

[10] Base rates and case-mix index originate from the AOK (the biggest German insurance fund). Since base rates were introduced in 2003 we use the same base rates for 2003 in 2002.

[11] Hospitals which do not receive public subsidies are on average small and specialised and probably not comparable to the other hospitals in our data.

[12] We thus refine our cost model of Herr (2008) using two more capital prices and defining the price for medical needs rather by the number of cases treated than by the number of installed beds. In that way, we may account for the origination of capital costs more precisely. Results do not depend on this choice.

Table 1: The Hospital Statistics: Mean values and standard deviations of selected variables

| | Total | | Public | | Non-profit | | Private | |
|---|---|---|---|---|---|---|---|---|
| **variable** | **mean** | **s.d.** | **mean** | **s.d.** | **mean** | **s.d** | **mean** | **s.d.** |
| *costs and profits* | | | | | | | | |
| EBIT/sales [in %] | 0.349 | 6.310 | -1.246 | 4.957 | -0.132 | 4.643 | 5.757 | 9.207 |
| EBITDA/sales [in %] | 7.761 | 6.779 | 6.804 | 5.285 | 6.326 | 5.579 | 13.477 | 9.396 |
| EAT/sales [in %] | 0.132 | 5.299 | -0.949 | 4.703 | -0.052 | 4.515 | 3.491 | 6.842 |
| Economic Profits/sales in [%] | -0.0005 | 0.0085 | -0.0009 | 0.0125 | -0.0003 | 0.0004 | 0.0000 | 0.0004 |
| *adjusted costs / beds* | 33,306 | 13,215 | 32,949 | 7,164 | 31,328 | 7,992 | 38,546 | 26,815 |
| *adjusted costs / case* | 2,828 | 1,022 | 2,747 | 476 | 2,736 | 608 | 3,250 | 2,134 |
| *output* | | | | | | | | |
| no. weighted of cases | 15,615 | 13,777 | 19,226 | 16,907 | 13,128 | 9,509 | 11,079 | 8,520 |
| unweighted no. of cases | 15,734 | 13,366 | 19,461 | 16,062 | 13,252 | 9,617 | 10,867 | 8,561 |
| *inputs* | | | | | | | | |
| doctors[a] | 94 | 101 | 118 | 128 | 77 | 63 | 66 | 52 |
| nurses | 261 | 252 | 325 | 319 | 216 | 159 | 186 | 142 |
| other staff | 296 | 335 | 385 | 438 | 232 | 182 | 191 | 157 |
| number of beds | 1,298 | 1,049 | 1,569 | 1,243 | 1,130 | 805 | 916 | 678 |
| *input and output prices* | | | | | | | | |
| costs per nurse[b] | 42,304 | 5,364 | 43,772 | 4,729 | 42,239 | 4,470 | 38,421 | 6,681 |
| costs per doc[b] | 83,021 | 10,302 | 84,180 | 9,010 | 82,739 | 9,562 | 80,454 | 14,048 |
| costs per other staff | 40,450 | 5,938 | 40,344 | 5,541 | 41,126 | 5,821 | 39,283 | 6,986 |
| medical requirements/ case[c] | 506 | 342 | 465 | 146 | 472 | 264 | 689 | 667 |
| administrative costs/ bed[d] | 835 | 698 | 777 | 515 | 794 | 330 | 1,080 | 1,358 |
| other material costs/ bed[d] | 5,534 | 2,685 | 5,327 | 1,684 | 5,307 | 1,749 | 6,588 | 5,193 |
| base rate | 2,698 | 321 | 2,729 | 302 | 2,652 | 304 | 2,710 | 390 |
| *exogenous variables* | | | | | | | | |
| eastern Germany[e] | 0.30 | 0.46 | 0.26 | 0.44 | 0.23 | 0.42 | 0.53 | 0.50 |
| urban | 0.52 | 0.50 | 0.44 | 0.50 | 0.64 | 0.48 | 0.49 | 0.50 |
| ratio of elderly patients[f] | 0.21 | 0.08 | 0.21 | 0.05 | 0.21 | 0.10 | 0.21 | 0.09 |
| surgery-ratio | 0.41 | 0.25 | 0.43 | 0.22 | 0.39 | 0.26 | 0.38 | 0.30 |
| ratio of female patients | 0.55 | 0.07 | 0.55 | 0.05 | 0.55 | 0.09 | 0.54 | 0.08 |
| HHI[f] | 0.43 | 0.28 | 0.53 | 0.29 | 0.30 | 0.22 | 0.41 | 0.25 |
| *further characteristics* | | | | | | | | |
| length of stay | 8.64 | 2.42 | 8.20 | 1.25 | 8.84 | 2.77 | 9.45 | 3.54 |
| mortality-ratio per 1,000 | 26.09 | 13.24 | 25.76 | 8.02 | 25.78 | 13.23 | 27.66 | 21.91 |
| doctors per 1,000 cases | 5.69 | 2.03 | 5.62 | 1.26 | 5.56 | 1.57 | 6.15 | 3.81 |
| nurses per 1,000 inpatient day | 1.98 | 0.49 | 1.98 | 0.31 | 1.96 | 0.58 | 2.04 | 0.64 |
| Case Mix Index (953 Obs.) | 1.02 | 0.37 | 0.96 | 0.18 | 1.00 | 0.22 | 1.24 | 0.76 |
| Sample size N | 1,026 | | 477 | | 375 | | 174 | |

Source: Final sample of the Hospital Statistics, Statistical Offices of the Länder, Germany. Economic Profits (EP)= sales-total costs)/ sales, a: number of full time equivalent employees, b: costs per full time equivalent employee (other staff= total number of employees minus doctors minus nurses), d: Costs for medical requirements (including drugs, transplants, implants) per unweighted case, e: Equals one if located in eastern Germany, including Berlin, f: Hirshman-Herfindahl Index (HHI) measured as squared market share [in installed beds] of each hospital (chain) per county the remaining material cost category *all other material costs*, respectively, by the number of installed beds. When estimating profit efficiency, we assume that the number of installed beds is a quasi-fixed input, which then serves as the measure for capital use instead of its price. Thus, we only keep the first of the three capital prices in the profit frontier. The hospital's output used in the cost frontier is the number of *weighted cases*. Analogously to Herr (2008), we construct weights based on the across-hospital average length of stay of each diagnosis relative to the overall length of stay assuming that the length of stay is correlated to the severity of illness.[13] The base rate serves as the price of one weighted case in the profit frontier. It is regulated and adjusted on an annual basis and may not be comparable to market prices used in other efficiency studies, e.g. in agriculture. However, it reflects the current price level, because the revenues for a certain case are the product of the cost weight of a case (depending on the severity of the case and equal for all hospitals) and the hospital-specific base rate. Hence, different hospitals receive different reimbursements for the same treatments. The base rate is set annually based on former budgets and case-mix weighted utilisation of the hospitals.

The following *exogenous variables* are included in all models to control for observable heterogeneity and to assess their direct effect on inefficiency. The dummy variable *eastern Germany* differentiates between hospitals located in eastern Germany (including Berlin) and those in western Germany. The Hirshman-Herfindahl index (*HHI*), defined as the squared market share of installed beds of hospitals and hospital chains per county, accounts for the degree of competition the hospital faces. The *ratio of female patients, of elderly patients* of at least 75 years of age, and of *patients receiving surgeries* are used to control for case-mix differences (Zuckerman et al., 1994). Unfortunately, the data do not provide any quality measures other than in-hospital mortality rates. Above average quality, which is probably more expensive, may also be captured by higher cost inefficiency or lower profit inefficiency.

In 2004 there was a fundamental reform of the remuneration system of hospitals in Germany. The new system is mainly based on diagnosis related groups (DRGs) and thus accounts for case severity. Until 2004, to a large degree, remuneration was proportional to length of stay and costs of treatment. Our data covers the period from 2002 to 2005 which includes the change in the system. To account for effects of the reform as well as other time trends, we include dummy variables for each year in most of the models to capture

[13] For robustness checks, we use the hospital specific Case-Mix-Index (CMI) to weight the number of cases. We observe the CMI only for one year, hence we lose 74 observations, which causes problems with the convergence rates in the general model. As it turns out that it does not have any explanatory power in either of the models when including it as an exogenous variable, we refrain from including the CMI in the final specifications.

technological change (in the profit frontier) as well as to capture the change of inefficiency over time (explaining the mode of the inefficiency distribution). Due to technical reasons, we cannot control for each single year from 2002 to 2005 in the computation intensive one-step model with truncated normally distributed inefficiency. Hence, we do only control for one year (year 2005, first year after the reform) in the profit function. If we did not control for the year of observation, we would assume that there is no technological change shifting the frontier in the four-years period.

# 3 Results

## 3.1 Cost Efficiency

Estimation results of the cost efficiency model specified similar to the model presented in Herr (2008) are shown in Table A-1 in the appendix. The first part of the table reports the coefficients on the input prices. The input prices positively influence the cost frontier. The model in which we control for technological change (left column) suggests that there had been cost decreasing technological change in 2005 compared to the years 2002-2004. The coefficients of the exogenous variables in the second part of the table are read as effects on *in*efficiency. The coefficients are jointly significantly different from zero, but not individually. Nevertheless, these results suggest that both private and non-profit hospitals are less cost efficient than public hospitals in Germany and are in line with the predictions of Herr (2008) and a deeper analysis of the estimated efficiency scores presented in Section 3.4.

## 3.2 Profit Efficiency

Tables 2 and 3 report the results on profit efficiency with three out of four different profit measures (EBIT, EBITDA, EAT, and EP) described in Section 2.2.[14] The two models use one-step SFA with normal truncated normal distributed inefficiency. In the following, we differentiate between the two approaches discussed in Section 2.1.

(i) Table 2 reports the results of the restricted model where we assume that there is no input-allocative inefficiency (Equation (2)). In the model which uses EBITDA as outcome measure all but one coefficient of the profit function are individually significant. F-tests indicate that the coefficients of the profit functions are jointly significantly different from zero in all models

[14] The data demanding models did not converge for all four profit variables in all specifications. Only converged models are presented.

and both approaches.[15] The coefficient of the dummy variable for the first year after the reform (year 2005) is significantly negative. This means that first technological change shifts the frontier over time and second that this technological change is profit decreasing.

The results of the second part of the table show the impact of exogenous factors on hospital *in*efficiency where a negative signs means lower inefficiency and thus higher efficiency. Our results suggest differences in the hospitals' profit efficiency across ownership types. In contrast to the results on cost efficiency, under the assumption that all hospitals use inputs allocative efficiently, private hospitals are less profit inefficient than public hospitals. This has several implications: First, it is in line with the findings of lower risks of insolvency and closure of private hospitals (Augurzky et al., 2008). Second, it shows that firms can simultaneously be less cost efficient and more profit efficient in price regulated markets. This means that private hospitals increase revenues by producing at higher costs. Third, it may imply that private hospitals maximise profits rather than minimise costs. The main result is robust to the way profits are measured (see columns 2 to 4, Table 2).

With respect to the other exogenous variables, the results indicate that hospitals in eastern Germany are more profit efficient considering EBITDA as a profit proxy but not when considering the other two profit proxies as outcomes. Non-profit ownership increases profit efficiency when considering EBIT as a proxy for profits. The HHI and the ratio of female or elderly patients and of surgeries do not affect profit efficiency significantly in model (i).

Although we find profit decreasing technological change, Augurzky et al. (2008) point out that profit margins (profits divided by sales) have increased in the same time period. This suggests that profits still increased relative to sales. One possible reason is shown in the second part of the table. All three year dummy variables have negative and significant coefficients which show that profit inefficiency has decreased over time. Tests on all coefficients of the exogenous variables being jointly zero (with and without the year dummies) are rejected, i.e. the mode of profit inefficiency is not constant but varies across the hospitals.

(ii) In Table 3 we report results of a model that allows for allocative inefficiency (Equation (3)). This is a more general model in which input prices are divided by the base rate. Furthermore, input prices, the quasi-fixed input and the profits are weighted by the returns to scale of the production function

[15] In contrast to the cost efficiency case, the signs of the coefficients in the production function are not clear a priori. While for example one more bed usually leads to higher costs, it might lead to higher or lower profits, depending on the actual number of beds compared to the individually optimal number.

Table 2: Profit efficiency, truncated, SFA, model (i) – assuming input allocative efficiency

| | EBITDA | EBIT | EAT |
|---|---|---|---|
| ln costs per doctors | -0.255 | 0.006 | -0.043 |
| | ( 0.124 )** | ( 0.036 ) | ( 0.040 ) |
| ln costs per other staff | -0.018 | -0.004 | 0.003 |
| | ( 0.133 ) | ( 0.040 ) | ( 0.039 ) |
| ln medical requirements per case | 0.166 | 0.044 | 0.028 |
| | ( 0.042 )*** | ( 0.016 )*** | ( 0.015 )* |
| ln base rate | 0.746 | 0.017 | 0.161 |
| | ( 0.051 )*** | ( 0.043 ) | ( 0.012 )*** |
| ln beds | 0.237 | -0.006 | 0.005 |
| | ( 0.023 )*** | ( 0.006 ) | ( 0.005 ) |
| year = 2005 | -0.434 | -0.191 | -0.462 |
| | ( 0.097 )*** | ( 0.082 )** | ( 0.022 )*** |
| Const. | 0.458 | 0.678 | 1.011 |
| | ( 0.344 ) | ( 0.164 )*** | ( 0.104 )*** |
| exogenous variables | | | |
| private | -0.229 | -0.176 | -0.140 |
| | (0.084)*** | (0.042)*** | (0.067)** |
| non-profit | 0.013 | -0.074 | -0.081 |
| | (0.052) | (0.035)** | (0.056) |
| eastern Germany | -0.128 | -0.024 | 0.019 |
| | (0.053)** | (0.041) | (0.059) |
| urban | -0.029 | 0.023 | 0.050 |
| | (0.048) | (0.041) | (0.061) |
| HHI | -0.050 | 0.019 | 0.019 |
| | (0.083) | (0.064) | (0.091) |
| ratio of elderly patients | 0.041 | -0.043 | -0.195 |
| | (0.271) | (0.14) | (0.139) |
| surgery-ratio | -0.009 | -0.094 | -0.084 |
| | (0.073) | (0.063) | (0.077) |
| ratio of female patients | 0.243 | 0.078 | 0.130 |
| | (0.316) | (0.208) | (0.139) |
| year = 2003 | -1.739 | -2.608 | -3.639 |
| | (0.418)*** | (0.485)*** | (0.959)*** |
| year = 2004 | -0.156 | -0.197 | -0.425 |
| | (0.038)*** | (0.034)*** | (0.050)*** |
| year = 2005 | -1.013 | 0.294 | -3.173 |
| | (0.421)** | (0.104)*** | (1.293)** |
| Constant | 0.901 | 1.111 | 1.310 |
| | (0.177)*** | (0.114)*** | (0.092)*** |
| Obs. | 1,026 | 1,026 | 1,026 |

Robust standard errors below coefficients in parentheses. Clustered at hospital level. Significance levels: *: 10%, **: 5%, ***: 1%. The signs of the exogenous variables' coefficients are to be read as effects on inefficiency.

Table 3: Profit efficiency, general truncated SFA, model (ii) – allowing for input allocative inefficiency and normalising with the output price (base rate)

| | EBIT | EAT | EP |
|---|---|---|---|
| ln costs per doctors | -0.008 | 0.006 | -0.002 |
| | ( 0.073 ) | ( 0.034 ) | ( 0.027 ) |
| ln costs per nurse | 0.143 | 0.062 | 0.068 |
| | ( 0.064 )** | ( 0.035 )* | ( 0.031 )** |
| ln costs per other staff | -0.041 | -0.025 | -0.029 |
| | ( 0.068 ) | ( 0.033 ) | ( 0.024 ) |
| ln medical requirements per case | -0.076 | -0.032 | -0.024 |
| | ( 0.024 )*** | ( 0.012 )*** | ( 0.010 )** |
| ln beds | 0.008 | 0.004 | -0.011 |
| | ( 0.009 ) | ( 0.005 ) | ( 0.004 )** |
| year = 2005 | -2.903 | -0.806 | -3.554 |
| | ( 0.089 )*** | ( 0.049 )*** | ( 0.059 )*** |
| Const. | 7.278 | 6.965 | 10.844 |
| | ( 0.365 )*** | ( 0.202 )*** | ( 0.224 )*** |
| exogenous variables | | | |
| private | -1.213 | -0.770 | -0.758 |
| | (1.290) | (0.743) | (0.615) |
| non-profit | -0.618 | -0.402 | -0.345 |
| | (0.718) | (0.449) | (0.336) |
| eastern Germany | 0.14 | 0.08 | 0.112 |
| | (0.486) | (0.379) | (0.34) |
| urban = 1 | 0.299 | 0.268 | 0.487 |
| | (0.551) | (0.441) | (0.457) |
| HHI | 0.086 | 0.192 | 0.126 |
| | (0.68) | (0.595) | (0.511) |
| ratio of elderly patients | -0.384 | -1.299 | -1.741 |
| | (1.634) | (1.367) | (1.403) |
| surgery-ratio | -0.696 | -0.545 | -0.541 |
| | (0.997) | (0.7) | (0.579) |
| ratio of female patients | -1.575 | 0.892 | 0.119 |
| | (2.651) | (0.861) | (0.719) |
| year = 2003 | -20.515 | -23.027 | -0.903 |
| | (16.879) | (15.056) | (0.367)** |
| year = 2004 | -2.363 | -2.816 | -27.020 |
| | (1.860) | (1.619)* | (19.797) |
| year = 2005 | -9.798 | -18.916 | -12.271 |
| | (9.860) | (15.510) | (8.964) |
| Constant | 3.463 | 2.815 | 3.405 |
| | (0.817)*** | (0.623)*** | (0.511)*** |
| Obs. | 1,026 | 1,026 | 1,026 |

Robust standard errors below coefficients in parentheses. Clustered at hospital level. Significance levels: *: 10%, **: 5%, ***: 1%. The signs of the exogenous variables' coefficients are to be read as effects on inefficiency.

$r = \sum_n \beta_n = 0.53$ and $\frac{1}{1-r} = 2.15$ according to Equation (3).[16]

Qualitatively the results are comparable to the ones before, except that the estimated parameters of the exogenous variables are not individually significantly different from zero at conventional levels. We tested for the case of excluding the year dummy variable for year 2005 in the profit frontier equation (results are not reported). This results in an increase of the constant term equivalent to the coefficient of the omitted year dummy variable. The coefficient on private ownership and the year dummy variables are then significantly different from zero for the two profit measures EBIT and EP ("economic profits"). This is the case since standard errors decrease more (by 1/3 to 1/4) than the coefficient on private ownership decreases (by 1/2). In the presented models in Table 3 the exogenous variables (with and without year dummy variables) are still jointly significantly different from zero when using EBIT and EP as profit proxies.

The following factors may explain the differences in the results across the two models. First, as the cost efficiency results showed that private hospitals are less technical and input allocative efficient than public hospitals, we conclude that the private hospitals' higher profit efficiency of the first model is due to higher output allocative efficiency. This positive effect seems to be dominated by the negative effect of input allocative inefficiency, which is introduced in model (ii). Private hospitals would therefore manage better to produce an efficient output mix, given output prices, but perform worse with respect to the input mix given input prices than public hospitals. Second, we restricted model (ii) assuming input allocative efficiency to make it comparable to model (i). This shows that normalising the input prices and the profits with the output price (base rate) explains the biggest part of the variation in results although it does not play a role which input price is used in model (i). Third, the new parameter and the generalisation of the model may come at a cost of lower accuracy of the estimates. However, as shown below, the estimated profit efficiency scores of the different ownership types are still significantly different from each other, which means that private hospitals have a significantly higher average efficiency score than public and non-profit hospitals also in this general framework.

[16] The production function is specified as follows: we regress the number of doctors, of nurses, of other staff, and of beds as well as the three year dummies on the number of weighted cases as discussed in Herr (2008). Then, we sum the coefficients of the variable inputs (thus excluding beds) to calculate the economies of scale based on $x$.

## 3.3 Estimated Efficiency Scores

In a last step, we use the stochastic frontier estimation results to estimate expected efficiency scores. Estimated average cost efficiency is approximately 92%. Although the estimates vary in magnitudes, they show that the hospitals in this study are relatively cost efficient when we compare the findings to former estimates of 82%-84% (Herr, 2008). The difference is due to the different samples used. In the first study, we looked at all general hospitals separately, while in this study, we consider less than one third of the hospitals (on hospital chain level, reporting detailed balance sheets). Furthermore, the cost efficiency scores imply that hospitals are quite technical and input allocative efficient. Thus, low or negative profits of some hospitals may be driven by ouput allocative or scale inefficiency only. Finally, model (i), in which we assume hospitals to be input allocative efficient, may apply to our data since on average input allocative efficiency is very high.

Profit efficiency scores vary across models and profit variables between 36% (EBIT) and 78% (EAT, both model (i)). In the two models presented, average profit efficiency for example using EAT as outcome is on average 78% in model (i) and 68% in model (ii).[17] Since profit efficiency is a combination of cost and revenue efficiency, profit efficiency scores are (on average) lower than cost efficiency scores.

To test for the difference in group means by ownership type, the standard errors of the estimated group mean scores are obtained by a bootstrapping procedure with 100 repetitions for the two preferred specifications and different cost and profit measures. The two-sample t-tests with unequal variances suggest that group means differ significantly from each other at a 5% level over the years from 2002 to 2005. Public hospitals have a higher average *cost* efficiency score than non-profit competitors, while the latter are still more cost efficient than private hospitals. In contrast, private hospitals have on average higher *profit* efficiency scores than public hospitals across all models. As our results suggest, the order of public and non-profit hospitals is less clear and varies across models. Considering EBIT for instance, non-profit hospitals have higher scores in model (i) but are not significantly different to public hospitals in model (ii).

## 3.4 Robustness Checks

We conduct several robustness checks with respect to selection of output and control variables and distributional assumptions.

[17]These values are presented for illustrative reasons and depend on model specification and the use of exogenous variables explaining inefficiency.

First, we re-estimate the cost model not weighting the number of cases or we include overall death rates in all models as a proxy for hospital quality (results are not reported). We obtain the same results regarding the sign and statistical significance of the ownership indicators in the inefficiency equation. The coefficient of the mortality rate turned out not to be significantly different from zero.

Second, we conduct a two-step SFA-approach in which, in the first step, we estimate the half-normal profit frontier while accounting for allocative inefficiency and time fixed effects. In a second step, the estimated efficiency scores are regressed on the exogenous variables. Although Wang and Schmidt (2002) point out that both regressions lead into biased estimates due to contradictory assumptions about the error terms in the two steps, this procedure has been commonly applied in the literature (e.g. Rosko, 1999).

Third, we estimate a fixed effects approach on the standard profit function exploiting the structure of our panel data set. The fixed effects approach allows us to relax the distributional assumption on the efficiency term. All we have to assume is that the inefficiency is constant over time. Therefore, it can be distinguished from a random error term that averages out over time.[18] Using the linear fixed effects approach, we calculate efficiency scores relative to the lowest fixed effect in the sample, which can be negative. In a second step, we regress the efficiency values estimated for each hospital on the exogenous hospital characteristics as the ownership type in the last year of observation of the hospital in our sample.

The regression results of both models are reported in Tables A-2 and A-3. A positive sign of the coefficients indicates higher profit efficiency scores. Qualitatively the results are comparable to the ones of Section 3. Private and non-profit hospitals are more profit efficient than public hospitals for most of the profit variables used. These models also suggest that non-profit ownership is correlated with higher profit efficiency compared to public hospitals. The weak results of the normal truncated normal models with respect to the higher efficiency of hospitals located in eastern Germany are confirmed by these alternative specifications. The HHI, being higher when hospitals face less competition in the market, is associated with higher profit efficiency in the two step model (Table A-2, EBIT and EP). Now, the other patients' characteristics also have individual explanatory power. However, it seems to make a difference which profit measure is used for one exogenous variable: Non-profit ownership is associated with higher profits when considering EBIT, EAT, or EP but changes signs when considering EBITDA in the fixed estimation approach.

[18]For this approach we can only use hospitals with at least two observations in the panel.

Table 4 shows pairwise correlation coefficients between hospital rankings obtained from the various models as well as between those hospital rankings and other selected variables. Although different distributional assumptions result in different magnitudes of the scores, our results turn out to be very robust with respect to ranking. Since theoretically only a cost efficient hospital can be fully profit efficient, the cost efficiency score ranking is positively and significantly correlated with the different rankings of the profit efficiency models. However, as expected, the correlation is lower than between the profit efficiency rankings. In the lower part of the table we show that public hospitals have a higher rank while private hospitals are correlated negatively with the hospital ranking based on cost efficiency scores.

The profit efficiency rankings are highly correlated by more than 93% when looking at the same profit measure (EBIT) and comparing the simple half normal model with model (ii). Furthermore, even the OLS fixed effects specification is correlated by more than 48% with the two rankings of the two different SFA specifications. In the second part of the table, the negative correlation coefficients of beds, the base rate and CMI indicate that an increase in size, output price or severity of illness is on average correlated with a lower hospital rank. The fixed effects specification differs from the stochastic frontier estimation by the sign on the correlations coefficients of the base rate and the CMI. In that specification, they are correlated with a higher rank. Private (public) ownership is again associated with higher (lower) ranks based on the profit efficiency scores while non-profit ownership is only significantly correlated with the ranking based on model (ii) (EAT).

# 4 Conclusion

This study is the first to analyse both cost and profit efficiency for German hospitals and to compare cost and profit efficiency analyses based on one data set.

Our results provide first insights into the question why private hospitals on average generate higher profits while simultaneously producing less cost efficiently than public hospitals. In contrast to lower cost efficiency, private and non-profit ownership are associated with higher profit efficiency compared to public ownership in the time period from 2002 to 2005. This result is robust to the choice of proxy to measure profits, different estimation techniques and different assumptions concerning the distribution of the inefficiency terms (except of the lack of individual significance of the ownership indicators in the most general model (ii)).

The main result may partly be explained by the fact that hospitals of differ-

Table 4: Pairwise correlation coefficients of profit efficiency rankings across different models for the profit variable EBIT.

| | SFA cost eff | SFA Profit Efficiency Models | | | | OLS FE |
|---|---|---|---|---|---|---|
| | truncated | half-normal | truncated, model (ii) | | | |
| | costs | EBIT | EBIT | EAT | EP | EBIT |
| SFA cost eff | 1 | | | | | |
| SFA half normal: EBIT | 0.1399 | 1 | | | | |
| SFA model (ii): EBIT | 0.0927 | 0.9357 | 1 | | | |
| SFA model (ii): EAT | 0.1244 | 0.7667 | 0.8253 | 1 | | |
| SFA model (ii): EP | 0.0757* | 0.5519 | 0.5575 | 0.5269 | 1 | |
| OLS Fixed Effects: EBIT | | 0.4884 | 0.6205 | 0.5485 | 0.2636 | 1 |
| Public | 0.1261 | -0.078* | -0.2082 | -0.2012 | -0.1542 | -0.2409 |
| Non-profit | | | | 0.073* | | |
| Private | -0.1183 | 0.074* | 0.2001 | 0.1733 | 0.1737 | 0.3341 |
| Beds | | -0.077* | -0.1625 | -0.1327 | -0.3478 | -0.065* |
| base rate | -0.2953 | -0.1719 | -0.079* | -0.1042 | -0.1016 | 0.066* |
| CMI | -0.2006 | -0.1878 | -0.072* | | -0.080* | 0.1759 |

The highest efficiency score has the highest rank. Printed correlation coefficients are significant at a 1% level, correlation coefficients additionally marked with $*$ are significant at a 5% level.

ent ownership types behave differently because they target different outcomes. While public hospitals probably seek to minimise costs, private hospitals are rather interested in maximising profits. This conclusion may have an impact on the future analysis of differences in the efficiency of hospitals, which is up to date focusing on the measurement of cost efficiency.

From the perspective of a policy-maker, cost reduction may be preferred to profit maximisation in publicly financed markets. However, higher profits allow hospitals to increase investments in their hospitals, e.g. in better technologies to improve outcome quality. The ability to finance investments by own resources becomes more and more important. Officially, hospital investments should be financed by the tax revenues of the federal states. However, in the last 20 years the federal states have substantially reduced their engagement in financing hospital investments. Thus, only hospitals with sufficiently high profit margins are able to fill the gap between necessary investments on the one hand and resources provided by the federal states on the other hand. Indeed Augurzky et al. (2009) show that investment rates are higher for private hospitals.

Whether higher profits are associated with better health care quality remains an open question. Hospitals are reluctant to publish quality indicators such as post-surgical infection rates and re-admission rates. Thus, we cannot judge objectively for or against privatisation for example with respect to cost-benefit criteria.

However, under the assumption that outcome quality does not differ between ownership types and since output prices are equal for all hospitals irrespective of ownership type, private hospitals are performing better in financing investments without recurring on taxpayers' money. Further research has to investigate quality differences between ownership types. Moreover, methodological improvements should be made by generalising the production function from a Cobb-Douglas to a translog type or by applying more advanced panel data analyses. Finally, the empirical models should incorporate more behavioural aspects of hospitals by ownership types.

# Appendix

The influence of the exogenous variables on cost inefficiency of German hospitals are given in Table A-1. The results of the robustness checks are presented in Table A-2 (2-step SFA) as well as Table A-3 (fixed effects estimations).

Table A-1: Cost efficiency, normal-truncated-normal model, SFA

| | truncated | truncated w/o 2005 |
|---|---|---|
| ln costs per doctor | 0.086<br>(0.058) | 0.096<br>(0.058)* |
| ln costs per other staff | 0.137<br>(0.046)*** | 0.135<br>(0.045)*** |
| ln administr. costs per bed | 0.039<br>(0.017)** | 0.039<br>(0.017)** |
| ln material costs per bed | 0.197<br>(0.024)*** | 0.195<br>(0.024)*** |
| ln medical requirements per case | 0.296<br>(0.033)*** | 0.291<br>(0.031)*** |
| ln weighted cases | 1.003<br>(0.013)*** | 1.004<br>(0.013)*** |
| year = 2005 | -0.030<br>(0.011)*** | |
| Constant | -0.978<br>(0.309)*** | -1.030<br>(0.296)*** |
| exogenous variables | | |
| private | 1.893<br>(2.639) | 2.157<br>(3.119) |
| non-profit | 0.513<br>(1.042) | 0.573<br>(1.196) |
| eastern Germany | -0.429<br>(0.944) | -0.464<br>(1.099) |
| urban | -0.154<br>(0.719) | -0.112<br>(0.758) |
| HHI | -2.119<br>(3.325) | -2.369<br>(3.864) |
| ratio of elderly patients | 7.902<br>(7.672) | 8.624<br>(8.594) |
| surgery-ratio | -0.840<br>(1.894) | -0.714<br>(1.674) |
| ratio of female patients | -7.380<br>(8.628) | -8.378<br>(9.625) |
| year = 2003 | 0.665<br>(0.824) | 0.658<br>(0.854) |
| year = 2004 | 0.079<br>(0.375) | 0.053<br>(0.380) |
| year = 2005 | 0.507<br>(0.622) | -0.121<br>(0.508) |
| Constant | -1.326<br>(2.573) | -1.224<br>(2.695) |
| Obs. | 1,026 | 1,026 |

Robust standard errors below coefficients in parentheses. Clustered at hospital level. Significance levels: *: 10%, **: 5%, ***: 1%. The signs of the exogenous variables' coefficients are to be read as effects on inefficiency.

Table A-2: Profit efficiency, normal-half-normal model, SFA, accounting for allocative inefficiency and year. Second Step: OLS, regressing estimated scores on exogenous variables

| | EBITDA | EBIT | EAT | EP |
|---|---|---|---|---|
| private | 0.071 | 0.050 | 0.018 | 0.032 |
| | (0.014)*** | (0.011)*** | (0.009)** | (0.010)*** |
| non-profit | -0.009 | 0.031 | 0.016 | 0.028 |
| | (0.011) | (0.009)*** | (0.007)** | (0.008)*** |
| eastern Germany | 0.064 | 0.022 | 0.025 | 0.013 |
| | (0.012)*** | (0.009)** | (0.007)*** | (0.009) |
| urban = 1 | 0.013 | -0.008 | -0.005 | -0.017 |
| | (0.010) | (0.007) | (0.006) | (0.007)** |
| HHI | 0.024 | 0.031 | 0.015 | 0.025 |
| | (0.020) | (0.015)** | (0.013) | (0.015)* |
| ratio of elderly patients | 0.146 | 0.123 | 0.024 | 0.126 |
| | (0.065)** | (0.049)** | (0.041) | (0.048)*** |
| surgery-ratio | -0.037 | -0.019 | -0.003 | -0.027 |
| | (0.020)* | (0.015) | (0.012) | (0.015)* |
| ratio of female patients | -0.179 | 0.042 | -0.007 | 0.170 |
| | (0.073)** | (0.055) | (0.046) | (0.054)*** |
| year = 2003 | 0.034 | 0.038 | 0.052 | -0.009 |
| | (0.014)** | (0.010)*** | (0.009)*** | (0.010) |
| year = 2004 | -0.008 | 0.017 | 0.014 | 0.037 |
| | (0.014) | (0.010) | (0.009) | (0.010)*** |
| year= 2005 | -0.010 | -0.053 | 0.045 | -0.094 |
| | (0.015) | (0.011)*** | (0.010)*** | (0.011)*** |
| Constant | 0.499 | 0.523 | 0.59 | 0.607 |
| | (0.041)*** | (0.031)*** | (0.026)*** | (0.031)*** |
| Obs. | 1,026 | 1,026 | 1,026 | 1,026 |

Robust standard errors below coefficients in parentheses. Significance levels: *: 10%, **: 5%, ***: 1%

Table A-3: Profit efficiency, OLS fixed effects in first step. Second Step: Regress scores on exogenous variables, OLS on last observation in sample

| | EBITDA | EBIT | EAT | EP |
|---|---|---|---|---|
| private | 0.029 | 0.075 | 0.020 | -0.061 |
| | (0.013)** | (0.014)*** | (0.01)** | (0.170) |
| non-profit | -0.023 | 0.017 | 0.014 | -0.055 |
| | (0.011)** | (0.011) | (0.008)* | (0.137) |
| eastern Germany | 0.023 | 0.028 | 0.009 | 0.274 |
| | (0.011)** | (0.011)** | (0.008) | (0.136)** |
| urban | 0.015 | -0.006 | 0.003 | 0.069 |
| | (0.010) | (0.010) | (0.007) | (0.124) |
| ratio of elderly patients | -0.122 | 0.018 | -0.008 | 0.077 |
| | (0.062)** | (0.066) | (0.044) | (0.785) |
| surgery-ratio | 0.021 | 0.040 | 0.009 | -0.006 |
| | (0.023) | (0.024)* | (0.016) | (0.289) |
| ratio of female patients | -0.229 | -0.251 | -0.077 | 0.167 |
| | (0.076)*** | (0.081)*** | (0.055) | (0.970) |
| Constant | 0.207 | 0.109 | 0.029 | -0.212 |
| | (0.040)*** | (0.042)** | (0.028) | (0.504) |
| Obs. | 364 | 364 | 364 | 364 |

Robust standard errors below coefficients in parentheses. Significance levels: *: 10%, **: 5%, ***: 1%

# References

Akhavein, J. D., Berger, A. N. and Humphrey, D. B. (1997). The effects of megamergers on efficiency and prices: Evidence from a bank profit function, *Review of Industrial Organization* **12**(1): 95–139.

Ali, F., Parikh, A. and Shah, M. (1994). Measurement of profit efficiency using behavioural and stochastic frontier approaches, *Applied Economics* **26**(2): 181–188.

Ali, M. and Flinn, J. C. (1994). Profit efficiency among Basmati rice producers in Pakistan Punjab, *Applied Economics* **26**(2): 181–188.

Augurzky, B., Budde, R., Krolop, S., Schmidt, C. M., Schmidt, H., Schmitz, H., Schwierz, C. and Terkatz, S. (2008). Krankenhaus Rating Report 2008 - Qualität und Wirtschaftlichkeit, *Materialien 41*, RWI Essen.

Berger, A. N. and Mester, L. J. (1997). Inside the black box; what explains differences in the efficiencies of financial institutions?, *Journal of Banking & Finance* **21**: 895–947.

Bradford, W. and Craycraft, C. (1996). Prospective payments and hospital efficiency, *Review of Industrial Organization* **11**(6): 791–809.

Coelli, T., Rao, D. P. and Battese, G. E. (2005). *An introduction to efficiency and productivity analysis, $2^{nd}$ edition*, Kluwer Academic Publishers, Norwell, Dordrecht.

Deprins, D. and Simar, L. (1989). Estimation de frontières déterministes avec facteurs exogènes d'inefficacité., *Annales d'Économie et de Statistique* **14**: 117–150.

Forschungsdatenzentrum der Statistischen Landesämter (2002-2005). Krankenhausstatistik: Grund- Diagnose- und Kostendaten, Antrag Nr. 615-2007.

Herr, A. (2008). Cost and technical efficiency of German hospitals: Does ownership matter?, *Health Economics* **17**: 1057–1071.

Hoerger, T. J. (1991). Profit variability in for-profit and not-for-profit hospitals, *Journal of Health Economics* **10**(4): 259–289.

Hollingsworth, B. (2008). The measurement of efficiency and productivity of health care delivery, *Health Economics* **17**(10): 1107–1128.

Huang, C. and Liu, J.-T. (1994). Estimation of a non-neutral stochastic frontier production function, *Journal of Productivity Analysis* **5**: 171–180.

Knox, K. J., Blankmeyer, E. C. and Stutzman, J. (1981). Relative economic efficiency in Texas nursing facilities: A profit function analysis, *Zeitschrift für die gesamte Staatswissenschaft* **137**: 45–61.

Kumbhakar, S. C. (2001). Estimation of profit functions when profit is not maximum, *American Journal of Agricultural Economics* **83**(1): 1–19.

Kumbhakar, S. C. (2006). Specification and estimation of nonstandard profit functions, *Empirical Economics* **31**: 243–260.

Kumbhakar, S. and Lovell, K. (2000). *Stochastic Frontier Analysis*, Cambridge University Press, Cambridge.

Mas-Colell, A., Whinston, M. D. and Green, J. R. (1995). *Microeconomic Theory*, Oxford University Press, New York.

Ozcan, Y., Luke, R. D. and Haksever, C. (1992). Ownership and organizational performance: A comparison of technical efficiency across hospital types, *Medical Care* **30**(9): 781–794.

Rosko, M. (1999). Impact of internal and external environmental pressures on hospital inefficiency, *Health Care Management Science* **2**: 63–74.

Rosko, M. (2001). Cost efficiency of US hospitals: A stochastic frontier approach, *Health Economics* **10**: 539–551.

Rosko, M. (2004). Performance of U.S. teaching hospitals: A panel analysis of cost inefficiency, *Health Care Management Science* **7**: 7–16.

Statistisches Bundesamt (2007). Grunddaten der Krankenhäuser - Fachserie 12 Reihe 6.1.1, https://www-ec.destatis.de/csp/shop/sfg/bpm.html.cms.cBroker.cls?cmspat%h=struktur,vollanzeige.csp&ID=1023232.

Tiemann, O. and Schreyögg, J. (2008). Effects of ownership on hospital efficiency in Germany – a Tobit panel data approach based on DEA efficiency scores, unpublished manuscript.

Villalonga, B. (2000). Privatization and efficiency: Differentiating ownership effects from political, organizational, and dynamic effects, *Journal of Economic Behavior & Organization* **42**: 43–74.

Wang, H.-J. (2002). Heteroscedasticity and non-monotonic efficiency effects of a stochastic frontier model, *Journal of Productivity Analysis* **18**: 241–253.

Wang, H.-J. and Schmidt, P. (2002). One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels, *Journal of Productivity Analysis* **18**: 129–144.

Zuckerman, S., Hadley, J. and Iezzoni, L. (1994). Measuring hospital efficiency with frontier cost functions, *Journal of Health Economics* **13**(3): 255–280.