

Strumann, Christoph; Herwartz, Helmut

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Spatial Interdependence of Hospital Efficiency in Germany

Helmut Herwartz* Christoph Strumann[†]

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Abstract

The introduction of the hospital reimbursement based on diagnosis related groups (DRG) in 2004 has been a conspicuous attempt to increase hospital efficiency in Germany. We analyze possible determinants of hospital performance before and after the DRG introduction. A two-stage semi-parametric efficiency model allowing for spatial interdependence among hospitals is applied. We consider cross-sectional regressions for the years 2002 to 2006 and discover an increase in the magnitude of negative spatial spillovers among German hospital performance after the DRG introduction. This result confirms the expected rise of competition for low cost patients due to the reform of the financing system. Moreover, the reform has no effect on the efficiency differential between private and public hospitals. Private hospitals are still less efficient after 2004. The estimated effects of other determinants might imply an increase in efficiency of German hospitals due to the reform in the long run.

JEL-Classification: C12, C13, C21, D61, I11, I12, I18

Keywords: Hospital efficiency, Data Envelopment Analysis, spatial analysis, diagnosis related groups

*Institut für Statistik und Ökonometrie, Christian-Albrechts-Universität zu Kiel, Ohlshausenstr. 40, D-24118 Kiel, Germany, Herwartz@stat-econ.uni-kiel.de

[†]Corresponding author. Institut für Statistik und Ökonometrie, Christian-Albrechts-Universität zu Kiel, Ohlshausenstr. 40, D-24118 Kiel, Germany, CStrumann@stat-econ.uni-kiel.de

1 Introduction

The German health sector is characterized by a steady increase in hospital expenditures. It has doubled from 1991 to 2007, reaching almost 60 billion euro in 2007 (Statistisches Bundesamt, 2008). This amounts to around 2.5% of German gross domestic product (GDP). The introduction of a prospective payment system based on diagnosis related groups (DRG) in 2004 has been a conspicuous attempt to increase efficiency in hospitals (e.g. Hensen et al., 2008 and Lungen and Lapsley, 2003). Under DRGs, hospitals receive a fixed rate for each admission depending on a patient's diagnoses. The long run effects on hospital efficiency in Germany has not been evaluated yet. However, there are some observations and suggestions about the consequences for hospitals, e.g. changes in incentives structures (Böcking, 2005), a trend of cooperation and merging (Rocke, 2003), specialization (Knorr, 2003), rise of competition for patients (e.g. Gorschlüter, 2004). The influence of some factors on hospital efficiency have been examined by several studies for Germany before the DRG introduction, e.g. Herr (2008), Steinmann et al. (2004), and Helmig and Lapsley (2001). This study examines the evolution of these and other determinants' impact due to the introduction of the DRG based hospital financing system.

Moreover, any study lacks of taking into account the interaction between hospitals. Especially the rise of competition for patients succeeding from the DRG introduction might increase the interdependence between hospitals; A hospital which is successful in recruiting patients with low complexity and diagnoses related to high reimbursements in the nearby area (e.g. due to reputation, bribery¹) might show a better performance than the neighbor hospitals. On the other hand, the existence of regional differences between medical treatments which cannot be explained by medical factors (e.g. Grytten and Sorensen, 2003 and Stano, 1993) could imply spatial clustering of hospital performance. Ignoring this form of dependence, biases the significance of the determinants and invalidates conclusions (Anselin, 1988a). If spatial clusters exist for both the dependent and explanatory variables, estimated relationships might appear stronger than they actually are (Bech and Lauridsen, 2008). Spatial regression models cope with such problems by taking into account direct and unobservable linkages of nearby observations. Since now, only Ferrier and

¹In Germany in summer 2009, there was an affair about bribery payments from several hospitals to general practitioner for the admission of low cost patients.

Valdmanis (2006) consider spatial interdependence of US hospital efficiency.

The aim of this study is to uncover the existence of possible spatial spillovers of hospital performance in Germany. Thus, this is the first approach examining potential determinants of hospital efficiency by means of spatial regression techniques. A cross section of around 1500 German hospitals is considered over 5 years (2002 to 2006) including the DRG introduction period. We apply a spatial two-stage semi-parametric efficiency model. Logarithmic *Data Envelopment Analysis* (DEA) efficiency scores are regressed on explanatory variables in a spatial setting. The functional form of the production does not need to be specified, avoiding assumptions about profit-maximization or cost-minimization behavior, which might be inappropriate for (non-profit) hospitals (Breyer et al., 2005). We consider a spatially autoregressive model with spatially autoregressive disturbances (SARAR). Two alternative spatial weights matrices are considered to address robustness of the empirical results.

The remainder of the paper is organized as follows: in Section 2 the motivation for spatial interdependence and possible determinants of hospital efficiency are discussed. Section 3 sketches the spatial two-stage semi-parametric efficiency model, data description, and the selection of the explanatory variables and the spatial weights matrices. Empirical results are encountered in Section 4. Section 5 concludes.

2 Hospital performance

In this Section, we first provide the rationale, why hospital performances might influence each other. Then the expected impacts of potential determinants of hospital efficiency are discussed.

2.1 Spatial interdependence

The introduction of DRGs has led to an increased pressure on the financial performance of hospitals and a higher risk of insolvency. The financial reimbursements are no longer related to the treatments and length of stay, but are paid to the hospitals corresponding to the patients' diagnoses. Thus, hospitals have an incentive to preferably treat cases with high reimbursement rates and low complexities (Böcking, 2005). As Ellis (1998) points out in a theoretical equilibrium approach, under prospective payment, health providers dump the

most severely ill patients and compete to attract low cost patients, i.e. patients with low complexities and an expected relatively short hospital stay. Empirical evidence for an implicit patients' selection after the shift to a prospective payment system is found for the US by e.g. Norton et al. (2002), and Ellis and McGuire (1996). Hospitals which are successful in recruiting low cost patients in the nearby area are able to use relatively less resources in comparison with hospitals treating patients with similar diagnoses but higher complexities. These might be associated with additional efforts and prolonged hospital stays. Hence, the performance of two contiguous hospitals is expected to be negatively correlated.

On the other hand, there are also reasons for positive spatial correlation. Hospitals which are in the same region face similar (unobservable) opportunities and constraints, e.g. market characteristics, composition of patients and regional legal requirements (Moscone et al., 2007). Empirical evidence for social interactions among Californian hospitals is found by Ferrier and Valdmanis (2006). They investigate the scope of peer effects in explaining variations of hospital efficiency and suggest that the performance of the competitor has a significantly positive influence. The growing competition among US hospitals after introducing DRGs in the mid-1980s has forced hospitals to produce more efficiently (Hadley et al., 1996). Therefore, the performance of hospitals which are located in the same competitive region or market is correlated as a consequence of spatial neighborhood. Similarly, Mobley (2003) and Mobley et al. (2008) estimate the impact of market structure on hospital pricing in California by modeling spatial spillovers among hospitals, which are found to be significantly positive.

Another potential trigger of positive spatial interdependence among hospital performances is the physician practice style. Numerous studies detect large regional differences between medical treatments which cannot be explained by medical factors (e.g. Grytten and Sorensen, 2003 and Stano, 1993). Stolpe (2004) refers these differences to physicians' uncertainty to make the correct diagnosis. This is underlined by Berger et al. (1997), who show the wide disuse of evidence based medicine that favors the formation of individual physician practice styles. These can be regionally strengthened by local communication among the physicians. The respective effect on hospital performance is considered by Jong et al. (2006), who show for New York hospitals, that physicians coming from another hospital adapt their decisions to what is common in the new hospital they work for. Considering physician efficiency in Virginia, Pai et

al. (2000) find substantial regional variation, which can be mainly attributed to differences in the use of prescriptions and laboratory procedures. Bech and Lauridsen (2008) investigate the inpatient hospital admission in Denmark and discover significant spillover effects across municipalities.

2.2 Determinants of hospital efficiency

Ownership form: The influence of hospital's ownership form on hospital performance is widely discussed. From theoretical aspects² one might conclude that private owned firms outperform public owned firms (Villalonga, 2000). However, there are several empirical studies which come to the opposite result (Herr, 2008, Farsi and Filippini, 2008, Barbetta et al., 2007, Helmig and Lapsley, 2001). In Germany, the private hospital sector grows rapidly, however, starting from a rather small fraction of hospitals (Krista and Berndt, 1998). Helmig and Lapsley (2001) explain the efficiency differential between private and public hospitals with efforts of local or regional governments to sell the most inefficient hospitals to private investors, while holding the more efficient ones. Herr (2008) argues that the financing system of cost reimbursement until 2004 has established profit incentives to keep patients longer than medically required. However, these incentives are discharged under DRGs (Böcking et al., 2005) suggesting a more efficient performance of private hospitals after 2004. For the case of Italy, Berta et al. (2009) observe a convergence in efficiency of private hospitals to the public counterparts after the introduction of DRGs.

Market share: To face the challenges of the DRG based financing system, Rocke (2003) expects a trend of cooperation and merging. Thus the effect of market share is of particular interest to draw conclusions for the long run effects of the DRG introduction. Ferrier and Valdmanis (2006) and Hadley et al. (1996) diagnose a weak impact of market shares on hospital efficiency. Town and Vistnes (2001) and Dranove and Ludwick (1999) confirm that higher market shares reduce costs or raise profits due to improvements of the hospital's bargaining power.

Specialization: Another expected consequence of the DRG introduction is an increase in specialization for smaller hospitals. Numerous studies affirm that hospitals offering a large number of service types face higher costs (e.g. Farsi and Filippini, 2008, Lee et al., 2008, Chang, 1998, and Linna and

²For example the agency theory (Sappington and Stiglitz, 1987 and Shapiro and Willig, 1990), property rights theory (Alchian, 1965) and public choice theory (Boycko et al., 1996).

Häkkinen, 1997). The management of hospitals with a more complex service-structure is likely to face additional difficulties to organize the production efficiently.

Quality: The approaches, which consider the effects of quality improvements on efficiency, do not come to conclusive results. Farsi and Filippini (2008) find a negative relationship for Swiss hospitals' costs, while McKay and Deily (2008) cannot detect a systematic pattern of association. Laine et al. (2005) find only for poor quality of care a negative linkage between quality and efficiency of Finnish hospital service. In contrast Deily and McKay (2006) detect a positive relationship for hospitals in Florida.

Occupancy rate: Following Chang (1998) for the case of Taiwan, a lower occupancy rate leads to higher inefficiency. Hospitals usually do not adjust their working staff promptly in response to changes in the number of treated patients. So hospitals with a relatively low occupancy rate are expected to have an oversized staff that is unlikely to meet the current demand for inpatient care efficiently.

Proportion of physicians: Linna and Häkkinen (1997) consider the proportion of physicians to all other staff as a measure for variation in the hospital's decisions about input allocations. They find like Luoma et al. (1996) a positive relationship to efficiency for Finish hospitals.

Budget size: Kjekshus and Hagen (2007) and Biorn et al. (2003) find for Norway that hospitals with a relative large budget tend to be inefficient, because they have more slack resources than hospitals with less financial means. Such resources could be employed for additional activities, which are indirectly related to the treatments, such as quality improvements, research, teaching or higher wages.

Demographic factors: The treatment of elder people is likely to be more cost- and resource-intensive, because they are often confronted with higher degrees of comorbidity and complications (Augurzky et al., 2006). Several authors (e.g. Herr, 2008, Chang, 1998) address the influence of the patients' age structure on hospital efficiency and find that higher proportions of older patients increase the inefficiency.

Financial situation of states: According to § 4 of the Hospital Financing Act (*Krankenhausfinanzierungsgesetz-KHG*) the financial support in the German hospital sector is dualistic: operating costs are paid by insurance companies, while investments are funded by federal states (§ 9 KHG). Thus, financial stress in the federal states could reduce the financial means for in-

vestments.

Region: The results of Herr (2008) show differences between hospitals located in Eastern Germany (including Berlin) and Western Germany. She argues that on the one hand hospitals in the East have profited by public investments after the German reunification. On the other hand the regions of the hospitals face higher unemployment rates, leading to migration of young and skilled inhabitants to the West.

3 Methodology

In this Section, we sketch the spatial two-stage semi-parametric efficiency model, data description, and the selection of explanatory variables and spatial weights matrices.

3.1 Spatial two-stage semi-parametric efficiency model

We consider a SARAR(1,1) model to account for two distinct channels of spatial dependence simultaneously. The model reads as

$$\ln(\boldsymbol{\theta}) = \lambda W \ln(\boldsymbol{\theta}) + \mathbf{Z}\boldsymbol{\beta} + \mathbf{e}, \quad \text{with} \quad \mathbf{e} = \rho M \mathbf{e} + \boldsymbol{\epsilon}, \quad (1)$$

where $\boldsymbol{\theta}$ is an $N \times 1$ vector consisting of efficiency scores $\boldsymbol{\theta} = (\theta_1, \dots, \theta_N)'$, \mathbf{Z} is an $N \times K$ matrix of observations of K explanatory variables, $\boldsymbol{\beta}$ a $K \times 1$ vector of parameters. The pattern of spatial dependence is captured by the $N \times N$ spatial weights matrices, W and M , with zero diagonals and row normalized constants (such that each row sums to unity), and λ and ρ as the spatial autocorrelation coefficients. Finally, $\boldsymbol{\epsilon}$ is an $N \times 1$ vector of location specific i.i.d. disturbances, $\boldsymbol{\epsilon} \sim N(0, \sigma^2 I_N)$.

The efficiency scores, $\boldsymbol{\theta}$, are estimated in a first step by non-parametric DEA. In this framework, the production or cost function does not need any functional specification avoiding assumptions about profit-maximization or cost-minimization behavior, which might be inappropriate for (non-profit) hospitals (Breyer et al., 2005). The relative efficiency of a hospital is evaluated through a comparison of its set of inputs and outputs to that of any other hospital. The obtained measure denotes the radial distance of the hospital to the frontier function, which is determined from a linear combination of the best practicing (efficient) units that compose the reference set. DEA scores are constrained to the interval $(0, 1]$, with 1 indicating an efficient hospital. To

avoid the censoring problem in regression analysis, we apply the tie-breaking procedure recommended by Andersen and Petersen (1993). The efficient units are ranked according to the amount by which their input vectors could be increased without becoming inefficient. Then a logarithmic transformation achieves an unbounded super efficiency measure (e.g. Burgess and Wilson, 1998). To compare hospitals facing different environmental settings, Banker and Morey (1986) introduce the use of non-discretionary input variables.

The efficiency score, θ_i , is obtained by solving the following linear program

$$\begin{aligned} \hat{\theta}_i &= \arg \min_{\theta_i, \mu} \{ \theta_i > 0 \mid \sum_{l \neq i}^N \mu_l y_{pl} \geq y_{pi} \quad \forall \quad p \in \{1, \dots, q\} \\ \theta_i x_{ji}^D &\geq \sum_{l \neq i}^N \mu_l x_{jl}^D \quad \forall \quad j \in \{1, \dots, m^D\} \\ x_{ki}^N &\geq \sum_{l \neq i}^N \mu_l x_{kl}^N \quad \forall \quad k \in \{1, \dots, m^N\} \\ \sum_{l \neq i}^N \mu_l &= 1, \quad \mu_l > 0 \quad \forall \quad l = 1, \dots, N \}, \end{aligned}$$

where y_{ri} , x_{ki}^N and x_{ji}^D denote output, non-discretionary and discretionary input variables of the i -th hospital. The number of outputs, non- and discretionary inputs, and hospitals is q , m^N , m^D , and N , respectively. The constraint $\sum_{l \neq i}^N \lambda_l = 1$ is imposed due to the assumption of variable returns to scale (Banker et al., 1984). As Kneip et al. (1998) show, $\hat{\theta}_i$ is a consistent estimator for the true efficiency score θ_i .³ Thus we substitute $\hat{\theta}_i$ for θ_i in (1) and obtain

$$\ln(\hat{\boldsymbol{\theta}}) \approx \lambda W \ln(\hat{\boldsymbol{\theta}}) + \mathbf{Z}\boldsymbol{\beta} + \mathbf{e}. \quad (2)$$

Assuming a multivariate normal distribution of the error terms, i.e.

$$\mathbf{e} = (I_N - \rho W)^{-1} \boldsymbol{\epsilon} \sim N(0, \Sigma), \quad \Sigma = E[\mathbf{e}\mathbf{e}'] = \sigma_\epsilon^2 (B'B)^{-1} \quad B = I_N - \rho W,$$

³Simar and Wilson (2007) mention that in finite samples the estimated efficiency scores are biased and serially correlated in an unknown complicated way. The convergence rate of $\hat{\theta}_i$ depends on the number of in- and outputs and is, thus, typically lower than $N^{-1/2}$. Therefore the bias and the serial correlation among the $\hat{\theta}_i$'s disappear asymptotically with the same rate as $\hat{\theta}_i$ converges. Maximum Likelihood estimates of regressions of $\hat{\theta}_i$ are consistent, but the inference based on the inverse of the negative Hessian of the log-likelihood is generally invalid. To overcome this problem, we apply an appropriate bootstrap suggested by Simar and Wilson (2007). However, the difference between the bootstrap and asymptotic results are negligible. For space consideration, we do not provide the bootstrap scheme in detail.

the model can be estimated in a second step by maximizing the log likelihood function

$$\ln L = -(N/2)\ln(2\pi\sigma^2) + \ln|A| + \ln|B| - (1/2\sigma^2)(\boldsymbol{\epsilon}'\boldsymbol{\epsilon}). \quad (3)$$

In (3), $A = I_N - \lambda W$, $\boldsymbol{\epsilon} = B(A \ln(\hat{\boldsymbol{\theta}}) - \mathbf{Z}\boldsymbol{\beta})$, $\sigma^2 = \boldsymbol{\epsilon}'\boldsymbol{\epsilon}/N$ and the ML estimator is

$$\hat{\boldsymbol{\beta}}_{ML} = \left(\mathbf{Z}' \hat{B}' \hat{B} \mathbf{Z} \right)^{-1} \mathbf{Z}' \hat{B}' \hat{B} \hat{A} \ln(\hat{\boldsymbol{\theta}}), \quad (4)$$

where $\hat{B} = (I_N - \hat{\rho}_{ML}M)$, $\hat{A} = (I_N - \hat{\lambda}_{ML}W)$. The error variance is estimated as

$$\hat{\sigma}_{ML}^2 = \hat{\boldsymbol{\epsilon}}'\hat{\boldsymbol{\epsilon}}/N,$$

where

$$\hat{\boldsymbol{\epsilon}} = \hat{B}(\hat{A} \ln(\hat{\boldsymbol{\theta}}) - \mathbf{Z}\hat{\boldsymbol{\beta}}_{ML}). \quad (5)$$

Due to the deterministic nature of DEA, measurement errors for observations of the reference set could cause severe distortions in the estimated efficiency scores for all hospitals (e.g. Burgess and Wilson, 1998) and might distort regression results. Additionally, hospitals performing particularly poor might also invalidate the regression results. So, we perform the outlier detection proposed by Johnson and McGinnis (2008) to identify hospitals having a particular good or poor performance. Hospitals are treated as an efficient outlier if it is possible to double the inputs without becoming inefficient. An inefficient outlier is detected if a convex-combination of worst performing hospitals can produce the same level of output using half the inputs.

3.2 Data and variable construction

3.2.1 The data set

The data is drawn from two distinct sources. The hospital data is extracted from the annual hospital statistics as collected by the statistical offices of the federal states (“Statistische Landesämter”). It includes basic hospital data, e.g. forms of ownership, the number of beds, staff, patients, etc. and data about the cost structure of the hospitals, as total costs, payroll costs, material expenses etc. The county- and state-level data is obtained from the “Regionaldatenbank Deutschland - GENESIS”, which is administered by the statistical office of North Rhine-Westphalia (“Landesamt für Datenverarbeitung und Statistik Nordrhein-Westfalen”). Annual data cover the period from 2002 until

2006 and has been provided by the “Forschungsdatenzentrum der Statistischen Landesämter - Standort Kiel”. Each year, around 450 hospitals have data inconsistencies, as facing costs of less than 100 Euro or having zero-values for beds, physicians etc. and are excluded from the sample (Herr, 2008). 146 (2005) to 251 (2004) hospitals are identified as outliers and also excluded from the sample. For a better comparison of the hospitals, university hospitals are not considered in the analysis.

3.2.2 Inputs and outputs

The inputs which are assumed to be controlled by the hospitals are the amount of material expenses (in 2005 prices), the number of employed physicians (*phys*), nurses (*nurses*) and other staff (*others*). Notably, the capacity of beds is imposed by the states for most hospitals and therefore a non-controllable instrument for these hospitals. Accordingly, the number of beds (*beds*) is treated as a non-discretionary input. For a hospital’s output we take the number of cases weighted for severities of illnesses of the hospitals’ patients (*wcases*) and the number of apprentices (*apprents*).

3.2.3 Constructing case-mix weights

A specialized hospital providing high tech medical treatments faces distinct costs and burdens for treating their patients in comparison with a non specialized primary health care hospital. To account for such differences between the severities of illnesses of the hospitals patients, it is common to weight the treated cases by a case mix measure (e.g. Rosko and Chillingirian, 1999). In Germany, the Institute for the Hospital Remuneration System (InEK) (“Institut für das Entgeltsystem im Krankenhaus”) provides cost weights for each DRG, which indicate efforts of a particular treatment relative to a reference case. The case mix, or number of weighted cases, is obtained for each hospital by summing up all the weights for all treated cases in the hospital. However, this case-mix measure is potentially biased, since patients do neither receive all diagnoses nor all treatments which emerges (Herr, 2008). Moreover, patient selection suggests, that DRG cost weights are insufficient measures of efforts, because associated complexities and subsequent illness are not reflected (e.g. Böcking, 2005). As an alternative to these cost-based case mix weights, Herr (2008) makes use of the information about the average length of stay of each inpatient diagnosis as a proxy for resource use. The more time a treatment

of a particular diagnosis takes relative to all other treatments, the higher the weight of the corresponding cases. Due to the lack of patient data we can only determine weights for the various clinical departments. Thus the number of weighted cases is obtained by summing up the treated cases multiplied with the weights of the respective clinical departments. These weights are constructed as the ratio of the mean length of stay of cases in that department over all hospitals and the mean length of stay over all departments and hospitals.

3.2.4 Explanatory variables

The explanatory variables are used to investigate the effects of possible determinants encountered in Section 2.2 and to control for observable heterogeneity between the hospitals.

hospital specific: The variable *private* is a dummy variable for private oriented hospitals. The market share, *ms*, is computed as the number of patients of a hospital relative to its competitors. The hospital's market is approximated by the county, where it is located. The variable measuring the occupancy rate is denoted as *occrate*. The quality of care is captured by two distinct variables. The mortality rate (*mort*) is used (e.g. Propper et al., 2004) as a proxy for poor quality. A hospital's nurse per bed ratio (*npbed*) is thought to represent the quality of nursing care (Farsi and Filippini, 2008). The variable *docshare* denotes the percentage of physicians to all staff and measures for variation in the hospital's decisions about input allocations. To approximate the hospitals' budget size, the total expenses (in 2005 prices) per bed are used and denoted by *budget* (Kjekshus and Hagen, 2007). The degree of specialization is obtained by applying a modification to the information theory index (Evans and Walker, 1972). Instead of the number of cases belonging to several DRG categories, the number of cases belonging to several clinical departments are used. Thus the specialization of a hospital is measured using differences between the hospital's proportions of cases belonging to several departments and national proportions. It is denoted as *spec* and might be a less ambiguous measure for specialization than indices based on DRG categories (e.g. Herr, 2008). On the one hand a high value of such an index might be due to services concentration and on the other hand to the selection of the more profitable DRGs (Berta et al., 2009). This phenomenon is known as "treatment cream skimming" and typically obtains under a prospective payment system (Ellis, 1998).

county/state specific: The fraction of people aged over 65 years and living in a hospitals' county is denoted by *age65*. To capture the degree of the county's urbanization, the population density (*popdens*) is also incorporated. Exogenous socioeconomic factors are controlled by a county's GDP per capita (*GDPpC*). The debts of the federal states per GDP are denoted by *debt*. The dummy variable *east* is one if a hospital is located in Eastern Germany (including Berlin). In each federal state of Germany, a commission composed of members of the state government and health insurances create the hospital requirement and financing plan ("Krankenhausbedarfsplanung") for providing inpatient care to the population in the hospitals' service area (Mörsch, 2008). Hence, hospitals which are in the same state face the same regional legal requirements. To account for this type of observable heterogeneity, we include non-city state dummy variables.⁴

3.2.5 Spatial weights matrices

Two alternative spatial weights matrices are used to implement the respective matrix in (2). Both are binary matrices, with the element $w_{ij} = 1$, if the i -th and the j -th hospital are contiguous. However, the definition about two hospitals being contiguous differs across the weight matrices. The first concept is to define hospitals as contiguous to each other if they are located in the same county. This yields the county weights matrix, denoted by \mathcal{W}_c . For the second weights matrix, \mathcal{W}_{nc} , two hospitals are considered contiguous if they are either located in the same county, or if their respective counties of residence are neighbors.

4 Results

The two-stage semi-parametric efficiency model is estimated for each year from 2002 until 2006. Several models, varying between four distinct weights specifications, are estimated. The first two specifications are $W = M = \mathcal{W}_c$ and $W = M = \mathcal{W}_{nc}$, i.e. we assume for the spatial lag and error specification the same spatial weights matrix. Additionally, the SARAR model is compared to the spatial error model (SEM) ($\lambda = 0$), the spatial lag model (SLM) ($\rho = 0$)

⁴The city states, Berlin, Bremen and Hamburg are not taken into account, because of identification considerations.

and a model, which ignores spatial interdependence and is estimated by ordinary least squares (OLS). Two further spatial specifications are derived by setting $W = \mathcal{W}_c$, $M = \mathcal{W}_{nc}$ and $W = \mathcal{W}_{nc}$, $M = \mathcal{W}_c$. Some of the introduced regressors (*ms*, *mort*, *npBed*, *occrates*, *docshare*, *budget*, *GDPpC*, *popdens* and *depts*) are measured in natural logarithms.

Model comparison

Table 1 displays the spatial correlation estimates for the distinct models. Under

Table 1: Spatial correlation estimates

		2002	2003	2004	2005	2006
	N	1474	1588	1496	1550	1520
$W=M=\mathcal{W}_c$	$\hat{\rho}$	0.111*	0.289***	0.186***	0.158***	0.345***
	$\hat{\lambda}$	-0.125**	-0.234***	-0.163***	-0.156***	-0.301***
	$\hat{\rho} _{\lambda=0}$	-0.005	0.100***	0.043	0.016	0.075**
	$\hat{\lambda} _{\rho=0}$	-0.036	-0.035	-0.026	-0.047*	-0.060**
$W=M=\mathcal{W}_{nc}$	$\hat{\rho}$	-0.156	0.328*	0.191	0.321*	0.336*
	$\hat{\lambda}$	-0.111	-0.330*	-0.247	-0.487**	-0.514**
	$\hat{\rho} _{\lambda=0}$	-0.258	0.158	0.074	0.083	0.031
	$\hat{\lambda} _{\rho=0}$	-0.204	-0.135	-0.159	-0.273*	-0.280**
$W=\mathcal{W}_c, M=\mathcal{W}_{nc}$	$\hat{\rho}$	-0.225	0.184	0.095	0.121	0.071
	$\hat{\lambda}$	-0.030	-0.039	-0.028	-0.050*	-0.061**
$W=\mathcal{W}_{nc}, M=\mathcal{W}_c$	$\hat{\rho}$	0.003	0.109***	0.050	0.023	0.092***
	$\hat{\lambda}$	-0.207	-0.231	-0.189	-0.289*	-0.376**

Notes: Significance level: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

the county weights matrix, \mathcal{W}_c , the SARAR estimates indicate substantial and significantly positive spatial error correlation and negative spatial spillovers for each year. The former varies between 0.111 in 2002 and 0.345 in 2006. The spatial lag parameter is around -0.16 for 2002 to 2005 and almost twice as large in 2006. Hence, in 2006, if the county members obtain an 1% increase in overall efficiency the hospital efficiency decreases on average by 0.301%. This result underlines the hypothesis of two distinct channels of spatial dependence on the county level. On the one hand the positive spatial error correlation occurs due to unobservable factors, may be in form of market constraints, practice variations etc. On the other hand the negative spatial spillovers might be explained by the competition for patients. The restricted models, SEM and SLM, obtain the same direction of spatial dependence as the SARAR model for the respective parameter, however, the estimates are smaller in absolute terms.

The estimated spatial error correlation parameter varies between -0.005 in 2002 and 0.100 in 2003 and is only significant in 2003 and 2006. The lag parameter is highest in 2004 with -0.026 and smallest in 2006 with -0.060. It is significant in 2005 at the 10% level and 2006 at the 5% level. The smaller magnitude of the estimates might be explained by the neglect of two distinct channels of spatial dependence. The positive spatial error correlation is annulled by the negative spatial spillovers and vice versa.

If the spatial pattern is extended to the neighbor-counties, \mathcal{W}_{nc} , the magnitude of the estimates increases slightly. The SARAR and SLM obtain significant negative spatial spillovers to the 10% and 5% level for 2005 and 2006, respectively. In the former model, the lag coefficient decreases from -0.247 in 2004 to -0.514 in 2006 and in the latter model from -0.159 in 2004 to -0.280 in 2006. Significantly positive spatial error correlation occurs in 2003, 2005 and 2006, however, only to the 10% level. Under the specification of distinct spatial weights matrices for the spatial error and lag process, the results are similar to the respective restricted models, SEM and SLM.

The log-likelihood values of the estimated models (table 2) indicate the SARAR model using \mathcal{W}_c as the best fitting model. For each year it has a

Table 2: Log-likelihood value

		2002	2003	2004	2005	2006
	N	1474	1588	1496	1550	1520
	OLS	-249.5	-406.7	-274.3	-489.3	-557.6
$W=M=\mathcal{W}_c$	SARAR	-246.9**	-382.6***	-267.1***	-482.5***	-521.5***
	SEM	-249.3	-401.5***	-273.3	-489.0	-554.5**
	SLM	-248.6	-405.7	-273.7	-487.6*	-554.4**
$W=M=\mathcal{W}_{nc}$	SARAR	-248.2	-404.6**	-273.0	-486.1**	-553.9***
	SEM	-248.4	-406.1	-274.0	-489.0	-557.4
	SLM	-248.4	-406.2	-273.6	-487.7*	-555.4**
$W=\mathcal{W}_c, M=\mathcal{W}_{nc}$	SARAR	-247.8*	-405.0*	-273.5	-487.3**	-554.3**
$W=\mathcal{W}_{nc}, M=\mathcal{W}_c$	SARAR	-248.4	-400.4***	-272.5*	-487.4*	-551.3***

Notes: Significance level of Likelihood Ratio test versus OLS: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Italic numbers indicate largest value (1% significance level).

significantly larger value than any other model. After 2004, the log likelihood values of the SARAR and SLM are significantly larger than the OLS model, indicating significant spatial lag dependence in 2005 and 2006, irrespectively of the spatial specification. These results convey evidence for rising competition among hospitals on the inter-county level due to the DRG introduction in 2004.

The estimated filtered residuals (5) are tested for spatial error correlation by the Moran's I test (Cliff and Ord, 1972) and for spatial lag correlation by the LM_{LAG} test (Anselin, 1988b). The results are shown in table 3. The

Table 3: Spatial correlation tests

		2002	2003	2004	2005	2006
	N	1474	1588	1496	1550	1520
Moran's I test						
$W=M=\mathcal{W}_c$	SARAR	0.723	0.931	0.796	0.810	0.646
	SEM	0.567	0.670	0.619	0.581	0.474
	SLM	1.485	4.695***	2.577**	2.392**	5.131***
	OLS	0.440	3.600***	1.825*	1.029	2.912***
$W=M=\mathcal{W}_{nc}$	SARAR	1.771*	1.899**	2.004**	1.864*	1.499
	SEM	1.716	1.842*	1.904*	1.801*	1.764*
	SLM	1.389	3.594***	2.948***	3.491***	3.439***
	OLS	0.389	2.982***	2.356**	2.366**	2.035**
$W=\mathcal{W}_c, M=\mathcal{W}_{nc}$	SARAR	1.751*	1.839*	1.918*	1.787*	1.709*
$W=\mathcal{W}_{nc}, M=\mathcal{W}_c$	SARAR	0.567	0.647	0.575	0.612	0.413
LM_{LAG} test						
$W=M=\mathcal{W}_c$	SARAR	0.046	0.281	0.111	0.077	0.000
	SEM	1.203	14.527***	3.873**	4.469**	21.695***
	SLM	0.003	0.004	0.003	0.007	0.001
	OLS	1.473	1.783	0.835	2.965*	6.304**
$W=M=\mathcal{W}_{nc}$	SARAR	0.002	0.035	0.057	0.090	0.003
	SEM	0.141	1.432	1.067	2.487	2.972*
	SLM	0.003	0.005	0.019	0.034	0.000
	OLS	1.434	0.603	0.755	1.864	2.676
$W=\mathcal{W}_c, M=\mathcal{W}_{nc}$	SARAR	0.018	0.003	0.001	0.005	0.008
$W=\mathcal{W}_{nc}, M=\mathcal{W}_c$	SARAR	0.004	0.770	0.131	0.083	0.744

Notes: Significance level: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

SARAR model under \mathcal{W}_c and the SARAR model under two distinct weights specifications ($W = \mathcal{W}_{nc}, M = \mathcal{W}_c$) are the only models obtaining neither significant spatial error nor lag correlation. The tests indicate for any other model at least some form of spatial dependence in each year, except in 2002.

Regression results

The regression results of the SARAR model under \mathcal{W}_c and the OLS model are considered in detail (table 4). In each year, the explained variation of the estimated log-efficiency scores is higher for the SARAR model. In 2006,

Table 4: Regression results

Regressor	2002		2003		2004		2005		2006	
	OLS	SARAR	OLS	SARAR	OLS	SARAR	OLS	SARAR	OLS	SARAR
<i>intercept</i>	0.025	0.137	-2.280**	-2.178*	0.446	0.881	-2.259***	-2.125**	-0.788	-0.680
SH	0.122*	0.148*	-0.131*	-0.139	-0.059	-0.059	-0.055	-0.056	-0.170*	-0.178
NI	-0.009	-0.010	-0.272***	-0.322***	-0.248***	-0.285***	-0.215***	-0.247***	-0.212**	-0.270**
NW	-0.081	-0.095	-0.298***	-0.363**	-0.322***	-0.381***	-0.239***	-0.283***	-0.234**	-0.303**
HE	-0.137	-0.163	-0.485**	-0.585**	-0.618***	-0.733***	-0.472***	-0.548***	-0.467***	-0.604**
RP	-0.006	-0.008	-0.357***	-0.409***	-0.304***	-0.345***	-0.215**	-0.247**	-0.193**	-0.224*
BW	-0.364	-0.419*	-0.709***	-0.844***	-0.956***	-1.124***	-0.642***	-0.743***	-0.632***	-0.806
BY	-0.519	-0.592	-0.910**	-1.066**	-1.371***	-1.607***	-0.865***	-0.993***	-0.823**	-1.044**
SL	0.191**	0.213**	-0.178*	-0.206*	-0.108	-0.124	-0.075	-0.089	-0.019	-0.024
BB	-0.248	-0.278	-0.449**	-0.497**	-0.633***	-0.732***	-0.410**	-0.449**	-0.475***	-0.537**
MV	-0.086	-0.098	-0.423**	-0.452*	-0.724***	-0.834***	-0.469***	-0.508**	-0.478**	-0.539**
SN	-0.556	-0.632	-0.936**	-1.097**	-1.470***	-1.733***	-0.896***	-1.032***	-0.878***	-1.110**
ST	-0.226	-0.250	-0.507***	-0.569**	-0.667***	-0.775***	-0.454***	-0.498***	-0.558***	-0.635***
TH	-0.297	-0.327*	-0.582***	-0.635**	-0.831***	-0.952***	-0.581***	-0.647***	-0.667***	-0.782***
<i>private</i>	-0.042**	-0.043**	-0.090***	-0.080***	-0.079***	-0.077***	-0.093***	-0.090***	-0.099***	-0.084***
ln(<i>ms</i>)	0.070***	0.081***	0.183***	0.223***	0.129***	0.151***	0.129***	0.149***	0.206***	0.259***
<i>spec</i>	0.014	0.021	0.052***	0.077***	0.038***	0.052***	0.061***	0.074***	0.077***	0.112***
ln(<i>mort</i>)	-0.024**	-0.021**	-0.030***	-0.016	-0.033***	-0.028***	-0.034***	-0.028***	-0.037***	-0.018*
ln(<i>npBed</i>)	-0.007	-0.006	-0.229***	-0.223***	-0.213***	-0.199***	-0.344***	-0.339***	-0.116**	-0.128***
ln(<i>occrate</i>)	0.346***	0.334***	0.594***	0.589***	0.283***	0.273***	0.489***	0.487***	0.587***	0.537***
ln(<i>docshare</i>)	0.102***	0.099***	-0.063*	-0.092***	-0.016	-0.035	0.071**	0.051	0.009	-0.044
ln(<i>budget</i>)	-0.306***	-0.317***	-0.178***	-0.225***	-0.117***	-0.145***	-0.082*	-0.106**	-0.418***	-0.431***
<i>age65</i>	0.012**	0.013**	0.009*	0.013*	0.003	0.005	0.003	0.005	-0.005	-0.002
<i>east</i>	0.342*	0.396*	0.408**	0.492*	0.804***	0.960***	0.488***	0.573***	0.491***	0.640**
ln(<i>GDPpC</i>)	0.125***	0.139***	0.209***	0.244***	0.130***	0.153***	0.157***	0.176***	0.203***	0.235***
ln(<i>popdens</i>)	0.012	0.014	0.066***	0.082***	0.048***	0.057***	0.053***	0.064***	0.084***	0.109***
ln(<i>depts</i>)	-0.315	-0.363	-0.365	-0.436	-0.716***	-0.852***	-0.410**	-0.479**	-0.338*	-0.450*
ρ	-	0.111*	-	0.289***	-	0.186***	-	0.158***	-	0.345***
λ	-	-0.125**	-	-0.234***	-	-0.163***	-	-0.156***	-	-0.301***
<i>LOGLIKE</i>	-249.5	-246.7	-406.7	-382.6	-274.3	-267.1	-489.3	-482.5	-557.6	-521.5
R^2_{adj}	13.74	16.86	31.13	42.58	24.53	31.40	26.86	31.95	33.80	46.03
<i>N</i>	1474		1588		1496		1550		1520	

Notes: Significance level: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; SARAR is estimated under W_c ; SH: Schleswig-Holstein, NI: Lower Saxony, NW: North Rhine-Westphalia, HE: Hesse, RP: Rhineland-Palatinate, BW: Baden-Wuerttemberg BY: Bavaria, SL: Saarland, BB: Brandenburg, MV: Mecklenburg-Western Pomerania, SN: Saxony, ST: Saxony-Anhalt, TH: Thuringia.

the adjusted R^2 is 46.04%, while for the OLS model it amounts to 33.80%. In some cases, the estimated coefficients show considerable distinctions between both models. However, the results of the other models are similar to the OLS estimates.⁵ This underlines the previous finding that the SARAR model implemental with spatial weights matrix W_c is the most appropriate specification.

In the following, the estimated coefficients of the explanatory variables on efficiency are considered. We start with hospital specific variables, followed by county and state specific variables. The estimation results indicate private hospitals to be less efficient than their public counterparts, which is in line with other empirical findings (Herr, 2008, Farsi and Filippini, 2008, and Helmig and Lapsley, 2001).⁶ The cross-sectional estimates do not vary much over time, except in 2002 it is around -0.04, half the value for the other years. Hence, there might be no particular impact on the efficiency of private hospitals due to the DRG introduction in 2004. Although profit incentives are no longer associated to inefficient long hospital stays leading to an inefficient performance (Herr, 2008). This result rather underlines the conjecture of Helmig and Lapsley (2001), local governments sell the most inefficient hospitals to private investors, while holding the more efficient ones. It may take some time until these private hospitals are successful in organizational restructuring. Furthermore, the results suggest a positive relationship between market share and efficiency.⁷ The estimate varies between 0.081 in 2002 and 0.259 in 2006. A positive relationship between specialization and efficiency is found, which slightly increases over time. Thus a specialized hospital is, on average, less inefficient in comparison with a non-specialized hospital. Due to the financial reform a trend of specialization (Knorr, 2003) and merging (Rocke, 2003) is expected. The latter might lead to an increased market share of the involved hospitals. The results indicate these strategies as promising options to increase the performance. The occupancy rate has a significantly positive coefficient. In 2006, a 1% increase in occupancy is associated with, on av-

⁵The results are available upon request from the authors.

⁶A dummy variable, termed *profit*, equal to unity for profit oriented hospitals has also been considered and leads to similar results.

⁷Augurzky et al. (2006) mention the importance of the geographic area, where the market share is built up. In a rural area a higher market share can be the result of being the only provider of inpatient treatments leading potentially to an inefficient production of medical care, due to the lack of competitors. At the opposite, a higher market share in an urban area can be the result of an efficient performance. We incorporate an interaction of the variable *mp* and an agglomeration dummy. However, there is no considerable difference between the impact of rural or urban market share.

erage, a 0.537% increase in efficiency. German hospitals face an increase in occupancy from 75.5% in 2004 to 77.4% in 2008 (Mörsch, 2009). However, the predefined occupancy rate for most hospitals is around 85%. A steadily reduction of hospital beds might be possible and could yield more efficiency. The results obtain ambiguous insights about the impact of quality on efficiency. Poor quality, indicated by high mortality, is connected to an inefficient performance. In contrast, in most years, an increase in quality of nursing care, indicated by a rising nurse per bed ratio, is associated with a decrease in efficiency. This result is in line with the findings of Farsi and Filippini (2008) for Swiss hospitals. The log of the physician's proportion obtain contradictory results and is insignificant in almost all periods. The estimated impact of $\ln(\text{budget})$ corroborates the presumption that a high budget size per bed leads to an inefficient production of medical inpatient care.

Next, the county- and state-specific variables are considered. The age variable, *age65*, is found to have the expected sign only in 2006, however, it is insignificant. This result show no clear impact and suggests that hospital performance may not depend on the age structure of the county population. The dummy variable *east* has a significantly positive impact on efficiency. This underlines the conjecture that hospitals which are located in Eastern Germany are less inefficient. This might be explained by public investments in eastern hospitals after the German reunification (Herr, 2008). This supposition is supported by the state debt variable. The debt per GDP influences negatively the performance of the hospitals. The higher the financial difficulties of the federal states the lower the financial means for investments in hospitals. The non-city state dummy variable estimates are significantly negative for all states in almost all years. Hospitals of the non-city states are, on average, less efficient than hospitals which are located in Berlin, Bremen or Hamburg.

5 Conclusion

This study is the first approach considering spatial interdependence of hospital efficiency in Germany for the years 2002 to 2006 including the DRG introduction period. A spatial two-stage semi-parametric efficiency model is applied. The results reveal two distinct channels of substantial and significant spatial interdependence on the county level. Namely, positive spatial error correlation and negative spatial spillovers. After 2004, the magnitude of negative spatial interdependence on the inter-county level increases and yield evidence

for rising competition among hospitals due to the DRG introduction. The competition for patients might have several effects. To attract patients, hospitals have to acquire reputation by quality of care, service, room facilities etc. On the other hand hospitals, which treat patients with high complexities, face inappropriate cost reimbursements and may experience solvency problems (Böcking, 2005). To save costs they might decrease the quality of treatment. Several studies (e.g. Perelman et al., 2008, Picone, 2003) find a positive relationship between social deprivation and the length of hospital stay, e.g. due to higher complexities (Krieger et al., 1997). Thus, there is a cost differential between unprivileged and well-off patients, which is not taken into account by the cost reimbursement. This typically yield an implicit patients' selection of the hospitals, which have dramatic consequences on social equity in health (Perelman et al., 2008). The results of this study highlights this issue to be of particular relevance for Germany, especially due to the reform of the financing system. To avoid the patients' selection, Perelman et al. (2008) suggest an integration of the impact of socio-economic status on length of stay to the cost reimbursement.

Further results are, privately owned hospitals are found to be less efficient than their public counterparts. This confirms the result of Herr (2008), who explains the discrepancy in efficiency due to the system of cost reimbursement until 2004 leading to the incentive that it is profitable for hospitals to keep patients longer than medically required. The result that privately owned hospitals are still less efficient (after 2004) might suggest a persistence in the hospitals' performance. On the other side the current DRG based financing system have may not (yet) obtained incentives for profit oriented hospitals to produce more efficiently. Or it may take some time until these private hospitals are successful in organizational restructuring. For future research it would be of interest, if the change of the financing system in 2004 may have an effect on private hospitals' efficiency in the long run. Some authors suggest further consequences succeeding from the introduction of a DRG based financing system, e.g. a trend of cooperation and merging (Rocke, 2003) and specialization (Knorr, 2003). Both factors, specialization and market share (as a result of cooperation and merging) are found to be positively connected to efficiency. Thus, these are two reasons for expecting an increase in efficiency of the involved hospitals due to the DRG based financing system. Hospitals which are fully stretched are found to be less inefficient. One might expect, the steady reduction of hospital beds, shifting the occupancy rate from re-

cently 77% to legally possible 85%, yield more efficiency. Federal states' debt influences negatively the performance of the respective hospitals. Debt-ridden federal states might be unable to finance investments, which are necessary to enhance the hospitals efficiency. If the financial responsibilities for investments are detached from the states, hospital performance could be detached from the performance of the states.

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