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Reimbursing for the costs of teaching and research in finnish hospitals: A stochastic frontier analysis

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Abstract In this study stochastic frontier cost function was used to estimate the teaching and research costs of Finnish hospitals. Predicted efficiency adjusted costs were calculated and compared to evaluate the current level of teaching and research reimbursement. The efficiency adjustment had significant impact on the marginal and average cost estimates of the teaching and research output.

The results suggest that the average rate of teaching and research reimbursement should be approximately 14.6% of the total operating costs in university teaching hospitals. The main finding was that the university teaching hospitals were underfunded with respect to both research and teaching output.

Keywords Reimbursement · Hospitals · Teaching · Cost efficiency · Stochastic frontier

JEL Code C14 · C23 · D24 · I10

Hospitals need to provide education for medical and nursing students, to conduct clinical research, and to adopt new medical technologies. While these activities are necessary to ensure the quality of future health-care, their interference with normal care routines inflates the costs of hospital services. Previous studies have demonstrated that the teaching and research activities in Finnish hospitals have a marked impact on hospital costs (Linna and Häkkinen, 1996; Linna, Häkkinen and Linnakko, 1998). The results of these studies suggest that the burden of teaching and research, including direct costs and indirect productivity losses, is approximately 11–15% of the total operating costs in university teaching hospitals.

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This has important consequences for unit prices, productivity comparisons and hospital reimbursement. Every health-care system seems to have designed their policy for teaching and research adjustments on different grounds which also depend on the overall payment system for hospitals. However, these supplementary payment systems require continuous evaluation and monitoring as they may create incentives for the hospitals to change their behavior (Nicholson and Song, 2001).

In Finland, the reimbursement of teaching and research was previously based on politically determined flat rate (about 12% of a hospital's operating costs), but the arrangement in the hospital financing system during the 1990's generated pressure to re-appraise the teaching reimbursement policy. The new reimbursement system was finally based on a 1993 study where marginal costs for teaching and research output were estimated using a linear average cost function. The marginal cost estimates in the 1993 study were neither directly used as a basis for reimbursement, nor did they affect the total monetary allocation for teaching and research. Yet the estimates were used to divide the total budget of EUR 112 million into teaching and research quotas, which were allocated to university hospitals according to their research and teaching outputs.

Later, the government's budget proposal for 1996 directed the Ministry of Social Affairs and Health to prepare an agenda for overhauling the teaching and research reimbursement system. A new study was conducted to reassess the teaching and research estimates (Linna, Häkkinen and Linnakko, 1998). In 1999, due to a significant increase especially in the research volume, a further study on teaching and research costs was considered necessary. In addition, there was increasing political pressure to cut down the teaching and research budget for hospitals.

The aim of the present study was to address these questions by estimating the effects of teaching and research activities on hospital cost structure. Predicted costs were compared to the current level of teaching and research reimbursement. A frontier cost function was used to base the average, marginal and total cost estimates for teaching and research on the most efficient production of services (taking into account the inefficiencies in production). Moreover, in this study the hospital-level data were disaggregated to clinic level within hospitals to improve upon the previous estimates based on hospital-level measurement.

The reimbursement for hospitals

Most of the teaching and almost all clinical research in Finland is concentrated at the five university teaching hospitals. However, all hospitals have some postgraduate posts for medical students and on-the-job training programs for nurses. The clinical education of postgraduate medical students for their consultant's degree takes six to ten years. Most of this is in the form of on-the-job training in hospitals. In addition, approximately 50% of basic nursing education and training takes place in hospitals, while undergraduate medical students have to undergo 50 weeks of clinical training in university hospitals.

At the start of 1994 the reimbursement system for hospitals' teaching and research costs was also changed to a formula with explicit rules governing the payment criteria. Until 1994 the Ministry of Social Affairs and Health had funded the costs of teaching at the five university hospitals. The subsidy was 12% of the annual net recurrent costs of these hospitals and was neither connected to the relative size of teaching and research programs nor based on any formal study. The system change in 1994 directed the state to reimburse the five university teaching hospitals all their costs (including indirect costs) due to research and teaching activities. The purpose of the new reimbursement system was to give fair compensation to the university teaching hospitals in order to level off the cost differentials. In 2000 the

Table 1 Teaching and research output and reimbursement in the university hospitals, 1994–2000, real prices (1994 = 100)

	Year						
	1994	1995	1996	1997	1998	1999	2000
Teaching output	911	956	966	901	842	792	971
Research output	3 368	3 712	4 050	4 481	5 065	5 750	6 233
Reimbursement/output unit for teaching (EUR)	53 653	49 528	47 840	50 147	52 302	54 480	50 294
Reimbursement/output unit for research (EUR)	17 801	15 636	14 019	12 528	10 795	9 318	7 310

compensation scheme was extended to make also the nonteaching hospitals eligible for research reimbursement.

Table 1 shows the recent changes in teaching and research output and the corresponding changes in the reimbursement per output unit. While the level of teaching output was quite stable during the 1994–2000 period, it is interesting to note a significant increase in the research output. During the period, the total number of impact-weighted publications produced at university teaching hospitals increased by 85%. Simultaneously, the ‘unit price’ paid by the Ministry of Social Affairs and Health for research output has declined.

The Ministry of Social Affairs and Health sets the total annual budget for teaching and research and the total budget is divided into teaching and research budgets. These budgets are allocated to hospitals according to their teaching and reseach outputs. Consequently, the unit price paid for teaching and research output varies annually due to changes in the output volumes and the total budget.

Since 1995, research costs have been reimbursed on the basis of the output of refereed and published scientific articles, and medical dissertations. The impact factor of the publishing journal (Table 2) is used to weight each article and the payment to each hospital is based on the weighted sum of publications. The impact factor is a citation index compiled for scientific journals by the Institute of Scientific Information. Impact factors have been used for ranking, evaluating, categorizing, and comparing journals, but they are only a crude approximation of true research output (Garfield, 1996).

Teaching subsidies are allocated according to the hospital’s teaching output. Teaching output is measured in terms of the types of medical examinations (consultant’s exam) passed and the total sum of resident labor input in a hospital (months in full-time work).

Table 2 Impact-factor equivalent weights for scientific articles used in the state subsidy scheme

	Impact factor	Weight
Finnish journals	–	0.5
International journals	Less than 1.0	1
”	between 1.0 and 4.0	2
”	over 4.0	3
Doctoral dissertation	–	6

Teaching and research costs in the literature

The most important objective for studies on teaching costs has been to estimate a fair level of reimbursement for teaching hospitals. These prices or 'cost elasticities' can be observed or estimated indirectly by constructing a cost function for the hospitals; this has been the most common approach in previous studies. Most studies use a behavioural cost function specification with a linear or log-linear functional form (Hadley, 1983; Culyer, Wiseman and Drummond, 1978; Anderson and Lave, 1986; Rogowski and Newhouse, 1992; Thorpe, 1988), while others have followed neoclassical production theory and used only cost, output and price variables in the specification (Sloan, Feldman and Steinwald, 1983; Grannemann, Brown and Pauly, 1986). In some studies the researchers have used so-called 'hybrid functions', in which variables other than output quantities and factor price variables are also included in the model (Grannemann, Brown and Pauly, 1986).

Teaching and research effects have been measured using a variety of indicators. A teaching dummy is the most commonly used variable. Sloan, Feldman and Steinwald (1983) employed three types of teaching dummy (medical school affiliation, approved residency program, membership on a council of teaching hospitals). Milne, Abebe and Torsney (1989) used a teaching status dummy as well as the number of medical students and nurses in training. A majority of the recent studies have also measured the number of residents as an indicator of teaching intensity (Lopez-Casanovas and Saez, 1999; Kittelsen, Piro and Magnussen, 2002). Perhaps the best known application of a cost function to teaching reimbursement is the Pettengill-Vertrees–specification (Sheingold, 1990), which was used in the early formulation of the U.S. prospective payment system (PPS). The model specification has evoked considerable interest because of its use in Medicare's indirect medical education payments to reimburse indirect teaching costs to hospitals (Rogowski and Newhouse, 1992; Dalton and Norton, 2000). More recently, some of the studies have also explicitly taken into account the effect of research activities in teaching hospitals. In an assessment of French hospitals, research was measured by the number of referenced medical articles published by the medical teams of the hospital (Huttin and Pourvoirville, 2001). Research intensity in Norwegian hospitals was measured using impact-weighted numbers of published articles (Kittelsen, Piro and Magnussen, 2002).

The overall impact of teaching and research on hospitals' costs has been estimated to vary between nil and 25%. For teaching hospitals, most estimates lie between 7 and 15%, and in most studies it has been found to depend on the number residents being trained in the hospital. The actual reimbursement of teaching and research costs in different countries varies from 8 to 22% of hospitals' recurrent costs.

In previous Finnish studies teaching output has been measured as the number of postgraduate medical students and the number of on-the-job training weeks of nursing students. The impact-weighted number of published studies has been used to measure research intensity. According to the first Finnish study, the additional costs to university teaching hospitals amounted to 15% (133 million EUR) of their operating costs. This study used a linear ordinary least squares cost function model (The Ministry of Social Welfare and Health, 1996).

A more recent Finnish study done in 1997 employed a different cost function specification (Box-Cox transformed cost function) and cross-sectional data from 1994 (Linna, Häkkinen and Linnakko, 1998). In addition, a frontier model was used to take into account the effect of inefficiency. The results yielded different estimates compared to the earlier study for the marginal costs for teaching and research, which also suggested a different split between the total teaching and research budgets. The cost of teaching and research activities was estimated to be approximately 11% of the total operating costs (88 million EUR) in university teaching hospitals.

Theoretical model

Hospitals produce two types of services, patient care $y = (y_1, \ldots, y_m) \in R_+^m$ and teaching and research services $z = (z_1, \ldots, z_p) \in R_+^p$, and the demand for both is determined exogenously. In Finland the municipalities are the main purchasers of patient services, and the state can be considered to be a purchaser of teaching and research services. Hospitals can choose teaching and research activities independently, although the number of students is determined by universities.In the production of both types of services the hospitals use inputs $x = (x_1, \ldots, x_k) \in R_+^k$ with input prices $w = (w_1, \ldots, w_k) \in R_+^k$, which will incur total costs $TC = w' \cdot x$. Hospitals must cover the total operating cost with the revenues obtained from the services (y and z) sold.

If we assume that hospitals are cost minimisers (which does not need to be a strict assumption and can be relaxed using frontier analysis), the cost function takes the form

$$c(y, z, w) = \min_x \{w \cdot x : T(y, z, x) = 0\} \quad (1)$$

where $T(y, z, x) = 0$ is the transformation function which gives the technological constraints. Solving (1) subject to the technological constraints, the total costs are realized as a function of y, z and w. Even if we did not know the form of the transformation function $T(y, z, x) = 0$, the relationship between outputs (y), teaching and research (z) and costs could be estimated using a cost function.

However, for various reasons some hospitals are not able to reach the efficient production or cost frontier. These might include random shocks in the production, managerial slack or preferences towards less effort, suboptimal allocation of inputs, and local bureaucracy. Since there is also a considerable informational asymmetry between providers and the municipal boards to which the hospital administrations are accountable, it is possible for the hospitals to choose an inefficient level of performance. It is generally considered fair to reimburse hospitals for teaching and research services (z), but only if produced at the efficient production frontier (hereafter "efficiency frontier") given in (1) (Welch, 1987). It is possible that there exist (exogenous) factors which both affect efficiency and are not directly controllable by the hospital management. In practice, it is very difficult to distinguish between 'acceptable' explanations for inefficiency (where the slack may be included in the reimbursement) and unacceptable explanations (where the slack is not reimbursed). Measured efficiency differences may be due to unobserved case-mix and quality.

Data and variables

Data

Cross-sectional data on 48 acute-care hospitals in 1998 were used. Military hospitals, psychiatric hospitals, and psychiatric wards of acute hospitals were excluded. The data were disaggregated from hospital-level to specialty-level measurements. Typical hospitals include between 3 and 12 medical specialties which are financially accountable and operate as managerially independent units. In this study we used only the largest specialties: internal medicine, surgical, obstetrics&gynecology and pediatrics. Thus the total number of units in this study was 187.

Primary output data were collected directly from the hospitals' patient administration systems and the National Discharge Register. These were supplemented by cost, research, and teaching variables obtained via a separate questionnaire sent to the hospitals. The data were sent to the hospital administrations for final checking and verification. Input prices were obtained from the wage statistics for 1998 compiled by Statistics Finland. A complete listing of the variables used is given in Table 3.

Inpatient and outpatient services

All inpatient admissions were grouped using the Finnish version (1999.b2) of the NordDRG patient classification system, which is a Nordic version of the CMS (Center for Medicare and Medicaid Services, former Health Care Financing Administration) DRG (Diagnostic Related Groups) grouping system. The DRG groups were weighted with actual average costs incurred by each episode. The DRG cost-weights were based on a study using data from two Finnish hospital districts. The variability in DRG groups was processed by analyzing

Table 3 Variable definitions

	Variable name	Definition
Output variables		
Outpatient treatment:	VISITS_WEIGH	Total weighted sum of emergency, scheduled and follow-up visits
Inpatient treatment:	DISCH_DRGW	DRG-weighted number of total admissions
	BED-DAYS	Total number of bed-days exceeding the cutoff point defined in the outlier analysis
Teaching variables:	TEACH	Total number of clinical training weeks for medical students
	RESIDENTS	Number of residents receiving 1 year of training at hospital unit
Research variable:	RESEARCH	Total number of impact-weighted scientific Publications
Cost variables:	TVC	Variable costs of a hospital unit
	CAPITAL	Capital costs of a hospital unit
Price variables:	W1	Average hourly wage-rate for nursing labour
	W2	Average hourly wage-rate for other staff
	W3	Average hourly wage-rate for physicians
Correlates of cost efficiency:	EMERG	The ratio of emergency visits to scheduled visits
	DEAD	The percentage of dead patients out of total admissions
	PRICEIND	Aggregate price index for wages
	HOME	The percentage of patients discharged home
	OPERATIVE	Surgical specialty
	NON-OPERATIVE	Non-surgical specialty
	OTHER	Other specialties

the outliers (measured by the length of stay) separately. If the inpatient episode exceeded a DRG-specific cut-off point, the remaining patient days were inserted into a separate variable (BED-DAYS).

There is no widely accepted classification system for outpatient visits. In this study two outpatient visit classes for each medical specialty (resulting in a total number of 24 groups) were used: (1) outpatient visits (VISIT) and (2) emergency visits (EMVIS). Cost weights for these 24 outpatient visit groups were calculated using a large sample of patient level cost data.

Teaching and research output

Medical and nursing students are also production factors. Students are, by definition, less productive; they use more time, materials and tests for the same task as professionals, while salaries for postgraduate medical students in Finland are nearly as high as for professionals. Patients who take part in clinical research projects stay longer in hospital and use more outpatient visits, tests and treatments. It is also time-consuming to gather new medical knowledge from scientific articles or by attending seminars, training programs, meetings, development projects, etc.

In this study it was possible to describe the teaching and research output fairly accurately. The number of postgraduate medical students (RESIDENTS) was used as one measure of teaching activity. This variable can be interpreted as a one-year postgraduate training output. In addition, the number of teaching periods (clinical weeks) for junior medical students was collected (TEACHING) Research output (RESEARCH) was measured by compiling the bibliographic data on refereed scientific articles and medical dissertations produced by all the hospital units in 1996–1998 and calculating the average. Following the weighting scheme used in the previous study (Linna, Häkkinen and Linnakko, 1998), each article was then weighted with the impact factor (Science Citation Index 1997) of the journal publishing it and assigned a corresponding weight given in Table 2.

Total variable cost and capital cost variables

Net operating costs were used as an explanatory variable in the cost function models. The net operating costs were obtained by subtracting additional personal revenues and purchasing costs for special services (not included in the outputs) from the total operating costs of a hospital unit. Net operating costs include all production-related (direct and indirect) costs of a hospital, including the capital costs such as depreciation and interest charges. Due to the common account-keeping systems it was possible to extract the capital costs (CAPITAL) from the net operating costs for each unit and it was possible to derive a variable cost measure by calculating total variable cost = net operating costs − CAPITAL.

Price variables

Input price variables were constructed by using the average total working hours and average total wages paid in three employee categories: (i) doctors, (ii) nurses and other high-level care personnel, and (iii) others, which included care personnel with lower levels of education, maintenance personnel, catering personnel, and administrative staff.

Efficiency effects

Various factors which were believed to affect the unit's distance from the efficiency frontier were included in the econometric model. Some of the tested factors were less controllable by managerial decision (e.g., the type of specialty, demand for emergency services, primary health-care organization, general price levels), and some were included to account for the remaining severity/complexity not captured by the DRG case-mix A weighted index of the wage variables (PRICEIND) was used to measure the general price level of services provided by a hospital unit.

In this study, explanatory variables reflecting environmental characteristics mostly beyond the influence of managerial actions were used. The provision of emergency services was measured as the proportion of emergency visits to scheduled visits (EMERG). Case complexity was measured by the percentage of died patients out of total admissions (DEAD) and by the percentage of patients who could be sent home when discharged (HOME). Four dummy variables were used to indicate the medical specialty type (internal medicine, operative specialty, obstetrics & gynecology, others).

Methods and specifications of the models

Due to failures in cost minimization, most empirical observations on hospital production do not satisfy (1). However, in econometric analysis it is possible to take the deviations from theoretically optimal cost levels into account by using a stochastic cost frontier model. A frontier cost function specification has the form

$$C_i = C(y_i, z_{i,} w_i) + \varepsilon_i \quad (2)$$
$$\varepsilon_i = |u_i| + v_i$$

where C stands for costs, v_i is the normally distributed random error term and u_i is a one-sided inefficiency term which gives estimates for the individual efficiency scores for each unit (viite). The cost function (2) in some econometric models takes the form $C(y, z, k, q)$, where q stands for some non-output controls (e.g. quality) and k for fixed inputs in the case of fixed short-run cost functions. In our variable cost function model we used capital costs as the fixed input.

The distribution for the component u_i is chosen to reflect the higher probability density of observations in the proximity of the frontier. The econometric frontier model differs from the traditional OLS-model by assuming a higher probability of observations above the stochastic cost frontier (or below it, if the stochastic production frontier is being modelled). The observations may in rare cases lie below the frontier due to the random component v_i. The one-sided inefficiency component u_i is typically assumed to be an absolute value of a normally distributed random variable, though several other specifications have been used, e.g. exponential, gamma, Erlang, and truncated models.

Specification of the cost function model

The use of parametric methods in cost function analysis involves a considerable risk of model misspecification. Not only the parametric form of the production or cost technology, but also the efficiency estimates are known to be sensitive to the choice of parametric specification

(Gong and Sickles, 1989). The choice of function form is usually based on its flexibility, but small samples often require the use of restricted parametric forms. Furthermore, as indicated by Gong and Sickles (1989), increasing complexity of the underlying technology deteriorates the performance of stochastic frontier models.

In the previously estimated cross-section study for year 1994 a set of statistical specification tests suggested that the Box-Cox transformed frontier cost function would best describe the costs of Finnish hospitals. Based on these findings, we chose the restricted Cobb-Douglas form instead of a more general translog form and allowed some generality into the specification by using the Box-Cox transformation for the output variables. The Box-Cox parameter was estimated with maximum likelihood methods. The Box-Cox transformed Cobb-Douglas form was:

$$\ln TVC_i = \alpha + \sum_{j=1}^{m} \beta_j y_{ij}^{(\lambda)} + \sum_{j=m}^{m+p} \beta_j z_{ij}^{(\lambda)} + \sum_j \delta_j \ln w_{ij} + \phi \ln(CAPITAL_i) + u_i + v_i \quad (3)$$

where the transformation is $y^{(\lambda)} = (y^{\lambda} - 1)/\lambda$. Linear homogeneity was preserved by using log transformation for the cost and price variables. The z_i variables included one research and two teaching variables: the total number of impact-weighted scientific articles (RESEARCH), the number of residents' working time (RESIDENTS), and the number of clinical training weeks for junior medical students (TEACHING).

There is little theoretical guidance for picking the distributional form for u, and the only solution is to try various alternative distributions. In a cost frontier model the composed error $u + v$ should be positively skewed with a nonzero mean. In this model based on the formulation of Battese and Coelli, inefficiency was chosen to be a parametric function of a set of exogenous variables g_i, (EMERG, HOME, DEAD, PRICEIND) and specialty dummies;

$$u_i = \sum_k \delta_k \cdot g_{ki} + \omega_t, \quad u_i \geq 0 \quad (4)$$

where $u_i \sim N(\sum_k \delta_k \cdot g_{ki}, \sigma_u^2)$ is truncated at zero from below (Battese and Coelli, 1995).

The frontier cost function was estimated using the FRONTIER 4.1 software. The algorithm uses maximum likelihood estimation that uses OLS estimates as starting values. The program automatically checks the OLS residuals for 'correct' skewness before proceeding to a maximum likelihood estimate of the frontier.

Elasticities, marginal costs and average incremental costs for teaching and research

Incremental cost was defined as the difference between the cost of producing all outputs (at some specified level) and the costs of producing all of these outputs except the one being examined. Thus the average incremental cost (AIC) for output i was defined as:

$$AIC_i = [\hat{C}(y_1, y_2, \ldots, y_i, \ldots, y_k) - \hat{C}(y_1, y_2, \ldots, 0, \ldots, y_k)]/y_i \quad (5)$$

Marginal costs (MC) for output i were calculated as follows:

$$MC_i = \frac{\partial C(y, w)}{\partial y_i} = \hat{\varepsilon}_i \frac{\hat{C}(y, w)}{y_i} \quad (6)$$

where ε_i is the elasticity of output i. In the Box-Cox model (3) the elasticity of output i was calculated as $\hat{\varepsilon}_i = \hat{\beta}_i \cdot y_i^{\lambda}$. The cost estimates used in (5) and (6) were the predicted costs from the frontier model (3). Sample averages were used to calculate the final AICs and MCs.

Results

The estimations using the Box-Cox models are presented in Table 4. There did not seem to be problems with heteroscedasticity according to the Breusch-Pagan test. The likelihood ratio test rejected the null hypothesis of $\lambda = 0$ and favoured the choice of the Box-Cox specification. The maximum likelihood estimation yielded $\lambda = 0.12$ as the transformation parameter and the likelihood ratio test indicated that the Box-Cox model outperforms the log-linear Cobb-Douglas model.

For the estimated cost frontier specifications all the cost elasticities were positive and the marginal costs were clearly plausible in magnitude compared to average cost estimates obtained from hospital cost accounting reports. The MC for an average DRG episode was 1 526 EUR and for an average outpatient visit was 160 EUR. The estimated parameters were all significant or almost significant except for the BED-DAYS variable and two of the input price variables.

Table 4 Parameter estimates for the frontier cost function model

	OLS			Stochastic frontier model		
	Coefficient	Standard error	*t*-ratio	Coefficient	Standard error	*t*-ratio
Constant	11.76714	0.301	39.11	1.08E+01	0.327	33.1
DISCH_DRGW	0.240683	0.014	17.11	2.17E−01	0.014	15.03
VISITS_WEIGH	6.23E−02	0.011	5.78	7.23E−02	0.009	7.729
BED-DAYS	2.72E−02	0.013	2.17	1.42E−02	0.011	1.318
RESEARCH	1.18E−02	0.004	2.76	9.12E−03	0.004	2.066
TEACH	9.51E−03	0.006	1.53	1.08E−02	0.006	1.883
W1 (physicians)	−0.21274	0.190	−1.12	−3.20E−01	0.166	−1.224
W2 (nurses)	0.79291	0.417	1.90	3.02E−01	0.322	0.94
W3 (others)	1.544903	0.484	3.19	8.58E−01	0.358	2.393
CAPITAL	9.12E−02	0.029	3.16	1.57E−01	0.033	4.804
σ^2				1.70E−01	0.056	3.044
γ				9.09E−01	0.039	23.317
Constant				−3.29E+00	1.439	−2.29
EMERG				−2.72E+00	1.248	−2.18
DEAD				−1.47E−02	1.006	−0.015
HOME				4.15E−01	0.196	2.117
PRICEIND				2.74E+00	1.115	2.453
DUMMY1[(a)]				2.06E−03	0.137	0.015
DUMMY2[(b)]				-5.27E−02	0.091	−0.58

(a) DUMMY1 = Surgical specialties
(b) DUMMY2 = Internal medicine

There was some multicollinearity between the teaching and research variables, especially between the RESEARCH and TEACHING variables. We thus decided to use only the teaching variable RESIDENTS to account for teaching activities. The correlations for the rest of the output variables were also positive and rather high, as they often tend to be in cost functions. For the same reason, university dummies were not used because they were highly correlated with the RESEARCH variable. Including it in to the specification seemed to affect the TEACHING and RESEARCH parameters (multicollinearity problem). However, the patient output variables y in the model seemed to be quite stable against removing or adding variables from/to the model. In addition, the standard errors of coefficients were small and the signs of coefficients positive, which suggests that multicollinearity was not a serious problem in this study. However, the teaching and research variables z (being rather highly correlated) were slightly sensitive to which variables were chosen in the inefficiency effects specification (4). The parameter estimates for RESEARCH and RESIDENTS ranged between 0.008 and 0.011, depending on which efficiency correlates were included in the specification of (4).

In the estimations of cost function models, the RHS variables are assumed to be exogenous. However, RESEARCH and to some extent also RESIDENTS can be suspected to be endogenous, because hospitals usually determine the level of research and teaching output. Since the lack of suitable instrumental variables prevented us from conducting proper endogeneity tests, there may be some endogeneity bias in the results.

According to the frontier model the average cost inefficiency was 18% for the whole sample (21% for the university units and 16% for units in other hospitals). The efficiency adjustment had significant impact on the MCs and AICs for the teaching and research output. The MCs and AICs for the research output were 16 to 22% higher when not adjusted for efficiency.

Parameters δ_i for EMERG, HOME, and PIND indicated statistically significant effects on efficiency. A larger share of emergency visits was associated with higher cost efficiency. Increasing the proportion of patients discharged home decreased efficiency. A higher overall price index predicted lower cost efficiency.

MCs and AICs of the Box-Cox model for teaching and research output were calculated at three different points of output space: the average hospital, the average non-university hospital and the average university teaching hospital.

The results indicated higher MCs with increasing unit size. The units in the university teaching hospitals were substantially larger and would have had higher MCs if the teaching or research intensity were fixed at the same level as in the non-university units (Fig. 1) However, the university teaching hospitals were able to produce both teaching and research output at lower MCs and AICs than other hospitals because the share of the teaching and research activities of the total output was significantly higher. The difference was most distinct for research output; while the MC for producing one scientific article with an impact factor of one point was 24 129 EUR for the non-university hospitals (the average specialty produced 3.1 units of output), it was only 3 189 EUR for university teaching hospitals (the average specialty produced 106.2 units of output). The MCs for teaching (RESIDENTS) were 18 685 EUR and 15 292 EUR, for non-university and university hospitals, respectively.

According to our results, in university hospitals the AICs for teaching and research output respectively would be 75 493 EUR and 14 192 EUR. The total costs for teaching and research were 156 million EUR in the university hospitals, split between teaching and research by a 51:49 ratio as opposed to the 45:55 ratio in the reimbursement plan for 1998. However, in our study the average level of teaching output is somewhat higher than reported in the official statistics in Table 1. Curiously, the latest reimbursement for 2001 was divided exactly according to the 51:49 ratio (Table 5). The total cost estimate for teaching output was

Table 5 Total costs of teaching and research

	Current study	1998 study (data 1994)	Reimbursement in 1998	Reimbursement in 2000	Reimbursement in 2001
University teaching hospitals					
Total costs of teaching and research, EUR 1 million	156	88	109	108	106
Costs of teaching, EUR 1 million	79	48	49	57	54
Research costs, EUR 1 million	77	39	61	53	52
Teaching costs/research costs—ratio	51/49	55/45	44/56	52/48	51/49
AIC for 1 research point, EUR	14 192	9 983	11 970	8 535	7 503

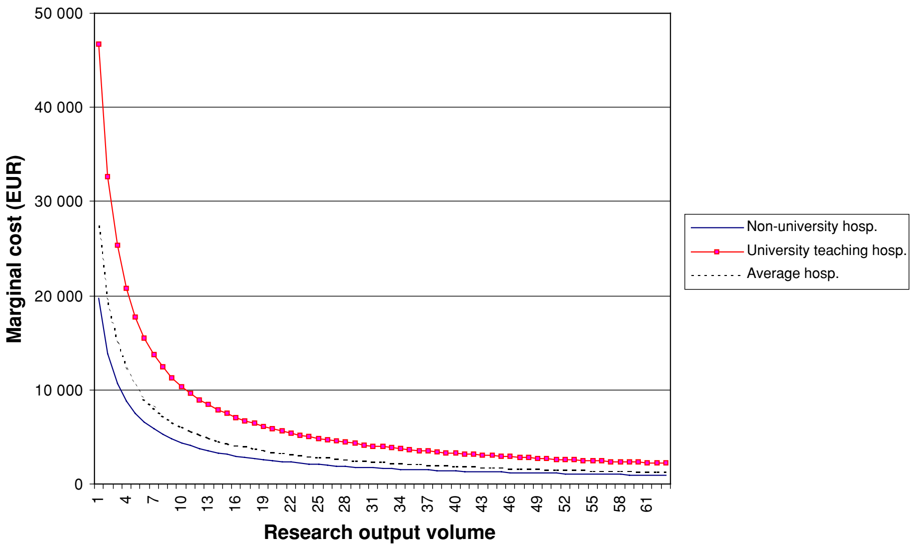

Fig. 1 Marginal costs for research at the university teaching hospitals, nonuniversity hospitals and average hospitals according to research volume

significantly higher than the 1998 reimbursement (Table 5). The total costs for university hospitals in the present study were 1.1 billion EUR, which means that teaching and research contributed 14.6% of the total operating costs in 1998.

Conclusions

In this study an empirical frontier cost function was used to evaluate the costs of teaching and research activities in Finnish hospitals. This study improved upon the previous Finnish studies by having more up-to-date and accurate data and different model specifications. The previous, most recent study ended up with clearly lower unit prices for teaching and research output for the university hospitals. On the basis of the results of that study, the total state reimbursement budget (112 million EUR) for the university hospitals for teaching and research would be divided so that 45% (51 million EUR) would be allocated to teaching and 55% (61 million EUR) to research. According to the present study 51% (79 million EUR) of the total budget of 155 million EUR should be allocated to teaching and 49% (76 million EUR) to research.

The results suggest that the average rate of teaching and research reimbursement should be (if full coverage were warranted) approximately 14.6% of the total operating costs in university teaching hospitals. The main finding is that the university teaching hospitals were underfunded with respect to both research and teaching output. However, it must be noted that it was not possible for us to collect information on other possible sources of research funding (e.g. private funding and research grants), which should be taken into account in the determination of reimbursement levels. Moreover, psychiatry was not included in our model.

Although the university hospitals have been continuously underfunded for their research activities, they have persistently increased their research output. Nevertheless, this seems sensible, since the difference between the MC of producing one additional unit of research output and the research reimbursement is larger compared to e.g. the DRGs where the MC of one discharge is quite close to the average price. Thus the behavior of the university teaching hospitals in the late 1990s was in some sense consistent with the objectives for profit maximization: Although the unit price paid for research output has been declining constantly (Table 1) it is still higher than the estimated MC. The reason that this is not observed in the teaching output may be due to the restricted supply of residents: the number of medical students is regulated by the state and the universities. Another explanation could be that hospitals have succeeded in financing their research activities through other sources (e.g. the pharmaceutical industry or research grants). The growing role of research and teaching in hospitals may bring out some concerns about the implications of this development for patient welfare: at some point in time the marginal benefits from increasing the research activity no longer compensate for the lost opportunities in actual patient treatment. However, since hospitals seem to have reacted to the new reimbursement system, it will be challenging to design better incentive-based financing mechanisms to steer the future levels of teaching and research activity within university hospitals.

One important policy implication is that university teaching hospitals are able to produce both teaching and research output at significantly lower marginal and average incremental costs than are other hospitals. This large difference is probably due to product-specific economics of scope; the production of research articles needs ‘critical mass’, i.e. research programs that are sufficiently large, which usually requires fixed and costly infrastructure. The large research programs generally take place in university hospitals. If, as proposed, the residency programs were to be shifted more to non-university hospitals, extra money would be needed.

Although the present findings are in broad agreement with most of the former studies, there are some potential flaws in the cross-sectional stochastic frontier methods. There was some multicollinearity between the medical teaching and research variables, which would possibly leave the split between research and teaching somewhat uncertain. Omitted variables may bias the coefficients in stochastic frontier models. Moreover, hospital-level effects and varying accounting conventions may affect the results when medical specialties are used as service units in the estimation. A number of studies have identified the problem of having to impose structure on the inefficiency distribution. Collecting panel data for several years and using total hospital costs or multi-level analysis could fix some of the problems in the present study.

Moreover, in the models it was not possible to control for the quality of care or quality of teaching activities. Quality adjustments have been found to be difficult to use (Zuckerman, Hadley and Iezzoni, 1994) in cost functions using hospital-level measurement. Commonly employed quality indicators, such as post-admission mortality rates, the number of wound infections and postoperative pneumonia, can be argued to be overly crude and to show that better indicators are needed. Given the limitations of measuring and controlling for output and quality differences in the cost function, some of the observed inefficiency may be unmeasured output differences across hospitals.

From a policy perspective the important question is the usefulness of frontier estimates in decision-making. In this study, reimbursement rates were evaluated using cost efficient local approximations for marginal and average costs for teaching and research output. While there are several limitations and uncertainties in the data and methodology, we believe that the cost estimates in this study provide the best contemporary knowledge about the impact of teaching and research in Finnish hospitals.

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