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PRODUCTIVE EFFICIENCY AND DETERMINANTS OF INEFFICIENCY AT HEALTH CENTRES IN FINLAND

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ABSTRACT: This paper examines productive efficiency of Finnish health centres by applying data envelopment analysis (DEA) and econometric methods. The Tobit model is used in an attempt to find out how various economic, structural and demographic factors affect efficiency. The dependent variable of the model, the coefficient of inefficiency, is obtained by deducting the DEA-efficiency score from one. According to our results a high percentage of a funding coming from the central government matching grants and high taxable income per inhabitant are significant predictors of inefficiency. The results suggest that more generous resources tend to increase inefficiency since they may lessen incentives for tight cost and performance control. A high share of doctors and low share of administrative, maintenance and support personnel promote efficiency. A low population share of the elderly and a long distance to the nearest hospital are also positively associated with inefficiency.

KEYWORDS: health centre, data envelopment analysis, Tobit model, productive efficiency, cost efficiency

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TIIVISTELMÄ: Tutkimuksen tavoitteena oli selvittää terveyskeskusten välillä havaittuja eroja palvelutuotannon tehokkuudessa, jotka aiemman tutkimuksen mukaan ovat varsin huomattavat. Tobit-malliin perustuvan analyysin selitettävänä muuttujana käytettiin DEA-tehokkuusluvun avulla määriteltyä tehottomuuslukua. Selittävinä muuttujina käytettiin terveyskeskuksen organisointia, henkilöstörakennetta, väestörakennetta, väestöpohjaa ja terveyskeskuspalveluille vaihtoehtoisten palvelujen tarjontaa kuvaavia muuttujia. Tulosten mukaan terveyskeskusten tehottomuutta lisäsivät väljät taloudelliset resurssit joko korkean valtionosuusprosentin tai korkeiden kunnallisveronalaisten tulojen kautta. Pieni lääkärinvirkojen osuus samoin kuin suuri talous-, hallinto- ja huoltohenkilöstön virkojen osuus lisäsivät tehottomuutta. Matala vanhusten väestöosuus ja pitkä etäisyys lähimpään sairaalaan ennustivat keskimääräistä vähäisempää tehottomuutta.

ASIASANAT: terveyskeskus, data envelopment analyysi, Tobit-malli, tuottavuus, taloudellisuus

CONTENTS

1. Introduction

Health centre expenditure and resources grew rapidly in Finland until 1991. Since then financial difficulties of the state and municipalities caused by reduced tax revenues and increased expenditures on income transfers have prompted the search for cuts in expenditure by improving productivity in public service provision. In health care this has meant that more emphasis has been devoted to the question: Can the volume or quality of services be maintained by improving the productivity and efficiency of health care when resources are reduced? The search for productivity improvement measures in order to cut health expenditure without compromising the availability of services can be expected to continue all through the 1990s.

For assessing the possibilities for productivity improvement, it is important to know how the productivity of health care has developed and whether there are large differences in productivity among producers of similar kinds of health services. During recent years many studies have presented evidence that the inefficiency in health care provision may have contributed substantially to rising health care costs in Finland in the 1980s. Significant negative productive trends have been estimated for hospitals (Alander et al. 1990) and health centres (Luoma and Järviö 1992). There are also large efficiency differences among health care institutions producing similar types of services (Pekurinen et al. 1990, Uusimäki et al. 1993, Luoma and Järviö 1994).

Health centres are in many ways typical public service production units. They are mainly tax-financed and their budgets are tied to the number of staff and inputs. They are the main providers of primary health care services within their catchment area. Tax financing and the monopolistic position of health centres mean that the need to minimise costs or exert pressure through the organisation to improve performance is weak. Higher costs can quite easily be passed on to taxpayers. Moreover, the effective control of health centres is difficult due to the multiple outputs health centres produce. Elected representatives of the municipalities who appropriate the budget for the health centre lack the expertise and experience to estimate the true minimum costs for health centre outputs. In addition, until 1993 part of the costs of health centres were covered by state subsidies in the form of open matching grants. Because of these grants, which varied from 29 percent to 66 percent of health centre costs, also the incentives for municipal decision makers to effectively control health centre costs were weak.

Weak incentives to exercise tight cost control and to exert pressure to improve performance can lead to organisational slack and cost inefficiency within health centres. The aim of our study is to investigate variation in the productive efficiency of Finnish health centres in 1991 and determinants of this variation. We first compare productive efficiency of health centres by calculating an index of cost efficiency for each health centre using data envelopment analysis (DEA). In the second stage we apply econometric methods to find out how various economic, structural and demographic factors affect the DEA efficiency measure. Our approach is broadly similar to methods used in studies on Swedish day-care centers by Bjurek et al. (1992) and Dutch nursing homes by Kooreman (1994), who have also applied DEA at the first stage of their analyses and then explained DEA scores by econometric methods.

2. Health care in Finland

In Finland health services are mainly produced by municipalities and municipal federations and financed by state subsidies and local taxes. Municipalities are responsible for organising health services for their inhabitants. These services can be divided into primary care and specialised care, both of which can be subdivided into outpatient and inpatient care. Health centres, which are operated either by municipalities or federations of municipalities, are the main providers of primary care. Following the Primary Health Care Act (1972) the health centres were included in a planning and budgeting system where annual increases of resources were tied on the founding of new staff posts and to the state budget. Parliament decided the priorities and the total level of resources. The cabinet approved a national four-year plan for public health services. The Ministry of Social Affairs and Health allocated these quotas to the provinces and Provincial Boards, who distributed them to municipalities and municipal federations. In 1991, the year providing the data for this study, part of the costs of municipal social and health services were financed by a state subsidy in the form of a matching grant from the central government. The proportion of costs covered by state subsidies varied from 29 to 66 per cent. If municipalities provided services which were not in the plan, they had to do so without state subsidies.

The reform of the state subsidy system for social and health care services came into force from the beginning of 1993. In the reformed system state subsidies for running costs of health care are calculated according to present criteria including population age structure, morbidity, population density, land area and the financial situation of the municipality. Subsidies are not earmarked for certain expenditures. They are paid automatically to the municipalities without a need for separate applications.

3. Measuring productive efficiency of health centres

3.1. Overview of data envelopment analysis

For assessing differences in productive efficiency among health centres we use data envelopment analysis (DEA) - a mathematical programming-based method that converts multiple input and output measures into a single summary measure of productive efficiency. DEA is based upon relative efficiency concepts proposed by Farrell

(1957). Charnes et al. (1978) extended and developed Farrell's approach. They showed how Farrell's technical efficiency could be made computationally tractable by casting it in a fractional linear programming format.

DEA can be said to utilise an extended concept of Pareto efficiency. A production unit is not efficient if it is possible to boost any output without increasing any inputs and without decreasing any other output. This definition reflects an output orientation. Pareto efficiency can also be characterised with an input orientation as follows. A unit is not efficient if it is possible to decrease any input without increasing any other input and without decreasing any output.

DEA uses linear programming methods to construct a piecewise linear convex hull of the observations. This surface can be referred as the efficient frontier. The remaining units are then evaluated relative to this efficient surface (Nunamaker 1985). The efficient units, which span the efficient frontier obtain a measure of one, while relatively inefficient units obtain an efficiency measure of less than one.

The calculation of relative efficiency using DEA can be illustrated with the help of Figure 1 (borrowed from Førsund 1992). For ease of illustration we present the case where there is only one output and one input although in actual DEA applications one always has a larger number of outputs and/or inputs. The calculation of DEA efficiency measures can be based either on constant returns to scale (CRS) or variable returns to scale assumption (VRS). If CRS applies, the efficiency frontier in the one-input, one-output case would be spanned only by the unit having the highest output per unit of input (with more output or input categories the efficiency frontier would be formed by many units). In the case of Figure 1 unit B will span the efficiency frontier. Its DEA efficiency score is one. Efficiency scores for other units are determined on the basis of the distance to the efficiency frontier. The input saving DEA score is the ratio of the minimal input coefficients at the frontier and the observed input coefficients of a unit. For unit D this would be GF/GD. The output increasing DEA score would be the ratio of observed productivities of a unit and the maximal productivities at the frontier. For unit D this would be JD/JI. With CRS the output increasing and input saving DEA scores are the same.

If we assume VRS, the efficiency frontier is determined by the units represented by points A, B and C. The input saving efficiency score is GE/GD and the output increasing efficiency score JD/JH.

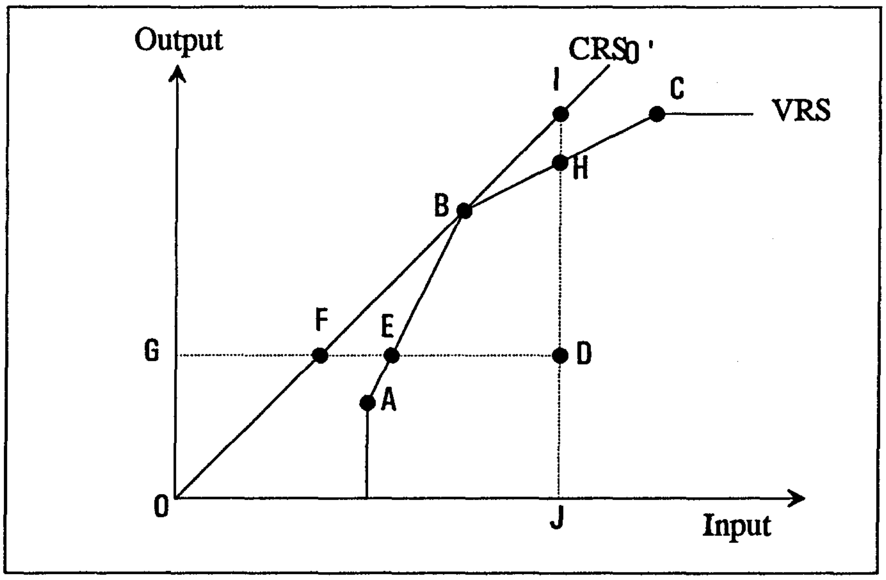

Figure 1. Efficiency frontier and efficiency measures in one-input, one-output case

To illustrate DEA in the multiple-output case, one can consider the case where CRS applies and where each unit of the same industry produces two different outputs, say outpatient visits and bed-days, with a single input. When each output is divided by the amount of input used to produce it, the units can be represented in a two-dimensional space as in Figure 2.

In Figure 2 the points A-F represent the production units of the same industry. The efficient surface or the best practice frontier, as it is often called, is determined by enveloping the observed points using piecewise linear segments. This results in the locus of points depicting the units which produce most of either output per unit of input. In our case of figure 1 units A,B,C and D have this property that no other unit is superior in both dimensions, so they form (with extensions to the axes) the best practice frontier. The measure of productive efficiency of the unit is given by dividing the actual output produced by the hypothetical output it could produce if it were on the frontier holding output mix constant. For observation E the efficiency measure would be the ratio of distance OE to the distance OE'. Respectively for unit F the efficiency measure would be OF/OF'.

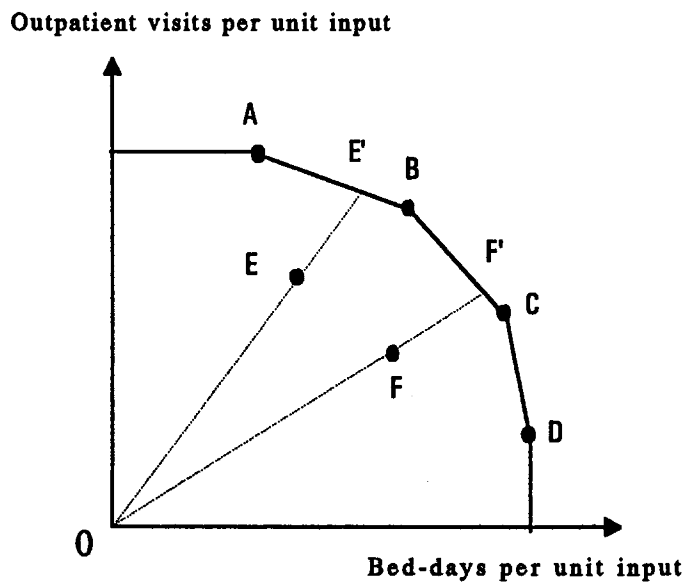

Figure 2. Efficiency frontier and efficiency scores in two-output, one-input case with constant returns to scale

Formally, calculations of productivity efficiency scores are made by solving the following fractional linear programming problem:

$$\max h_0 = \frac{\sum_{r=1}^{s} u_r y_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}} \qquad (1)$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1; \; j = 1, ..j_0...,$$

$$u_r \geq 0; \; r = 1, ..., s; \; and \; v_i \geq 0; \; i = 1, ...,$$

The terms y_{rj0} and x_{ij0} represent the amount of output r and the amount of input i for the production unit j_0. Optimisation is performed separately for each unit to compute an optimal set of weights (u_r ,v_i) and efficiency measure h_0. The method chooses values of u_r and v_i which are most favourable to the unit that is being studied. As a consequence a unit that is superior to all others on any single output-input ratio will be rated efficient.

3.2. Reducing weight flexibility in data envelopment analysis

In the standard DEA model the relative efficiency of a production unit is defined as the ratio of the sum of its weighted outputs to the sum of its weighted inputs, the weights having been determined so as to show the production unit at maximum relative efficiency. Dyson and Thanassoulis (1988) have argued that DEA allows too great a flexibility in the determination of input and output weights when assessing the relative efficiency of a production unit. They point out that this can lead to some production units being assessed only on a small subset of their inputs and outputs, while their remaining inputs and outputs are all but ignored. In our case with as many as nine different outputs this could be a particular problem, so we decided to follow Dyson and Thanassoulis in setting lower bounds on output weights.

In general the weights in a DEA model do not have a clear interpretation, which makes constraining them arbitrary. In our application resources have been reduced to a single input, total running costs of health centres. In single-input cases the weight on each output in the DEA model can be related to the amount of resources the production unit may be deemed to consume per unit of that output. Dyson and Thanassoulis (1988) have shown how with the constant returns to scale assumption this interpretation can be deduced after a straightforward manipulation of the model (M1). If we let w_r stand for the agreed minimum resource input per unit of output r and set $u_r = u_{r,}/v$, the model (1) can be modified as follows for assessing the relative efficiency of production unit j_0:

$$Max\ h_0 = \sum_{r=1}^{s} = u_r y_{rj_0} \qquad (2)$$

subject to

$$\sum_{r=1}^{s} u_r y_{rj} \leq x_j \ \ j=1 \ldots j_0 \ldots$$

$$u_r \geq w_r \ \forall r.$$

3.3. Data

The data used in our DEA analysis is based on cost and output information derived from the report information register (KETI) and financial statistics of health centres (Terveyskeskusten talous 1992) for the year 1991. Our analysis is based on the subset of 202 health centres, which are led by a general practitioner and which provide both inpatient and outpatient care. We excluded those 22 health centres which did not provide inpatient care or which were led by a specialist practitioner (instead of a general practitioner) in order to form a reasonably homogeneous set of health centres. From the register we picked up 30 output variables, which were aggregated into six output measures for outpatient care: (i) health care and medical care visits to a physician, (ii) health care visits to other personnel, (iii) medical care visits to other personnel, (iv) visits of supervised domiciliary care, (v) dental care visits and (vi) special examinations.

For inpatient care we used three output measures: (i) short-term inpatient days, (ii) long-term inpatient days for patients in the heavy dependency category and (iii) long-term inpatient days for patients in other dependency categories. For dividing inpatient days reported in KETI into these three categories we used information from a patient census in health centre hospitals carried out in 1991.

The input data consists of operating costs without rehabilitation costs and costs of purchased services. These were excluded because corresponding outputs were not included in our output measures due to great heterogeneity of rehabilitation services. The personnel costs were adjusted by a cost-of-living bonus and by a bonus for service in remote areas to eliminate the main differences in input prices between health centres. In specifying lower bounds we at first estimated rough average unit costs for our output categories using cost information from financial statistics of health centres (Terveyskeskusten talous 1992) and unit cost estimates from the health centre of Helsinki (Terveydenhuollon toiminnallinen tilinpäätös 1992). Then we assumed that minimum resource costs for these outputs were forty per cent of average unit costs (details of our output and input measures are presented in Luoma and Järviö 1992 and 1994). It should be emphasised that considerable flexibility in the determination of weights is maintained even after setting lower bounds for output weights.

3.4. DEA results

Using an input minimising constant returns to scale DEA model with lower bounds for output weights, an index of productive efficiency was calculated for 202 health centres. The efficiency measures obtained can be interpreted to show how much each health centre could reduce its input usage without reducing output if it were as productive as the best practice units. In our case where we estimated input usage by operating costs, efficiency measures can also be interpreted to indicate the cost saving potential of different health centres.

The results imply considerable variation in the productive efficiency of Finnish health centres, as the distribution of efficiency scores presented in figure 3 shows. The figure presents efficiency scores obtained by DEA with the help of a Salter-diagram, where each histogram represents one health centre. The size of health centres measured by operating costs is shown by the width of the histogram. The efficiency scores are measured on the ordinate axis. The health centres are ordered according to increasing value of the efficiency score.

Twelve per cent of health centres got an efficiency score of one. The lowest efficiency score is 0.664. The deciles (unweighted) are 0.764, 0.809, 0.839, 0.860, 0.881, 0.900, 0.924, 0.966 and 1. Input saving potential of health centres measured as the weighted average of efficiency scores, weighting the efficiency score of each health centre by its operating costs, is 13.4 per cent.

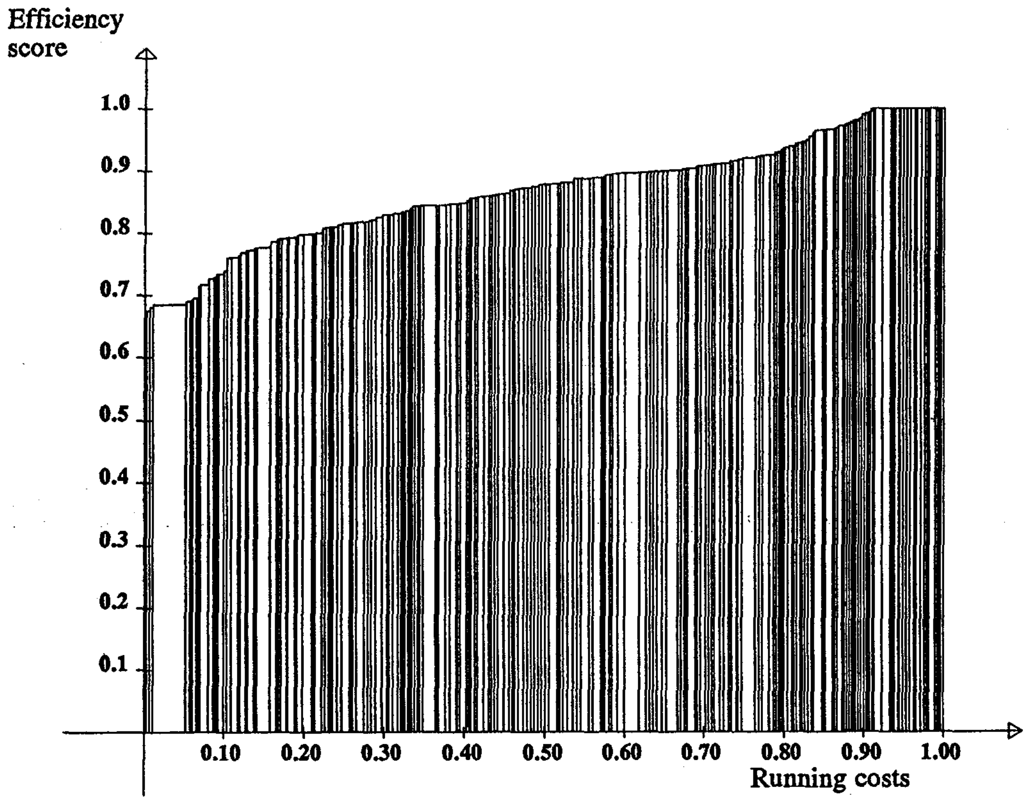

Figure 3. Input saving efficiency of health centres in Finland in 1991

4. Determinants of inefficiency of health centres

The second part of the study seeks to find determinants of inefficiency of health centres by applying a Tobit model. The dependent variable is one minus the value of the efficiency score obtained by DEA. The regressors include various economic, structural and demographic variables, which are related to the health centre or health centre district.

4.1. Theoretical background for the choice of explanatory variables

The DEA score reflects the relative productivity of health centres. There are at least three types of reasons why productivity of health centres can vary. It may vary because of differences in production technology, differences in the efficiency of the production process, and differences in the environment in which production occurs (Lovell 1993).

Organisational and structural characteristics of health centres can be thought to reflect differences in production technology. Here scale effects may have a role. We measure scale effects by including among the explaining variables the number of beds in the health centre hospital. The input mix of health centres reflects also differences in production technology. The differences in input mix are controlled by two variables: the number of total staff posts in health centre divided by the number of doctors' posts, and the share of administrative and service posts of the total number of posts.

Of special interest is to find out to what extent financial incentive mechanisms and constraints generate variation in efficiency. In order to outline these kinds of effects the interplay of public managers in health centres and elected representatives of the public owner could be modelled along the lines of Mackay and Weaver (1983); a similar analysis has been presented by Moene (1986). Mackay and Weaver analyse the game between a bureaucrat and voters. The voters decide the total budget by majority voting while the bureaucrat controls the budgetary mix. The voters cannot commit themselves to the budget size they initially choose. By selecting the mix strategically, the bureaucrat is able to extract a larger budget. In Finnish health centre management the budgetary control has to a great extent been based on the number and type of personnel employed and therefore the above model may be appropriate. It is not a priori clear whether the inefficiency is manifested in the form of price inefficiency due to a nonoptimal input-output mix or technical inefficiency due to slack and insufficient activity levels.

The percentage of state subsidy can be considered as a kind of price variable for health care. A high subsidy rate will lower the costs that a municipality has to pay for both efficient and inefficient use of resources. Consider interest groups which lobby for health services of a private and redistributive character. When services are partly financed by national taxation, the groups impose negative externalities on each other when they lobby for higher spending levels. This leads to higher demand for these services when financial externalities i.e. the subsidy rates are set at higher levels. Häkkinen and Luoma (1994) have found empirical evidence that the effect of subsidy rate on health service expenditure in Finland is quite strong, Furthermore, elected representatives of local voters may be driven by motives other than efficiency in the production of health services. Local incentives to maintain employment may push the use of labour inputs to technically inefficient levels when the subsidy rates offered by the central government are favourable. With more generous resources, which higher budgets imply, the cost of organisational slack for persons responsible for health centre management can be expected to be lower. The prediction that higher taxable income per inhabitant tends to lead to higher cost inefficiency can be derived by similar kinds of arguments.

The health centre management can also be assumed to have superior information about the costs of producing health centre services than elected officials. Elected officials could plausibly learn more about the cost of services by allocating resources for monitoring. However, if the state subsidy is generous, the payoff for more careful monitoring may seem modest compared to payoffs that can be anticipated if monitoring efforts are directed to municipal activities not subsidised by the state grant.

It can be argued that there is greater room of discretion in health centres run by a federation of municipalities than in one-municipality health centres. This can be exploited by public managers. To test this effect we include among the regressors a variable that describes whether a health centre is run by a federation of municipalities or whether it is a one-municipality health centre.

The dependent variable in our application is based on the efficiency score obtained by data envelopment analysis. In our application we formed a data set where we measured health centre activities by nine output measures. A considerable amount of aggregation is involved in forming the output measures. Therefore our efficiency measure is only a proxy for "true" efficiency measure of health centres. Due to possible heterogeneity of aggregated outputs the DEA measure may be contaminated by differences in the composition of aggregated variables. In order to control for these we included among the independent variables a number of variables which can be thought to reflect the case-mix of patients: demographic variables, distance to the nearest hospital and population density.

The structure and volume of the demand for health centre services may depend on alternative sources of health care supply. Therefore we include among the explanatory variables the utilisation of specialised hospital care and private physician fees per health centre district population.

4.2. The econometric model

An econometric model is used in an attempt to find systematic differences in productive efficiency among the health centres. The dependent variable of the model, the coefficient of inefficiency, is obtained by deducting the (DEA) efficiency score from one. The (input-based) coefficient of inefficiency gives directly the share of total inputs wasted due to productive inefficiency for each unit. The variable takes only non-negative values and has the value zero in those observations that correspond to the efficient units.

Since the dependent variable of the model has a limited range of values, we use a Tobit model to describe the statistical properties of the data. The model is defined by

$$TE^{*} = X_i \beta + u_i, \qquad (3)$$
$$TE = TE^{*}, \text{ if } TE^{*} > 0 \text{ and}$$
$$TE = 0, \text{ otherwise.}$$

In the above equation TE is the DEA coefficient of inefficiency, and TE^* is a latent, unobservable variable. The probability density of the latent variable is used to model the statistical properties of the observed coefficient of inefficiency TE and has as such no economic interpretation. The researcher's main subjects of interest include the fit of the model, which consists of the vector of explanatory variables, X_i , and an estimable parameter vector, β. The random errors of the model u_i , are assumed to be independently and identically distributed with a zero mean and variance σ^2.

The parameters of the model are estimated by the method of maximum likelihood assuming normally distributed errors. In contrast to the ordinary regression models Tobit models are not robust against specification errors such as heteroscedasticity and non-normality which are known to produce asymptotically biased estimates. This is due to the fact that the regression function of the coefficient of inefficiency TE is not a linear function of the parameters, although the fit of the latent variable $X_i\beta$ is linear. The regression function which is of main interest to the researcher in interpreting the results of the model is defined by the conditional expectation

$$E(TE_i \mid TE_i > 0) = X_i\beta + \sigma\phi(X_i\beta/\sigma) \,/\, \Phi(-X_i\beta/\sigma) \qquad (4)$$

where Φ is the cumulative distribution function of the standardised normal distribution and ϕ is the corresponding density function. By (4) one is able to simulate changes in DEA-efficiency scores due to a hypothetical change in explanatory variables X_i.

The lack of robustness of the Tobit models calls for a careful examination of the correctness of the distributional assumptions before, say the effects of a policy change are simulated by the use of an estimated model. In the paper we use a test diagnostics which has a χ^2 distribution with one degree of freedom under the null hypothesis of no misspecification (Suoniemi, 1992). The test statistic is derived by applying a general transformation test principle in Tobit models which MacKinnon and Magee (1990) presented for ordinary regression models. The test statistic is simultaneously sensitive for (1) linearity of the fit, (2) the type of heteroscedasticity which is related to the fit, and (3) excess skewness of the error term.

Because our model is not a standard regression model, two separate statistics are needed to examine the goodness of fit of our model. The first of these measures how well the model succeeds in explaining the partition of the data into efficient and inefficient units. Here a pseudo-R^2 specifically constructed for the analysis of discrete dependent variables is used (for details, see Maddala, 1983, p. 40). The second statistic measures the deviance of the inefficiency coefficients from those predicted by our model. In the paper the statistic is calculated using the ratio of the variance estimates from our model and a baseline model. Here, the baseline model uses the constant term as the only explanatory variable. Our measure naturally generalises the coefficient of determination in regression models in the sense that if the data has no 'zero observations' the measure is equal to the ordinary R^2.

4.3. Data sources

Data for explaining and predicting differences in productive efficiency of health is based on a data set which has been collected from several sets of statistics, studies and registers by the National Research and Development Centre for Welfare and Health (Häkkinen and Salonen 1994). All data are from the year 1991. The observation unit is a health centre district, which can be either a single municipality, or a federation of municipalities, responsible for providing primary health care services to residents within a specified area.

4.4. Estimation results

The results are shown in Table 1, which presents the coefficient estimates from the model including only those variables that differed statistically significantly from zero. Descriptive statistics for these variables are presented in the appendix. The model seems quite satisfactory in terms of statistical criteria and explanatory power. The value for the test statistics does not indicate problems with the distributional assumptions made in our Tobit model. The goodness of fit statistics for the Tobit model, R^2 , is reasonably high for this kind of application, but the corresponding statistic for the implicit probit model, pseudo-R^2 , has a rather low value. The reason for this is that partitioning the sample into efficient and inefficient units is not alone sufficiently informative regarding the explanatory factors involved. This is partly due to a small number of efficient units (12 per cent of observations).

The above observations suggest that a misspecification test based on comparing the coefficients of the Tobit and the corresponding Probit model has a relatively low power in our case as opposed to the cased considered by Kooreman (1994). The test for misspecification that we employ (row χ^2 in table 1) is statistically insignificant.

Table 1. Determinants of inefficiency of health centres; Parameter estimates from the Tobit model

Variable	Coefficient	t-ratio
Constant	-0.700	-3.052
Percentage of state subsidy	0.531	2.618
Income subject to local government taxation per inhabitant	0.007	3.424
Distance to the nearest hospital	0.0004	1.878
Proportion of population over 65 years of age	-0.540	-2.769
Posts of other personnel/ posts of physicians and dentists	0.007	3.005
Proportion of administration and service personnel	0.310	2.884
One-municipality health centre (dummy-variable)	-0.029	-2.283
Log-Likelihood / N (=202)	0.818	
Proportion of the efficient health centres	0.119	
R^2	0.25	
Pseudo-R^2	0.04	
X^2 (khi-square)	3.24	

Variables which reflected economic incentives and constraints of the municipality proved to be significant predictors of cost inefficiency. The higher the state subsidy rate was, the more inefficiency there tended to be. Health centres that are run by a federation of municipalities tend to be slightly less efficient than one-municipality health centres.

The two indicators for the personnel mix were significantly associated with the DEA efficiency score. The higher the ratio of the number of total personnel posts to the number of doctors' posts in health centre was, the more inefficient the health centre tended to be. Also a high share of management and service personnel predicted inefficiency. These results suggest that inefficiency of health centres is not purely technical inefficiency. There is also allocative or input-mix inefficiency present.

The coefficient estimate for the share of the elderly in a health district population was negative and significant implying that the higher the share of the elderly, the higher the DEA score (i.e. the lower the measured inefficiency) tended to be. This finding can be given at least two interpretations. First, it may reflect case-mix variation in health centres. Elderly people are heavy users of health services. They may generate a high number of visits, but these visits may be on average less resource intensive than visits of the non-elderly. The other possible interpretation is that the high share of the elderly increases the demand for health centre services. If this is not fully offset by a similar increase in resources, health centres may be forced to satisfy the demand for services by a more intensive use of available resources.

The proportion of the elderly in the health centre district population and the distance to the nearest hospital can be thought of as control variables. These variables can be considered to reflect variation in the patient mix of health centres, which the output variables used in our DEA model do not take fully into account. The distance to the nearest hospital would according to the results of the Tobit analysis tend to decrease the DEA efficiency score. It might be argued that this is due to the fact that health centres situated in localities where there is no hospital providing specialised care within reasonable distance, provide more demanding services than health centres on average. This, however, is just one possible interpretation for the association between the distance to the nearest hospital and the efficiency score. It is also possible that these health centres have been more successful in getting their applications for new posts approved by provinces and provincial boards, who used to allocate increases in manpower across the health centres in the province within the limits set by the national plan for public health services.

To illustrate the relative importance of different factors Table 2 presents the estimated effects of the change in the value of the variable from its first decile to its ninth decile.

Table 2. The effects of the change in the value of the variable from the first decile to the ninth decile.

Variable	The effect on the inefficiency score
Percentage of state subsidy (from 46% to 66%)	+0.10
Income subject to local government taxation per inhabitant (from 50310 Fim to 69350 Fim)	+0.12
Proportion of over 65 years of age (from 0.10 to 0.19)	-0.04
Distance to the nearest hospital (from 6.1 km to 69.6 km)	+0.02
Posts of the other personnel/ posts of physicians and dentists (from 12.2 to 19.5)	+0.05
Proportion of administration and service personnel (from 0.19 to 0.31)	+0.03

The effects of the state subsidy rate and income level of health centre district population are substantial implying that economic incentives and constraints are significant determinants of health centre efficiency. The effects of other variables are much smaller but notable.

5. Discussion

We have applied the mathematical programming approach known by its descriptive title data envelopment analysis to calculate efficiency scores for Finnish health centres. We introduced into the standard DEA model with constant returns to scale additional constraints based on estimated lower bounds for output weights. Differences in productive efficiency among health centres were found to be considerable implying that the input saving potential of health centres would be at least 13 per cent.

In the second stage we applied an econometric technique based on the Tobit model to explain variation in inefficiency. The results imply that the higher the percentage of the central government matching grant (state subsidy) for health care is (varied between 29 and 66 per cent in the study year 1991), the more inefficiency there tends to be. This lends support to the view that the old state subsidy system (in force until 1992) did not promote efficiency in the provision of health services. Taxable income per capita, which can be thought to reflect possibilities to finance health care costs from the municipality's own sources, has a similar impact as the generosity of the state subsidy.

The results support the often expressed view that in the former state subsidy system incentives for cost efficient behaviour were weak. In the current system reformed in 1993 state subsidies for running costs in health services provided by municipalities are calculated according to various present demographic criteria (age structure, morbidity, population density etc.). Under the new system municipalities have to bear the full marginal costs of health services they provide. Our results suggest that the state subsidy reform could lead to major efficiency gains.

The fall in average income levels of health centre district populations experienced in Finland since 1991 should according to our estimates also tend to increase pressure in more efficient operation of health centres.

The effects of two variables depicting the input mix of health centres are considerable implying that health centres could promote their efficiency significantly by eliminating allocative inefficiency in their use of inputs.

Of course, the choice of output and input variables is always a problem in studies which seek to assess productivity and efficiency of health care production. Although by using DEA one can avoid the problem of agreeing on a common set of weights for inputs and outputs, one cannot avoid the problem of which inputs and outputs should be included in the comparisons (Boussofiane et al. 1991). In health care applications the number of possible output measures is very large. For DEA these have to be aggregated into a manageable number of output variables. In our case we started with thirty variables and ended up with nine variables. One can, of course, question whether the output variables we used are reasonably homogeneous. The results of the Tobit analysis suggest that this may not be the case although the effects of variables which indicate a potential lack of homogeneity are not large. However, one might with the help of results of the Tobit regression take a step further, and adjust DEA efficiency scores on the basis of coefficient estimates for variables which can be thought to be related to the patient mix of health centres (distance to the nearest hospital, share of the elderly within the health centre district population).

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Appendix

Descriptive statics

	mean	st.dev.	min.	max.
Inefficient score	0.12	0.09	0	0.34
Percentage of state subsidy	57	8	29	66
Income subject to local government taxation per inhabitant, 1000 mk	57.98	7.65	43.71	92.43
Proportion of population over 65 years of age	0.15	0.04	0.05	0.25
Distance to the nearest hospital, km	35.93	33.84	0	263.60
Posts of other personnel/posts of physicians and dentists	15.52	2.99	5.40	24.38
Proportion of administration and service personnel	0.25	0.06	0.10	0.55
Dummy-variable:				
One-municipality health centre	0.48			