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Productivity Measurement in Swedish Departments of Gynecology and Obstetrics

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Preface

Productivity Measurement in Swedish Departments of Gynecology and Obstetrics is a working paper within CEFOS research area 'Administrative and organizational aspects of the public sector'. This study is concerned with the specification and estimation of total factor productivity growth using the primal panel data approach. The total factor productivity growth is decomposed into technical change and scale components. Several competing parametric and non-parametric models are used to explore whether there are any similarities in the estimates of total factor productivity growth and technical change among these models. The parametric models are estimated using different estimation methods. Some of the models, although assuming a restrictive Cobb-Douglas technology, exhibit firm-specific technical change. These models are used to measure productivity growth in 7 departments (28 ward units) of gynecology and obstetrics in Sweden during 1993-1996. In comparison among different specifications proposed, the level and the time pattern of productivity measures vary substantially across models and estimation methods. The working paper is written by Associate Professor Almas Heshmati.

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Lars Strömberg
Director, CEFOS

1. Introduction[1]

The tremendous growth of public spending and the need to assess its impact on the welfare system and fiscal management has made the studies of productivity in the public sector an important subject for policy-makers and economists. The Expert Group on Public Finance has published a number of reports on the measurements and development of productivity in the public sector in Sweden, covering the period 1960-1992. Large segments of the public sector (national and local governments) producing individual services were included in these studies. Changes in the composition and quality of outputs were incorporated in the measurements. With the exception of a few areas (e.g., health care), quality was not changed enough to significantly affect the productivity measurements. The aggregate productivity change during the period 1970 to 1980 was calculated to be -1.5% per year. Other productivity studies with less coverage during 1960-1970 showed productivity decrease at a higher rate. The recent studies for the period 1980-1990 indicate a continued productivity decrease of 0.4% per year. The development has however been different for national and local governments. Unlike local governments, the national government budget constraint had a positive impact on the levels of productivity.[2]

Over the period 1960 to 1992 the real cost of the weighted average visit to doctors and nurses and admission to hospitals for treatment has increased by 235%. Taking into account the increased visits and admissions per habitant by 66%, productivity dropped by 100%. Previous studies of cost of treatment and quality change in health care, comparing a number of diagnoses

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[2] For details on the development of productivity in various segments of the public sector, see Finansdepartementet (1986, 1994a, 1994b).

treated in the 1960s and at the beginning of the 1990s, indicate that there has been a marked increase in quality over the period. However, no correlation between the increase in quality and the increase in costs was found. The issues of trade-off between the quality and quantity of care will certainly be reflected in an over/underestimation of the productivity change.

From the beginning of the 1990s, the public sector, in general, and the health care sector in particular, have been allocated relatively less resources as a consequence of the economic recession in Sweden. Financial difficulties have arisen because of the continued increased demand for public sector outputs due to the growth in the number of children, the elderly, the unemployed, the handicaps, refugees, criminals, etc. The increased demands for services is expected to be satisfied by using the reduced resources available, especially staff members. Thus, increased productivity is regarded as a solution to the structural budget deficit problem of the government sector. The total cost of health care as a percentage of the gross domestic product has decreased. Despite this sharp decline in the share of health care expenditures, there has been a desire to maintain a high capacity in terms of bed occupancy in hospitals and the provision of health care services with improved quality. The expected outcome of these changes is an improvement in resource utilization, primarily through the increased productivity of doctors and nurses, together with a higher bed occupancy rate.

The measurement of technical change and total factor productivity growth has for a long time been the focus of attention in empirical studies in agriculture and industry (see Antle and Capalbo (1988) and Jorgenson, Gallop and Fraumeni (1987)). Diewert (1981) classified the various measures of technical change into four groups: (i) econometric estimation of production and cost functions, (ii) Divisia indexes, (iii) exact index numbers, and (iv) non-parametric methods using linear programming.

In the econometric approach, technical change has generally been represented by a simple time trend. Estimates of rate of technical change are then calculated as the percentage change in production or cost over time. With the advent of flexible functional forms (Christensen, Jorgenson and Lau (1973)), the simple time trend representation of technical change has been modified to include time squared and interactions between time and the other explanatory variables. The non-neutral component of technical change allows for firm- and time-specific technical change. This is true unless the rate of technical change is independent of all the explanatory variables, i.e. the coefficients of the interactions between time and the input variables are all zero.

A time trend approach is attractive in the analysis of manufacturing or industrial production, where long-run technical change is mainly determined by capital equipment and short-run changes in productivity caused by cyclical factors. Access to panel data allows a much more detailed evaluation of the relative performance of micro units and, therefore, a richer specification of technical change. A general index of technical change was introduced by Baltagi and Griffin (1988a) where the time trend is replaced by a vector of time dummies. They argue for the advantages of the general index over the time trend model in measuring technical change.[3]

This paper adopts mainly the econometric approach and uses a Cobb-Douglas production function with heteroscedastic disturbances to measure technical change and total factor productivity growth. Alternative non-parametric measures of total factor productivity growth such as the Divisia index are also considered. As a starting point, the traditional representation of technical change, i.e. a time trend model is considered. The time trend is extended to a general index model. The main advantage of the general index model in comparison with the time trend model is that it does not impose any structure on the time pattern of technical change. In restrictive technologies, technical change in a time trend model is a constant (firm- and time-invariant), while in the general index model the rate of technical change varies only over time. Thus, following Baltagi, Griffin and Rich (1995) and Kumbhakar, Heshmati and Hjalmarsson (1997), the models are developed in a number of ways to incorporate firm-specific technical change, even though neutral technical change and restrictive technologies are employed. Despite the simple functional forms used in the extended models, the total factor productivity growth is however both firm- and time-specific. The choice of a restrictive technology has been motivated due to the small number of observations available.

In the literature on factor productivity measurement, several models are proposed to allow technical change to be firm-specific. However, in the empirical literature, the issues of model specification and selection of various specification forms are rarely emphasized. In this paper we

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[3] For other applications of the General Index model of technical change see Kumbhakar, Heshmati and Hjalmarsson (1997), Kumbhakar and Heshmati (1996), Nakamura (1996), and Kumbhakar and Hjalmarsson (1995). For an intermediate (between a time trend and a general index) approach with multiple time trends, see Heshmati (1996).

consider the issues related to the specification and estimation of various models incorporating firm-specific technical change. First, a standard time trend model specification is presented and estimated. Second, a general index model is specified and estimated with different estimation methods assuming heteroscedastic disturbances. Third, the time trend and general index models are modified, as suggested in Cornwell, Schmidt and Sickles (1990) and in Lee and Schmidt (1993) to incorporate firm-specific technical change. Fourth, total factor productivity growth is calculated using the Divisia index and the results are compared with those obtained using parametric models. The benefits and limitations of the different specifications are analyzed and the impacts of these specifications on the results obtained are quantified. In the empirical part, a short panel of data from Swedish departments of gynecology and obstetrics, observed during the period 1993-1996 is used. The aim is to compare the productive performance of these departments in terms of the size of input elasticities, returns to scale, technical progress and total factor productivity growth. An analysis of the productivity in gynecological care provides useful information considering the utilization of health care resources and the impacts of recent years of changes on productivity in health care.

The paper is organized as follows. In the next section Swedish gynecology and obstetrics data are described. In Section 3 the econometric production function models with various specifications considering the rate of technical change are presented. In Section 4 the estimation methods are discussed and Section 5 contains the specification tests and empirical results along with a comparison of the performance of the different model specifications. Finally, Section 6 presents the summary and conclusions of this study.

2. The Data

The data used in this study covers all the departments of gynecology and obstetrics located in the County of Stockholm, Sweden. The gynecological health care services are provided by seven department units, which is divided into four different wards: institutional care, day-surgery, emergencies and others. Institutional care refers to care given to patients admitted to a hospital or other establishments providing in-patient care and others refer to out-patient care. The final data set consists of an unbalanced panel of 28 ward units (i.e. seven departments each disaggregated into four wards) observed on an annual basis over the years 1993 to 1996.[4] The unbalancedness arises due to the exit of department No. 5 in 1996. The total number of observations is 108. The departments are part of the public health care service and are financed by the County of Stockholm.

The data include values of inputs and outputs related to the total cost and total DRG[5] points produced at the ward levels. The dependent variable, DRG points, (Y_{DRG}), is a measure of the total quantity of services produced by a ward during a year. Y_{DRG} is the sum of relative DRG weights of all individual admissions during a year. It is a measure of an individual patient's intensity of resource use. In order to reimburse the departments for their services provided, the total Y_{DRG} produced is multiplied with a pre-determined fixed amount of money per unit of DRG. The input variables include costs associated with doctors, nurses, other staff members, rent, material, services and administration. All input variables are expressed in Swedish currency (1000 SEK) and are transformed to 1996 prices using the municipality net cost price index. In calculation of the price index, changes in the value added tax component during the period of study were taken into account. Summary statistics of the data are presented in Table 1.

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[4] Each department can be broadly divided into two main departments: gynecology and obstetrics. We did not have access to disaggregated data during the first year. Thus, the analysis here is based on an aggregate data level. However, a further disaggregation is possible by approximating the input weights in the first year with the observed input weights in the second year.

[5] Diagnosis Related Groups, DRG, is a system for classification of patients into about 500 homogenous groups, based on their diagnosis and treatments, see Fetter (1991) and Casas (1993).

In Table 1, a summary of the statistics over the total cost and associated cost shares are given. The cost shares of services (0.41), nurses (0.21) and doctors (0.18) are among the largest input shares. In general large variations in the cost shares among the sample wards are found. In a number of observations, we find the cost shares of the important inputs to be zero. The relatively large cost share variability together with zero inputs is an indication of unreliable accounting practices and the presence of measurement error in variables.

Table 2 contains a correlation matrix for the values of the inputs and output variables. The output, other, material and rent are negatively correlated with time while doctors, nurses, services and administration are positively correlated with time. None of these correlation coefficients are found to be statistically significant. Thus, the expected decline in the use of inputs over time is not evidenced. On the other hand, we find positive and highly significant correlation between output and inputs. The lowest and highest estimated correlation coefficients belong to output-others (0.81) and those of output-nurses (0.98). The estimated correlation coefficients among the inputs vary in the interval 0.68 (administration-others) and 0.96 (services-nurses).

The variables, doctors (X_D), nurses (X_N) and others (X_O), are the total cost of hiring doctors, nurses and other medical and non-medical staff members involved in health care activities. They cover both salary and payroll taxes related to each category of employees. The variable rent (X_R), is the sum of the internal leasing costs associated with the department use of its own buildings, equipment and rental of other premises. It is a measure of user cost of capital and includes cost related to depreciation, interest rate expenses and maintenance of buildings and equipment. Material (X_M) consists of costs related to drugs, blood products, food, material, etc. The variable, services (X_S), is an aggregate of all health care services that a ward buys from other units, such as lab-tests, X-rays, surgery, anaesthetics, etc. Administration (X_A) is an aggregate of both local and central administration. It also includes common overhead costs and rent for common premises.

Unfortunately, we do not have access to information related to the production characteristics of the departments such as the number of patients treated and their main diagnosis, the departments bed-day capacity, capacity utilization, the number and types of doctors, nurses and other medical staff, their levels of education, staff-patient ratio, the frequency and amounts of time that doctors/nurses spent with patients on a daily basis during their stays, patient service satisfaction, accident rate, etc to approximate the quality and heterogeneity of services produced.

The use of the DRG point as a measure of services produced has both benefits and limitations. Four important limitations are the following: First, the use of the DRG point as a measure of output makes the additional information on the patient heterogeneity, such as number of patients and their main diagnosis, superfluous. This can be considered as an advantage of the DRG point as an output measure as well. DRG points embodies patient heterogeneity but a direct observation of such characteristics would have been valuable in explaining the factors affecting the level and the time patterns of productivity growth. Second, lack of prices for the public sector gives rise to the issue of whether the DRG point is a good measure of the real resources used. Third, in the classification of patients into different DRG groups, one may suspect that the producers purposely place the patient in a group with an overestimated DRG point for reimbursement reasons. Fourth, a unit cost analysis cannot be performed to compare patients with particular diagnoses but treated at different departments. A cost analysis among the departments and over time would shed light on the structure and development of cost.

Given the limitations of the DRG point, the absence of a better measure and the difficulties associated with the measurement of the public services produced, the DRG point is used as an aggregate measure of all service produced. Thus, the main benefit of the DRG point is its simplicity. By transforming all the services produced for all patients into a common unit of measurement, i.e. DRG point, one avoids the problem associated with aggregation of output services with different units of measurement and the difficulties in estimation of multi-output production functions.

The most frequent DRG groups at departments of gynecology and obstetrics are the following DRG numbers: 359-surgery on uterus and adnexa for benign illnesses and complications; 371-caesarean section without complications; 372(and 373)-vaginal delivery with (and without) complications; 381-abortion without curettage or hysterectomy; and 383(and 384)-other illnesses during pregnancy with (and without) medical complications.

3. The Models of Productivity Change

3.1 Productivity and Technical Change

Let the production function be characterized by

$$(1) \qquad Y = f(x, t)$$

where Y is output, X is a vector of J input variables, and t is a time trend variable. Taking the total differential of (1) we get

$$(2) \qquad \dot{Y} = \sum_j (f_j X_j / Y) \dot{X} + (f_t / Y)$$

where the • indicates growth rate (log derivative with respect to time) and f_j is the marginal products of the jth input variable. The relationship in (2) can be rewritten as

$$(3) \qquad \dot{Y} - \sum_j S_j \dot{X}_j = (RTS - 1) \sum_j S_j \dot{X} + (f_t / Y)$$

where $S_j = (W_j X_j / C)$ is the cost share, $C = \sum_j W_j X_j$ is the total cost, $RTS = \sum_j \partial y / \partial x_j$ is the returns to scale, W_j the input price and x and y are log of inputs and output, respectively. The left-hand side of (3) is labeled as the Divisia index of total factor productivity growth $(\dot{TFP})$, expressed as

$$(4) \qquad \dot{TFP}_{DIVX} = \dot{Y} - \sum_j S_j \dot{X}_j$$

where only information on growth rates in output and inputs and the cost shares are required for the calculation of the index. However, in practice, one might face the problem related to zero inputs and large fluctuations in the growth rates of inputs. This problem can be avoided by aggregating all inputs and considering the growth in total cost instead of the product of cost shares and the growth rates in inputs as follows

$$(5) \qquad \dot{TFP}_{DIVC} = \dot{Y} - \dot{C}$$

where

$$(6) \qquad \begin{aligned} \dot{C} &= \frac{\partial \ln C}{\partial t} = \frac{1}{C}\frac{\partial C}{\partial t} = \frac{1}{C}\left[\sum\nolimits_j W_j X_j \frac{\partial X_j}{\partial t}\frac{1}{X_j} + \sum\nolimits_j W_j X_j \frac{\partial W_j}{\partial t}\frac{1}{W_j}\right]. \\ &= \sum\nolimits_j S_j \dot{X}_j + \sum\nolimits_j S_j \dot{W}_j \end{aligned}$$

In order for equality between (4) and (5) measures to hold it is assumed that changes in factor prices, $\dot{W}_j$ are zero.

In the absence of prices, the estimation of TFP growth requires that the production function is estimated using econometric methods. The main advantage of using a parametric approach over the non-parametric approach of the Divisia index is that one can decompose TFP growth into technical change (f_t / Y) and scale $((RTS-1)\sum_j S_j \dot{X}_j)$ components as indicated in equation (3). In the calculation of various TFP growth rates we used a Törnqvist index, where instead of cost shares in period t, S_{jt}, the average of the cost shares in period t and t-1, $1/2(S_{jt} + S_{j,t-1})$ is used.

3.2 The Time Trend (TT) and General Index (GI) Models of Technical Change

Let the production function model with panel data be

(7) $$y_{it} = \beta_0 + x_{it}'\beta + u_{it}$$

where y_{it} is the log output of the producer i (i=1,2,...,N) at time t (t=1,2,...,T), x_{it} is the corresponding matrix of J inputs and β is Jx1 vector of unknown parameters to be estimated. The variables included in the x-vector vary both across producer (product of departments and their associated wards) and over time. The error term, u_{it}, is specified as

(8) $$u_{it} = \mu_i + \lambda_t + v_{it}.$$

The μ_i, λ_t and v_{it} represent producer-specific effects, time-specific effects and statistical noise, respectively. The error term, v_{it}, represents those effects which cannot be controlled by the producers, such as advantages or disadvantages in the location of the department, quality and access to labor, labor market conflicts, measurement errors in the dependent variable, and other left-out explanatory variables. It is assumed to be independently and identically normally distributed with zero mean and constant variance, σ_v^2. The producer- and time-specific effects, μ_i and λ_t, are factors representing producer efficiency and the exogenous rate of technical change, respectively. To avoid an over-parameterization of the model a Cobb-Douglas functional form is chosen and the producer specific-effects, μ_i, are replaced by two vectors of ward-specific and department-specific effects, γ_w and η_d. Thus, the production technology with a time trend representation of technical change is written as

(9) $$y_{it} = \beta_0 + \sum_j \beta_j x_{jit} + \gamma_w + \eta_d + \delta_t t + 1/2\,\delta_{tt} t^2 + v_{it}$$

where y and x are defined as previously, t (t=1,2,...,T) is a single time trend representing the exogenous rate of technical change, and the subscripts w (w=1,2,...,W) and d (d=1,2,...,D) indicate ward and departments identification numbers. The γ_w and η_d are fixed ward- and department-specific effects to be estimated.[6] In order to make the model flexible, the square term,

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[6] In order to save degrees of freedom, instead of N-1 (28-1) producer-specific intercepts, W-1 (4-1) ward-specific and D-1 (7-1) department-specific intercepts are estimated. The intercepts vary between departments and between wards which implies that the effects are restricted to be constant within a department for different wards

t^2, is added to the specification. The corresponding production function assuming a general index representation of technical change is given by

$$(10)\qquad y_{it} = \beta_0 + \sum_j \beta_j x_{jit} + \gamma_w + \eta_d + \lambda_t + v_{it}$$

where the time trend and its square terms are replaced by T-1 fixed time-specific effects, λ_t. These effects are to be estimated along with the other ward- and department-specific intercepts and slope coefficients. Technical change defined as the log derivative of output with respect to time, $(\partial y / \partial t)$, in the time trend and general index models can be expressed as

$$(11)\qquad TC_{TT} = \delta_t + \delta_{tt} t$$

and

$$(12)\qquad TC_{GI} = (\lambda_t - \lambda_{t-1}).$$

Both TC_{TT} and TC_{GI} measures consist of only pure time-specific components. Thus, they are only time-specific (not producer-specific). It is to be noted that there are some restrictions built in on the nature of technical change in the TT model. First, the rate of technical change either increases ($\delta_{tt} > 0$) or decreases ($\delta_{tt} < 0$) linearly as a function of time. Second, in the case with a relatively short panel, a time trend model might not be an appropriate representation of the exogenous rate of technical change. Both of these problems are avoided in the GI model by estimating one parameter specific to each time period. It is possible to test hypotheses of no technical change as: $\delta_t = \delta_{tt} = 0$ in the time trend model, and λ_t is equal to a constant for all t in the general index model. Total factor productivity growth in the TT model can be calculated from

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specific and D-1 (7-1) department-specific intercepts are estimated. The intercepts vary between departments and between wards which implies that the effects are restricted to be constant within a department for different wards or between departments for same ward.

(13) $$\dot{TFP}_{TT} = TC_{TT} + (RTS_{TT} - 1)\sum_j \beta_j \dot{x}_j \, .$$

The coefficients of the log linear production functions have a direct interpretation. The β_j parameters are the log derivatives of output with respect to the inputs, $(\partial y / \partial x_j)$. They are defined as input elasticities, which are measures of the percentage responsiveness of output to a one percent increase in respective inputs. The $\dot{x}_j$ are growth in the input use. Returns to scale is calculated as the sum of the input elasticities, $RTS = \sum_j \beta_j$. If RTS is greater than (equal to or less than) one, then there are increasing (constant or decreasing) returns to scale. Similarly, TFP growth in the GI model can be expressed as

(14) $$\dot{TFP}_{GI} = TC_{GI} + (RTS_{GI} - 1)\sum_j \beta_j \dot{x}_j \, .$$

The TFP growth and TC measures differ only by the RTS. If the technology exhibits constant returns to scale, then the two measures are identical. Although the RTS is a constant (time- and producer-invariant) and TC measures are time-specific, the TFP growth rates are changing both over time and producers. Different growth rates in the input use are the sources of variations in both dimensions.

3.3 The Extended Time Trend Model (ETT)

In the time trend model, technical change is only time-specific and some restrictions are imposed on the temporal pattern of technical change among departments. The temporal pattern is the same for all departments. This restriction can be removed by specifying technical change in a much more flexible manner. Using the model proposed by Cornwell, Schmidt and Sickles (1990) the extended time trend model, hereafter referred to as ETT, can be specified as

(15) $$y_{it} = \alpha_{dt} + \sum_j \beta_j x_{jit} + \gamma_w + v_{it}$$

where α_{dt} are department- and time-specific intercepts. Cornwell, Schmidt and Sickles allowed the department-specific effects to vary over time by replacing the α_{dt} by a parametric function of time. The model for the intercepts is given by

(16) $\alpha_{dt} = \eta_{1d} + \eta_{2d} t + 1/2 \eta_{3d} t^2$

where η_{1d}, η_{2d} and η_{3d} are unknown parameters. Thus α_{dt} is a quadratic function of time and it varies across departments. No assumption other than this specification is involved here. The temporal pattern of α_{dt} is quite flexible. The parameters of the production function, β, can be estimated by least squares, within, generalized least squares, Hausman and Taylor instrumental variable estimators or maximum likelihood methods. For this model, the technical change is expressed as

(17) $TC_{ETT} = \eta_{2d} + \eta_{3d} t$.

Thus, TC is department-specific and it also changes over time. The restriction placed on the patterns of technical change is that the temporal pattern is the same among departments but the level is department-specific. This generalization introduces substantial increase in the number of parameters because η_{1d}, η_{2d} and η_{3d} are department-specific. Again, the hypothesis of no technical change in the above model can be tested as: $\eta_{2d} = \eta_{3d} = 0$. Total factor productivity growth in the extended time trend model can be obtained from

(18) $\dot{TFP}_{ETT} = TC_{ETT} + (RTS_{ETT} - 1)\sum_j \beta_j \dot{X}_j$.

3.4 The Extended General Index Model (EGI)

Under the specification of the general index, technical change, TC_{GI}, varies over time, but it is the same for all departments. This undesirable feature of constant rate of technical change across departments can be eliminated by the extension of the GI model in such a way that the rate is department-specific although one uses a simple functional form to represent the underlying technology. Using the Lee and Schmidt (1993) model, the intercept parameters in equation (15) can be specified as[7]

$$\alpha_{dt} = \eta_d \lambda_t \tag{19}$$

where η_d and λ_t are unknown parameters to be estimated.[8] The rate of technical change in this model, hereafter denoted as EGI, can be written as

$$TC_{EGI} = \eta_d \{\lambda_t - \lambda_{t-1}\} \tag{20}$$

where η_d are department-specific effects. Thus, two departments with same values of output and inputs will exhibit different rates of technical change provided that the η_d parameters are not identical. Unlike the ETT model, no functional form is assumed here, but again the temporal pattern of TC (not the magnitude) is assumed to be the same for all departments. This assumption might be useful and reasonable when the number of periods (T) are small. For identification purposes, λ_t is normalized by allowing $\lambda_1 = 1$. The model is non-linear and allows for the inclusion of variables that are time- or department-invariant in the specification.

Depending on the type of assumptions made regarding the correlation between the effects and the explanatory variables, the parameters $\beta, \lambda_t, \sigma_v^2$ and η_d are then to be estimated in either a fixed-effects model or in a random-effects model where instead of η_d the variance, σ_η^2 is

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[7] Another extension of the time trend model to make the rate technical change producer-specific was introduced by Stevenson (1980). This model is a truncated third order approximation of an unknown production function in which only the third order interaction terms with the time variable is used. The number of estimated additional parameters is less than in the Cornwell, Schmidt and Sickles (1990) model. We have not applied this model because it is specified for a flexible functional form. Thus, we avoid this extension in the current case and use a CD function. For another application of the Stevenson model, see Kumbhakar, Heshmati and Hjalmarsson (1997).

[8] Cornwell, Schmidt and Sickles (1990) and Lee and Schmidt (1993) both used these forms of producer- and time-varying intercepts, $\alpha_{it} = \mu_{1i} + \mu_{2i} t + ½ \mu_{3i} t^2$ and $\alpha_{it} = \mu_i \lambda_t$, to model producer-level technical inefficiency in production. Kumbhakar, Heshmati and Hjalmarsson (1997) applied these models in the context of estimation of technical changes. Due to the limited number of observations in the current case, the intercepts (15) and (18), α_{it}, are restricted to be time- and department-specific.

estimated. In a fixed-effects model, the number of parameters, η_d, depends on the department sample size resulting in the large number of parameters to be estimated.

The present model is much more flexible than the GI model so far as specification of technical change is concerned. The model is highly non-linear but it does not have any additional parameters. It is to be noted that the GI model accommodates department-specific parameters via the error term. The error term is assumed to follow a two-way error component model, i.e., the fixed department specific-effects appear in an additive form. Furthermore, technical change is department-specific, although a Cobb-Douglas production technology is used. Thus, the EGI model is suitable for measuring inter-department and inter-temporal technical changes, even when technical change is neutral. If $\eta_d = 1$ for all d, then the present model reduces to the standard GI model. Such a hypothesis is statistically testable. The TFP growth in the extended GI model can be obtained as

$$(21) \qquad \dot{TFP}_{EGI} = TC_{EGI} + (RTS_{EGI} - 1)\sum_j \beta_j \dot{X}_j .$$

4. Estimation Methods

In panel data literature, the estimation of the model in (7) and (8) has been developed in two directions. First, the fixed effects (FE) model, where μ_i and λ_t are assumed to be fixed and correlated with the explanatory variables. Second, the random effects (RE) model, where μ_i is assumed to be random and not correlated with the explanatory variables.[9] Efficiency, unbiasedness and consistency are properties affecting the choice of FE or RE treatment of the μ_i and λ_t effects. In this study, we use both types of model specifications.[10] The time effects, λ_t, are replaced either with time dummies or a time trend. In a homoscedastic RE model, the number of parameters associated with μ_i is reduced to only two, the mean and variance, σ^2_μ, and in the heteroscedastic RE case, at most N variances, $\sigma^2_{\mu_i}$, to be estimated, depending on the source of heteroscedasticity. One of the advantages of a RE model is that time invariant regressors can be included in the model specification. The desirable feature of the FE model is, on the other hand, inclusion of department- and time-specific effects in the production function to capture unobservable effects, such as managerial differences and policy changes.

The modeling of heteroscedasticity may differ according to the way the producer-specific variances are defined and also by whether heteroscedasticity is of specified or unspecified form. In the latter case, one alternative is to estimate one producer-specific variance for each producer. Treating μ_i and v_{it} as random and using the Baltagi and Griffin (1988b) approach, the following distributional assumptions on the heteroscedastic error components are imposed: (i) $\mu_i \sim i.i.d.\, N(0, \sigma^2_{\mu_i})$, (ii) $v_{it} \sim i.i.d.\, N(0, \sigma^2_v)$, (iii) μ_i and v_{it} are independent of each other and of the explanatory variables. Given the above distributional assumptions and stacking the time-series observations for the ith producer, the variance-covariance matrix for u_i ($u_i = \mu_i + v_{it}$) is

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[9] For reviews of various approaches to the estimation of error component models, see Baltagi (1995) and Hsiao (1986).

[10] The subscript i in the RE models indicate producer number, while it indicates department number in the FE models. This was motivated by the fact that we have only 4 time-series observations on each producer unit.

(22) $\Omega_i = E(u_i^{'} u_i) = \sigma^2_{\mu_i} J_T + \sigma^2_{v} I_T$

where Ω is a block diagonal matrix, J_T is a $T_i \times T_i$ matrix with all elements equal to one; and I_T is an identity matrix of order T_i. The inverse of Ω_i is

(23) $\Omega_i^{-1} = (1/\sigma^2_{v})\left[I_T - (\sigma^2_{\mu_i} / (T_i \sigma^2_{\mu_i} + \sigma^2_{v}))J_T\right].$

The GLS estimates of β are equivalent to the least square estimates when the following transformations are applied to the data

(24) $y^*_{it} = y_{it} - \theta_i \bar{y}_i$ *and* $x^*_{it} = x_{it} - \theta_i \bar{x}_i$

where $\bar{y}_i = \sum_t y_{it} / T_i, \bar{x}_i = \sum_t x_{it} / T_i$ *and* $\theta_i = \left[1 - \sqrt{(\sigma^2_{v} / T_i \sigma^2_{\mu_i} + \sigma^2_{v})}\right]$. The model in vector form is rewritten as

(25) $y^*_i = \beta^*_0 + x^{*'}_i \beta + \gamma^*_w + u^*_i$.

The variance components, $\sigma^2_{\mu_i}$ and σ^2_{v}, are unknown and have to be estimated. A multi-step GLS estimation procedure is used. First, consistent estimates of the variance components are obtained. Second, the estimated variance components are used to transform the data and ordinary least squares regression is applied to the transformed data. The overall estimation procedure has the following steps:

(i) regress the within mean transformed $y^w_{it} = y_{it} - \bar{y}_i$ on the within transformed $x^w_{it} = x_{it} - \bar{x}_i$ to get the within parameter estimates and the mean squared error which are unbiased and consistent estimates of the variance, σ^2_{v},

(ii) ignore the department-specific effects and regress the y_{it} on the x_{it} variables without any transformation to obtain the OLS residuals, u_{it}, and estimate $\operatorname{var}(u_{it}) = \zeta_i^2 = \sigma_{\mu_i}^2 + \sigma_v^2$,

(iii) estimates of the producer-specific variance, $\sigma_{\mu_i}^2$, and the total variance, $\sigma_{u_i}^2$, are obtained as $\sigma_{\mu_i}^2 = \zeta_i^2 - \sigma_v^2$ and $\sigma_{u_i}^2 = T_i\sigma_{\mu_i}^2 + \sigma_v^2$ using steps (i) and (ii), and then calculate the transformation factor, θ_i, for each producer. If θ_i for a producer is found to be negative, it is replaced by zero,

(iv) given the $\theta_i s$, transform the y and x variables as in (24) and regress y_{it}^* on $(1-\theta_i)$ and x_{it}^* by using OLS to get GLS estimates of the parameters of the model. If $\theta_i = 0$ for some producers, the estimator collapses to the OLS estimator and if $\theta_i = 1$, it collapses to the within estimator. In GLS, θ_i is within the interval 0 and 1. In the homoscedastic GLS case, $\sigma_{\mu_i}^2 = \sigma_\mu^2$, $\sigma_{u_i}^2 = \sigma_u^2$, and $\theta_i = \theta$ for all i.

A number of hypotheses regarding the producer-specific variance component can be performed as follows: (i) no producer-specific variance component, (ii) homoscedastic variance component, (iii) an RE or an FE treatment of the producer-specific error component, using Chow, Breusch and Pagan, Barlett and Hausman tests statistics.

5. Empirical Results

5.1 Specification Tests

The four model specifications (Time Trend, General Index, Extended Time Trend and Extended General Index) presented above are used to estimate productivity growth of seven Swedish departments of gynecology and obstetrics observed during 1993-1995. The general index model is estimated using the OLS, Within, and the GLS methods, the latter by assuming both homoscedastic and heteroscedastic variances. The extended general index (EGI) is non-linear and estimated using a non-linear iterative procedure. Thus, seven parametric models are estimated by accounting for the rate of technical change. The Cobb-Douglas production function is used to represent the production technology in all specifications. With the exceptions of the two GLS models, the remaining models are estimated using a fixed effects model. The estimates of the parameters of the models are given in Table 3.

One could expect multicollinearity among the inputs (explanatory) variables to be a problem. The higher the correlation among the regressors, the less precise are the estimates. Most of the data sets exhibit some degree of multicollinearity. A simple measure of its degree can be obtained by regression of an input variable on the remaining input variables. The R^2 obtained can be taken as a measure of the degree of multicollinearity. The R^2 values obtained were as follows: doctors (0.49), nurses (0.92), others (0.90), material (0.95), rent (0.95), services (0.51) and administration (0.95). The R^2 values close to unity indicate that the degree of multicollinearity is high.

The R^2 values are quite high in all models, 0.37 in Within, 0.72 in the homoscedastic GLS, 0.99 in heteroscedastic GLS, and 0.93 in the OLS, TT, EGI and ETT models, respectively. The RMSE is 0.16 in the Within, 0.21 in the homoscedastic GLS, 0.29 in the heteroscedastic GLS and 0.37-0.38 in the remaining models. Although, a large number of parameters are estimated in the ETT model, the RMSE is not reduced compared with the TT model. In general the heteroscedastic GLS model fits to the data best. In all model specifications the null hypothesis of constant returns to scale was rejected in the favor of variable returns to scale.

The parameter estimates are mostly insignificant (heteroscedastic model being excepted) and vary by the size and, in some cases, even by sign among the models. The coefficients associated with administration and other are insignificant in all models. The ward dummies are highly significant, and all of the seven department dummy variables are significant at less than the 10% level of significance. The coefficients of time and time squared are not significantly different from zero. Most of the time dummy variables are highly significant in all model specifications. Only five of the department-specific coefficients in the ETT model are significant at any reasonable levels of significance. The statistically insignificant parameters are retained for model comparisons and for maintaining flexibility of the production function. Various Chow tests on the inclusion of the set of ward, department and time dummy variables indicate that these should be included in the model specifications. For details on these specification test results see Table 9.

A critical assumption in the error component model is that $E(u_{it} | x_{it}) = 0$. The producer-specific effects might be correlated with x_{it}. In this case, the GLS estimator, β_{GLS} becomes biased and inconsistent but the within estimator β_{WHN} is unbiased and consistent. At the absence of correlation the GLS is preferred since in addition to being consistent it is also asymptotically efficient. The Hausman test-statistic is given by

$$(26) \qquad m_h = q_h' \left[\operatorname{var}(q_h)\right]^{-1} q_h \quad h = 1, 2$$

where $q_1 = (\beta_{GLS} - \beta_{WHN})$, $q_2 = (\beta_{GLS} - \beta_{OLS})$, $\operatorname{var}(q_1) = \operatorname{var}(\beta_{WHN}) - \operatorname{var}(\beta_{GLS})$ and $\operatorname{var}(q_2) = \operatorname{var}(\beta_{OLS}) - \operatorname{var}(\beta_{GLS})$. Under the H_0, m is asymptotically distributed as χ_k^2, where k denotes the dimension of slope vector β. The resulting test-statistics are given in Table 9. The null hypothesis of no correlation between producer-specific effects and explanatory variables is rejected when testing OLS vs $\mathrm{GLS}_{\mathrm{HOM}}$ and $\mathrm{GLS}_{\mathrm{HET}}$ and Within vs $\mathrm{GLS}_{\mathrm{HET}}$, while it is accepted when Within vs $\mathrm{GLS}_{\mathrm{HOM}}$ is considered.

The heteroscedastic variances are presented in Table 4. The heteroscedasticity is based on the producer-specific effects. Thus, one important feature of this study is the introduction of producer heterogeneity into the production function. As mentioned earlier the approach used to estimate the variance components may result in negative variances. An inspection of the frequency of negative variances showed that 5 out of 28 variances were found to be negative and replaced with zeros. Four of these variances are related to the ward No. 1, i.e. institutional care.[11] Application of Barlett's test (see Kmenta 1986, p. 297), hereafter referred to as BT,

$$(27) \qquad BT = \left\{ \frac{-4.60517 \log M}{1 + N^*} \right\} \sim \chi^2_{n-1}$$

where

$$\log M = \left\{ \frac{\sum_i (T_i - 1)}{2} \log \sigma^2_{\mu_i} \right\} - \left(\frac{NT_i - N}{2} \right) \log \left\{ \frac{\sum_i (T_i - 1)\sigma^2_{\mu_i}}{NT_i - N} \right\}$$

$$N^* = \frac{\sum_i (1/T_i) - (1/NT_i)}{3(N-1)}$$

for testing the null hypothesis of homoscedasticity yields the value of the test-statistics of 278.21, which exceeds the critical value of 46.96, for the χ^2 with 27 degrees of freedom. This implies that we reject the null hypothesis of homoscedasticity at the 1% level of significance. The producer-specific variances, $\sigma^2_{\mu_i}$, are estimated to vary from 0.002 to 0.346 (excluding those with zero values), with an overall sample mean of 0.096 and standard deviation of 0.107. The heteroscedastic variance as expected is much higher for the department No.4 and the emergency wards, compared with the other specialization. The common error variance, σ^2_v, is estimated to be 0.024. The total variance, $\sigma^2_{u_i}$, is estimated to range in the interval, 0.024 and 1.407. The corresponding sample mean and standard deviations are 0.397 and 0.420. Producer-specific variance makes the transformation parameter, θ_i, also producer-specific, ranging from zero to 0.871. The $\sigma^2_{\mu_i}$ and σ^2_v variance components obtained using a homscedatsic GLS model are very close to the corresponding values obtained from the heteroscedastic GLS model. However, the

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[11] In order to reduce the occurrence of negative variances, instead of estimating one variance for each producer, we estimated only department-specific variances (constant variances for wards within a department). The variance of department No.1 was found to be negative. Thus, the final GLS estimate is based on the producer-specific heteroscedastic variances.

σ_u^2 and the θ transformation parameters differ somewhat among the models.

5.2 Input Elasticities and Returns to Scale

The coefficients of the CD production functions have a direct interpretation as the elasticities of output with respect to each of the inputs. The estimate of returns to scale, RTS, is calculated from the sum of the input elasticities, $RTS = \sum_j \beta_j$. In Tables 3 and 7, the input elasticities and RTS from different model specifications are reported. The input elasticities and RTS measures are constant both over time and across departments. As mentioned above, the input elasticities do not always have the expected signs (positive marginal contribution to the production of DRG points). However, in some cases the signs are negative and/or insignificant. In general the input elasticities differ considerably across models but are mostly of reasonable sizes.

In most of the models, material is found to have negative and insignificant marginal effect. The largest input elasticity was that for the service input (0.53-0.64). The cost share of service input is on average 41%, with a large standard deviation (19%) among the sample departments. The other large input elasticities are associated with doctors (0.07-0.13) and nurses (0.08-0.17).[12] The smallest elasticities are related to the other staff members and administration. These values reflect the relative importance of services (high service-use intensity), doctors and nurses and the relative unimportance of administration and other staff members. The relative low rent (capital) elasticity may reflect that output is not constrained by capacity shortage.

The value of the elasticity of scale (RTS) is, in all models, below 1.0, suggesting that the current sample of gynecology and obstetrics departments has been facing a technology with decreasing returns to scale (see Table 7). On average, gynecological departments are found to be above the minimum efficient size or are of sub-optimal size. The RTS depending on the model specification varies in the interval, 0.70 to 0.92. It is very low in the homoscedastic GLS (0.18) and zero in the Within models. These two models did not perform as well as expected. Due to the restricted model specification no variations are observed when looking at individual department's efficient size or technically optimal scale level. A priori, one should not expect

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[12] Within and homoscedastic GLS models are not accounted for. Due to the short time period and the relatively small within (over time) variations in the dependent and the independent variables, the Within model does not perform well.

increasing returns to scale in the types of health care services considered here which are also confirmed by the results. The heteroscedastic GLS model shows perhaps the most reasonable RTS value of 0.80.

5.3 Technical Change

The rate of technical change in the Within model is constant across wards and departments. Technical change varies both over time and across wards in the remaining six models. However, it also varies across departments in the extended models referred as the ETT and EGI models. The mean estimates of technical change are given in Table 7.

The rate of technical change in all models is negative, indicating technical regress. Although, we have only four years of observations, it is found to be decreasing over time. The average rate of technical regress varies among the alternative model specifications, within the interval 0.5 to 17 percent per year during the period of this study. In the ETT and EGI models the rate is department-specific. Large variations among the sample departments are observed. The mean rate of change varies in the interval 0% to -21% and -0.76% to +48%, respectively. The main reason for the negative rate of technical progress is the decline in the fertility rate and lag adjustment process combined with maintained high capacity during this period (see Table 10).

The decline in the birth rate in Sweden was 16.6% during 1990 to 1995. The corresponding rate for the County of Stockholm was much lower (10.7). The number of beds (26.6%), admissions (13.2%), total bed days produced (24.0%), induced abortions (16.1%), total employment by health care (18.4%) and the average length of stay (0.6 days) has decreased, while number of visits to doctors (8.6%) and the occupancy rate (2.5%) has increased. The numbers in parentheses are the percent changes in respective variable from 1990 to 1995.

The nature of service (being partially emergency) requires high capacity to be available at any time, resulting in very low or negative productivity growth rate. The models generate somewhat unexpected results considering the rate and patterns of technical changes. The results obtained from models with various degrees of flexibility are however consistent with each other. Unfortunately, the low number of observations did not allow for incorporation of non-neutral components of technical change in the models. Thus, we find the GLS_{HET}, ETT and EGI models as the most satisfactory candidates.

5.4 Total Factor Productivity Growth

The single factor productivity (FP), a measure of produced output per unit of input, was calculated for each individual input and positive observation. A summary of statistics of the FP measures is given in Table 1. The FP values are measured in the DRG point produced per 1000 SEK. The FP values are inversely related to their shares of the total cost. The mean DRG point per total cost is 0.05 (0.02) and varies in the interval 0.02 and 0.15. The smallest FP measure is related to services and the largest one to material input. Large variations in the main factor productivity of doctors, nurses and services are found. Most parts of the variation might be explained by extreme values caused by unit measurement errors in the data.

The mean single factor productivity by department, ward and years is presented in Table 5. Department No. 4 and day surgery are found be least productive in terms of DRG per total expenditure while department No. 2 and other wards are the most productive ones. The productivity is declining over time. No systematic patterns in the levels of individual factor productivities over time and by department or wards can be distinguished.

A better measure of factor productivity can be obtained from the inverse of FP. It is interpreted as the factor requirement measured in 1000 SEK for production of a unit of output. The mean values by year, department and wards are given in Table 5. The total cost per DRG points produced varies in the interval 6720 to 59120 SEK. The sample mean is 22900 SEK, with standard deviation 9300 SEK. In principle, the variations should be very small since the DRG points are based on the resource intensity/requirement. The large variations are explained by the types of diagnosis of the individual patients and also by the unit cost differences attributed to the departments. We observe large variations in the intensity of different factor inputs. The largest standard deviations are found in doctors 4520 (4390), nurses 5600 (2910) and services purchased 9780 (7290), where all values are given in SEK. The aggregate unit cost is only 19500 for department No.2 compared to 30580 for department No.4. In similarity with the between department variation, the between ward variations are quite high. The unit cost was constant during 1993/94. It increases during the following two years by 34%.

Table 6 contains a correlation matrix over various factor input productivities. The aggregate factor productivity, DRG per total cost, is negatively correlated with the time variable and is significant. Doctors, others, administration and services show a negative development in factor productivity over time. The latter is found to be insignificant. A positive but insignificant correlation with time is found considering the material, rent and nurses. The correlation coefficients between the aggregate factor productivity and individual inputs are all positive and highly significant. A positive and significant association between productivity of others and administration and remainder factor productivity measures is found. The estimated correlation coefficient between doctors and nurses is negative but insignificant. The correlation coefficient between administration, nurses and rent, doctors and others are relatively large, positive and significant at the 1% level of significance. Looking at the correlation coefficients based on unit cost measures show that these results imply that the administration and nurses increased rents over the years involved, while doctors increased the expenses related to services and other costs.

The rate of total factor productivity growth was estimated for all parametric models, as indicated in the equation (13), (14), (18) and (21). The non-parametric Divisia indexes were also calculated by using equation (4) and (5). The mean rate of TFP growth by department, ward and year is shown in Figure 1 and also in Table 7.[13]

A general impression is that there is substantial covariation among the models when mean values are considered. Although the level differences over time are substantial. The models mean values range from -9% to -15% in 1993/4, -15% to -27% in 1994/5 and 10% to 25% in 1995/6. The pattern is very much similar to that of the technical change component. The models overall means are between -8% and –16%. Technical change is the main contributor to the rate of TFP growth.

As regards the department-specific TFP growth, all four wards have a negative value in all models. Emergencies shows a lower negative TFP growth rate than the remaining three wards in all other model specifications. The levels and the distributions of mean values of the growth rate differ by model specification. Considering the mean TFP values by departments, we observe negative growth rate in all departments and models. Again, the levels differ by model specifications and departments. The highest variations are found in the ETT model. The range is between 16% and -83%. When looking at TFP growth rates of individual wards, the range of

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[13] The rate of TFP growth for individual producers and any other results not reported here can be obtained from the author upon request.

variation is again high. In general, all models produce a positive lower rate of TFP growth for ward No.3 located at the department No.6.

The TFP growth rates calculated using the non-parametric Divisia index, differ both by patterns as well as the levels compared with the parametric models. The overall mean TFP growth rates using the changes in individual inputs is estimated to be -14%, while the overall mean using changes in an aggregate of input costs is -13%. Again we observe a higher rate of regress in 1995/6, compared with 1994/5. The range of TFP growth rate varies substantially among the sample producers. Department No. 6 is the most productive department among the sample departments. Day surgery is found to be the least productive ward across the departments.

The rank correlation of TFP growth rates among the seven parametric models and the two non-parametric indexes mentioned above are presented in Table 8. The TFP growth rate obtained using the Within model is found to be negatively correlated with all other models, the homoscedastic GLS model being excepted. All other pairs of cases are positively correlated. In general, the lowest and insignificant values of correlation coefficients are found to be associated with the Within model. The highest correlations are found among the OLS, GLS, TT and EGI models, respectively. The coefficients are reasonable, highly significant and within the interval 0.76 to 0.96. The correlation coefficient between the non-parametric models is 0.93 and significant. However, the correlation coefficients between parametric and non-parametric models are significant, but are much lower being about 0.33-0.63.

6. Summary and Conclusions

The growth of public spending and the need to assess its impact on the welfare system and fiscal management has made the studies of productivity in the public sector an important issue. Previous studies on the measurements and development of productivity in the public sector in Sweden during the period 1960-1990 showed a negative aggregate productivity growth but at a decreasing rate. The development of productivity in the health care sector was also fund to be negative.

In recent years, the public sector in general, and the health care sector in particular, have been allocated relatively less resources as a consequence of the economic recession in Sweden. Increased productivity is regarded as a solution to the structural budget deficit problem of the government sector. Despite declines in the share of health care expenditures, there is a desire to maintain a high capacity in terms of bed occupancy in hospitals and the provision of health care services with improved quality and also to satisfy the increased demands for services by using the reduced resources available. The expected outcome is an improvement in resource utilization, primarily through the increased productivity of doctors and nurses, together with a higher bed occupancy rate.

In this paper we consider the specification and estimation of productivity growth and technical change using panel data from a small segment of Swedish heal care namely gynecology and obstetrics. Several parametric and non-parametric competing models are used to examine robustness of results. The models include the time trend model, the more flexible general index model, and some extensions of the time trend and the general index models to incorporate department-specific rate of technical change. Thus, time is used to represent shifts (productivity changes) in the production function over time.

The general index model specification was further estimated using different assumptions regarding the structure of the model's error components and estimated using different estimation methods. A total of seven parametric models are estimated. Total factor productivity (TFP) growth is also calculated using two non-parametric Divisia indexes. The parametric models differ by the specification and estimation of the rate of technical change, and also by the way department-specific effects are treated. We applied each of them to estimate the TFP growth rate of seven Swedish departments of gynecology and obstetrics, observed during the period, 1993-1996. The objective was to see whether there are any differences in the productivity growth estimates derived from these alternative models. The underlying production technology was in all model specifications represented by the Cobb-Douglas functional form.

From an empirical point of view the Ordinary Least Squares, heteroscedastic Generalize Least Squares, Time Trend and Extended General Index models produce somewhat similar results when mean levels of technical change, TFP growth rates as well as the returns to scale measures are considered.

Empirical results show: (i) large and negative rates of technical progress, (ii) decreasing returns to scale, indicating inoptimality of the efficient scale among the sample departments, (iii) large and negative rate of TFP growth, (iv) substantial variations in the exogenous rate of technical change and TFP growth among departments, wards and over time, (v) a high covariation between the models as regards to total factor productivity growth, and (vi) large differences among some of the models, so far as technical change and productivity growth are concerned. The differences stem from the differences in the way department- and time-specific effects are accounted for in the models. Among factors causing the large negative TFP growth rate are: decline in the birth rate, reduced length of stay, changes in the distribution of services provided among the gynecological departments and the regular health care centers. A decomposition of the total growth rate into the underlying factors is not possible.

Future research should emphasize the issues of improvements on the specification of the above models in analyzing the gynecological health care services. The improvements should account for quality variables, in addition to incorporating new input variables. The output and input measures should be adjusted for quality differences by using various input and output quality indicators. The adjusted and unadjusted measures can then be compared to quantify significance of quality of services to be accounted for in the prospective payment system. The new information should contain prices as well as production characteristics at the department levels as well as for groups of patients. A further disaggregation into gynecology and obstetrics observed during several time periods is desirable to improve the stability of the parameter estimates. To our knowledge, this paper is the first attempt to analyze gynecological data in Sweden from an economics and productivity perspective and it shows that it is encouraging to continue along this line.

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Table 1 Summary statistics on departments of gynecology and obstetrics in Stockholm County, 1993-1996, in 1996 prices.

Variable	Mean	Std dev.	Minimum	Maximum
Output and inputs(Y, X):				
DRG points (Y_{DRG})	1498.37	1927.00	42.00	7022.00
Doctors (X_D)	3390.51	3317.66	0.00	16349.00
Nurses (X_N)	10234.01	15625.40	0.00	60849.00
Others (X_O)	1198.94	1822.96	0.00	12438.52
Material (X_M)	1555.58	2184.45	0.00	9873.11
Rent (X_R)	2161.00	2734.04	0.00	11994.72
Services (X_S)	9624.17	11460.39	26.99	49897.00
Administration (X_A)	2165.16	3036.80	0.00	13683.00
Total cost and cost shares (C, S_j):				
Total cost (TC)	30328.30	38462.46	836.00	158593.00
Doctors (S_D)	0.18	0.13	0.03	0.64
Nurses (S_N)	0.21	0.14	0.00	0.44
Others (S_O)	0.03	0.03	0.00	0.14
Material (S_M)	0.04	0.04	0.00	0.27
Rent (S_R)	0.06	0.06	0.00	0.27
Services (S_S)	0.41	0.19	0.09	0.90
Administration (S_A)	0.05	0.04	0.00	0.16
Percent annual changes $(X_t-X_{t-1})/X_{t-1})$:				
DRG (ΔDRG)	-0.11	0.22	-0.68	0.56
Total cost (ΔC)	0.02	0.27	-0.68	0.80
Doctors (ΔD)	0.06	0.35	-0.77	1.42
Nurses (ΔN)	0.00	0.39	-1.41	1.56
Others (ΔO)	0.08	0.47	-1.48	1.93
Material (ΔM)	-0.11	0.58	-2.00	1.52
Rent (ΔR)	0.02	0.48	-2.00	2.00
Services (ΔS)	0.07	0.49	-2.00	2.00
Administration (ΔA)	0.03	0.63	-2.00	2.00
Factor productivity FP=(DRG point/X):				
Total cost (FP_C)	0.05	0.02	0.02	0.15
Doctors (FP_D)	0.42	0.32	0.04	1.59
Nurses (FP_N)	0.31	0.44	0.07	3.19
Others (FP_O)	1.59	1.08	0.33	7.22
Material (FP_M)	1.96	3.79	0.17	30.08
Rent (FP_R)	1.05	1.87	0.13	16.20
Services (FP_S)	0.16	0.16	0.02	1.56
Administration (FP_A)	1.25	2.09	0.18	14.91

Total number of observations is 108. All input values and total cost are expressed in 1000 SEK and are transformed to 1996 prices.

Table 2 Correlation matrix of outputs and inputs.

	Year	DRG	Doctors	Nurses	Others	Material	Rent	Services	Administration
Year	1.00 (0.00)								
DRG	-0.06 (0.56)	1.00 (0.00)							
Doctors	0.07 (0.47)	0.86 (0.00)	1.00 (0.00)						
Nurses	0.02 (0.86)	0.98 (0.00)	0.85 (0.00)	1.00 (0.00)					
Others	-0.01 (0.90)	0.81 (0.00)	0.81 (0.00)	0.80 (0.00)	1.00 (0.00)				
Material	-0.13 (0.18)	0.90 (0.00)	0.79 (0.00)	0.88 (0.00)	0.82 (0.00)	1.00 (0.00)			
Rent	-0.04 (0.69)	0.95 (0.00)	0.84 (0.00)	0.94 (0.00)	0.80 (0.00)	0.89 (0.00)	1.00 (0.00)		
Services	0.07 (0.48)	0.96 (0.00)	0.86 (0.00)	0.96 (0.00)	0.76 (0.00)	0.83 (0.00)	0.91 (0.00)	1.00 (0.00)	
Administ.	0.03 (0.74)	0.87 (0.00)	0.81 (0.00)	0.88 (0.00)	0.68 (0.00)	0.79 (0.00)	0.83 (0.00)	0.86 (0.00)	1.00 (0.00)

The values in brackets under the estimated correlation coefficients are p-values, associated with the null hypothesis that the true correlation coefficient is zero.

Table 3 Parameter estimates (n=108).

Parameter	OLS	Within	GLS_{HOM}	GLS_{HET}	TT	EGI	ETT
β_0	1.450^a	.	1.791^a	0.589^a	1.597^b	.	.
β_{DOC}	0.072	0.005	0.026	0.116^a	0.071	0.121^a	0.129^a
β_{NUR}	0.079^c	0.044	0.021	0.095^b	0.080^c	0.138^a	0.168^a
β_{OTH}	-0.016	0.018	0.001	-0.010	-0.016	-0.040	-0.070
β_{MAT}	0.006	-0.100^a	-0.007^c	-0.083^c	0.005	-0.067	-0.084
β_{REN}	-0.026	0.039	0.061	0.102^b	-0.027	0.048	0.047
β_{SER}	0.527^a	-0.005	0.112^b	0.530^a	0.529^a	0.639^a	0.639^a
β_{ADM}	0.060	-0.002	0.032	0.046	0.061	0.076	0.085
$\gamma_{\text{day-surgery}}$	-0.734^a	.	-0.479^a	-0.390^a	-0.734^a	.	.
$\gamma_{\text{emergencies}}$	-1.033^a	.	-0.649^a	-0.385^a	-1.033^a	.	.
γ_{others}	-0.450^a	.	-0.328^a	-0.365^a	-0.447^a	.	.
λ_{1993}	.	0.179^a	.	.	.	1.000	.
λ_{1994}	-0.099	0.061^c	-0.105^c	-0.098	.	1.115^a	.
λ_{1995}	-0.269^a	-0.095^a	-0.282^a	-0.306^a	.	1.388^a	.
λ_{1996}	-0.407^a	-0.170^a	-0.374^a	-0.457^a	.	1.610^a	.
δ_t	.	.	.	.	-0.090	.	.
δ_{tt}	.	.	.	.	-0.010	.	.
η_{11}	.	.	.	.	.	-0.710^c	-1.686^a
η_{12}	.	.	.	.	.	-0.720^b	0.114
η_{13}	.	.	.	.	.	-0.708^b	-0.644
η_{14}	.	.	.	.	.	-1.014^a	-1.108^c
η_{15}	.	.	.	.	.	-0.839^a	-1.434^c
η_{16}	.	.	.	.	.	-0.646^b	-0.548
η_{17}	.	.	.	.	.	-0.664^c	-0.510
η_{21}	.	.	.	.	.	.	0.871^c
η_{22}	.	.	.	.	.	.	-0.684
η_{23}	.	.	.	.	.	.	-0.158
η_{24}	.	.	.	.	.	.	-0.096
η_{25}	.	.	.	.	.	.	0.821
η_{26}	.	.	.	.	.	.	-0.153
η_{27}	.	.	.	.	.	.	0.042
η_{31}	.	.	.	.	.	.	-0.193^b
η_{32}	.	.	.	.	.	.	0.087
η_{33}	.	.	.	.	.	.	0.012
η_{34}	.	.	.	.	.	.	-0.003
η_{35}	.	.	.	.	.	.	-0.263
η_{36}	.	.	.	.	.	.	0.005
η_{37}	.	.	.	.	.	.	-0.061
F-value	104.416^a	6.743^a	22.160^a	682.122^a	114.186^a	.	.
R^2	0.926	0.369	0.720	0.988	0.927	0.926	0.927
RMSE	0.368	0.162	0.206	0.295	0.366	0.369	0.367
Iterations	1	1	1	1	1	21	1

The two GLS models above are the general index (GI) models of technical change assuming homoscedastic and heteroscedastic variances. The superscripts a, b and c indicate statistical significance at <1%, 1-5% and 5-10% levels.

Table 4 Heteroscedastic variance components.

IDNR	θ_i	$\sigma^2_{\mu i}$	σ^2_v	σ^2_{ui}
11	0.0000	0.0000	0.0236	0.0236
12	0.7217	0.0702	0.0236	0.3044
13	0.7476	0.0866	0.0236	0.3700
14	0.6749	0.0499	0.0236	0.2230
21	0.0000	0.0000	0.0236	0.0236
22	0.8176	0.1712	0.0236	0.7083
23	0.8031	0.1461	0.0236	0.6082
24	0.1381	0.0020	0.0236	0.0317
31	0.2878	0.0057	0.0236	0.0465
32	0.4550	0.0139	0.0236	0.0793
33	0.7641	0.1000	0.0236	0.4236
34	0.6792	0.0514	0.0236	0.2290
41	0.3906	0.0100	0.0236	0.0635
42	0.8541	0.2709	0.0236	1.1071
43	0.8706	0.3459	0.0236	1.4073
44	0.8545	0.2726	0.0236	1.1140
51	0.0000	0.0000	0.0236	0.0236
52	0.8294	0.2622	0.0236	0.8103
53	0.6678	0.0633	0.0236	0.2136
54	0.0000	0.0000	0.0236	0.0236
61	0.6160	0.0341	0.0236	0.1598
62	0.6865	0.0541	0.0236	0.2398
63	0.8691	0.3380	0.0236	1.3754
64	0.6138	0.0336	0.0236	0.1581
71	0.0000	0.0000	0.0236	0.0236
72	0.7343	0.0776	0.0236	0.3339
73	0.8138	0.1641	0.0236	0.6798
74	0.6408	0.0398	0.0236	0.1827
Heteroscedasticity (GLS$_{HET}$):				
Mean	0.5613	0.0956	0.0236	0.3970
Std dev	0.3064	0.1072	0.0000	0.4202
Homoscedasticity (GLS$_{HOM}$):				
Mean	0.7534	0.0941	0.0236	0.3331
Std dev	0.0110	0.0000	0.0000	0.0297

In the homoscedastic case the variances differ due to the unbalancedness of the data.
IDNR 23 is the identity number for ward number 3 located at department number 2.

Table 5 **Single factor productivity (FP=DRG/1000 SEK) and single factor cost (1000 SEK/DRG).**

IDNR	Cost	Doctors	Nurses	Others	Material	Rent	Services	Administ.
A. Factor Productivity (DRG/X):								
Mean by Department:								
1	0.051	0.469	0.290	1.893	4.426	2.188	0.136	1.009
2	0.061	0.437	0.550	1.696	1.628	1.516	0.156	0.954
3	0.052	0.473	0.427	1.375	2.492	0.747	0.136	1.350
4	0.039	0.307	0.151	1.369	1.258	0.524	0.120	0.721
5	0.050	0.468	0.229	2.183	1.236	0.745	0.161	1.904
6	0.049	0.306	0.258	1.396	1.045	0.733	0.274	1.119
7	0.050	0.507	0.207	1.426	1.300	0.710	0.148	1.824
Mean by Ward:								
1	0.051	0.645	0.129	1.698	1.076	0.773	0.171	0.810
2	0.062	0.578	0.361	2.066	2.784	1.773	0.151	1.629
3	0.042	0.169	1.215	1.530	5.187	2.251	0.120	3.810
4	0.046	0.285	0.219	1.035	1.171	0.479	0.204	0.691
Mean by Year:								
1993	0.060	0.555	0.290	2.272	1.084	0.897	0.187	1.204
1994	0.055	0.481	0.363	1.736	2.202	0.813	0.161	2.070
1995	0.046	0.364	0.255	1.268	2.677	1.457	0.184	0.911
1996	0.040	0.267	0.354	1.075	1.620	0.926	0.106	0.652
Mean	0.050	0.422	0.314	1.590	1.955	1.047	0.162	1.246
Std dev	0.021	0.319	0.441	1.084	3.795	1.869	0.162	2.095
B. Factor Cost (X/DRG):								
Mean by Department:								
1	22.484	4.124	4.761	0.905	0.731	1.756	11.651	1.265
2	19.500	3.228	4.472	1.113	0.947	1.318	7.593	1.678
3	20.317	3.496	4.703	0.898	1.228	1.589	8.642	1.042
4	30.579	7.535	7.670	0.937	1.181	2.551	11.638	1.699
5	22.681	3.001	5.495	0.695	0.962	1.789	11.386	2.118
6	21.800	6.388	5.659	0.803	1.224	1.571	7.809	1.478
7	22.863	3.410	6.581	0.969	1.306	1.687	10.154	1.875
Mean by Ward:								
1	20.070	1.642	7.846	0.705	1.039	1.334	6.082	1.423
2	19.880	2.912	3.964	0.681	1.017	1.702	9.099	1.267
3	28.275	9.279	3.005	0.795	0.514	0.627	17.934	0.813
4	23.361	4.418	5.595	1.374	1.356	2.427	6.012	2.179
Mean by Year:								
1993	20.289	3.937	5.090	0.727	1.435	1.683	8.893	1.253
1994	20.506	4.024	5.316	0.877	0.864	2.006	8.179	1.518
1995	24.018	4.666	5.677	0.933	0.917	1.572	10.101	1.654
1996	27.420	5.581	6.399	1.150	1.196	1.795	12.316	1.907
Mean	22.897	4.519	5.598	0.915	1.084	1.754	9.782	1.573
Std dev	9.302	4.392	2.913	0.588	0.881	1.163	7.292	1.064

Wards: Institutional care (1), Day surgery (2), Emergencies (3) and Others (4). The department identities are kept confidential.

Table 6 Correlation matrix of single factor productivities (FP).

	Year	Cost	Doctors	Nurses	Others	Material	Rent	Services	Administration
Year	1.00 (0.00)								
Cost	-0.37 (0.00)	1.00 (0.00)							
Doctors	-0.34 (0.00)	0.52 (0.00)	1.00 (0.00)						
Nurses	0.02 (0.89)	0.24 (0.03)	-0.10 (0.38)	1.00 (0.00)					
Others	-0.41 (0.00)	0.65 (0.00)	0.53 (0.00)	0.24 (0.03)	1.00 (0.00)				
Material	0.07 (0.53)	0.19 (0.08)	-0.03 (0.76)	0.73 (0.00)	0.08 (0.47)	1.00 (0.00)			
Rent	0.05 (0.65)	0.35 (0.00)	0.09 (0.44)	0.70 (0.00)	0.22 (0.05)	0.95 (0.00)	1.00 (0.00)		
Services	-0.14 (0.14)	0.28 (0.00)	0.07 (0.48)	-0.08 (0.46)	0.24 (0.03)	0.07 (0.52)	-0.01 (0.98)	1.00 (0.00)	
Adminis	-0.15 (0.18)	0.40 (0.00)	0.20 (0.07)	0.29 (0.00)	0.41 (0.00)	0.17 (0.12)	0.18 (0.10)	0.08 (0.47)	1.00 (0.00)

The values in brackets under the estimated correlation coefficients are p-values, associated with the null hypothesis that the true correlation coefficient is zero.

Table 7 Mean parametric and non-parametric total factor productivity (TFP) growth.

IDNR	DIVX	DIVC	OLS	Within	GLS$_{HOM}$	GLS$_{HET}$	TT	EGI	ETT
Mean TFP Growth by Department:									
1	-0.089	-0.047	-0.147	-0.088	-0.152	-0.167	-0.160	-0.160	-0.295
2	-0.195	-0.205	-0.131	-0.072	-0.131	-0.154	-0.145	-0.153	-0.160
3	-0.139	-0.126	-0.137	-0.045	-0.113	-0.149	-0.151	-0.153	-0.084
4	-0.090	-0.092	-0.126	-0.062	-0.120	-0.146	-0.140	-0.151	-0.113
5	-0.198	-0.206	-0.157	-0.162	-0.174	-0.174	-0.162	-0.156	-0.506
6	-0.064	-0.042	-0.149	-0.071	-0.140	-0.164	-0.162	-0.159	-0.128
7	-0.207	-0.205	-0.188	-0.089	-0.175	-0.196	-0.202	-0.176	-0.349
Mean TFP Growth by Ward:									
1	-0.077	-0.078	-0.145	-0.083	-0.140	-0.161	-0.158	-0.157	-0.220
2	-0.330	-0.311	-0.161	-0.061	-0.144	-0.170	-0.173	-0.162	-0.223
3	-0.081	-0.063	-0.139	-0.068	-0.129	-0.156	-0.152	-0.154	-0.216
4	-0.062	-0.061	-0.145	-0.110	-0.156	-0.168	-0.158	-0.159	-0.221
Mean TFP Growth by Year:									
1993	.	.	.	.	.	.	.	.	.
1994	-0.065	-0.058	-0.094	-0.150	-0.121	-0.100	-0.125	-0.087	-0.147
1995	-0.148	-0.160	-0.172	-0.162	-0.183	-0.211	-0.152	-0.208	-0.267
1995	-0.210	-0.174	-0.181	0.096	-0.119	-0.183	-0.212	-0.184	-0.250
Sample Mean TFP Growth:									
Mean	-0.138	-0.128	-0.148	-0.080	-0.142	-0.164	-0.160	-0.158	-0.220
Std dev	0.307	0.322	0.088	0.128	0.069	0.075	0.087	0.061	0.218
Minimum	-1.255	-1.311	-0.441	-0.384	-0.354	-0.379	-0.474	-0.292	-0.830
Maximum	0.717	0.721	0.145	0.182	0.008	0.011	0.167	-0.025	0.165
Sample Mean Rate of Technical Change:									
Mean TC	.	.	-0.100	-0.004	-0.094	-0.113	-0.138	-0.113	-0.166
Std dev	.	.	0.065	0.143	0.064	0.078	0.022	0.081	0.250
Sample Mean Returns to Scale:									
RTS	.	.	0.703	0.000	0.182	0.796	0.703	0.915	0.912

Departments: Institutional care (1), Day surgery (2), Emergencies (3) and Others (4). The clinic identities are kept confidential. Mean rate of technical change (TC) and returns to scale (RTS) measures.

Table 8 Correlation matrix of estimated total factor productivity (TFP) growth.

	DIVX	DIVC	OLS	Within	GLS_{HOM}	GLS_{HET}	TT	EGI	ETT
DIVX	1.00								
	(0.00)								
DIVC	0.93	1.00							
	(0.00)	(0.00)							
OLS	0.62	0.50	1.00						
	(0.00)	(0.00)	(0.00)						
Within	-0.16	-0.13	-0.22	1.00					
	(0.15)	(0.26)	(0.05)	(0.00)					
GLS_{HOM}	0.48	0.41	0.76	0.37	1.00				
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)				
GLS_{HET}	0.55	0.45	0.94	-0.09	0.83	1.00			
	(0.01)	(0.00)	(0.00)	(0.43)	(0.00)	(0.00)			
TT	0.63	0.48	0.96	-0.36	0.65	0.82	1.00		
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)		
EGI	0.42	0.36	0.80	-0.20	0.63	0.93	0.64	1.00	
	(0.00)	(0.00)	(0.00)	(0.07)	(0.00)	(0.00)	(0.00)	(0.00)	
ETT	0.33	0.33	0.43	-0.06	0.39	0.45	0.40	0.40	1.00
	(0.00)	(0.00)	(0.00)	(0.58)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

The values in brackets under the estimated correlation coefficients are p-values, associated with the null hypothesis that the true correlation coefficient is zero. DIVX is Divisia index calculated based on changes in the individual inputs, while the DIVC is Divisia index calculated using changes in the total cost.

Table 9 Model specification tests.

Parameter	OLS	Within	GLS_{HOM}	GLS_{HET}	TT	EGI	ETT
F-value	104.416^a	6.743^a	22.160^a	682.122^a	114.186^a	-	-
RMSE	0.368	0.162	0.206	0.295	0.366	0.369	0.386
Chow Tests:							
H0: $\gamma=0$	5.226^a	-	21.004^a	3.928^a	5.272^a	-	-
H0: $\lambda=0$	5.830^a	16.654^a	16.160^a	12.124^a	-	7.563^a	-
H0: $\delta=0$	-	-	-	-	8.776^a	-	-
H0: $\eta_1=0$	-	-	-	-	-	3.569^a	-
H0: $\gamma=\lambda=0$	6.487^a	-	21.066^a	7.666^a	-	-	-
H0: $\gamma=\delta=0$	-	-	-	-	7.838^a	-	-
H0: $\lambda=\mu=0$	-	-	-	-	-	5.114^a	-
H0: $\eta_i=1$	-	-	-	-	-	-	-
H0: $\eta_1=0$	-	-	-	-	-	-	1.118
H0: $\eta_2=\eta_3=0$	-	-	-	-	-	-	2.694^a
H0: $\eta_1=\eta_2=\eta_3=0$-	-	-	-	-	-	3.012^a	
Lagrange Multiplier Tests:							
H0:$\sigma^2_\mu = 0$	-	-	0.941				
H0:$\sigma^2_\lambda = 0$	-	-	25.341^a				
H0:$\sigma^2_\mu = \sigma^2_{\lambda =} 0$	-	-	26.282^a				
Hausmans Tests:							
H0: OLS vs GLS	-	-	55.178^a	17.588^a	-	-	-
H0: Within vs GLS	-	-	3.180	87.239^a	-	-	-
Barletts heteroscedasticity test:							
H0:$\sigma^2_{\mu i} = \sigma^2_\mu$				278.210^a	-	-	-

The superscript a, b and c indicates statistical significance at <1%, 1-5% and 5-10%.

Table 10 Changes in the birth rates and the health care employment and financial resources.

	Sweden			Stockholm County				
Year	Births	Percent	%change	Births	Deaths	Total	Percent	%change
Birth rate:								
1990	123938	100.0	.	25293	443	25736	100.0	.
1991	123737	99.8	-0.2	24932	464	25396	98.7	-1.3
1992	122848	99.1	-0.7	25503	396	25899	100.6	2.0
1993	117998	95.2	-3.9	24779	400	25179	97.8	-2.8
1994	112257	90.6	-4.9	24352	348	24700	96.0	-1.9
1995	103423	83.4	-7.9	22626	350	22976	89.3	-7.0

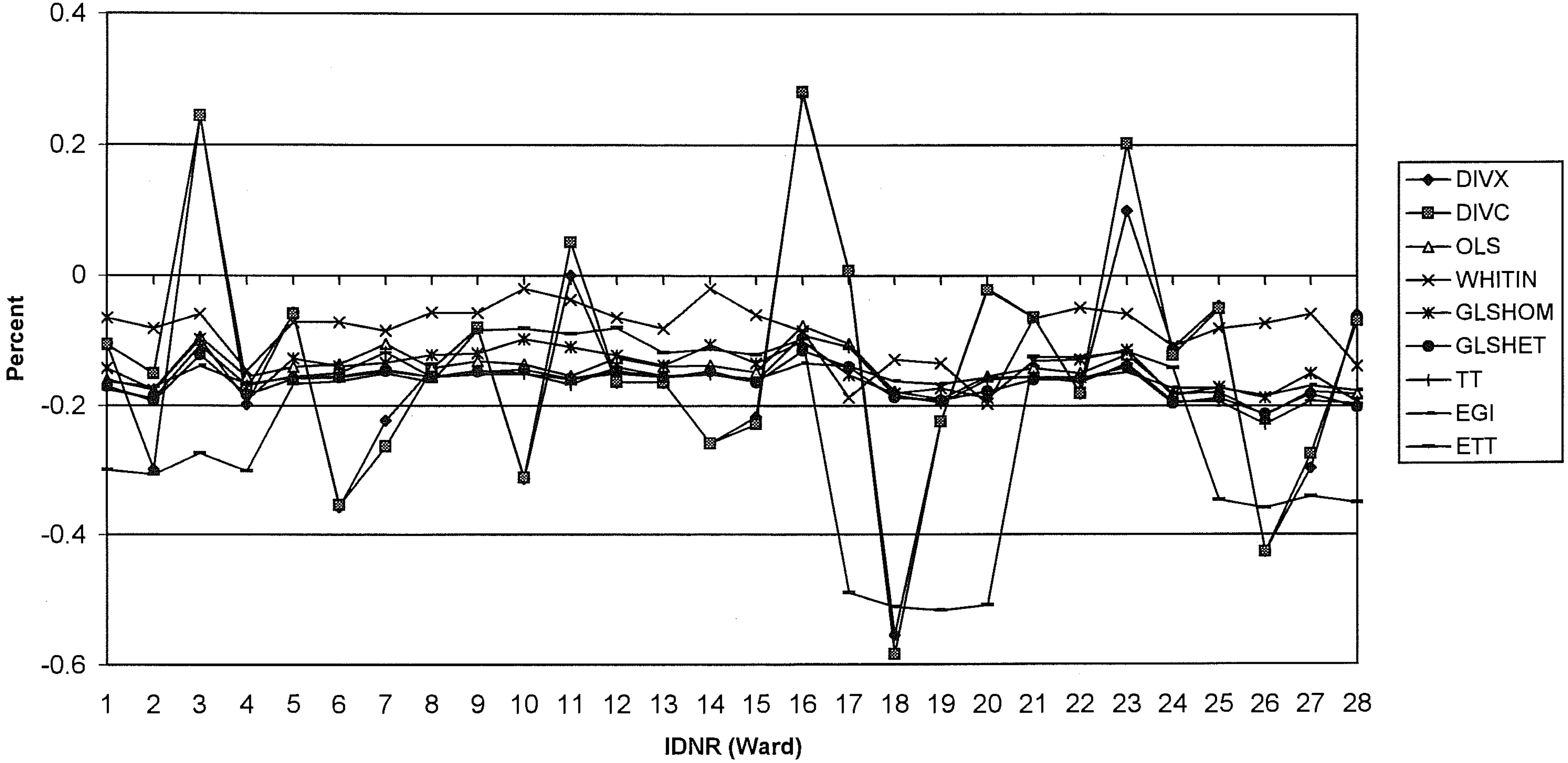
Year	Beds	%	Admis.	%	Beddays	%	Occup.	Days	Visits	%
Hospital Service,Gynecology and Obstetrics:										
1990	4074	100.0	231245	100.0	1063000	100.0	71.5	4.6	915.6	100.0
1991	3449	84.7	227757	98.5	997900	93.9	71.0	4.4	894.8	97.7
1992	3545	87.2	220221	95.2	928600	87.4	71.8	4.2	957.1	104.5
1993	3227	79.3	208752	90.3	853600	80.3	72.5	4.1	991.5	108.3
1994	2990	73.4	200638	86.8	807600	76.0	74.0	4.0	994.1	108.6
1995	-	-	-	-	-	-	-	-	-	-

Year	Abortions	%	Chlamydia	%	Gonorrhoea	%
Induced Abortions and Common Infection Diseases:						
1990	37489	100.0	26764	100.0	840	100.0
1991	35788	95.5	20986	78.4	617	73.5
1992	34849	93.0	17081	63.8	474	56.4
1993	34169	91.1	14963	55.9	367	43.7
1994	32293	86.1	13625	50.9	307	36.6
1995	31450	83.9	13785	51.5	246	29.3

Year	State	Local	County	Private	GDP	Employ.	%	% change
Health Care Expenditure, GDP and Employment by Health Care:								
1990	6518	14233	128221	14094	1668563	376000	100.0	-
1991	5810	14126	126906	15517	1622564	368100	97.9	-2.1
1992	4556	12390	116009	17265	1580837	343200	91.3	-6.8
1993	2736	12159	128407	18450	1515946	323500	86.0	-5.7
1994	-	-	-	19540	1577362	314600	83.7	-2.7
1995	-	-	-	20830	1634877	306700	81.6	-2.5

Births and deaths indicate live births and late foetal deaths.
Financial resources are expressed in 1.000.000 SEK and transformed to 1995 prices using consumer price index.

Figure 1. Total factor productivity (TFP) growth, gynecology and obstetrics, 1993-96.



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