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Quality Adjusted Measures of Services in Public Schools

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Preface

Quality Adjusted Measures of Services in Public Schools is a working paper within CEFOS research area 'Administrative and organizational aspects of the public sector'. The study considers specification and estimation of cost and production functions in public schools. A number of production characteristics are included in the specification to control for and explain the quality differentials as well as producer effectiveness across municipalities in the provision of their school services. The working paper is written by Research Fellow Almas Heshmati.

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Lars Strömberg
Director, CEFOS

Introduction[1]

In the last three decades, the economics of schooling in general, and production and efficiency in schools in particular, has been the subject of many economists' attention. However, education has for long time been intensively analyzed by other social scientists. American studies dominate the research when the use of education production functions following Coleman el al. (1966) are considered.[2] The research has been policy oriented concerning the issues of cost, effectiveness, fairness, structure and quality. Any successful educational policy formulations are an outcome of research from different disciplines. Lack of knowledge about complicated educational production process has made policy recommendations difficult to derive and the implications for school policy less attractive.

The existing methodology used to analyze the educational process, with emphasis on the production and efficiency aspects, is reviewed by Hanushek (1986). The economics research on schooling are generally empirical in nature. The economic models of production theory and firm behavior are used to model the educational process. The standard formulation is modified in empirical formulations to accommodate issues of policy, measurement, etc. for research on

[2] Coleman et al. (1966), report, *'Equality of Educational Opportunity'*, was mandated by the Civil Rights Act of 1964 to study the distribution of educational resources within the US by race or ethnic background. In addition to the inventory of school resources, the report investigates the importance of various inputs, family background and student characteristics in the educational process to the achievement of students.

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schooling. The relationships among different inputs and outcomes of the education process are examined using quantitative methods. The objective is to find the optimal combination of inputs that produces a given level of output at the minimum cost. Quantitative studies in general, and the production function approach in particular, have been subject to criticism by educational decision makers for the reason that these studies suggest schools are very inefficient in their use of resources.[3] A successful measurement of inputs and their definitions in empirical analysis is important and restricted to access to information of high quality. The relevant inputs include inputs related to the students, family, school, teacher and municipality. If a large number of inputs and characteristics are included in the specification, they cause multicollinearity, inconsistent effects and difficulties in interpretation of the results obtained. A wide variety of approaches to estimation exist based on individual or aggregate performance across schools or districts in a single or simultaneous equation estimation (see, for example, Atkin and Longford (1986), Chizmar and Zak (1983), Hanushek (1990), Barro and Lee (1993)). In a majority of studies, the model estimations are conducted in value-added or level form.

Although the results from various studies differ from one another, a summary of the findings are: (i) variations in the schools resources explain only a small part of the variation in students' achievement (see, for example, Hanushek (1986), Bonesronning and Ratso (1994), Lupos (1990)), and in general, no systematic relationship between school expenditures and student performance is found, (ii) teachers and schools differ in their effectiveness (Lima (1981)), (iii) teacher density, teachers education/experience have positive effects on student achievement, (iv) individual quality, family background, characteristics of the schools, organizational aspects of the schools, and racial composition of the

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[3] The expenditure per student varies among districts or municipalities. There is a systematic pattern in the variations which can be related to demographic, geographic, family, student, teacher, school and municipality characteristic factors. Many of these factors are exogenous to the policy makers or schools. One should adjust output measures for these factors using a quality type index and estimate efficiency of schools based on the quality adjusted output measures.

schools are important in explaining the differences in achievement (Murnane et al. (1981), Card and Krueger (1992), Hanushek (1992)), (v) schools are technically inefficient[4] (Heshmati and Kumbhakar (1997), Färe et al. (1988), Bonesronning and Ratso (1994)), (vi) deregulation improves efficiency (Grosskopf et al. (1996)). The diversity of the individual study results can be due to incomplete information, poor quality of data, measurement error, insignificance of effects, relationship between variables, distortions in statistical results, etc.

The Swedish Primary and Secondary school system is governed and financed by the local governments (municipalities). They are characterized as public and compulsory schools, providing equal educational opportunities to all citizens with standardized teaching programs and resources. The present study addresses the issues of statistical modeling of the educational production function approach, resource use and quality of service production in public schools. The objective is to provide alternative parametric and non-parametric adjustments of output measures used in statistical modeling of education for various quality variables. In the adjustment, we account for average individual performance, average family, average teacher and aggregate municipality characteristics, as well as effects with a direct link to the students' continuation to higher levels of education. We examine performances of 286 Swedish municipalities in production of primary and secondary school education during the period 1992/3-1994/5.

The rest of the paper is organized as follows. Different stages in the development of the structure of the primary and secondary school education in Sweden are discussed in the next section. Econometric production and cost models, with various output quality adjustments and estimation methods, are set out in the third Section. The school data is described in the forth Section. The fifth Section contains empirical results along with a comparison of the outcome of different model specifications and service quality adjustments. Finally, the sixth Section concludes this study.

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[4] However, private schools are found to be technically more efficient and in general perform better than public schools.

The Swedish Primary and Secondary Schools

From the sixteenth century, the grammar school (Läroverket) was responsible for the national school education. The service was utilized only by the upper class. The elementary schooling (Folkskolan) in Sweden was first introduced in 1842. In order to provide education to the entire population, the reform included compulsory schooling. The church communities, by law, had to make the facilities available and children of school age had to go to school. However, at this time the length of the compulsory schooling was not determined. Since children in their school age were also part of the labor force, their education was limited to only a short period of time. The two authorities mentioned above had different objectives in pursuing schooling services. The elementary schooling was aimed at providing the entire population with elementary education, while the grammar school was responsible for higher education to the elite class. The quality of education of the elementary schooling was poor. After 1894, efforts were mainly directed to make their activities in concord. After three to six years of schooling students from elementary schooling were allowed to continue their education at the grammar school.

The decision to have a uniform school system was made by the parliament (Riksdagen) in 1952. The current primary and secondary schooling (Grundskolan), with 9 years of compulsory education, was introduced in 1962. The period of education can be divided into three phases, each lasting for three years. The program of a uniform schooling throughout the country was completed first in 1972. There were three national curriculum (Läroplan 1962; 1969; 1980) worth mentioning when considering the school system in Sweden. The implementation of these plans has a major impact on the development path and structure of Swedish education. In general, the policy has been directed towards creating

uniform schools with minimum ability differentiation of students. According to the first plan, all students should follow the same program during the first two phases of their education. During the first two years of the last phase, there were optional courses available. In the final year, at the third phase, they were divided by their choice of major lines of study. The 1969 plan can be distinguished from the previous one by being more preparatory for high school education. For admission to a number of majors at high school, a number of special courses were required. The final plan of 1980 allows the schools to choose the optional subjects. The students, irrespective of their qualifications, were allowed to apply for their desired majors at high school.

A new plan is under implementation. It is planned to be completed before 1998.[5] This plan emphasizes social issues, rather than teaching. The main objectives are not only to acquire basic knowledge, but also how to use the acquired knowledge in practice. Among other important objectives are mediation of the cultural heritage and values. A partial decentralization on the choice of topics to teach makes the schools more flexible and result oriented.

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[5] For an excellent description of the school system in Sweden and the objective and implementation of different national curriculums, see Finansdepartementet (1994:56).

The Econometric Models

We approach modeling and estimating service production in schools from both the production and cost sides. In the production function model, it is assumed that resources such as teachers, space, etc. are annually given and the objective of each municipality (average school) is to maximize output, which is number of students. Special production characteristics are taken into account. We consider both quality-adjusted and quality-unadjusted measures of output. In the cost function approach, the underlying assumption is that output (number of students to be served adjusted for student hours), is exogenously given to a municipality (average school) and each municipality tries to minimize resource cost in producing the given level of output. Again we use both quality-adjusted and quality-unadjusted measures of output. In the specification of the variable cost function, we consider teachers, space, school meals and busing as variable inputs - the costs of which are explained by their prices, output, and other municipality characteristics.

The production function approach

We specify the service production function as

(1) $\quad y_{it} = \beta_0 + \Sigma_j \beta_j x_{jit} + \Sigma_m \gamma_m z_{mit} + \Sigma_k \zeta_k d_{kit} + \epsilon_{it}$,

where

(2) $\quad \epsilon_{it} = \mu_i + u_{it}$,

$\quad$ i = 1, 2, ..., N, t = 1, 2, ..., T, j = 1, 2, ..., J, m = 1, 2, ..., M, k = 1, 2, .., K.

y_{it} is log of output for municipality i in period t defined as either (i) the number of students, (ii) the product of the number of students and student hours, or (iii) student hours output adjusted for a number of output quality indicators. x is a vector of log of J inputs or resources such as expenses related to teaching, materials, library, meals, health care, counseling, administration, complementary education, rent and busing. z is a vector of M municipality characteristics and d is a vector of time period and organizational variables. These variables are related to the teacher, school, municipality and population characteristics including non-Swedish citizens, Swedish as second language, native language, levels of education and income of the families, young population, per capita tax, general state support, distance measure, private schools, types of policy, renting practices, types of organization, and time periods. The quality indicators used in the adjustment of the output include teaching hours, the number of students with incomplete grades, average grades, space per student, trained teachers, teacher absence hours, teacher density, and transition to high school. Another possible quality indicator is expenditure related to meals, health care, counseling, complementary education and busing. These services are produced as complements to the number of student. A number of other studies consider earnings, expenditure/pupil, teacher salary, teacher density, and number of school years (in inter country studies) as measures of quality.[6] β, γ and ζ are vectors of unknown parameters to be estimated. The error term, ϵ_{it} is composed of two components: a time-invariant municipality effect, μ_i representing municipality management; and a random noise component, u_{it} representing un-anticipated changes in government support over time, local policy decisions affecting the school education program, migrations, etc.

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[6] See Moffitt (1996) and a selection of papers related to the Symposium on School Quality and Educational Outcomes published in the special issue of The Review of Economics and Statistics, LXXVIII (1996), pp 559-691.

The estimated values of the parameters (β, γ, ζ and μ) can be used to analyze sensitivity of the results due to various adjustments in the output variable. The β coefficients show the effect of a percentage change in the x variables on the percentage change in output. The γ coefficients, on the other hand, show the effect of a change in the z variables on the logarithm of output since all the z variables are not measured in logarithms. The ζ effects represent shifts in the production function compared to the base year 1992 and compared to no changes in the organization. μ is a measure of individual municipality effects of school services. Thus, the β, γ, ζ and μ parameters give some useful information about the technical aspect of the production of education services.

The assumptions made about the error terms are as follows:(i) μ_i are fixed parameters, (ii) $u_{it} \sim$ i.i.d.$N(0, \sigma^2_u)$, (iii) μ_i and u_{it} are independent, and finally (iv) μ_i and u_{it} are independent of x and z variables. The model can be estimated by the ordinary least squares (OLS) or the maximum likelihood (ML) methods. To avoid distributional assumptions about u and estimation of large number of municipality effects, we follow the OLS method where the large number of municipality effects are represented by few municipality type effects.[7]

The Cost Function Approach

The production function approach assumes that x and z variables are all exogenously given and output (number of students adjusted for student hours), is endogenous. A potential problem in this relation is that output is hardly a decision variable to a municipality. Due to the compulsory nature of the program, the municipalities have to provide school services to all citizens. Instead, schools take students as exogenously given subject to their capacity limits, and provide their services with minimum cost. Thus, it is perhaps reasonable to assume that

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[7] We assume that the between type variation dominates the within type variation.

schools use inputs in such a way that the cost of providing services is minimized. So the choice variables are inputs rather than outputs and the objective is to minimize cost rather than maximize output.

With this objective in mind, we estimate a variable cost function with four variable inputs, viz., teachers, space, school meals and busing. These four variables constitute 76% to 89% of the total cost, with an average of 84%.[8] Assuming that panel data is available, the translog variable cost relationship is specified as

$$(3) \quad vc_{it} = \beta_0 + \Sigma_j \beta_j p_{jit} + \beta_y y_{it} + \tfrac{1}{2} (\Sigma_j \Sigma_k \beta_{jk} p_{jit} p_{kit} + \beta_{yy} y^2_{it}) + \Sigma_j \beta_{jy} p_{jit} y_{it} + \Sigma_m \gamma_m z_{mit}$$
$$+ \Sigma_k \zeta_k d_{kit} (1 + \delta_2 dt2 + \delta_3 dt3) + \xi_i + \omega_{it},$$

where vc_{it} is the log of costs of teaching, rent, meals and busing for municipality i in period t, p is a J vector of the log of salary, rent per square meter space and the prices of meals and busing per day, y is the log of output, first defined (i) without any quality adjustment (y2)[9], and then quality adjusted (ii) non-parametrically (y3) and (iii) parametrically (y3'). z is a M vector of teacher, student and municipality characteristics, β, γ and ζ are unknown parameters, and ξ are fixed municipality effects to be estimated. It should be noted that the specification in (3) allows for a non-linear interaction between organizational and time variables to capture the adjustment patterns of cost following organizational changes. The non-parametric quality adjusted output y3 is defined as[10]

$$(4) \quad y3_{it} = y2_{it} (\Sigma_q w_{qit} / n_q)$$

where the weights w_{qit} are defined either as

$$(5a) \quad w_{qit} = (100 - \sqrt{(100 - z_{qit})}) / 100,$$

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[8] The remainder inputs can be considered as quasi-fixed factors and subsequently be included as explanatory variables in the variable cost function.

[9] Output is adjusted for average teaching hours per student.

[10] The overall quality index can be decomposed into input and output quality index parts.

if the quality indicator variables are expressed as percent, or

(5b) $w_{qit} = \sqrt{(z_{qit} / \bar{z}_{qt})}$

when the quality indicator variables are not expressed in percent. The $\bar{z}_{qt}$ is the sample average of the characteristic variable z_q in year t, n_q is the number of quality indicators.[11] The weights lie in the neighborhood of unity. $w_{qit}<1$(or $\bar{w}_q$) indicates a downward adjustment of output while $w_{qit}>1$(or $\bar{w}_q$) indicates an upward adjustment of output. Square roots of the weights (chosen arbitrary) is used to avoid large impacts from extreme observations by shrinking the deviation. Thus, we take into account the quality difference, but at a decreasing rate.

In the parametrically quality adjusted model, the variable cost function can be written as

(6) $vc_{it} = \beta_0 + \Sigma_j \beta_j p_{jit} + \beta_y(y2_{it} + \Sigma_q \lambda_q z_{qit}) + \frac{1}{2}(\Sigma_j \Sigma_k \beta_{jk} p_{jit} p_{kit} + \beta_{yy}(y2_{it} + \Sigma_q \lambda_q z_{qit})^2)$
     $+ \Sigma_j \beta_{jy} p_{jit}(y2_{it} + \Sigma_q \lambda_q z_{qit}) + \Sigma_m \gamma_m z_{mit} + \Sigma_k \zeta_k d_{kit}(1 + \delta_2 dt2 + \delta_3 dt3) +$
     $\xi_i + \omega_{it}$

where output is adjusted without any restriction on the λ_q parameters.[12] We choose a translog cost function because it imposes minimum a priori restrictions on the underlying production technology and it approximates a wide variety of functional forms.[13] The following homogeneity and symmetry restrictions are imposed $\Sigma_j \beta_j=1$, $\beta_{jk}=\beta_{kj}$, $\Sigma_j \beta_{jk}=0 \; \forall \; k$, $\Sigma_j \beta_{jy}=0$.

Although one can obtain estimates of all parameters from estimating the variable cost function alone, it is customary to use the cost share equations along with the variable cost function in estimating the model as a system to improve the

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[11] An alternative measure to the use of mean as a reference point is the median value of the quality variable.

[12] The model can be generalized by allowing the constant quality effects, λ_q, to vary across municipalities and over time.

[13] No interaction between z_q and z_m with p_j and y variables in the cost models are allowed to avoid an over-parametrization of the model.

efficiency of the parameter estimates. We consider a seemingly unrelated regression (SUR) framework which consists of the variable cost function in (3) or (6) and (J-1) cost share equations. The cost share equation for the jth input is

$$(7) \quad s_j = \partial vc_{it} / \partial p_{jit} = \beta_j + \Sigma_k \beta_{jk} p_{kit} + \beta_{jy} y_{it} + \eta_{jit}, \quad \text{for } y=(y2, y3, y3^*)$$

where the η_{jit} is the error term associated with the jth cost share equation. In this model, cross equation restrictions on the parameters are imposed and the variances and covariances of the error terms in the share equations are unconstrained other than being constant for all i and t. The assumptions made about the error terms are: (i) ξ_i are fixed parameters, (ii) $\omega_{it} \sim$ i.i.d. $N(0, \sigma^2_\omega)$, (iii) $\eta_{jit} \sim$ i.i.d. $N(0, \Sigma)$, (iv) ξ_i and ω_{it} are independent, and finally (v) ξ_i, ω_{it} and η_{jit} are independent of p, y and z variables. Depending on the type of adjustment employed, we apply the iterative linear SUR techniques to estimate the set of equations in (3) and (7) and iterative non-linear SUR techniques to the alternative set of equations (6) and (7), respectively.

The Data

The data cover the primary and secondary school services provided by the entire population of 286 Swedish municipalities during the 1992/3-1994/5 school years. On behalf of the The National Agency for Education, the data has been collected and processed by Statistics Sweden (SCB). The data are aimed at providing municipalities with various measures of performance. These include the issues of organization, teaching, resource-use, and performance for different schools and types of education. The school sector can be broadly classified into four categories or subsectors: primary and secondary schools, high schools, schools for adults and special schools. This study is restricted only to the primary and secondary schools. The resources used are found to be disaggregated, thereby allowing for a partial subsectorial analysis. The intensive controls performed following the data collection reduced possible measurement errors. The data are thus considered by the SCB to be of relatively high quality.

Information used in this study consist of input and output data as well as a number of variables representing the quality of education and municipality characteristics variables. Output (dependent variable in the production functions and explanatory variable in the cost functions) is defined as the product of the number of students and the average teaching hours per student at the primary and secondary schools.[14] The number of students is an aggregate number of both resident and non-resident students in the respective municipality. We consider both quality adjusted and unadjusted measures of output.

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[14] The average number of teaching hours differs across municipalities due to the variations in the composition of different levels. The number of teaching hours is increasing with the age of students.

The inputs are based on resources used including expenses related to teaching, materials, library, school meals, health care, counseling, administration, complementary education, rent and busing. The variable cost (dependent variable in the cost functions) is defined as the sum of costs of teaching, rent, school meals and busing per municipality. The factor input prices of teaching, rent, school meals and busing are defined as the average annual salary per full time equivalent teacher, annual rent per square meter space, average price of school meals and price of busing per day. The number of school attendance days per year is estimated as 200 days.

The quality indicators used in adjustment of the output include the number of students with incomplete grades, average grades, space per student, trained teachers, teacher absence hours, teacher density, and transition to high school.[15] The other municipality characteristics include the student density in schools, non-Swedish citizens, Swedish as second language, native language, levels of education and income of the families, young population, per capita tax, general state support, distance measure, and private schools.[16] A number of qualitative variables related to the types of policy, renting practices, organizations, and time periods are introduced. The policy variables indicate whether the municipality is governed by a socialistic majority, a conservative majority or a coalition. The renting variable indicates whether the contracts were based on cost price, market clearing price, or other types of pricing practices. The organization variables indicates whether the organization of the municipality has changed very much,

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[15] Another possible adjustment in output is to take into account the frequency of students at a certain municipality for their intensity in resource-use. The policy promotes students with different backgrounds and learning capabilities to join the same program. Some students with reduced capabilities related to, hearing, seeing or functional handicaps do have special needs which increases the cost. We incorporated a number of characteristics in the model specification which partially capture the resource-use effects. To our knowledge, no data on a direct measures of individual resource-use is available. Access to information on the resource requirement for these reasons will certainly improve the models' performance.

[16] Share of different stages of the primary and secondary schools (three stages: 1-3, 4-6, and 7-9) affects e.g. teaching hours and teacher densities. No data on the share of different stages at municipality level is available.

moderately, or not at all.[17] Time dummies are introduced to control for year effects. Summary statistics of the data are given in Table 1.

The teaching cost variable refers to costs of teachers' salary including payroll taxes. Material cost is defined as the sum of expenses related to the purchase of books, newspapers, printing, computers facilities, equipment, wages for technicians, and study related travels. The library variable represents costs to the municipalities associated with operating schools libraries including purchases of books and salaries paid to librarians. The school meal measures costs of providing the student with a school meal. It covers wages, food, administration and transportation costs. It does not include the rent of spaces and fees paid by students. However, it has been adjusted for certain revenues. The health care variable is an aggregate of all expenses in providing school health care services including salaries to doctors, nurses, psychologists, advisors, support personnel, as well as medicine and insurances. The counseling variable includes all costs associated with different programs informing the students about the issues related to the job market. The administration variable is defined as the primary and secondary schools share of the total costs to the municipality associated with the administration of the schools. It includes both local and central administration. Different weights have been used in the distribution of the total cost among various types of schools within a municipality. The complementary education variable includes all expenses related to complementary education of both administrative and teaching staff. It also includes costs associated with hiring substitute teachers, traveling and organizing seminars. The rent variable includes the cost of renting, cleaning, maintenance and the other costs related to the school buildings. Busing (taxi) is defined as cost of bus (taxi) transportation to the municipality per student.

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[17] Change is defined in terms of purchasing practices of services. Data on the issues of changes in organization was collected by SCB of the behalf of The Swedish Agency for Administrative Development.

Student density per classroom (per school) is obtained by dividing the number of students by the number of classrooms (the number of schools) in the municipality, respectively. Incomplete grades are defined as the percent of students who did not receive any grades (during the spring semester, in 2 or more subjects). Average grade is defined as the average grade at the end of the last (ninth) year of the secondary school at the municipality level. The space variable is measured as the average square meter space per student. Trained teacher is defined as the share of certificated teachers. Teachers absence hours are measured as the percentage of hours absent due to sickness, temporary lay-off or care of child. Teacher density is defined as the number of full-time equivalent teachers per 100 students. Transition to high school is the percent of students at the ninth grade in the spring semester, who started the high school program in the subsequent semester.

The non-Swedish citizen variable is the share of population at the age of 20-64 years, not holding a Nordic citizenship and who did immigrate to Sweden sometime during 1984-1994. The Swedish language variable is defined as the share of students with Swedish as their second language. Native language is defined as the share of students attending courses in their native language. The low education variable is defined as the percent of population at the age of 20-64 years, with at most 9 years of education. Low income is defined as the percent of municipality population at the age of 0-17 years, being a member of households receiving social security benefits. The per capita tax variable is obtained by dividing the total tax revenue by the entire municipality population. The variable population, is the percent of population at the school age of 7-15. State support is the sum of general support provided by the state to promote the municipalities production of services. Distance is a measure of housing (population) density within a municipality measured as the average equi-distance between two neighboring houses.

The municipalities are divided into nine different groups depending on the size of population, the geographic location and the degree of industrialization. This classification is used to capture possible municipality heterogeneity. The

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municipality types include: three largest cities, suburban, large, medium, industrial, rural, thinly populated, other large and other minor. For comparison purposes we have expressed the variables per student in Table 1. The characteristics variables are measured mainly in percent. In estimating the production and cost function models, we use total costs of inputs to the municipality, instead of their physical quantities or costs per student. All variables expressed in SEK are transformed to fixed 1994 prices using the net municipality cost price index.

Empirical Results

The Production Function Approach

Three types of production models are estimated. In the first model, no adjustment is performed on the output. Output is measured simply as the number of students. The second model adjusts number of students for variations in teaching hours. In the third model, student teaching hours are non-parametrically adjusted for variation in 7 quality indicator variables.[18] A number of municipality characteristics related to organization, type, population, policy, financial situation, and other relevant characteristics are used as control variables and enter all three model specifications. The parameter estimates for the production models are reported in Table 2.

Most of the x variables in these models are statistically significant at the 1% level of significance. The coefficients of library, counseling and complementary education are found to be insignificant. The statistically insignificant parameters are retained for maintaining flexibility of the production function. The models in general fit quite well to the data. The R^2 measures are around 0.99. The x variables also have correct signs (positive) indicating that marginal contribution of money spent on education is positive. The exceptions being library in the first model and complementary education variables in the remaining two models. The most important variable is teaching. The coefficients are interpreted as elasticities since the x variables appear in logarithms. Thus, a one percent increase in expenditure on teaching, depending on the type of adjustment, will increases the student

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[18] No parametric adjustment to the output variable is performed when it is used as dependent variable.

output by 0.70-0.72 percent. We find evidence of constant returns to scale in all three production models.[19]

In all models, we find the group of municipalities which were subjected to major changes in their organization, to be about 3 percent more productive compared to those with no changes. A longer period than 3 years is required to observe the full impact of changes of organization on the cost structure. The effects of minor changes are not found to be statistically different from zero. The time dummy variables, representing the exogenous rate of technical change, are statistically significant. The overall rate of technical progress is about 3%. The rate of progress during the period 1992/93 was 2.5%. It declined to only 0.3% during 1993/94.

In the production models, several z variables including the share of foreign students attending the Swedish language, share of low income families, conservative majority, and market clearing renting practices are found to be insignificant at any reasonable levels of significance. The share of non-Swedish citizens, low education families, school age and average cost rent pricing are found to have positive and significant effects on the productivity of municipalities. On the other hand, the share of students attending native language classes, per capita tax, state support, distance and social democratic majority municipal governments are found to have significant, but negative effects on the level of productivity. Although the education program at the current level is compulsory and the number of students (not number of hours) joining the program not affected by the financial situation, we expected a positive effect from the per capita tax and state support on the level of productivity. That is, given everything else, an increase in tax revenue and state support[20] will decrease the output of education.[21]

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[19] Possible scale difference among municipalities is presumably eliminated following inclusion of a large number of production characteristics. Restricted forms of all three production models were also estimated excluding all characteristic variables. The RTS measures calculated were 1.01 indicating increasing returns to scale. However, it was not significantly different from unitary returns to scale.

[20] State support received is a general support to promote all types of municipality services

Although there are variations across municipality types when the number of students, teaching hours and other quality indicators are considered (see Table 5.b), none of the municipality type effects (μ_i) in any of the three production models are statistically significant. This can be explained by the fact that the μ effects are captured by other (time-invariant) municipality characteristics entering the models or the way municipalities are grouped is not adequate for schooling education. The most probable explanation is that most of the variation could be characterized as within types variations.

The annual number of teaching hours per student is 1,129 hours with a standard deviation of 43 hours. The range of teaching hours is 659. We observe large variations in most of the seven quality indicators among the municipalities. The average grade, percent trained teachers, percent transition to high school, and teacher density show relatively small standard deviations (less than 10 percent). Those of percent with incomplete grades, space and teachers absence hours show very large standard deviations. In the non-parametrically output quality adjusted model, we used the square roots of percent incomplete grade, percent non-trained teachers, percent absence hours, and percent non-transition to high school, i.e. deviations from 100% as adjustment factors. In the case of the average grade, space and teacher density we used the square of the ratio of the variable and their sample mean as adjustment factors.[22] The measured weights on average lie in the interval 0.97-1.00. The largest deviations are: space (0.11) and teachers density

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and is not earmarked to finance only school education.

[21] One possible explanation to the negative association between financial resources and investment in education during the period of this study is the changes in investment priorities caused by the recent years of economic recession.

[22] In addition to the above 7 quality factors we also used the number of students per classroom as another quality variable. The resulting overall weight was on average, 1.00 (0.04) and within the interval 0.90-1.24. The impact on the results of both parametric and non-parametric models was very small. Due to the correlation with student hours, teacher density and space it was dropped from the adjustment procedure.

(0.05) variables (see Table 5.c). The impact of the overall adjustment is calculated to be on average 1.35% (2.02%). The minimum and maximum percent changes are -9.92 and 7.04. The numbers in parentheses are standard deviations (see Table 1).

The root mean square error (RMSE) of the first and third production models are very close, 0.0618 and 0.0619, respectively. It increases to 0.0647 following the student hour adjustment. Thus, taking into account student hour differences results in a higher dispersion as expected. The increased dispersion is eliminated if the characteristic variables are used in the specification as control variables. The characteristic variables are divided into three groups and their coefficients are indicated by ζ, γ, and μ. Various F-tests are performed to test their within groups and between groups joint significance. All tests are significant at the 1% level of significance, indicating that all characteristics should be included in the specification of the production function (see Table 2).

To summarize the results from the production function approach, we note that given the objective of the municipality is output maximization, no price information is required for the analysis. The results obtained are found to be reasonable and appropriate in explaining variations in the dependent variable, the number of students to be trained. Inclusion of the large number of characteristics and quality indicators certainly causes severe multicollinearity. However, the problem of multicollinearity can not be avoided in such studies. The imprecise effects are the price to pay for improvement in the specification for public service production. The presence or absence of quality adjustment has no impact on the fit of the model in terms of R^2 and RMSE measures. An adjustment for the student hours increases the variation in the output measure and the RMSE. We believe the most general production model i.e. the non-parametric adjustment model is the most appropriate production model specification.

The Cost Function Approach

We distinguish between a variable cost function and the usual cost function approach with prices of inputs excluded treated as constants. The inputs excluded are materials, library, health care, counseling, administration and complementary education. Lack of data on prices of the above inputs at individual municipality or municipality type levels is the main reason for using a variable cost function approach. The variable input includes costs associated with teaching, rent, school meals and busing. The share of variable cost to the total cost per student is on average 84%, within the interval 76% to 89% (see Table 1).

In Table 3, we report the results associated with the variable cost models and the cost share equations. The busing share equation is excluded (due to the normalization) from estimation in all three models. As mentioned before, we estimate cost models using various output (independent variable) quality adjustments. In the first model, a non-parametric adjustment is performed on the output measure. The second model uses a parametric quality adjustment on output using the same quality indicators. Other than this, they are specified using the same input prices and organization and time variables. The third model is a generalization of the second model and includes production characteristics and municipality type dummy variables as control variables.

The RMSE of the non-parametric quality adjusted model is 0.0820. A parametric adjustment of the model results in a sharp decline in the RMSE value to 0.0394 and 0.0385, depending on whether the characteristic variables are included in the model specification or not.[23] The R^2 values of the cost and the cost share equations are quite high in all models. The R^2 in the cost models are (0.99) indicating a good fit. The corresponding R^2 for the cost share equations are about 0.53 for both teaching and rent shares and 0.83 for the meal share equations. The

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[23] The variable cost models using unadjusted output and adjusted for only student hours were also estimated. The results are not reported here. However, they can be obtained from the authors upon request.

variable cost percent prediction errors calculated using the three cost model parameter estimates on average are 0.15% (8.22), 0.07% (3.96) and 0.07% (3.86), respectively. The numbers in parenthesis are standard deviations given in percent. The parameter estimates associated with the input prices, output and their interactions, are mostly highly significant in all models. However, this is not true when the other parameter estimates are considered.

Again, the characteristic variables used in the specification are divided into three groups and their coefficients are represented by ζ, γ, and ξ parameter vectors. The coefficients associated with the quality indicators in the parametric models are represented by λ. Various F-tests are performed to test their within groups and between groups joint significance. χ^2 tests based on the sum of the squared residuals (SSE) of non-parametric and parametric models (both excluding and including characteristic variables, respectively), reject the non-parametric model in favor of the parametric models at the 1% level. The more general parametric model including characteristic variables was also rejected against the alternative model excluding characteristic variables. However, the reduction in the mean square error (MSE) was lower in the former case (see Table 3).

The coefficients associated with quality indicator variables average grade, absence hours and transition to high school are negative (a positive association between the teachers absence hours and teaching cost was expected). This is interpreted as, an increase in those variables has a negative impact on the cost. However, the latter two variables are close to zero and not significant at any reasonable levels of significance. The coefficients associated with incomplete grades and trained teachers are positive, close to zero and insignificant. On the other hand, those of space and teacher density are as expected - positive and highly significant. With the exception of one of the time dummy variables in one of the parametrically quality adjusted cost models, none of the organization or time dummy variables are significantly different from zero. Among the characteristic variables, the share of native language and social democratic

majority are found to have, as expected, positive and significant marginal effects on the cost, while those of tax and private schools are significant but negative. We expected an increase in the per capita tax to result in more investment in education. Similar to the municipality type dummy variables, the remaining characteristic variables are found to be insignificant.

Since the coefficients of the translog cost functions (with the exceptions of characteristic and municipality dummy variables) do not have any direct interpretation, we calculate the elasticities of variable cost with respect to each factor prices and outputs. Since cost, factor prices and output are all expressed in logarithms, the elasticities are simply obtained from the partial derivative of the cost function with respect to the appropriate prices and outputs. The price elasticity, E_j, measuring the responsiveness of cost to a one percent change in the jth factor price, is given by

(8) $E_j = \partial vc_{it} / \partial p_{jit} = \beta_j + \Sigma_k \beta_{jk} P_{kit} + \beta_{jy} y_{it}.$ for y=(y3 and y3˙).

The price elasticity with respect to the excluded factor, busing, is obtained as $(1 - \Sigma_j E_j)$. The elasticity of variable cost with respect to output, E_y, measuring the responsiveness of cost to a percent increase in the output, is given by

(9) $E_y = \partial vc_{it} / \partial y3_{it} = \beta_y + \beta_{yy} y3_{it} + \Sigma_j \beta_{jy} P_{jit},$

in the non-parametrically adjusted cost models, and

(10) $E_y = \partial vc_{it} / \partial y3˙_{it} = \beta_y + \beta_{yy}(y2_{it} + \Sigma_q \lambda_q z_{qit}) + \Sigma_j \beta_{jy} P_{jit},$

in the parametrically adjusted cost models case.

The estimates of returns to scale (RTS), defined as the percentage change in output due to a proportional increase in the factor inputs, is calculated as the reciprocal of output elasticity from the following

(11) $RTS = 1 / E_y.$

If the estimate of RTS is greater than, equal to, or less than unity, the returns to scale is classified as increasing, constant, or decreasing. The input elasticities vary over time[24] and across municipalities. Output elasticity and returns to scale vary only across municipalities. The elasticity of cost with respect to the output quality indicators in the parametric quality adjustment model, E_q, measuring the adjustment of output to a unit change in the quality indicator, is given by

$$(12) \quad E_q = \partial vc_{it} / \partial z_{qit} = \{\beta_y + \beta_{yy}(y2_{it} + \Sigma_q \lambda_q z_{qit}) + \Sigma_j \beta_{jy} p_{jit}\} \lambda_q = E_y \lambda_q$$

where q is the index for the quality indicator variable z_q.[25] From the cost function, we can also calculate the exogenous rate of technical change defined as the percentage change in the total variable cost over time, *ceteris paribus,*

$$(13) \quad E_t = \partial vc_{it} / \partial t = \Sigma_k \zeta_k d_{kit} \delta_t.$$

Since we are using a cost function, technical progress (regress) will be manifested by a negative (positive) value of E_t, representing cost diminution over time, everything else being constant. Finally, the elasticity of variable cost with respect to various degrees of changes in the organization of municipalities can be obtained as

$$(14) \quad E_k = \partial vc_{it} / \partial d_{kit} = \zeta_k(1 + \delta_2 dt2 + \delta_3 dt3),$$

where organizations not subject to any changes is reference group.

The cost elasticity with respect to teaching is the highest with about 0.60 (0.03) in all three models. The second largest elasticity is related to space with an average of 0.28 (0.04). The elasticity of meals and busing are small, 0.05 (0.02) and

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[24] There is no interaction between the time periods and the factor prices and output variables. However, variation in the factor prices and output over time allows price elasticities to vary over time.

[25] If returns to scale is found to be constant (RTS=1), $E_q = \lambda_q$. In a generalized cost model with quality effects varying across municipalities and/or over time, the elasticities E_q also will be changing over time and/or municipalities.

0.07 (0.01), respectively. The numbers in parenthesis are standard deviations. With the exception of meals, all other elasticities are constant across different types of municipalities and over time. The meal price elasticity is negative but small (-0.01) for the largest three municipalities. The model with no adjustment shows increasing returns to scale (1.03), while the other two cost models show constant returns to scale (see Tables 4a-4c).

The cost elasticity with respect to changes in organization is very close to zero both over time and across municipality types. This can be explained as follows. First, major changes have taken place following municipalities facing economic difficulties in 1991/92. Thus, we can not observe significant cost reductions during the period of this study. Second, changes in organization usually involve new investments and costs associated with the implementation of the changes. Thus, a longer period is required for costs to adjust. Third, the municipalities belonging to the category subjected to organizational changes are those with average costs exceeding those with no changes. Their service cost has been increasing prior to the changes. Any positive impact has only reduced the increasing pattern of cost but the level remains above the sample average cost.

The mean cost elasticities with respect to changes in the quality indicator variables by the type of municipality and over time are reported in Tables 5.d and 5.e. The results show that the mean elasticities from both of the cost models (with and without municipality characteristics) are very close. We do not observe any significant changes in the patterns of the elasticities over time or by municipality types. The standard deviations of the elasticities are very small. The elasticities of incomplete grades, trained teachers, teacher absence hours and transition to high school are found to be zero. The teacher density (0.521) and space, (0.245) elasticities are positive, while that of average grade is negative, (-0.035). The numbers in parenthesis are mean values from the cost model where characteristic variables are excluded. The corresponding elasticities for the alternative cost models including characteristic variables, are very close to the above levels. Given the results, we find the signs to be as expected. However, the magnitude of the

non-zero and high frequency of zero effects indicates that the models' performances to be very poor in adjusting for output quality.[26]

To sum up the evidence from the cost function approach, we note that all three cost models perform well in explaining variations in the variable cost. The RMSE is reduced from 0.0820 in the model without any adjustment to 0.0394 and 0.0385 in the parametric adjustment models, respectively. However, the reductions in RMSE following the inclusion of the characteristic variables is very small. χ^2 tests calculated using RSS from the cost function reject the non-parametric adjustment in favor of the parametric adjustment where characteristic variables not included. However, a F-test indicates that the characteristic variables (although mostly insignificant) should be included in the specification of the cost model. For details of the specification tests, see Table 3.

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[26] One way to improve performance of the parametric adjustment model is by restricting the sum of λ_q to unity through a normalization. This will allow for adjustment of output for quality differences but only within a limited range proportional to the size of output. Another possibility is to normalize the z_q variables using their mean by time or by municipality type.

Summary and Conclusion

This study considers specification and estimation of cost and production functions in public schools. A number of production characteristics are included in the specification to control for quality differentials as well as the producer effectiveness across municipalities in the provision of their services. Both parametric and non-parametric approaches are used to take into account the quality differences in school services. These approaches are then compared to the alternative output measure without adjustment for quality. In the empirical section we examine performances of 286 Swedish municipalities in the production of primary and secondary school education during the 1992/3-1994/5 school years.

The main findings of this study are as follows. First, given that the objective of municipalities is output maximization, a production function approach does not require any factor price information for the analysis. The results obtained are found to be reasonable and appropriate in explaining variations in the dependent variable, the number of students to be trained. Inclusion of a large number of characteristics and quality indicators to improve the specification for public service production introduces uncertainty about the sign as well as the magnitude of the effects. The presence or absence of quality adjustment has no impact on the fit of the model in terms of R^2 and RMSE measures. An adjustment for the student hours increases the variation in the output measure and the RMSE. The most general production model i.e. the non-parametric adjustment model, is found to be the most appropriate production model specification.

Second, assuming a cost minimization behavior, the cost function approach has the advantage that in addition to the non-parametric adjustment, a parametric quality adjustment to output is also possible. The disadvantage is that it requires

factor prices. Lack of prices for the public sector allows only for the use of a restricted (variable) cost function. The assumption of constant prices for excluded factors is not likely to be true. It might cause specification errors. The price information has impact on the returns to scale measures obtained. All three cost models perform well in explaining variations in the variable cost. The parametric adjustment causes a sharp decline in the RMSE. However, the reductions in RMSE following the inclusion of the characteristic variables is very small. χ^2-tests calculated rejects the cost model with non-parametric quality adjustment in favor of the parametric quality adjustment. The F-test indicates that inclusion of the characteristic variables does not improve specification of the cost model.

Third, in all production models we find the group of municipalities who were subjected to major changes in their organization are 3% more productive compared to those with no changes. A longer period than 3 years is required to observe the full impact of changes of organization on the cost structure. The effects of minor changes are not found to be statistically different from zero. The overall rate of technical progress during the entire period is estimated to be 3%.

Fourth, in the cost models no significant changes in the cost structure due to the organizational changes over time and across municipality types are found. This can be explained by the fact that major changes have taken place following the years with financial difficulties in 1991/92. Changes in organization usually involve new investments and costs associated with the implementation of the changes. A longer period is required for costs to adjust and the positive effects, if any, to be observed. Municipalities belonging to the category subject to organizational changes are those with an average cost exceeding those with no changes. Their service cost has been increasing prior to the changes. Any positive impact has only reduced the increasing pattern of cost remaining above the sample average cost. In general the changes have made the school services more productive but less cost efficient.

Fifth, we observe large variations in most of the seven quality indicators among the municipalities. In the non-parametric output quality adjusted model, we used the square roots of percent incomplete grade, percent non-trained teachers, percent absence hours, and percent non-transition to high school, i.e. deviations from 100% as adjustment factors. In the case of the average grade, space and teacher density we used the square roots of the ratio of the variable and their sample mean as adjustment factors. The measured weights on average within the interval 0.97-1.00. The largest deviations are observed in the cases of space and teachers density variables. The impact of overall adjustment is calculated to be on average 1.35%, in the interval of -9.92 and 7.04.

Finally, the quality differences are hopefully eliminated in the direction it was aimed to be, by accounting for many quality indicators. Inclusion of characteristic variables in the cost models does not make any changes in the mean cost elasticities with respect to changes in the quality indicator variables. We do not observe any significant changes in the patterns of the elasticities over time or by the type of municipalities. The elasticities of incomplete grades, trained teachers, teacher absence hours and transition to high school are found to be zero. The teacher density and space elasticities are large and positive, while that of average grade is small and negative. Given the results, we find the signs to be as expected. However, the magnitude of the non-zero and the high frequency of zero effects indicates that the parametric adjustment models perform poorly in adjusting for output quality. The models can be more flexible by allowing for non-constant effects. In order to reduce the effects of outlier observations, one should modify the parametric model in similar way as with the non-parametric approach to shrink the large quality differences measured or restricting the range of adjustment parameters through some normalization process or alternatively through normalization on the quality variables.

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Table 1   Summary statistics of the variables, 1994 prices, (No of obs=858).

Variable	Definition	Mean	Std Dev	Minimum	Maximum
Output measures:					
Y1	No of students	3080.21	4315.62	284.00	51200.00
ELETIM	Hours school/student	1129.52	43.41	853.85	1512.77
Y2	Adj. for stud hour	3485424.89	4957880.69	325874.26	56667961.17
Y3	Adj. for 7 factor	3421189.97	4845948.71	340334.76	55792628.30
DY23	Y2-Y3 difference	64234.92	139720.48	-122340.61	1792894.86
PY23	Percent difference	1.35	2.02	-9.92	7.04
Input and output quality variables:					
OBETYG	% incomplete grades	2.04	1.55	0.00	8.49
GBETYG	Average grades	3.19	0.09	2.91	3.61
OVEXKL	Transition excl prog	92.68	3.29	80.56	100.00
ELEKVM	Space/student	16.48	3.94	6.00	42.73
PEDUTB	% trained teachers	93.05	4.87	72.73	100.00
FRANVA	% teacher absence hours	5.52	2.25	0.00	14.20
LARARE	Teachers/100 student	8.47	0.80	6.74	13.83
Non-parametric input and output quality indices:					
w1	% incomplete grades	0.99	0.01	0.97	1.00
w2	Average grades	1.00	0.01	0.95	1.06
w3	Transition excl prog	0.97	0.01	0.96	1.00
w4	Square m space	0.99	0.11	0.60	1.61
w5	% trained teacher	0.98	0.01	0.95	1.00
w6	% teacher absence hours	0.98	0.01	0.96	1.00
w7	Teacher/100 student	1.00	0.05	0.89	1.28
ELEVKL	Students/classroom	21.46	1.78	14.03	26.61
ELSKOL	Students/school	175.59	54.94	67.77	333.59
Inputs in SEK/student and year:					
KELUND	Teaching	25161.27	2972.47	17900.00	43128.96
KELUTR	Materials	1903.11	495.98	800.00	4154.00
KELBIB	Library	196.40	120.46	0.00	1035.94
KELMAL	Meals	3106.02	699.78	1268.50	6600.00
KELVAR	Health care	1506.48	516.29	405.27	4863.22
KELSYO	Counseling	280.24	105.06	81.05	800.00
KELADM	Administration	3634.95	905.76	1500.00	9017.22
KELPER	Compl. education	529.29	210.83	74.00	1960.00
KELLOK	Rent	11935.46	3008.79	4700.00	24620.06
KELSKJ	School bus	2083.34	1081.47	40.00	5630.00

Table 1   continued

Variable	Definition	Mean	Std Dev	Minimum	Maximum
Costs in SEK/student and year:					
ETCOST	Total cost/student	50336.54	6298.04	35900.00	87933.13
EVCOST	Variable cost/stud	42286.08	5527.85	30490.00	73637.28
SVCOST	Share of variable cost	0.84	0.02	0.76	0.89
Factor prices:					
PTEACH	Teacher salary	297238.55	23025.45	187918.90	447705.51
PSPACE	Rent price	746.55	203.97	294.94	1823.08
PSKJUT	School bus price	10.42	5.41	0.20	28.15
PMALTI	School meals price	15.53	3.50	6.34	33.00
Cost shares:					
S1	Share teaching cost	0.60	0.05	0.45	0.74
S2	Share rent cost	0.28	0.05	0.13	0.45
S3	Share school bus cost	0.05	0.02	0.00	0.12
S4	Share meals cost	0.07	0.01	0.03	0.14
Characteristic variables:					
UTLMED	% non-Swedish citizens	2.35	1.42	0.00	10.00
SV2UND	% Swedish as 2nd lang.	4.29	4.71	0.00	38.42
HEMSPR	% native language	3.73	5.19	0.00	38.70
LAGUTB	% low education	31.99	6.57	8.13	48.00
BIDHUS	% low income	10.82	3.73	0.00	29.54
SKAINV	Per capita tax	891.19	133.44	638.30	1617.34
ALDER1	% popul. 7-15 years	10.96	1.07	6.58	15.00
BIDRAG	State support/student	88.81	37.63	6.79	259.48
DISTAN	Distance in meter	273.02	261.19	17.67	2003.00
Organizational variables:					
HOT	Very much org. changes	0.13	0.34	0.00	1.00
SEMI	Little org. changes	0.38	0.49	0.00	1.00
COLD	No org. changes	0.36	0.48	0.00	1.00
Policy variables, renting practices:					
BORGE	Conservative majority	0.60	0.49	0.00	1.00
SOCIA	Social Democ majority	0.25	0.44	0.00	1.00
OKLAR	Unclear, coalition	0.15	0.35	0.00	1.00
SJALV	Average cost rent	0.56	0.50	0.00	1.00
MARKN	Market clearing rent	0.09	0.29	0.00	1.00
ANNAT	Other rent pricing	0.34	0.48	0.00	1.00
FRISTA	% private schools	0.65	1.28	0.00	7.80

Table 2   Parameter estimates, production models.

Dep. Variable	No adjustment(Y1)		Student hour adj.(Y2)		Non-parametric adj.(Y3)	
Parameter	estimate	std error	estimate	std error	estimate	std error
β_0	-8.4342a	0.2473	-1.5076a	0.2588	-1.5802a	0.2480
$\beta_{teaching}$	0.7035a	0.0191	0.7177a	0.0200	0.7074a	0.0192
$\beta_{materials}$	0.0473a	0.0091	0.0513a	0.0095	0.0499a	0.0091
$\beta_{library}$	-0.0002	0.0009	0.0004	0.0009	0.0010	0.0009
$\beta_{school\ meals}$	0.0747a	0.0121	0.0737a	0.0127	0.0765a	0.0121
$\beta_{health\ care}$	0.0114c	0.0067	0.0101	0.0070	0.0113c	0.0067
$\beta_{counseling}$	0.0034	0.0080	0.0049	0.0083	0.0082	0.0080
$\beta_{administration}$	0.0678a	0.0099	0.0629a	0.0104	0.0568a	0.0099
$\beta_{comp.education}$	0.0021	0.0065	-0.0007	0.0068	-0.0015	0.0065
β_{rent}	0.0620a	0.0102	0.0469a	0.0106	0.0595a	0.0102
β_{busing}	0.0343a	0.0061	0.0332a	0.0064	0.0298a	0.0061
$\zeta_{much\ change}$	0.0310a	0.0075	0.0288a	0.0078	0.0249a	0.0075
$\zeta_{little\ change}$	0.0069	0.0048	0.0089c	0.0050	0.0070	0.0048
ζ_{1993}	0.0269a	0.0093	0.0225b	0.0097	0.0244a	0.0093
ζ_{1994}	0.0300a	0.0105	0.0310a	0.0110	0.0301a	0.0106
$\gamma_{non-Swede}$	0.0079a	0.0028	0.0096a	0.0029	0.0103a	0.0028
$\gamma_{Swed.language}$	0.0001	0.0009	0.0008	0.0009	0.0000	0.0009
$\gamma_{native\ language}$	-0.0073a	0.0008	-0.0085a	0.0009	-0.0074a	0.0008
$\gamma_{low\ educ}$	0.0023a	0.0006	0.0019a	0.0006	0.0017a	0.0006
$\gamma_{low\ income}$	0.0023a	0.0008	0.0017b	0.0008	0.0010	0.0008
$\gamma_{tax\ per\ capita}$	-0.1128a	0.0260	-0.0910a	0.0272	-0.0848a	0.0261
$\gamma_{school\ age}$	0.0072a	0.0027	0.0069a	0.0028	0.0050c	0.0027
$\gamma_{state\ support}$	-0.0697a	0.0116	-0.0604a	0.0121	-0.0541a	0.0116
$\gamma_{distance}$	-0.0595a	0.0082	-0.0555a	0.0086	-0.0457a	0.0083
$\gamma_{conservative}$	-0.0010	0.0067	-0.0063	0.0070	-0.0073	0.0067
$\gamma_{social\ democratic}$	-0.0194a	0.0076	-0.0247a	0.0080	-0.0207a	0.0076
$\gamma_{average\ cost}$	0.0102b	0.0049	0.0109b	0.0051	0.0113b	0.0049
$\gamma_{market\ pricing}$	-0.0014	0.0087	-0.0077	0.0091	-0.0113	0.0087
$\gamma_{private\ schools}$	-0.0001	0.0022	0.0045b	0.0023	0.0039c	0.0022
$\mu_{suburban}$	-0.0020	0.0291	0.0416	0.0305	0.0461	0.0292
μ_{large}	0.0105	0.0137	0.0195	0.0143	0.0175	0.0137
μ_{medium}	0.0107	0.0121	0.0124	0.0127	0.0140	0.0122
$\mu_{industrial}$	-0.0114	0.0130	-0.0111	0.0136	-0.0060	0.0130
μ_{rural}	-0.0049	0.0142	-0.0099	0.0149	-0.0132	0.0142
$\mu_{thinly\ populated}$	-0.0286	0.0179	-0.0425b	0.0188	-0.0290	0.0180

Table 2   continued

Dep. Variable	No adjustment (Y1)		Student hour adj.(Y2)		Non-parametric adj.(Y3)	
Parameter	estimate	std error	estimate	std error	estimate	std error
$\mu_{other\ large}$	0.0178	0.0132	0.0157	0.0139	0.0151	0.0133
$\mu_{other\ minor}$	0.0002	0.0126	0.0007	0.0132	-0.0028	0.0126
R^2adj.	0.9944	.	0.9938	.	0.9943	.
RMSE	0.0618	.	0.0647	.	0.0619	.
F-value	4211.0300a	0.0001	3837.9810a	0.0001	4119.9210a	0.0001
F-test, H0: $\zeta=0$	6.7948a	0.0001	5.6832a	0.0002	5.0827a	0.0005
F-test, H0: $\gamma=0$	39.0104a	0.0001	34.1772a	0.0001	28.3723a	0.0001
F-test, H0: $\mu=0$	2.5018a	0.0109	3.2272a	0.0013	2.3127b	0.0187
F-test, H0: $\zeta=\gamma=\mu=0$	47.7166a	0.0001	42.1008a	0.0001	31.6029a	0.0001
RTS incl. charact.	1.0060	.	1.0000	.	0.9999	.
RTS excl. charact.	1.0130	.	1.0130	.	1.0100	.
OBS	858	.	858	.	858	.

Significant at the less than 1% (a), 1-5% (b) and 5-10% (c) levels of significance.

Table 3   Parameter estimates, variable cost models.

Output Parameter	Non-parametric adj.(Y2) estimate	std error	Parm adj excl.char(Y3) estimate	std error	Parm.adj.incl.char(Y3[*]) estimate	std error
β_0	-0.1430	0.3797	-3.2367a	0.4520	-2.1758a	0.7058
β_{r1}	-0.7181a	0.0329	-0.6383a	0.0348	-0.6405a	0.0347
β_{r2}	0.8799a	0.0324	0.7963a	0.0346	0.7992a	0.0345
β_{r3}	0.2897a	0.0088	0.3061a	0.0093	0.3058a	0.0093
β_{r11}	0.1720a	0.0041	0.1628a	0.0041	0.1630a	0.0041
β_{r22}	0.1384a	0.0036	0.1217a	0.0040	0.1219a	0.0040
β_{r33}	0.0257a	0.0005	0.0253a	0.0005	0.0253a	0.0005
β_{r12}	-0.1124a	0.0037	-0.1046a	0.0038	-0.1047a	0.0038
β_{r13}	-0.0148a	0.0011	-0.0158a	0.0011	-0.0157a	0.0011
β_{r23}	-0.0085a	0.0009	-0.0057a	0.0010	-0.0057a	0.0010
β_Y	0.9589a	0.0473	1.0711a	0.0496	0.9868a	0.0825
β_{YY}	-0.0007	0.0031	-0.0060b	0.0029	-0.0009	0.0051
β_{r1Y}	0.0029b	0.0014	0.0014	0.0014	0.0014	0.0014
β_{r2Y}	-0.0020	0.0015	0.0027c	0.0015	0.0026c	0.0015
β_{r3Y}	-0.0032a	0.0005	-0.0040a	0.0005	-0.0040a	0.0005
$\lambda_{incomplete\ grade}$	.	.	0.0000	0.0009	-0.0005	0.0010
$\lambda_{average\ grade}$	.	.	-0.0331b	0.0155	-0.0349c	0.0185
λ_{space}	.	.	0.2484a	0.0069	0.2458a	0.0076
$\lambda_{trained\ teachers}$	.	.	0.0003	0.0003	0.0001	0.0003
$\lambda_{absence\ hours}$	.	.	-0.0005	0.0006	-0.0005	0.0006
$\lambda_{teacher\ density}$	.	.	0.5626a	0.0174	0.5225a	0.0216
$\lambda_{transition}$	.	.	-0.0004	0.0004	-0.0008c	0.0005
$\zeta_{much\ org.\ change}$	0.0007	0.0023	-0.0007	0.0052	0.0018	0.0039
$\zeta_{little\ org.\ change}$	-0.0019	0.0048	-0.0067	0.0045	-0.0039	0.0045
δ_{1993}	-5.3375	11.521	-1.6990b	0.8303	-1.4234	1.1101
δ_{1994}	0.8723	5.0187	-0.5017	0.6226	0.5724	1.9752
$\gamma_{non\text{-}Swede}$	.	.	.	.	-0.0024	0.0017
$\gamma_{Swedish\ language}$	.	.	.	.	0.0001	0.0006
$\gamma_{native\ language}$	.	.	.	.	0.0015a	0.0005
$\gamma_{low\ education}$	.	.	.	.	0.0001	0.0004
$\gamma_{low\ income}$	.	.	.	.	0.0003	0.0005
$\gamma_{tax\ per\ capita}$	.	.	.	.	-0.0262b	0.0126
$\gamma_{school\ age}$	.	.	.	.	-0.0001	0.0016
$\gamma_{state\ support}$	.	.	.	.	-0.0053	0.0058
$\gamma_{distance}$	.	.	.	.	-0.0022	0.0041

Table 3 continued

Output	Non-parametric adj.(Y2)		Parm.adj.excl.char(Y3)		Parm.adj.incl.char(Y3')	
Parameter	estimate	std error	estimate	std error	estimate	std error
$\gamma_{conservative}$	.	.	.	.	0.0053	0.0041
$\gamma_{social\ democratic}$	.	.	.	.	0.0076c	0.0046
$\gamma_{average\ cost}$	.	.	.	.	0.0022	0.0030
$\gamma_{market\ prices}$	.	.	.	.	0.0066	0.0052
$\gamma_{private\ schools}$	.	.	.	.	-0.0051a	0.0013
$\xi_{suburban}$	.	.	.	.	-0.0369	0.0249
ξ_{large}	.	.	.	.	-0.0046	0.0094
ξ_{medium}	.	.	.	.	-0.0045	0.0072
$\xi_{industrial}$	.	.	.	.	-0.0070	0.0077
ξ_{rural}	.	.	.	.	-0.0025	0.0085
$\xi_{thinly\ populated}$	.	.	.	.	0.0085	0.0107
$\xi_{other\ large}$	.	.	.	.	-0.0038	0.0079
$\xi_{other\ minor}$	.	.	.	.	-0.0108	0.0076
Iteration	16	.	62	.	45	.
O-value	3.9779a	0.0013	3.9697a	0.0060	3.9441a	0.0102
RMSE	0.0820	.	0.0394	.	0.0385	.
$R^2_{adj\ cost\ model}$	0.9917	.	0.9981	.	0.9981	.
$R^2_{teaching\ share}$	0.5434	.	0.5407	.	0.5407	.
$R^2_{rent\ share}$	0.5169	.	0.5335	.	0.5334	.
$R^2_{meals\ share}$	0.8299	.	0.8324	.	0.8323	.
χ^2-test, (1 vs 2, 7 df), H0: $\lambda=0$			397.3937a	0.0001	.	.
χ^2-test, (1 vs 3, 27 df), H0: $\lambda=\zeta=\delta=\gamma=\mu=0$			.	.	99.1507a	0.0001
χ^2-test, (2 vs 3, 22 df), H0: $\gamma=\mu=0$			.	.	1.7507	0.9999
OBS	858	.	858	.	858	.

Significant at the less than 1% (a), 1-5% (b) and 5-10% (c) levels of significance.

Table 4.a   Mean returns to scale and price elsticities, non-parametric output (Y3) quality adjustment, cost model.

	Returns to scale		Price elasticities			Org. Change	
Munic.type,year	RTS	teacher	space	meals	busing	much	little
Largest three	1.027	0.615	0.334	-0.011	0.063	-0.000	0.001
Suburban	1.027	0.603	0.309	0.016	0.072	-0.000	0.001
Large	1.030	0.600	0.299	0.034	0.068	-0.000	0.001
Medium	1.030	0.611	0.273	0.046	0.070	-0.000	0.001
Industrial	1.029	0.604	0.266	0.052	0.078	-0.000	0.001
Rural	1.031	0.589	0.275	0.065	0.072	-0.000	0.001
Thinly populated	1.031	0.593	0.250	0.071	0.087	-0.000	0.001
Other large	1.031	0.601	0.271	0.056	0.072	-0.000	0.001
Other minnor	1.030	0.582	0.293	0.054	0.071	-0.000	0.001
1992	1.030	0.608	0.271	0.049	0.072	0.001	-0.002
1993	1.030	0.596	0.281	0.049	0.074	-0.003	0.008
1994	1.030	0.591	0.285	0.048	0.075	0.001	-0.004
Mean	1.030	0.598	0.279	0.049	0.074	-0.000	0,001
Std dev	0.002	0.033	0.040	0.021	0.014	0.002	0.005

Table 4.b   Mean resturns to scale and price elsticities, parametric output (Y3ˈ) quality adjustment, cost model exclusive characteristic varibles.

	Returns to scale		Price elasticities			Org. Change	
Munic.type,year	RTS	teacher	space	meals	busing	much	little
Largest three	1.009	0.614	0.336	-0.012	0.062	-0.000	-0.002
Suburban	0.998	0.603	0.306	0.017	0.074	-0.000	-0.002
Large	1.008	0.598	0.303	0.033	0.066	-0.000	-0.002
Medium	1.004	0.609	0.276	0.046	0.069	-0.000	-0.002
Industrial	0.999	0.603	0.267	0.052	0.077	-0.000	-0.002
Rural	1.000	0.588	0.275	0.065	0.072	-0.000	-0.002
Thinly populated	0.999	0.592	0.253	0.070	0.085	-0.000	-0.002
Other large	1.003	0.600	0.274	0.055	0.071	-0.000	-0.002
Other minor	0.998	0.582	0.291	0.055	0.072	-0.000	-0.002
1992	1.001	0.607	0.273	0.049	0.072	-0.001	-0.007
1993	1.001	0.595	0.282	0.049	0.074	0.000	0.005
1994	1.001	0.591	0.286	0.048	0.075	-0.000	-0.003
Mean	1.001	0.598	0.280	0.049	0.074	-0.000	-0.002
Std dev	0.004	0.031	0.035	0.021	0.013	0.001	0.005

Table 4.c Mean resurns to scale and price elsticities, parametric output (Y3*) quality adjustment, cost model inclusive characteristic varibles.

Munic.type,year	Returns to scale RTS	Price elasticities teacher	space	meals	Org. Change busing	much	little
Largest three	0.996	0.614	0.335	-0.012	0.062	0.001	-0.003
Suburban	0.997	0.603	0.306	0.017	0.074	0.001	-0.003
Large	1.002	0.598	0.303	0.033	0.066	0.001	-0.003
Medium	1.002	0.609	0.276	0.046	0.069	0.001	-0.003
Industrial	1.002	0.603	0.267	0.052	0.077	0.001	-0.003
Rural	1.004	0.588	0.275	0.065	0.072	0.001	-0.003
Thinly populated	1.005	0.592	0.253	0.070	0.085	0.001	-0.003
Other large	1.003	0.600	0.274	0.055	0.071	0.001	-0.003
Other minor	1.002	0.582	0.291	0.055	0.072	0.001	-0.003
1992	1.002	0.607	0.272	0.049	0.072	0.002	-0.004
1993	1.002	0.595	0.282	0.049	0.074	-0.001	0.002
1994	1.002	0.591	0.286	0.048	0.075	0.003	-0.006
Mean	1.002	0.598	0.280	0.049	0.074	-0.001	-0.003
Std dev	0.003	0.031	0.035	0.021	0.013	0.001	0.003

Table 5.a Mean cost in SEK per student by the type of municipality and by year.

Munic.,year	Teach.	Rent	Admin.	Meals	Busing	Other	Total	Non-Swed	Tax/capita
Largest 3	25246	14136	5237	2374	264	4335	51592	6.69	984
Suburban	24005	12459	3860	2977	751	4159	48211	3.40	1018
Large	25025	12917	3605	2776	1238	4160	49720	3.00	911
Medium	25030	11443	3423	2844	1698	4378	48816	2.06	888
Industrial	25123	11009	3504	3185	1979	4475	49274	2.65	865
Rural	24528	11039	3325	3103	3040	4340	49375	1.80	813
Thinly pop.	28919	14228	4160	3917	3647	5246	60118	1.45	924
Other large	24473	11090	3436	2994	2281	4269	48543	2.12	869
Other minor	24518	12058	3751	3079	2229	4276	49910	1.89	854
1992	27075	11986	3720	3146	2135	4433	52494	2.01	990
1993	24447	11818	3615	3043	2046	4307	49277	2.35	835
1994	23962	12003	3570	3129	2069	4506	49239	2.70	848
Mean	25161	11935	3635	3106	2083	4416	50337	2.35	891
Std dev	2972	3009	906	700	1081	899	6298	1.41	133

Table 5.b Mean quality indicator variables by the type of municpilaity and by year.

Munic.,year	Incom.	Grade	Space	Tradined	Absence	Teacher	Transition
Largest three	5.86	3.23	14.55	94.48	5.50	8.37	87.37
Suburban	2.77	3.27	14.63	94.98	5.15	8.01	92.27
Large	2.29	3.22	15.25	95.69	5.24	8.29	92.12
Medium	2.02	3.19	16.28	94.60	5.52	8.34	92.56
Industrial	2.13	3.15	17.05	92.09	5.91	8.66	92.87
Rural	1.93	3.16	15.38	92.67	5.32	8.27	92.56
Thinly popul	1.23	3.22	22.07	88.55	5.50	9.51	94.29
Other large	1.91	3.16	16.30	92.97	5.72	8.33	93.07
Other minor	1.63	3.18	15.12	93.26	5.58	8.33	92.19
1992	2.12	3.19	16.75	92.08	5.99	8.67	92.78
1993	2.07	3.19	16.50	93.89	5.28	8.49	92.50
1994	1.95	3.19	16.19	93.20	5.28	8.25	92.77
Mean	2.04	3.19	16.48	93.05	5.52	8.47	92.68
Std dev	1.55	0.09	3.94	4.87	2.25	0.80	3.29

Table 5.c Mean non-parametric quality index by the type of municipality and by year.

Munic.,year	Y1	Hours	Y2	Incomp.	Grade	Space	Trained	Absence	Teacher	Transit.	Y3
Larg. 3	34515	1165	40094	0.98	1.01	0.94	0.98	0.98	0.99	0.96	39195
Subur.	3771	1125	4229	0.98	1.01	0.94	0.98	0.98	0.97	0.97	4128
Large	9135	1130	10330	0.99	1.00	0.96	0.98	0.98	0.99	0.97	10114
Medium	3497	1128	3939	0.99	1.00	0.99	0.98	0.98	0.99	0.97	3875
Indust.	1599	1131	1806	0.99	0.99	1.01	0.97	0.98	1.01	0.97	1785
Rural	1440	1126	1623	0.99	0.99	0.96	0.97	0.98	0.99	0.97	1587
Thinly p.	952	1128	1070	0.99	1.00	1.15	0.97	0.98	1.06	0.98	1087
O. Large	2386	1130	2692	0.99	1.00	0.99	0.97	0.98	0.99	0.97	2648
O. Minor	1279	1135	1448	0.99	1.00	0.95	0.98	0.98	0.99	0.97	1416
1992	3054	1136	3465	0.99	1.00	1.00	0.97	0.98	1.01	0.97	3415
1993	3073	1122	3465	0.99	1.00	0.99	0.98	0.98	1.00	0.97	3401
1994	3114	1130	3526	0.99	1.00	0.98	0.98	0.98	0.99	0.97	3447
Mean	3080	1129	3485	0.99	1.00	0.99	0.98	0.98	1.00	0.97	3421
Std dev	4316	43	4958	0.01	0.01	0.11	0.01	0.01	0.05	0.01	4846

Y2 and Y3 are in 1000.

Table 5.d Mean elasticity of cost with respect to changes in quality indicators by the type of municipality and by year, cost model without characteristics.

Munic.,year	Y2	Y3*	Incompl.	Grade	Space	Trained	Absence	Teacher	Transition
Largest 3	40094	228370	0.000	-0.033	0.246	0.000	-0.001	0.558	-0.000
Suburban	4228	23456	0.000	-0.033	0.249	0.000	-0.001	0.564	-0.000
Large	10330	58606	0.000	-0.033	0.247	0.000	-0.001	0.558	-0.000
Medium	3939	22823	0.000	-0.033	0.248	0.000	-0.001	0.560	-0.000
Indusrial	1806	10817	0.000	-0.033	0.249	0.000	-0.001	0.563	-0.000
Rural	1623	9255	0.000	-0.033	0.248	0.000	-0.001	0.563	-0.000
Thinly pop.	1069	7151	0.000	-0.033	0.249	0.000	-0.001	0.563	-0.000
Other large	2692	15641	0.000	-0.033	0.248	0.000	-0.001	0.561	-0.000
Other minor	1448	8233	0.000	-0.033	0.249	0.000	-0.001	0.564	-0.000
1992	3465	20389	0.000	-0.033	0.248	0.000	-0.001	0.562	-0.000
1993	3465	19913	0.000	-0.033	0.248	0.000	-0.001	0.562	-0.000
1994	3526	19838	0.000	-0.033	0.248	0.000	-0.001	0.562	-0.000
Mean	3485	20047	0.000	-0.033	0.248	0.000	-0.001	0.562	-0.000
Std dev	4958	28076	0.000	0.000	0.001	0.000	0.000	0.002	0.000

Y2 and Y3* are in 1000.

Table 5.e Mean elasticity of cost with respect to changes in quality indicators by the type of municipality and by year, cost model with characteristics.

Munic.,year	Y2	Y3*	Incompl.	Grade	Space	Trained	Absence	Teacher	Transition
Largest 3	40094	197200	-0.000	-0.035	0.247	0.000	-0.001	0.524	-0.001
Suburban	4229	20272	-0.000	-0.035	0.246	0.000	-0.001	0.524	-0.001
Large	10330	50629	-0.000	-0.035	0.245	0.000	-0.001	0.522	-0.001
Medium	3939	19713	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
Industrial	1806	9322	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
Rural	1623	7999	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
Thinly pop.	1070	6142	-0.000	-0.035	0.245	0.000	-0.001	0.520	-0.001
Other large	2692	13509	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
Other minor	1448	7114	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
1992	3465	17584	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
1993	3465	17197	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
1994	3526	17153	-0.000	-0.035	0.245	0.000	-0.001	0.522	-0.001
Mean	3485	17311	-0.000	-0.035	0.245	0.000	-0.001	0.521	-0.001
Std dev	4958	24248	0.000	0.000	0.001	0.000	0.000	0.002	0.000

Y2 and Y3* are in 1000.

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