Competition and Public School Efficiency in Sweden

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Competition and Public School Efficiency in Sweden – An Empirical Evaluation of Second Stage Regression Results for Different Models of Non-discretionary Inputs in Data Envelopment Analysis (DEA)

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Abstract

The focus in this study is on how efficiency in public education is affected by competition from private schools. The Swedish educational system is used, since the Swedish large scale voucher program implies that private and public schools compete on similar terms. In 2002 approximately 5% of the Swedish children attended private schools, and the share is rapidly increasing. Public school efficiency is estimated using Data Envelopment Analysis (DEA). Modelling education is difficult since educational production is not only dependent on factors under control of the school management, but also on the students' socio-economic backgrounds. A number of approaches have been proposed concerning how to model this in a DEA setting. In this study, four different approaches are used and compared. Special focus is put on a second stage regression, where the efficiency estimates are regressed on competition and other explanatory variables. We can not show that the share of children attending private schools is related to public school performance.

JEL classification: H73, I21

Key words: Data Envelopment Analysis, competition, education

1 Introduction

How private schools affect the performance of public schools is not only a controversial topic, it has also turned out to be difficult to estimate it empirically. First we have to model the production of education. Education is a complex process with multiple objectives and inputs from school and home and also from personal characteristics of the students. When studying efficiency in education, a useful method is Data Envelopment Analysis (DEA). DEA is based on linear programming and can easily handle production with multiple inputs and multiple outputs. The basic (input oriented) DEA model estimates the radial reduction of inputs possible for a provider of education without decreasing student outcomes. Such a reduction can, however, only refer to inputs that are under managerial control, i.e. school inputs. A number of approaches of how to model student inputs and home production have been proposed: Banker and Morey (1986), Ruggiero (1996), Muniz (2002), Fried, Lovell and Yaisarwarng (1999), and Grosskopf, Hayes, Taylor and Weber (2001). Ruggiero (2004) provides an extensive discussion of the topic. While attention has been paid to the relations between the estimates of different models, such as the ranking of units etc, the present study focuses on how different model specifications affect the results from further analysis of what explains efficiency differences. The approach is to estimate efficiency using a number of different models of non-discretionary variables and then to regress the efficiency scores on competition from private schools.

The empirical application is from the large scale school voucher program that was introduced in Sweden in 1992/93. Data is from the school year 2001/2002 for 105 urban municipalities (the municipalities are the providers of public education). The Swedish voucher program ensures a school market that is highly competitive. All students achieve a voucher that can be used to attend either a public or a private school. The budget of both public and private schools are directly linked to the number of students attending. No additional payments from parents to private schools are allowed in order to ensure that students are not excluded from the private schools due to low family income. Out of 479 private schools in 2001/2002, 177 were regular schools and 165 had some kind of special teaching methods (such as Waldorf or Montessori schools). Only 87 schools had an ethnic or confessional focus. Sweden had approximately 4500 public schools, and approximately 5% of the students attend a private school.

The Swedish voucher program has been studied by e.g. Sandström and Bergström (2005). They find that competition has positive effects on outcomes for public school students. Ahlin (2005) finds positive effects from competition on test scores in mathematics in Sweden when restricting the sample in Sandström and Bergström to students where test scores from earlier grades were available. Björklund, Edin, Fredriksson and Krueger (2003) find some positive effects on native born students, but not for foreign born students or students from households with a low level of education. A number of studies have been performed on the American school system, where e.g. Hoxby (1994), Dee (1998) and Couch, Shughart and Williams (1993) find positive impacts from competition on student outcomes. Sander (1999) finds no effect from competition from private schools in Illinois, and Newmark (1995) questions the robustness in Couch, Shughart and Williams (1993). The impact of competition on public school costs has been studied by Björklund et al (2003) for the Swedish school system. They do not find competition to increase costs. The National Agency for Education (2004) finds that competition does not increase costs for public education in general, but in a sub-sample consisting of large municipalities they find a positive correlation between competition and costs.

The results in the literature on competition and efficiency in education show disperse results. Waldo (2003) finds no relation between private school competition and technical efficiency in Swedish municipalities, Grosskopf et al (2001) find that competition is related to allocative but not technical efficiency for Texas school districts, Bradley, Johnes and Millington (2001) find a strong relation between competition and efficiency when studying English secondary schools, while Duncombe, Miner and Ruggiero (1997) find a negative influence for New York school districts. The divergent results may of course have a number of reasons, but one possibility is the fact that the important non-discretionary inputs are modelled in different ways. E.g. Muñiz (2002) argues that this may cause large differences in the efficiency results for many observations.

The aim of this paper is to analyze if estimates of the influence of private school competition on public school efficiency are robust to how non-discretionary inputs are treated in the DEA-models. Efficiency is estimated using one stage models, i.e. it is only necessary to solve one linear programming problem for each unit. Four models are estimated. In the first model, the non-discretionary variables are not taken into account, but this is done in the second stage regression. The second model is proposed by Banker and Morey (1986) and includes the non-discretionary variables directly into the linear programming problem. The unit under evaluation is modelled to have at least as much of the non-discretionary input as the reference point on the frontier (which may be a linear combination of units having both more and less of the input). Ruggiero (1996, 2004) points out that this may not take the non-discretionary variables into account properly, and proposes a model where a unit is only compared with other units having less or equal of the non-discretionary inputs. Grosskopf et al (1999) adjust the outputs for differences in the non-discretionary variables using regression analysis. All models are estimated using GAMS. A Tobit model is used for the second stage analysis. This is a common way of analyzing efficiency scores estimated with DEA, and the Tobit model is available in standard econometric software. (An alternative approach is Simar and Wilson (2003) who propose a truncated model and a bootstrapping procedure.)

A widely discussed topic is how to model competition from private schools, since there is an obvious risk of endogeneity in the emergence of alternatives to public education. The establishment of a private school may not be located as a competitor to a public school by exogenous circumstances, but because the public school is low performing. Without taking this into account, it may seem as if competition causes public schools to perform poorly. Hoxby (1994) proposes an instrumental variable approach to the problem, which has been used by e.g. Dee (1998) and Sander (1999). Endogeneity has been a major topic when estimating the effect of competition on public school outcomes. In the present study we test if private school competition is exogeneous to public school efficiency.

The outline of the study is the following: In section 2 the different DEA models are presented, followed by the empirical application and comparisons of the DEA results in section 3. Section 4 contains a presentation of the second stage analysis including data, exogeneity tests and empirical results. The study is summarized in section 5.

2 Modelling Non-discretionary Inputs in Data Envelopment Analysis (DEA)

In section 2, four different ways of treating non-discretionary variables are described. The first, described in section 2.1, is the basic DEA model, where the non-discretionary variables are not included at all. The second approach, described in section 2.2, is the Banker and Morey (1996) model. The third approach, described in section 2.3, is the Ruggiero (1996) model, and the fourth approach, the output regression model, is described in section 2.4.

2.1 The Basic DEA model (NoSES-model)

In the basic (input oriented) DEA model all variables are considered as discretionary, and efficiency is estimated as the maximum possible radial contraction of all inputs without decreasing production. The input requirement set is defined

$$L(y) = \{x : x \text{ can produce } y\}$$

where x are the inputs and y are the outputs. Efficiency is defined as the maximum possible decrease in inputs such that production is still within the set:

$$Eff = \inf\{\theta : \theta x \in L(y)\}$$

The minimum inputs required, or *production frontier*, is unknown in general and must be estimated. In DEA this is done in a linear programming (LP) problem, where the best performing observations span the production frontier. Efficiency is estimated for each observation in relation to the estimated frontier. Efficiency for a unit j is estimated as

$$Eff_i^j = \min_{z,\theta} \theta \qquad (2.1\ \text{a})$$

$s.t.$

$$\sum_{k=1}^{K} z_k y_{km} \geq y_m^j, \quad m = 1,\ldots,M \qquad (2.1\ \text{b})$$

$$\sum_{k=1}^{K} z_k x_{kn} \leq \theta x_n^j, \quad n = 1,\ldots,N \qquad (2.1\ \text{c})$$

$$z_k \geq 0, \quad k = 1,\ldots,K \qquad (2.1\ \text{d})$$

$$\sum_{k=1}^{K} z_k = 1, \quad k = 1,\ldots,K \qquad (2.1\ \text{e})$$

where M is the number of outputs, N the number of inputs, K is the observations, and z are activity variables. y_m^j is thus output m for observation j. Restriction 2.1e implies that efficiency is estimated using variable returns to scale. Without this restriction, constant return to scale is assumed. In the LP problem the N inputs are decreased radially by the factor θ. θ is the *efficiency score*. An efficient unit will have an efficiency score equal to one and an inefficient unit will have an efficiency score smaller than one. DEA is most easily illustrated by means of a figure, see figure 3.1.

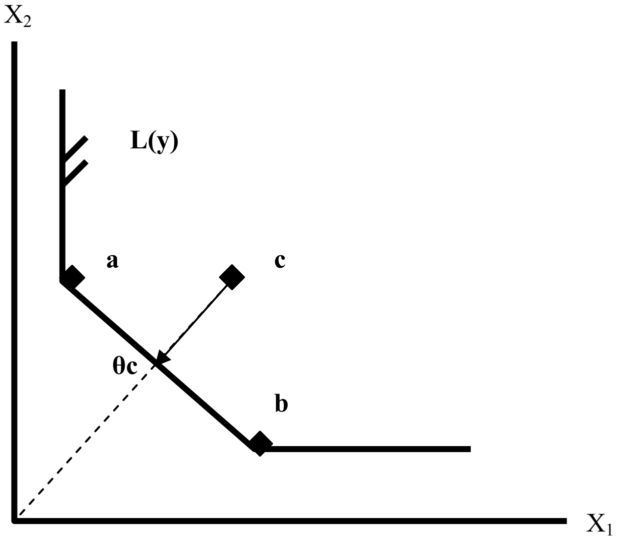


Figure 2.1 Estimating efficiency

In figure 2.1, three units, *a*, *b*, and *c*, are observed. They all produce the same amount of outputs, with different combinations of the two inputs x_1 and x_2. The input requirement set, L(y), is defined by units *a* and *b*. Units *a* and *b* are defined as efficient, since it is not possible to contract inputs radially with θ and still remain within the input requirement set. The minimum θ possible to multiply these units with is one, i.e. the efficiency score is equal to one. Unit *c* is defined as inefficient, since it is possible to multiply all inputs with a θ that is less than one and still remain within the input requirement set. For unit *c*, it would be possible to produce y at the point θc, where less is used of both inputs, but the input mix is unchanged. Since the student's socioeconomic background (SES) is not included in the model as non-discretionary variables, we denote the approach as the NoSES-model. For a more thorough discussion of DEA, see Färe, Grosskopf and Lovell (1994).

2.2 The Banker and Morey Model

Banker and Morey (1986) suggested that the non-discretionary variables should be included into the DEA model as variables that are not possible to contract. In the model below they are denoted *a* and are included as other inputs with the exception that the θ is excluded from the restriction. The procedure ensures that the unit under evaluation does not have a better production environment than the point on the production frontier to which it is compared (this point may be a combination of units with both more and less of the non-discretionary inputs). The linear programming problem becomes:

$$Eff_i^j = \min_{z,\theta} \theta \qquad (2.2\text{ a})$$

s.t.

$$\sum_{k=1}^{K} z_k y_{km} \geq y_m^j, \quad m = 1,\ldots,M \qquad (2.2\text{ b})$$

$$\sum_{k=1}^{K} z_k x_{kn} \leq \theta x_n^j, \quad n = 1,\ldots,N \qquad (2.2\text{ c})$$

$$\sum_{k=1}^{K} z_k a_{kl} \leq a_l^j, \quad l = 1,\ldots,L \qquad (2.2\text{ d})$$

$$z_k \geq 0, \quad k = 1,\ldots,K \qquad (2.2\text{ e})$$

$$\sum_{k=1}^{K} z_k = 1, \quad k = 1,\ldots,K \qquad (2.2\text{ f})$$

By imposing the additional restrictions in equation 2.2d in the linear programming problem, we know that the Banker&Morey efficiency score cannot be smaller than the efficiency score in the NoSES model.

2.3 The Ruggiero Model

Ruggiero (1996) argues that by having units with a better production environment in the reference set, as is done in the Banker&Morey model, a unit may be defined as inefficient despite the fact that it produces *y* with the smallest observed amount of discretionary inputs given the non-discretionary inputs. Ruggiero (1996) suggests the following model

$$Eff_i^j = \min_{z,\theta} \theta \qquad (2.3\text{ a})$$

s.t.

$$\sum_{k=1}^{K} z_k y_{km} \geq y_m^j, \quad m = 1,\ldots,M \qquad (2.3\text{ b})$$

$$\sum_{k=1}^{K} z_k x_{kn} \leq \theta x_n^j, \quad n = 1,\ldots,N \qquad (2.3\text{ c})$$

$$z_k = 0 \quad if \quad a_{kl} > a_{jl}, \quad l = 1,\ldots,L \qquad (2.3\text{ d})$$

$$z_k \geq 0, \quad k = 1,\ldots,K \qquad (2.3\text{ e})$$

$$\sum_{k=1}^{K} z_k = 1, \quad k = 1,\ldots,K \qquad (2.3\text{ f})$$

In this model, the unit under evaluation is only compared with units that have less or equal non-discretionary inputs. That is, all units with a more favourable environment than the unit under evaluation are excluded from the reference set. The Ruggiero model has stronger restrictions than the Banker&Morey model, and thus the efficiency scores of the Ruggiero model cannot be smaller than those of the Banker&Morey model.

2.4 The Output Regression Model

The linear programming problem for the output regression model is identical with that of the basic DEA model. The difference lies in the definition of the outputs. In the output regression model the outputs are adjusted for differences in student inputs, following Grosskopf, Hayes, Taylor and Weber (1999). By regressing the outputs on the non-discretionary variables, the error term will constitute the output that is not explained by differences in non-discretionary variables. The outputs are calculated as $Output = \alpha + \beta A + \varepsilon$ where A are the non-discretionary variables and ε is output that is not explained by A. ε is not used as output directly since it is possible for ε to be negative, and the DEA models require positive outputs. The output in the DEA model is the observed mean output for the sample adjusted with the estimated residual: $y = \overline{Output} + \varepsilon$, where $\overline{Output}$ is the sample average.[1]

3. Efficiency

In section 3 data, models and results for the efficiency estimations are discussed. 3.1 contains a discussion of data concerning school inputs, student inputs and student outcomes. In 3.2 the empirical specifications are presented, and in section 3.3 the results are analysed.

3.1 Data

Data is administered by the Swedish National Agency for Education (NAE) and published for all Swedish municipalities each year (NAE (2002)).

Two types of inputs are used in the empirical models: School costs and student inputs. School costs are under the control of the school management and are discretionary in the models. Student inputs are not under managerial control, since the school administration cannot choose which students are going to attend the municipal schools. Such inputs are non-discretionary in the models. School costs are defined as total costs for education net of costs for premises and school buses. The cost for premises is administratively set within the municipality, and thus does not necessarily reflect the

[1] The output regressions are performed on average outputs for all students in a municipality. The results are therefore multiplied by the number of graduating students in order to make them comparable to the aggregate inputs used in the DEA models.

size and quality of the premises. The cost for school buses is not included since it probably reflects the geographical character of the municipality rather than actual inputs in the educational process. Included in the costs are primarily costs for teaching, school management, books, computers, lunch, libraries, school health care, education for teachers, and overhead administrative costs. Value added measures are not possible using Swedish student data and thus the educational results are dependent on school resources used during the entire education. To take this into account the average cost (in 1999 year's prices) for three years of education preceding graduation is used.

As student inputs in the empirical models we use the share of Swedish (i.e. non-immigrant) students in the municipal schools and the educational level of the students' mothers. The academic climate at home is highly determining the educational outcomes. If two municipalities have students with different academic climates at home, they also have different production possibilities. The mother's education is divided into a scale with three levels: Primary education, secondary education, and university education. This is translated into levels one, two and three. The educational level in the municipality is the average educational level of all mothers. Also, a municipality with a large share of immigrant students may not have the same production possibilities as municipalities with a large share of Swedish students, since immigrant students may e.g. need additional training in Swedish language.

As outputs from the educational process we use the academic achievement in terms of final grades in the municipality and students that pass all subjects. Final grades are the main instrument for measuring academic achievement in Sweden and the grades are used as instrument for selecting students for higher education etc. Full grades has been a politically important area since at some schools a large share of the students do not pass the courses e.g. in Swedish language and mathematics. When using grades as output it is important to recognize that the comparability between grades may be problematic due to e.g. differences between teachers in how to interpret the educational goals etc. Data on test scores is not available for the students in this study.

In order to be comparable to total costs, the outputs are defined as the number of students with full grades in a municipality and the total sum of grades in a municipality (expressed in thousands). Summary statistics for inputs and outputs is presented in table

3.1. In the output regression model, the outputs are adjusted for differences in the student's socio-economic background as described in section 2.4. They are presented as 'adjusted' in the table.

Table 3.1. Summary statistics for inputs and outputs in the efficiency models

	Min	Max	Mean	Std. dev.
Inputs				
Total cost (thousand SEK)	3 767,28	33 7648,6	29 488,92	38 640,1
Non-Discretionary Inputs				
Swedish students	0,544	0,987	0,8829	0,0846
Mother's education	1,839	2,63	2,1680	0,1277
Outputs				
Credit value (thousand)	19,24	1 314,16	139,40	157,46
Full grades	77	4 458,96	504,61	543,47
Adjusted credit value (thousand)	18,89	1 277,64	139,04	155,42
Adjusted full grades	74,85	4 505,11	509,60	562,52

3.2 Empirical specifications

The inputs, non-discretionary inputs, and outputs of the estimated models are presented in table 3.2.

Table 3.2. Efficiency Models

	No SES	Banker and Morey	Ruggiero	Output regression
Inputs				
Total cost	X	X	X	X
Non-Discretionary Inputs				
Swedish students		X	X	
Mother's education		X	X	
Outputs				
Credit value	X	X	X	
Full grades	X	X	X	
Adjusted credit value				X
Adjusted full grades				X

The Banker&Morey and Ruggiero models have identical variables, but differ in how the reference sets are constructed as discussed in section 2. Efficiency is estimated using variable returns to scale for each of the four models. The results are presented in section 3.3.

3.3 Results

The efficiency estimates for each of the four models are presented in table 3.3. We recall that the theoretical relationship between the efficiency scores is NoSES < Banker&Morey < Ruggiero.

Table 3.3. Estimated Efficiency

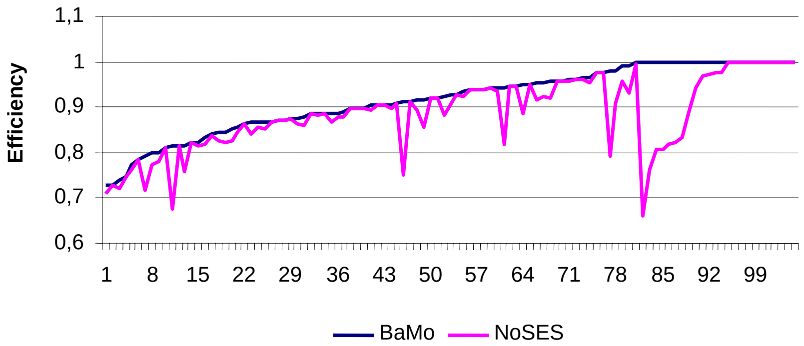
Model	Min	Max	Mean	Std	No. Eff
NoSES	0,6608	1	0,8845	0,0816	11
Banker and Morey	0,7261	1	0,9166	0,0733	24
Ruggiero	0,7290	1	0,9443	0,0652	38
Output regression	0,6572	1	0,8633	0,0841	8

As shown in table 3.3 the average efficiency scores have the correct relations in the empirical estimates. Without taking the student input into account in the model, mean efficiency is 0.88. For many municipalities part of the efficiency score depends on less favourable production conditions. When including the student inputs as additional dimensions in the DEA linear programming problem the mean efficiency scores increase to 0.92 in the Banker and Morey model and to 0.94 in the Ruggiero model. However, the difference between the NoSES model and these two models cannot be directly interpreted as the effect of student inputs, since additional restrictions by definition increase the efficiency scores. This is not the case for the output regression model, where the student inputs are used for adjusting the outputs and thus are not included directly into the DEA model. The mean efficiency score in the output regression model is 0.86, which is less than the NoSES estimate.[2] By including additional dimensions, the number of fully efficient units will increase and thus lower the discriminatory power of the model. This is clear from figure 3.3 where the NoSES and output regression models have 11 and 8 fully efficient units respectively, but the Banker&Morey model has 24 and the Ruggiero model has 38. In the Ruggiero model 36 % of the municipalities are defined as fully efficient.

The efficiency scores may change considerably for individual municipalities when taking the production environment into account. Below, it is analysed how the efficiency scores are affected when including the student inputs in the different models.

The first models that are compared are the NoSES and Banker&Morey models. In figure 3.1 the municipalities are ranked by the efficiency scores from the Banker&Morey model. The least efficient municipalities are to the left in the figure and the most efficient to the right. The corresponding NoSES efficiency scores are shown for each municipality.

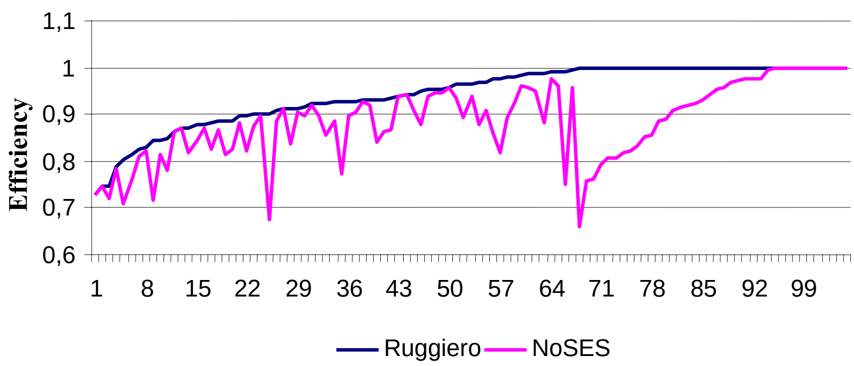
Figure 3.1 NoSES and Banker&Morey



The Banker&Morey efficiency scores are always higher than the NoSES scores. The difference is largest for a number of municipalities defined as efficient in the Banker&Morey model but are highly inefficient in the NoSES. These municipalities use more inputs than others having the same outputs, but it is not possible to find any other municipality or linear combination of municipalities that have used less input *given* the observed production environment. The difference between the NoSES model and the Ruggiero model is presented in figure 3.2.

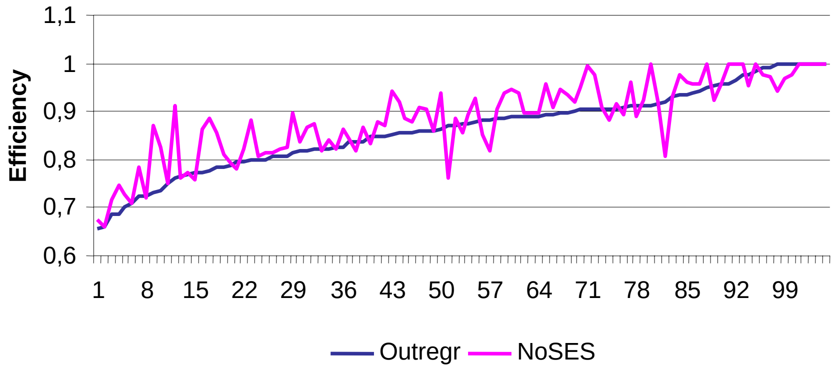
[2] Some of the municipalities achieve considerably higher outputs when calculating the adjusted outputs. If these are part of the production frontier of the other municipalities, the estimated efficiency may be lower than for the NoSES model.

Figure 3.2 NoSES and Ruggiero



As expected, the more restrictive Ruggiero model also shows larger differences from the NoSES model than the Banker&Morey model does. In the Ruggiero model, 27 municipalities are defined as efficient which are not so in the NoSES model. The difference between the NoSES model and the output regression model is presented in figure 3.3.

Figure 3.3 NoSES and Output regression



The figure shows that there is no clear relation between the efficiency scores estimated with the NoSES model and the output regression model. For most, but not all, municipalities the output regression model generates lower efficiency scores. While including the student inputs in the Banker&Morey and Ruggiero models will cause obvious changes in the ranking of the municipalities, this is not equally clear for the output regression model. The rank correlations between the four models are presented in table 3.4.

Table 3.4 Rank correlations

	NoSES	Banker and Morey	Ruggiero	Output regression
NoSES	1			
Banker and Morey	0.67	1		
Ruggiero	0.53	0.89	1	
Output regression	0.86	0.76	0.69	1

The rank correlation between the NoSES model and the output regression model is 0.86. This is considerably higher than the correlations between the NoSES model and the other two models, which is 0.67 for the Banker&Morey model and 0.53 for the Ruggiero model. The output regression model is similar to the NoSES model both in terms of mean efficiency and rank correlation, but many of the efficiency scores deviates from the ones estimated in the NoSES model (see figure 3.3). The Banker&Morey and Ruggiero models have very similar estimates for a large share of the municipalities compared to the NoSES model, but deviate heavily for a number of municipalities that are defined as efficient by the Banker&Morey and Ruggiero models, but as inefficient by the NoSES model. This phenomenon is discussed in Muñiz (2002) who prefers a multi-stage model to the Banker&Morey model because of the definition of efficient units in the Banker&Morey approach. The Ruggiero model is more restrictive than the Banker&Morey model and has both the effect that a large share of the municipalities are defined as efficient, and lower scores in general for the inefficient municipalities (this can be seen in figure 3.2).

The choice of how to include the non-discretionary student inputs is important for the outcomes of the model. The output regression model clearly has the highest discriminatory power, so if the purpose of the estimation is to get a clear ranking of the units this model is preferred. The high rank correlation with the NoSES model, however, indicates that if it is of importance that no unit is defined as inefficient, when this is in fact due to different production possibilities, one of the other models might be preferred. Ruggiero (1996) shows that the Ruggiero model is preferred to the Banker&Morey model if it is important that no unit is defined as inefficient, if in fact it has the lowest resource use observed given the observed production environment. This scenario is possible in the Banker&Morey model. However, the Banker&Morey and Ruggiero models are highly correlated (0.89).

4. Explaining Efficiency Differences

4.1. Data and Theoretical Considerations

The relation between competition and efficiency can be determined by analysing differences in efficiency between public producers of education facing different market conditions. If competition from private schools has an influence on public school efficiency, we would expect municipalities with a high share of students attending private schools to differ from municipalities with a low share of private school students. From economic theory we would in general expect competition to enhance efficiency, but the regulatory system under which the municipal schools operate causes the municipalities to claim that their operating costs increase with the establishment of private alternatives. The arguments are that the public schools must keep “vacancies” since they cannot reject private school students that want to attend a public school, and that the administrative costs increase. An increase in costs for the former public monopoly would not be surprising since the market is at present transforming and a large number of new schools are entering. The empirical evidence shows no general cost increases due to the increase in competition, but indicates that costs have increased in urban areas (Björklund et al (2003) and The National Agency for Education (2004)). The type of costs that increase is also important for the development of public school efficiency. If the major increase in costs is due to excess capacity in the form of too much resources, this may also be viewed as an increase of resources for the public school student, which is expected to improve the results. On the other hand, if the costs increase due to e.g. an increase in administrative cost, the cost efficiency is expected to decrease. A topic that is frequently discussed is the possibility that high ability students attend private schools to a larger extent than low ability students, so called “cream-skimming”. Since we do not have information about the students’ abilities we cannot control for cream-skimming. A possible cream-skimming effect will tend to lower the educational results (and thus cost efficiency) in the public schools. The National Agency for Education provides data on the share of the municipal students that attend a private school. Both students attending a school in the municipality and students commuting to other municipalities are included. Such a measure of competition includes both competition from schools within and outside the local market. The share of private school students in the municipalities ranges from 0 to 18 %.

Of course, competitive forces are not the only influence on efficiency in public education, but a number of other factors may be important. One of these is the political majority in the city council where conservative parties in general tend to be more in favour of private alternatives. To control for differences in political preferences we use a dummy for municipalities that have a tradition of socialist governments, i.e. they have had a socialist majority in the city council during the entire period after the school reform.

To control for other municipal characteristics that may affect the possibility to provide education, we include a number of variables describing the structure of the municipalities. These variables are included primarily in order to capture effects that may otherwise distort the results of the competition variable. The first variable of importance is the geographical situation: Some municipalities are located in more sparsely populated regions which might make education more expensive. This is estimated as the average distance between municipal residents. The tax base, which is the average taxable income of the citizens, is included to control for differences in municipal incomes. Tax base is an important control variable since income may e.g. capture attitudes towards education both among parents (which will directly affect educational results) and among other municipal citizens (which may affect school quality etc.). Tax base is not included as non-discretionary variable directly in the efficiency estimations since we only have the municipal average and not separate information for the households with school children (as is the case for the non-discretionary variables). Tax base may also affect efficiency through the municipal incomes. A high tax base will generate higher tax incomes and thus less pressure to have an efficient production.

Other structural variables are the municipal population and a dummy if the municipality is a suburb or not. In general we expect education to have some scale advantages so that larger municipalities would be more efficient. However, the variable returns to scale assumption will take the scale of operation into account and we will not define small municipalities as inefficient simply because of scale disadvantages. Thus, we do not have any theoretical expectations about the coefficient for the municipal population. Suburbs are expected to be more efficient than other municipalities due to competition between public school providers. Education is an important factor when choosing what municipality to live in, and moving between municipalities is the major way for parents to choose between public providers. Suburbs are located close to each other and close to a major labour market in a larger city, which is expected to promote competition.

Summary statistics for the variables are presented in table 4.1.

Table 4.1. Explanatory variables

Variable	Min	Max	Mean	Std.
Competition	0	18.433	3.8683	3.9217
Socialist majority	0	1	0.1619	0.3701
Tax base (thousand SEK)	97.654	210.474	118.644	16.8149
Population (thousand)	7.890	754.948	61.8882	88.4504
Pop density	17.000	970.000	147.029	139.448
Suburb	0	1	0.3333	0.4737

Data is provided by the National Board for Education, except for population and suburb which are based on data provided by Statistics Sweden in the data base "Sveriges statistiska databaser".

4.2 Exogeneity of Private School Competition

A major concern in the econometric estimation of competition is the possible endogeneity of the location of private schools. The theoretical model predicts competition to enhance efficiency in public schools, but the result may be distorted since private schools may be more likely to start where funding is high and public school quality is low. The funding of private schools is based on the costs for public schools in the municipality where the private school is located. If public schools perform poorly considering the resources spent (i.e., they are inefficient producers), there will be incentives for private schools to enter the market. Thus, endogeneity may be a problem in the empirical setting. The issue is primarily discussed when estimating the role of competition in public school *outcomes*, where e.g. Hoxby (1994) addresses the problem by using instrumental variables based on the Catholic population. This approach is not valid for the Swedish case since Sweden is very homogeneous regarding religion and only a minority of the private schools are confessional. We use the share of private day-care and grades from before the voucher reform as instruments for private education. Children that are too young for primary education have the right to public day-care, and private provision has a long tradition (from before the voucher reform) as an alternative to public day-care centres. The share of children in private day-care is correlated to private schools, but assumed to be unaffected by the efficiency in public *education*. The mean grades from 1992 are used as the second instrument. The voucher reform was introduced in 1992/93 and before 1992 public education was centralized and not a municipal responsibility. The grades in 1992 were determined in a setting with a centralized school system without private competition. Thus, these are not expected to be determined by public school efficiency in 2001/02. The first requirement of a valid instrument is that it is correlated with the variable for which it serves as an instrument. The correlations between private school competition and its instruments are presented in table 4.2.

Table 4.2 Correlation between private school competition and its instruments

Variable	Correlation
Private day-care	0.57
Grades in 1992	0.34

Both variables are positively correlated to private school competition, and the private day-care is rather highly so. To be valid instruments, the variables should not have an explanatory power of their own when included in the same model as the variable for which they serve as instruments. I.e., the only explanatory power of the instruments should be through the endogenous variable. To test for this (which is not a full test for endogeneity), we regress the efficiency scores on all the explanatory variables and the instruments. The regression is specified as a Tobit model, which is the most common specification when using efficiency scores as dependent variable (see e.g. Kirjavainen and Loikkanen (1998) and McCarty and Yaisawarng (1993) for applications on education). The Tobit model is

$$\begin{cases} y_1 = \beta' X_1 + \varepsilon_1 & \text{if } y_1^* < 1 \\ y_1 = 1 & \text{if } y_1^* \geq 1 \end{cases} \qquad 4.1$$

where y_1 is the dependent variable and y_1^* is the unobserved underlying variable, X_1 are the explanatory variables and ε_1 is a normally distributed residual. The coefficients and significance of the instruments are presented in table 4.3.

Table 4.3. Explanatory power of the instruments

Variable	NoSES		Banker and Morey		Ruggiero		Output regression	
	Coeff	P-value	Coeff	P-value	Coeff	P-value	Coeff	P-value
Grades in 1992	-0.0733	0.6087	-0.1982	0.1472	-0.1146	0.4977	-0.0684	0.5498
Private day-care	-0.0002	0.8403	0.0006	0.5364	0.0002	0.8559	-0.0007	0.3413

In table 4.3 it is shown that the variables used as instruments do not have any significant explanatory power when the school competition variable is simultaneously included in the model.

To test for endogeneity of competition we perform a Hausman tests following Smith and Blundell (1986). The test is performed is in two steps. In the first step, the possibly endogeneous variable is regressed (OLS) on the exogeneous variables of the Tobit model and the instruments:

$$y_2 = \pi_e^{'} X_e + \pi_i^{'} X_i + \varepsilon \qquad 4.2$$

where y_2 is the endogeneous variable, X_e are the exogeneous variables and X_i are the instruments. In the second step, the predicted residuals, $\hat{\varepsilon}$, are included as an explanatory variable in the Tobit regression as defined in 4.1 so that

$$y_1 = \beta' X_e + \gamma y_2 + \rho \hat{\varepsilon} + v \qquad 4.3$$

where y_1 is the dependent variable in the Tobit model. Exogeneity is tested by testing if $\rho=0$. The results for the models are presented in table 4.5.

Table 4.5 Test statistics – Smith and Blundell

Model	Test statistic	P-value
NoSES	0.0001	0.9922
Banker and Morey	0.0149	0.1926
Ruggiero	-0.0059	0.6081
Output regression	0.0049	0.6541

The Hausman test statistic does not indicate that private school competition should be endogenous. [3] This is in line with previous results for the Swedish case. Sandström and

[3] A similar test can be performed in a simultaneous equations model setting according to the LIMDEP 7.0 manual where

Bergström (2005), and Ahlin (2005) find no endogeneity in their studies of private school competition and educational outcomes in the Swedish voucher system. The underlying reasoning behind endogeneity is that poor public school quality causes the emergence of private alternatives. This can be argued not to be the primary reason for private schools in Sweden. E.g. the Swedish National Agency for Education (1996) finds that only 20% of the parents that had children in private schools claimed low public school quality to be an important aspect.

4.3. Empirical Results

4.3.1 Second Stage Model with the Full Set of Explanatory Variables

As is clear from the Hausman test statistics in table 4.5, there is no need for an instrumental variable (IV) specification. The Tobit estimates are presented for all four models in table 4.6. Since endogeneity is a frequently discussed topic, we present the IV estimates in appendix B for comparison.

$$y_1 = \beta' X_1 + \gamma y_2 + \varepsilon_1$$
$$y_2 = \pi' X_2 + \varepsilon_2$$

and where y1 is defined as a Tobit model according to 4.1. X_2 are the instruments in this setting. Exogeneity is tested by testing if the correlation between ε_1 and ε_2 is zero. Test statistics and probability values for the Hausman test are presented in table 4.4. The null-hypothesis is that there is no endogeneity problem.

Table 4.4 Exogeneity test statistics

Model	Test statistic	P-value
NoSES	0.0065	0.3096
Banker and Morey	0.0045	0.5113
Ruggiero	0.0045	0.4494
Output regression	0.0059	0.2660

The interpretation of the test results from this approach is the same as the results from the Smith and Blundell approach. We find no endogeneity.

Table 4.6. Explaning efficiency differences (marginal effects)

Variable	NoSES		Banker and Morey		Ruggiero		Output regression	
	Marg eff	P-value	Marg eff	P-value	Marg eff	P-value	Marg eff	P-value
Constant	-0.5911	0.0000	0.0323	0.6679	0.1026	0.1414	0.1083	0.1147
Competition	-0.0026	0.3866	-0.0031	0.3000	-0.0017	0.5749	-0.0044	0.0982
Socialist majority	-0.0389	0.0938	-0.0323	0.1332	-0.0243	0.2323	-0.0356	0.1025
Population	0.0006	0.0479	0.0003	0.2694	0.0003	0.3604	0.0004	0.0992
Pop density	-0.0001	0.0210	-0.0001	0.0718	-0.0001	0.0296	-0.0001	0.2329
Suburb	0.0144	0.5546	0.0390	0.1641	0.0485	0.1042	0.0241	0.2964
Tax base	-0.0015	0.0937	-0.0009	0.1703	-0.0012	0.0578	-0.0021	0.0009
Mother’s edu	0.1455	0.1880	-	-	-	-	-	-
Swedish	0.3928	0.0100	-	-	-	-	-	-

In none of the models it can be shown that private school competition is correlated to efficiency in the provision of public education at 5% level of significance. As discussed in the theoretical considerations, a positive effect is expected from economic theory, but other effects as well may be present. The first is cream-skimming, which would imply that competition decreases the average ability of the public school students. This will tend to decrease the empirical estimates of cost efficiency in municipalities facing competition and may thus decrease a possible positive correlation in the empirical estimates. A second possible effect is that competition may imply cost increases that cannot be used for increasing the outcomes of public school students. Also this effect will tend to decrease cost efficiency. The sign of the coefficient is negative in all models and significant at 10 % in the output regression model. The coefficients vary from -0.0017 in the Ruggiero model to -0.0044 in the output regression model. The interpretation of the value -0.0044 is that a 1 % increase in the share of the municipal students attending a private school causes efficiency in public education to decrease with 0.44 %.

Socialist majority has a negative sign in all model specifications, but is only significant at 10% level in the NoSES model. Population and population density are included to control for structural differences among the municipalities, although we expected a large share of the variation to be eliminated already when restricting the sample to urban areas. Population has a positive sign in all models, while population density has a negative sign as expected. Population is significant at 5 % in the NoSES model and at the 10 % level in the output regression model. Population density is significant at 5 % in the NoSES and Ruggiero models. Suburb has a positive sign in all models but is not significant. The tax base has a negative sign in all models, and is significant at 5 % in the output regression model and at 10% in the NoSES and Ruggiero models. The interpretation is that municipalities with a high tax base are less efficient producers than other municipalities.

4.3.1 Alternative Specification of the Second Stage Model

One of the control variables, tax base, is highly correlated with the share of children attending private schools. The correlation coefficient is almost 0.63. This multicollinearity problem could be the reason for the insignificant results in table 4.6. Although tax base is an important control variable, we estimate an alternative model where the variable is excluded from the regression.

Table 4.7. Explaning efficiency differences (marginal effects) , without tax base in the model

Variable	NoSES		Banker and Morey		Ruggiero		Output regression	
	Marg eff	P-value	Marg eff	P-value	Marg eff	P-value	Marg eff	P-value
Constant	-0.5579	0.0001	-0.0624	0.0224	-0.0137	0.6692	-0.1031	0.0000
Competition	-0.0047	0.0817	-0.0051	0.0556	-0.0045	0.1167	-0.0089	0.0004
Socialist majority	-0.0451	0.0533	-0.0369	0.0895	-0.0312	0.1403	-0.0468	0.0458
Population	0.0006	0.0225	0.0003	0.2892	0.0003	0.4184	0.0005	0.0989
Pop density	-0.0001	0.0231	-0.0001	0.0610	-0.0001	0.0199	-0.0001	0.2166
Suburb	-0.0008	0.9718	0.0205	0.4074	0.0209	0.4404	-0.0073	0.7478
Mother's edu	0.0305	0.7184	-	-	-	-	-	-
Swedish	0.4497	0.0026	-	-	-	-	-	-

The estimated coefficients for competition have a negative sign in all specifications. Ignoring the NoSES model for the moment, we note that the variable is significant at 5 % in the output regression model, significant at 10% in the Banker&Morey model and insignificant in the Ruggiero model. The significance of private school competition is related to the share of fully efficient municipalities presented in table 3.3. The number of fully efficient units is largest for the Ruggiero model, followed by the Banker&Morey model, and smallest for the output regression model. Turning to the NoSES model, it has only few fully efficient observations, but the competition variable is only significant at the 10 % level. The low significance is due to the variable for the share of Swedish students which is correlated to a number of the other explanatory variables (the correlation with competition is -0.41).

The negative sign for competition is robust to whether tax base is included or not as an explanatory variable. The significance is stronger when excluding tax base, but part of the variation that is explained by competition might be variation due to differences in the tax base. Competition is only significant at 5 % in the output regression model, so the main conclusion is that we cannot prove a significant relation between competition and public school efficiency.

5 Summary

In this study cost efficiency is estimated for public education in 105 Swedish municipalities using four different model specifications regarding how to include student inputs: NoSES, BankerMorey, Ruggiero, and output regression. The estimated efficiency scores are then regressed on private school competition and a set of control variables in order to test if competition affects public school efficiency. In two of the efficiency models, the Banker&Morey and the Ruggiero models, the student inputs are included in the efficiency models as additional restrictions. The Banker&Morey and Ruggiero models have a high rank correlation of the efficiency scores. In the output regression model, the outputs are adjusted for differences in student inputs, while in the NoSES model the student inputs are used as explanatory variables in the second stage regression. The output regression model and the NoSES model have a similar ranking of the efficiency scores. The Banker&Morey and Ruggiero models deviate primarily from the NoSES and output regression models by ranking a number of municipalities that are defined as inefficient in the NoSES model as fully efficient. This is due to the additional restrictions in the linear programming problem. Thus, when analysing the efficiency scores in the second stage, the models may point in different directions. The coefficient for competition is negative in all models, but the significance is dependent on the model specifications. Efficiency models with stronger restrictions when modelling the student background have lower significance in the second stage.

However, considering the results from all estimated models, the conclusion is that the coefficient for private school competition is not significant.

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Appendix A Variable Definitions

Table A.1. Variable definitions – efficiency models

Variable	Definition
Inputs	
Total cost	Total cost for education excluding costs for premises and costs for school buses. 1999 year prices. Mean for the years t to t-2
Non-Discretionary Inputs	
Swedish students	Share of the graduating students that have a Swedish origin
Mother's education	Mean educational level of the mothers of the graduating students, defined from SUN-codes
Outputs	
Credit value	Aggregate credit value for graduating students year t
Full grades	Graduating students that have passed all subjects year t
Adjusted credit value	Aggregated credit value for graduating students year t adjusted for ethnicity and SES
Adjusted full grades	Number of the graduating students that have passed all subjects year t adjusted for ethnicity and SES

Table A.2. Variable definitions – Tobit models

Variable	Definition
Competition	Share of students (%) attending a private school, mean for t to t-2 (NAE)
Socialist majority	Socialist majority in the city council (NAE). Equal to one if there has been a socialist majority continuously since the school reform. Zero otherwise.
Population	Population in thousands 2001 (Statistics Sweden)
Pop density	Mean distance in meters between citizens 2001 (NAE)
Suburb	Dummy that is equal to one for suburbs, zero otherwise (Statistics Sweden)
Tax base	Taxable income in thousand Swedish kronor 2001 (NAE)
Instruments	
Grades 1992	Average grades in the municipality 1992 (NAE)
Private day-care	Share of children in private day-care 2001 (NAE)

Appendix B Explaining efficiency differences with instrumental variable estimation

Table B.1. Explaining efficiency differences (marginal effects)

Variable	**NoSES**		**Banker and Morey**		**Ruggiero**		**Output regression**	
	Marg eff	P-value	Marg eff	P-value	Marg eff	P-value	Marg eff	P-value
Constant	-0.5098	0.0001	0.1541	0.0014	0.1622	0.0008	0.1401	0.0197
Competition	0.0040	0.5262	0.0034	0.5419	0.0020	0.6318	0.0018	0.7721
Socialist majority	-0.0415	0.1018	-0.0372	0.1433	-0.0372	0.0470	-0.0319	0.2151
Population	0.0006	0.0060	0.0004	0.0716	0.0003	0.1440	0.0006	0.0021
Pop density	-0.0001	0.0473	-0.0001	0.1488	-0.0001	0.0067	-0.00005	0.3849
Suburb	0.0205	0.3680	0.0518	0.0104	0.0440	0.0143	0.0329	0.2239
Tax base	-0.0019	0.0046	-0.0021	0.0000	-0.0017	0.0001	-0.0026	0.0000
Mother’s edu	0.0894	0.2701	-	-	-	-	-	-
Swedish	0.4609	0.0015	-	-	-	-	-	-
Instruments (coefficients)								
Constant	13.413	0.2321	14.4869	0.2118	12.8366	0.2431	13.8151	0.2238
Grades 1992	-4.6231	0.1852	-4.9621	0.1693	-4.4412	0.1951	-4.7500	0.1793
Private day-care	-0.1506	0.0000	-0.1493	0.0000	-0.1513	0.0000	-0.1501	0.0000