Chapter 9
Are Swiss Secondary Schools Efficient?

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9.1. Introduction

Since the disappointing performance of Switzerland in the year 2000 PISA survey, carried out by the OECD,[1] the quality of schools in Switzerland has become a particularly sensitive issue. The concern about the efficiency of educational production is now a key point raised in debates about schools. The aim of this paper is to measure the efficiency of Swiss secondary schools in order to make an academic contribution to this topic. The Data Envelopment Analysis (DEA) method was used to define the efficiency scores and production frontiers (Charnes et al. 1978).

The relationship between efficiency and size of school has also been given special attention (Kirjavainen and Loikkanen 1998; Bradley et al. 2001; Barnett et al. 2002). Interest in this question is motivated by the fact that the organisation of education in Switzerland is going through a process of complete transformation. Given that in Switzerland not one but 26 different scholastic systems[2] coexist on the same territory, in attempts to

[1] *Programme International pour le Suivi des Acquis des élèves* (Programme for International Student Assessment). In an international comparison of 32 participating countries (classification in reading): Finland (1st) had an average score of 547, France (14th) scored 505, Switzerland (17th) 494, Italy (20th) 488, Germany (21st) 484, Brazil (last) 396, and the average score of OECD countries was 500.

[2] Switzerland is a federal state with a three-tier political structure: the (federal) Confederation, the (regional) cantons (26), and the (local) communes. The Constitution only grants a very limited number of tasks in educational matters to the

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develop a national education system, the question of harmonising public state education[3] recurs again and again (Swiss Confederation 2006). In fact, this leads to and will continue to lead to the making of numerous decisions.[4] The question of the optimum size of schools might be one of these. The results show that the larger the size of the school, the larger the percentage of efficient schools.

This chapter is organised as follows. The next section presents the DEA model, after which the database is explained in Section 9.3, followed by the selection of outputs and inputs in Section 9.4. The results are analysed in Section 9.5. The final section concludes with the implications for public political choices and possible future research.

9.2. Methodology

Educational researchers have been implementing the DEA methodology that began development in the United States in the early 1980s (Charnes et al. 1981; Bessent et al. 1982, 1984). DEA is a mathematical technique that estimates a frontier (Charnes et al. 1978). This frontier is determined by defining for each observation variables as either inputs (resources used in production) or outputs. The idea of efficiency, as defined by Farrell (1957), is the success (of a firm) "in producing as large an output as possible from a given set of inputs".

Let X_i be a vector of inputs and Y_i a vector of outputs for the school i ($i = 1,...,N$). Suppose X_0 and Y_0 are, respectively, the inputs and outputs of school 0 whose efficiency score needs to be determined. The measurement of efficiency for school 0 may be defined as follows:

Confederation. It is the cantons who control the structure and content of training and education (art. 62 of the federal Constitution).

[3] In late May 2006, the Swiss people took part in a popular vote aiming to change the articles in the Constitution governing education and (vocational) training. One issue in this vote was the harmonisation of state education. For the first time the majority of voters (85%) voted yes to national involvement of the federal state in education (voter participation rate: 27%).

[4] For example, harmonisation of the new school year. Until the mid-1980s, the cantons in favour of the autumnal new school year were opposed to those defending the spring start of the new school year. Following the results of the popular vote of 22 September 1985, the start of the new school year was finally set between mid-August and mid-September throughout the country.

$$Min\ \eta_0 \tag{9.1}$$

s.t.

$$\sum_{i=1}^{n} \theta_i Y_{ij} \geq Y_{0j} \qquad \forall\ j = 1,...,s \tag{9.2}$$

$$\sum_{i=1}^{n} \theta_i X_{ik} \leq \eta_0 X_{0k} \qquad \forall\ k = 1,...,m \tag{9.3}$$

$$\sum_{i=1}^{n} \theta_i = 1 \tag{9.4}$$

where η_0 represents the efficiency score of school 0 and θ_i the weight given by the school i in order to dominate school 0, j represents the outputs and k represents the inputs. Optimal η_0 cannot be greater than 1. If the score of school 0 is equal to 1 ($\eta_0 = 1$), then the school is efficient whereas if it is less than 1 ($\eta_0 < 1$), the school is inefficient.

In order to illustrate this in graph form, an example composed of four schools (A, B, C, and G) is now considered in which only one input (X) is used so that only one output (Y) is produced. Figure 9.1 represents the two dimensions of a plane on which the four schools are positioned. Schools A, B, and C are efficient as they are situated on the frontier. On the other hand, school G is inefficient. The degree of inefficiency can be measured (graphically) in two ways: either as the vertical distance between point G

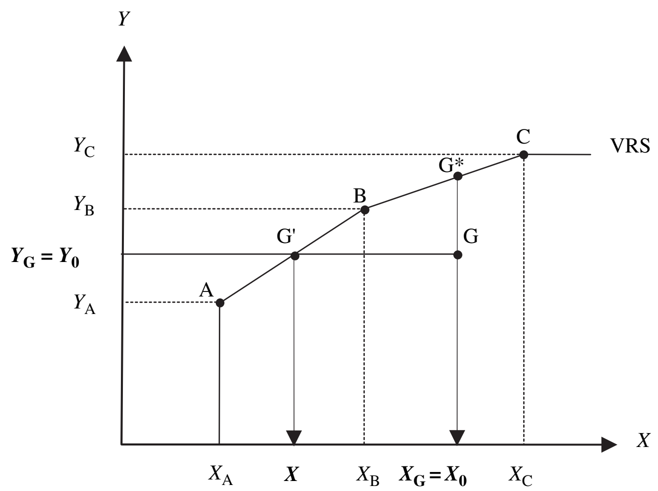

Fig. 9.1. The DEA frontier

and point G* (output oriented) or the horizontal distance between point G and point G′ (input oriented). The output-oriented measurements indicate the amount by which the outputs must be proportionally increased in order to reach the frontier while keeping inputs constant. The input-oriented measurements indicate the amount by which inputs could be proportionally reduced while keeping output quantities constant.

If it is considered that the aim of school headmasters is to obtain the best results possible using the resources available (over which they exercise little or no control), the output-oriented version is appropriate (Mancebón and Bandrés 1999). On the other hand, if the goal is that schools minimise the use of inputs while keeping their output level constant, then it is better to opt for an input-oriented model (Kirjavainen and Loikkanen 1998). In this chapter, we share the view that because of difficult budgetary context, educational policies are aimed at improving the use of resources (Diagne 2006). The results are therefore input oriented, that is to say, a school is not efficient if an input can be reduced without increasing another input and decreasing the output (Charnes et al. 1981).

To determine the (in)efficiency score of school G, then:

$$X_G = X_0 \tag{9.5}$$

and

$$Y_G = Y_0 \tag{9.6}$$

$\sum_{i=1}^{n} \theta_i Y_{ij}$ represents the weighted sum of Y_i, i.e. $\theta_A Y_A + \theta_B Y_B + \theta_C Y_C + \theta_G Y_G$ with $\theta_A + \theta_B + \theta_C + \theta_G = 1$ (hypothesising variable returns to scale). Assuming that:

$$\sum_{i=1}^{n} \theta_i Y_i = Y_0 \tag{9.7}$$

$\sum_{i=1}^{n} \theta_i X_i$ represents the weighted sums of X_i and assuming that:

$$\sum_{i=1}^{n} \theta_i X_i = \eta_0 X_0 = X \tag{9.8}$$

The efficiency score is:

$$\eta_0 = \frac{X}{X_0} \tag{9.9}$$

If η_0 is 0.8, the inefficiency of school G is 20% (1 – 0.8=0.2). In other words, school G must decrease its input by 20% if it is to become efficient, that is to say, to be placed on the segment of the frontier linking school A and school B.

Initially, Charnes et al. (1978) assumed the scale returns were constant (CRS). In a production process constant returns to scale indicate that production varies in the same proportion as the production factors involved. If all the schools perform optimally, then the CRS hypothesis is appropriate. Banker (1984) then modified the CRS model in order to account for situations in which the returns to scale are variable (VRS). This hypothesis means a more flexible frontier can be estimated.

Figure 9.2 shows the distinction between technical inefficiency (starting measuring from the VRS frontier) and the scale inefficiency (starting measuring from the CRS frontier). The technical inefficiency corresponds to the inefficiency defined in Eq. 9.9. However, it seems that at point G′, the productivity ratio Y_G/X is weaker than the maximum ratio Y_G/X_A of school A. Even though its technical efficiency places it at point G′, the size of school G means it cannot have the maximal average production per factor unit. Compared to the latter, which is situated at the optimal size, school G suffers from scale inefficiency measured by the relationship $X_{G''}/X$. Its total inefficiency combines the two forms of inefficiency and is measured by the relationship $X_{G''}/X_G$.

One advantage of DEA is that by using several inputs and outputs, it considers the multidimensional characteristics of education. Another advantage is the non-parametric character of the method. However, the results are sensitive to choice of inputs and outputs and since a non-stochastic method is used, the classic statistical tests do not allow the specifications used to be tested.

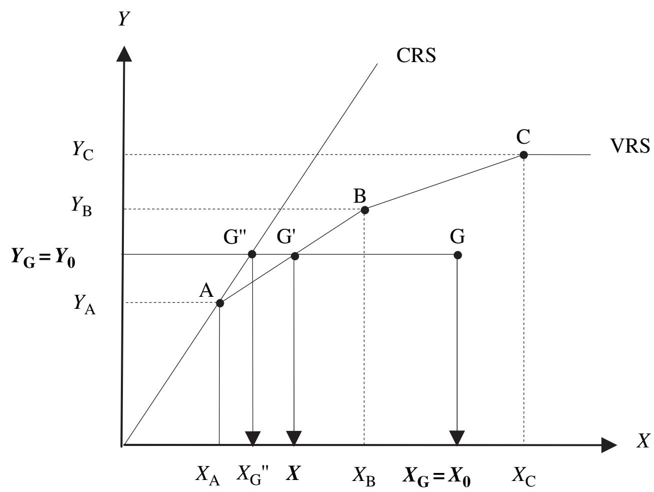

Fig. 9.2. The technical efficiency and the scale efficiency

9.3. The Data

The data used in this study were obtained from the PISA survey national sample for Switzerland. This survey was carried out by the OECD in the year 2000 (OECD 2002). The aim of this survey was to test the ability of pupils so that the educational achievement of the young could be compared. Three fields were examined: reading, mathematics and science. The sample population was defined in agreement with the school year. The final obligatory year of schooling in the Swiss scholastic system is Year 9.[5]

Representative samples in the three large linguistic regions in Switzerland were taken by the PISA survey national management (i.e. the Swiss Confederation and the cantons).[6] In the first stage, the schools were sorted on the basis of the 1998/1999 school data of the Swiss Federal Statistical Office (SFSO). In the second stage, the pupils were randomly selected from the schools considered. Therefore, not all pupils participated in the PISA survey, and only certain pupils in certain schools took the tests.

The sample used in this study only treats the schools in which less than 20 pupils took part in the PISA survey. This was the case in 156 schools in 22 cantons.[7] This number is based on the average number of pupils per class (only for state schools) which was 19.1 in Secondary 1 in 1999–2000 (SFSO 1999). In order to verify that there was no attrition bias, the descriptive statistics from this sub-sample were compared to those of the total sample (243 schools).

9.4. Selection of Outputs and Inputs

Considering schools as companies specialising in educational production, Schultz (1963) opened the way to evaluation of production frontiers and

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[5] Compulsory schooling lasts 9 years and is composed of the primary and secondary I levels. In most cantons, primary education lasts 6 years (from 6/7 years old to 11/12) and secondary I lasts 3 years (from 12/13 years old to 14/15). For more details on the Swiss education system see the CDIP web-site (http://www.ides.ch/umfrage2003/mainUmfrage_F.html).

[6] It concerns German (spoken by 64% of the resident population as mother tongue), French (20%), and Italian (7%). The remaining 9% use other languages to express themselves.

[7] Two cantons (Uri and Appenzell Rhodes-Intérieur) did not take part in the PISA and the schools in the cantons of Glaris and Nidwald did not reply to certain questions.

the measurement of efficiency in education. The school is therefore considered to be an entity carrying out a production process (in this case educational) by transforming inputs into outputs (Thanassoulis and Dunstan 1994). Given the present state of knowledge concerning this process of acquisition, the school is generally considered to be a black box. In addition to measuring inputs and outputs, the conceptualisation also forms part of recurring problems found in numerous studies (Mancebón and Bandrés 1999).

9.4.1 The Outputs

The educational output should represent the aim of the school. As an institution, the school has the essential function of transmitting a curriculum. This formal curriculum is what is officially designated and supposed to be transmitted to the students (mainly composed of cognitive abilities). But the school is situated in a world of socialisation meaning the pupils also learn what some sociologists call the hidden curriculum: affective abilities (Duru-Bellat and van Zanten 1999). The whole problem lies in the multidimensional nature of education, in other words, the multiplicity of aims pursued by the school cannot be aggregated into one single measurement (Bessent et al. 1982). Furthermore, it is not always easy to measure educational production. And yet, if one wishes to analyse the production of the schools, it is nevertheless essential to employ appropriate measurements of the outcomes.

From the moment when the subject selection decisions of the students are taken, which are theoretically based on school criteria objectives such as the marks obtained by the students, these represent a measure recognised by the institution itself. In most Swiss cantons, the average mark obtained at the end of the academic year forms the basis for provisional or definitive promotion to the class above (CDIP 2001). The majority of studies in the literature use standardised test scores (Bradley et al. 2001). This output fulfils one of the essential aims of schools: obtaining knowledge for guidance and therefore selection within the education system. The score for reading in the PISA 2000 test is used as the output (READ) in this study. This means the arithmetic average of pupils taking part in the survey by school. The school is therefore the educational production unit. The pupils taking part in the 2000 survey all answered the questionnaire on reading. Unfortunately, this was not the case in mathematics or science, which resulted in considerable attrition of the data.[8] Consequently, only the reading results are used in this paper.[9]

In order to measure the homogeneity of pupil performances within the establishments, the inverse standard deviation (by school) of the reading score (INVRSD) was used. This variable takes the dispersion of results inside the school into account. The greater the value, the more homogeneous the results of the pupils within the school, that is to say, concentrated around the average of the school considered. In addition, particular attention needs to be given to the idea of equity. In fact, if two schools having the same average score are considered, the one in which all the pupils are concentrated around the average will be preferable to that in which the pupils are split into a wider spectrum, with the good on the one side and the poor on the other. Seldom present in the literature, this consideration deserves more attention from those who do research into efficiency.

Figure 9.3 illustrates the relationship between the two outputs used in the DEA. The degree of pupil homogeneity correlates positively with the average performance level in reading (the coefficient of correlation is 0.6009). There are two possible interpretations. The first is that the level of performance within the establishments leads to homogenisation of pupil results, i.e. performance and equity are not contradictory. The second is that the schools situated in a homogeneous environment obtain the best results. The causality between performance and equity is therefore the inverse of the first explanation.

9.4.2 The Inputs

As accurately as possible, the selected inputs must represent the characteristics of the educational system impacting on the process of educational production. However, this selection is restricted by the availability of information in databases. There is no unanimous choice of inputs in the literature (Hanushek 1986).

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[8] Of all the students in the original sample taking the reading test (7997 pupils) only 2653 replied to the questions on both reading and science, 2647 to those on reading and mathematics, and 1804 on reading, mathematics, and science, and 893 on reading only.

[9] The correlation coefficients between the subjects studied by the 1804 pupils who replied to the three questionnaires were: reading and mathematics (0.8120), reading and science (0.8983), and mathematics and science (0.7979).

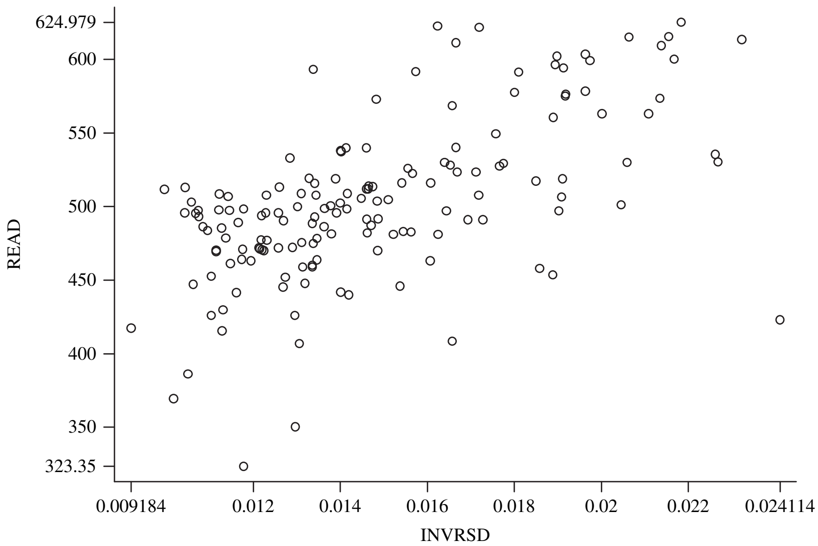

Fig. 9.3. The two DEA outputs (READ and INVRSD)

In that the DEA results are sensitive to the inputs used, this forms an important stage in the modelling. There is a methodological divide in the literature resulting from the precise choice of inputs made. On the one hand, there are the studies that suggest using only discretionary inputs in the DEA, i.e. under the control of the schools (Charnes et al. 1981; Bessent et al. 1982, 1984; Kirjavainen and Loikkanen 1998; Mancebón and Bandrés 1999; Diagne 2006). On the other hand, there are studies simultaneously using discretionary and non-discretionary inputs, such as environmental or socio-economic inputs (Ray 1991; Ruggiero 1996).

The choice of methodology has empirical implications. Studies which introduce only discretionary inputs into the DEA use the non-discretionary inputs in a second stage (OLS or tobit) in order to explain the distribution of efficiency scores (Bradley et al. 2001). The others generally use the econometric method of stochastic frontiers (Barrow 1991; Cooper and Cohn 1997).

In order to understand the resources allocated to teaching from a quantitative point of view,[10] the inputs of human capital considered in the analysis

[10] The importance of class size to scholastic performance has been highlighted in literature (Summers and Wolfe 1977; Arias and Walker 2004). It is therefore unfortunate that this variable does not appear in the PISA, all the more when considering the virulent debate surrounding this problem (Krueger 2003).

presented in this chapter include the number of teachers per pupil[11] (TEACHER). They also include the number of hours of supervision per year (TOTHRS) so as to take the annual time available for teaching pupils into consideration. This input is important in the Swiss case since there is a great variation between establishments because the responsibility for setting the Secondary 1 study plan lies with the cantonal authorities. For example, during the course of their obligatory schooling a pupil in the canton of Fribourg attends school for at least 700 h more than a pupil in the canton of Geneva (CDIP 2001). Finally, in order to quantitatively consider the resources allocated to teaching, the number of teachers per pupil having a teaching diploma (QUAL) was also taken into consideration. While the Coleman report (1966) concludes that the experience of teachers makes only a marginal contribution, the results of Summers and Wolfe (1977) and Goldhaber and Brewer (1997) disagree with Coleman. In the Swiss case, given that the teacher training system is governed by cantonal legislation, this input is also important.[12] The working conditions of teachers, salary level, and type of post are also fixed by the cantons (CDIP 2001). Unfortunately, this information is not available in the PISA survey.

Following Ruggiero (1996) we consider an input in physical capital as well.[13] The number of computers per pupil (COMPUTER) provides an approximate idea of the availability of information technology equipment, and so the financial commitment of the school to new technology can be measured. The descriptive statistics of the variables used are presented in (Table 9.1) along with the correlation matrices (Table 9.2).

[11]The quantity of available educational resources can be measured in different ways: the number of professionals per 100 pupils (Bessent et al. 1982), the number of teachers per pupil (Mancebón and Bandrés 1999; Diagne 2006), or the pupil/teacher ratio (Mizala et al. 2002). With regard to homogeneity, the pupil measurements for all the variables were considered.

[12]Since 2005 all teacher training has been carried out to university degree level. The hautes écoles pédagogiques (HEP) were created for this (Universities of Teacher Education).

[13]Ruggiero (1996) also uses the number of classrooms per pupil as an input to measure capital.

Table 9.1. Descriptive statistics

Variables		Mean	Std. Dev.	Min	Max
Outputs	READ	503.5198	54.4640	323.35	624.98
	INVRSD	0.0148	0.0033	0.0092	0.0241
Inputs	TEACHER[a]	0.0875	0.0214	0.0203	0.1751
	TOTHRS	987.4615	80.6980	579	1261
	QUAL[a]	0.5734	0.3309	0.01	1
	COMPUTER[a]	0.1158	0.0723	0.018	0.571
Others	SCHLSIZE	409.8077	295.0303	35	1715

Source: PISA 2000.
Sample size N = 156 schools. [a] Variables measured *per pupil.*

Table 9.2. Correlation matrices of the variables used in the DEA

	READ	INVRSD	TEACH	TOTHRS	QUAL	COMP
READ	1.0000					
INVRSD	0.6009	1.0000				
TEACH	0.0397	0.0390	1.0000			
TOTHRS	0.1149	0.0706	0.1194	1.0000		
QUAL	0.4151	0.2121	–0.1025	0.1123	1.0000	
COMP	–0.0019	0.1035	0.2954	0.1995	0.2023	1.0000

Source: PISA 2000.
Notes: N = 156 schools. TEACH = TEACHER, COMP = COMPUTER.

9.5. Results

The production frontiers were determined using the DEA model and the Efficiency Measurement System software (Scheel 2000). The basic specification included two outputs (READ and INVRSD) and four inputs (TEACHER, TOTHRS, QUAL, and COMPUTER). Table 9.3 shows that when variable scale returns are used, the average efficiency score is 0.8348 (standard error of 0.1147). This means that on average the schools could reduce their resources by approximately 16% while maintaining the same level of educational production. The minimum efficiency score is 0.5264 and the number of efficient schools is 24 (out of 156), i.e. 15% of the sample.

When constant scale returns are used, the average efficiency score is lower (0.8043 with a standard error of 0.1194). The minimum efficiency score is also lower (0.4421) and the number of efficient schools is no more than 16 (out of 156), i.e. 10% of the sample. In terms of effectiveness, the

Table 9.3. Average efficiency score, minimum and maximum scores and percentage of efficient schools (CRS and VRS)

	Mean	Minimum	Maximum	% of efficient schools
CRS	0.8043	0.4421	1.0000	10% (16/156)
VRS	0.8348	0.5264	1.0000	15% (24/156)

Source: PISA 2000.

16 efficient schools are attended by only 851 of the 5870 pupils attending the 156 schools in the sample (14.5%). The average size of the 16 efficient schools is much higher (579) than the 140 inefficient schools (390.47). Figure 9.4 represents the distribution of schools classified in order of increasing efficiency when constant scale returns are used.

One question which deserves attention is whether school size matters for efficiency. This topic is frequently discussed in the literature but the authors do not agree on the link between size and efficiency. For example, the results of Barnett et al. (2002) show that the performance of schools correlates positively with their size. On the other hand, Kirjavainen and Loikkanen (1998) remark that efficiency scores correlate less with the size

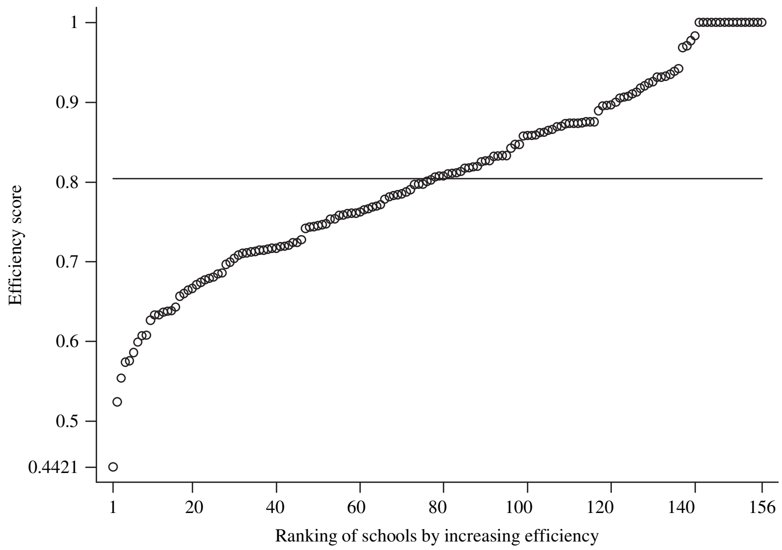

Fig. 9.4. The efficiency distribution of input-oriented DEA model (CRS is assumed)

of the school and more positively with class size.[14] According to Bradley et al. (2001) the greater is the degree of competition between schools and pupils, the more efficient the schools tend to be. There will be a contradictory effect between the fact that the larger the schools the more the efficiency and the fact that the more numerous the schools are (and therefore small in size), the more they compete against each other and are efficient.

Figure 9.5 represents the efficiency scores of the 156 schools by size of school. The average size is approximately 410 pupils and it is quite clear that the more the size of the school increases, the more the dispersion of the school efficiency scores decreases (the coefficient of correlation is 0.3545). Analysis of the quartiles (Table 9.4) also shows that when schools situated in the 1st quartile are compared to the 4th quartile, the number of efficient schools increases (from 2.6% for the 1st quartile to 18% in the 4th

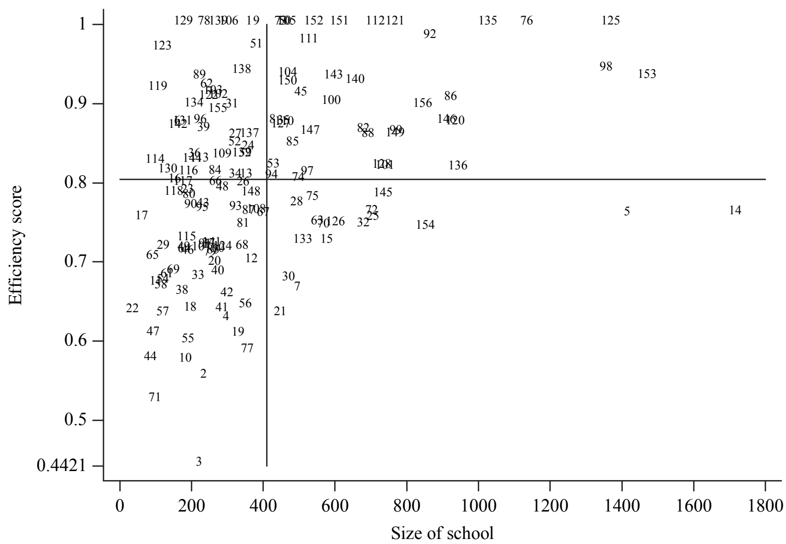

Fig. 9.5. Efficiency scores and size of school (CRS is assumed)

[14] Barnett et al. (2002) do not control for the class sizes. According to the results of Kirjavainen and Loikkanen (1998), inefficiency initially increases with class size then decreases from an average class size of 11 pupils (inefficiency is minimised when average class size is 27 pupils).

Table 9.4. Efficiency (CRS) according to size of school

Size of school	Efficient *n*	(%)	Reading mean	INVRSD mean	Efficiency mean	Total
1st quartile	1	(2.56)	496.7762	0.0149	0.7460	39
2nd quartile	3	(7.69)	492.1934	0.0138	0.7865	39
3rd quartile	5	(12.82)	491.2368	0.0143	0.8192	39
4th quartile	7	(17.95)	533.8729	0.0162	0.8655	39

Source: PISA 2000.
1st quartile (less than 213), 2nd quartile (213 to 326.5),
3rd quartile (326.5–516.5), 4th quartile (more than 516.5).

quartile).[15] The average efficiency score also increases with size of school (0.7460 for the 1st quartile to 0.8655 for the 4th quartile).

The explanation of this result is probably inherent to the notion of returns to scale. Indeed, having a critical mass of pupils enables the school to save money on some items; indeed, we can reasonably assume that there exists an optimum school size. However, as Bradley et al. (2001) suggest, while closing a school can certainly lead to a reduction in public expenditure, it can also reduce competition between schools.

9.6. Conclusion

The analysis of efficiency scores obtained using the DEA method highlights the fact that out of 156 Swiss secondary schools in the national sample taken in the PISA 2000, only 10% are efficient (when the scale returns are assumed to be constant). This figure is low not only in terms of schooling but also in terms of effectiveness since only 14.5% of the pupils in the sample attend an efficient school.

It seems that the more the size of the school increases, the greater is the proportion of efficient schools (2.65–18%), and the average efficiency score (0.7460–0.8655) also increases. Moreover, the closure of a school can have a contradictory effect on efficiency. On the one hand, increase in size of establishments (for a given class size) means the school can benefit from economies of scale and increased efficiency. On the other hand, the closure of several establishments reduces competition among schools and the incentive to be efficient.

[15]Tests were carried out to compare the averages of the reading scores and the efficiency scores of schools in the 1st and 4th quartiles. These are significantly different (to 1%).

One limit of this research was that DEA was applied to the data in cross-section. If the efficiency of Swiss secondary schools is going to be understood and each school advised individually, repeated information needs to be available. Only annual national evaluation (for example in the final year of obligatory schooling) will mean the performance of Swiss schools can really be followed. An effective redistribution system would then be able to take place between the schools. Analysis of efficiency of the sample group data would also make it possible to consider frontier displacements.

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