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Jean-Marc HUGUENIN

Determinants of school efficiency : the case of primary schools the State of Geneva, Switzerland

IDHEAP Working Paper 1/2014
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Determinants of school efficiency : the case of primary schools in the State of Geneva, Switzerland

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January 2014

Abstract

The public primary school system in the State of Geneva, Switzerland, is characterized by centrally evaluated pupil performance measured with the use of standardized tests. As a result, consistent data are collected among the system. The 2010-2011 dataset is used to develop a two-stage data envelopment analysis (DEA) of school efficiency. In the first stage, DEA is employed to calculate an individual efficiency score for each school. It shows that, on average, each school could reduce its inputs by 7% whilst maintaining the same quality of pupil performance. The cause of inefficiency lies in perfectible management. In the second stage, efficiency is regressed on school characteristics and environmental variables; external factors outside of the control of headteachers. Unlike most similar studies, the model is tested for multicollinearity, heteroskedasticity and endogeneity. Four variables are identified as statistically significant. School efficiency is negatively influenced by *(1)* operations being held on multiple sites – a variable never tested so far, *(2)* the proportion of disadvantaged pupils enrolled at the school and *(3)* the provision of special education, but positively influenced by school size (captured by the number of pupils). The proportion of allophone pupils, schools located in urban areas and the provision of reception classes for immigrant pupils are not significant. Although the significant variables influencing school efficiency are outside of the control of headteachers, it is still possible to either boost the positive impact or curb the negative impact.

Dans le canton de Genève (Suisse), les écoles publiques primaires sont caractérisées par un financement assuré par les collectivités publiques (canton et communes) et par une évaluation des élèves à l'aide d'épreuves standardisées à trois moments distincts de leur scolarité. Cela permet de réunir des informations statistiques consistantes. La base de données de l'année 2010-2011 est utilisée dans une analyse en deux étapes de l'efficience des écoles. Dans une première étape, la méthode d'analyse des données par enveloppement (DEA) est utilisée pour calculer un score d'efficience pour chaque école. Cette analyse démontre que l'efficience moyenne des écoles s'élève à 93%. Chaque école pourrait, en moyenne, réduire ses ressources de 7% tout en conservant constants les résultats des élèves aux épreuves standardisées. La source de l'inefficience réside dans un management des écoles perfectible. Dans une seconde étape, les scores d'efficience sont régressés sur les caractéristiques des écoles et sur des variables environnementales. Ces variables ne sont pas sous le contrôle (ou l'influence) des directeurs d'école. Contrairement à la plupart des études similaires, le modèle est testé pour la multicolinéarité, l'hétéroscédasticité et l'endogénéité. Quatre variables sont statistiquement significatives. L'efficience des écoles est influencée négativement par *(1)* le fait d'opérer sur plusieurs sites différents – une variable jamais testée jusqu'ici, *(2)* la proportion d'élèves défavorisés et *(3)* le fait d'offrir un enseignement spécialisé en classe séparée*)*. L'efficience des écoles est influencée positivement par la taille de l'école, mesurée par le nombre d'élèves. La proportion d'élèves allophones, le fait d'être situé dans une zone urbaine et d'offrir des classes d'accueil pour les élèves immigrants constituent autant de variables non significatives. Le fait que les variables qui influencent l'efficience des écoles ne soient pas sous le contrôle des directeurs ne signifie pas qu'il faille céder au fatalisme. Différentes pistes sont proposées pour permettre soit de réduire l'impact négatif soit de tirer parti de l'impact positif des variables significatives.

CONTENTS

1. Context

Worldwide, school efficiency has been widely studied and measured by researchers using both statistical[1] and non-statistical[2] approaches (Johnes, 2004, pp. 644-649). Among those methods, Data Envelopment Analysis, Stochastic Frontier Analysis and Corrected Ordinary Least Squares regression are the three most commonly used (Taylor, 2010, p. 208)[3].

The measurement of school efficiency is a major concern in Switzerland: improving efficiency in compulsory education is one of four reforms recommended by a recent OECD analysis to raise education outcomes (Fuentes, 2011). Efficiency happens to be one of three criteria[4] selected by the Swiss Conference of Cantonal Ministers of Education (SCCM) to assess the national education system (Wolter, 2010). More specifically in the State of Geneva, efficiency is one of three criteria[5] selected by the State government to assess the cantonal education system (République et canton de Genève, 2012, pp. 75-86). According to the Swiss Federal Statistical Office, public expenditure on education represented 17.3% of total public expenditure (federal, cantonal and local levels) and 5.2% of gross domestic product in 2010. In the State of Geneva, the proportion of public expenditure on education rises to 24% (5'934 Swiss francs per capita)[6].

Despite this, studies about efficiency of Swiss universities and schools are virtually non-existent. Olivares and Schenker-Wicki (2012, 2010), Solaux, Huguenin, Payet and Ramirez (2011), Meunier (2008), Diagne (2006) and Schenker-Wicki and Hürlimann (2006) represent the only studies to conduct efficiency analysis on this topic. As a result, decision makers still rely on partial productivity ratios (mainly cost per pupil), to monitor the education system.

Measuring school efficiency is not an easy task, especially considering that multiple inputs, such as capital, labour, energy, materials and services according to the OECD (2001) KLEMS terminology, are combined in order to produce multiple outputs (pupils, courses, competences, etc.). As Sheldon (1995, pp. 67-68) points out, there has long been a lack of comparable data, especially output data, on a national level and often on a cantonal level. Although progress is being made, this finding still unfortunately holds today.

Within Switzerland, education is a decentralized task. 26 States (or cantons) are responsible for organizing and managing their own educational system. In order to measure school efficiency, one has to select a State and a level of the education system where data *(1)* exist, *(2)* are available and *(3)* are consistent. For this reason, this study focuses on primary schools in the State of Geneva.

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1. Statistical approaches use econometric techniques to measure school efficiency. Among those techniques are Ordinary Least Squares regression, Corrected Ordinary Least Square regression, Probit and Logit models, Ordered Probit and Logit models, Stochastic Frontier Analysis and Maximum Likelihood Estimation.
2. Non-statistical approaches use linear programming techniques or mathematical algorythms to measure school efficiency. Among those techniques are Data Envelopment Analysis and Free Disposal Hull.
3. The current study focuses on Data Envelopment Analysis. Readers interested in statistical approaches applied to education to measure efficiency will refer to Smith and Street (2006) and Johnes and Taylor (1990) for applications using Ordinary Least Squares, Bifulco and Bretschneider (2001) and Barrow (1991) for applications using Corrected Ordinary Least Squares, Chakraborty (1998) for an application using Maximum Likelyhood Estimation, Blank, van Hulst, Koot and van der Aa (2012), Smith and Street (2006) and Stevens (2001) for applications using Stochastic Frontier Analysis. For a general discussion about these techniques, see Johnes (2004).
4. Effectiveness and equity are the other two criteria.
5. Effectiveness and quality are the other two criteria.
6. These statistics are available at : http://www.bfs.admin.ch/bfs/portal/fr/index/themen/15/02/data/blank/01.html.

2. Geneva public school system

In the State of Geneva, education is compulsory at early childhood (corresponding to the international standard classification of education 0, ISCED # 0) for a duration of 2 years, at primary school (ISCED # 1) for a duration of 6 years and at lower secondary education (ISCED # 2) for a duration of 3 years.

In 2010-2011, there was a total count of 90 public primary schools in the State of Geneva. These schools are funded by the State government (chiefly for staff salary) and by local authorities – municipalities (chiefly for school infrastructure). Pupil competences are assessed with the use of standardized tests at three different times in two or three subjects. At the end of the second grade, French (mother tongue) and mathematics are assessed; at the end of the fourth and sixth grade, French, German (first foreign language) and mathematics are assessed.

Primary schools are managed by headteachers assisted by one or several teachers working part time as headteachers' assistants. Staff consists of teachers, secretaries and schoolkeepers (maintenance). In some schools, educators are also active.

In order to adjust to local environment, partial autonomy in management is granted to schools. For instance, headteachers define job profiles and recruit teachers; they are responsible for school quality (and hence pupil performance); and they also chair the school board.

Every school has a board composed by representatives of the school staff, parents and city civil-servants and is chaired by the headteacher. The board demonstrates instances of democracy where stakeholders are informed and consulted. Whilst they only have limited authority about school management, they can make propositions about day-to-day school life. School boards aim to develop better relationships between school, families and local communities.

The main characteristics of primary schools are as follows:

- A school can be located on one or several sites (up to five), which implies that school buildings can be spread over several locations (or sites);
- Special education is only available in a limited number of schools (21 schools out of 90), which implies that pupils with special needs are grouped in the schools where special education is available;
- Special reception classes for immigrant pupils are available only in a limited number of schools (35 schools out of 90).

3. Objectives

The first objective of this study is to measure school technical efficiency using Data Envelopment Analysis (DEA). As far as the author is aware, this has never been done before for primary schools in Switzerland in general and in the State of Geneva in particular[7].

The second objective of this study is to identify the determinants of school efficiency. Again, as far as the author is aware, this has never been done before for primary schools in Switzerland in general and in the State of Geneva in particular.

[7] Solaux, Huguenin, Payet and Ramirez (2011) measure, using DEA and the same database as in this study, scale efficiency of primary schools, but not technical efficiency.

4. Methodology

A two-stage DEA analysis of school efficiency, as initially developed by Ray (1988, 1991), is conducted. At the first stage, DEA is employed to calculate an individual efficiency score for each school. At the second stage, efficiency is regressed on school characteristics and environmental variables, all outside of the control of headteachers[8]. As mentioned by Bradley, Johnes and Little (2010):

> The underlying assumption of the two-stage approach is that the variables in the second stage affect the *efficiency* with which outputs are produced from the inputs, and this forms the basis of the decision of which variables to include in the first stage and which to include in the second stage (p. 7)[9].

Advantages of the two-stage DEA approach are described in Coelli, Prasada Rao, O'Donnel and Battese (2005, pp. 194-195) or in Pastor (2002, p. 899) while drawbacks are identified in Johnes (2006, p. 276) or Simar and Wilson (2007, p. 33).

According to Coelli (2005, pp. 194-195), the two-stage model presents the advantages of being able to accommodate *(1)* more than one variable and *(2)* both categorical and continuous variables. Moreover, it does not require a prior understanding of the direction of influence of the non-discretionary variables. It is also easy to calculate. The method is simple and therefore transparent. As the second stage introduces a regression analysis, the two-stage model presents the disadvantages inherent to such techniques. Mainly, it requires the specification of a functional form to the regression model. Any misspecification may distort the results. Cordero, Pedraja and Santín (2009) also point out that the adjustment of efficiency scores takes into account only the radial component of inefficiency and not the potential inefficiency derived from slacks[10].

First stage

DEA is used to measure the performance of entities (schools in this study) which convert multiple inputs into multiple outputs. Entity efficiency is defined as the ratio of the sum of its weighted outputs to the sum of its weighted inputs (Thanassoulis, Portela and Despic, 2008, p. 264). The two basic models of DEA are formulated in Charnes, Cooper and Rhodes (1978) and in Banker, Charnes and Cooper (1984). The first one assumes constant returns to scale (CRS). The second one assumes variable returns to scale (VRS)[11].

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8 Following Coelli, Prasada Rao, O'Donnel and Battese (2005, p. 190), this paper considers an environmental variable to be a factor that could influence the efficiency of a school, where such a factor is not a traditional input and is assumed to be outside of the control of headteachers. Because of this, such a factor is also called a non-discretionary variable. It cannot be varied at the discretion of an individual headteacher but nevertheless needs to be taken into account to measure efficiency (Cooper, Seiford & Tone, 2007, p. 215).
Traditional inputs are those covered by the OECD (2001) KLEMS categories.

9 In contrast, a one-stage approach assumes that all the inputs, including the non-discretionary inputs, affect the process of production of the outputs from the inputs (Johnes, 2004, p. 657).

10 Efficiency scores generated by DEA are similar with or without the calculation of slacks. In the two-stage method, the coefficients of the regression are calculated towards the efficiency scores as a dependent variable. Their values will be identical whether these scores belong to entities whose inefficiency is composed by only a radial factor or a radial and a slack factor.

11 The CRS model is appropriate when all entities are operating at an optimal scale (Coelli, 2005, p. 172). When this is not the case, and especially when entities face imperfect competition or are regulated by the state, the VRS model should be used.

DEA is based on the earlier work of Dantzig (1951) and Farrell (1957). Cook and Zhu (2008), Cooper, Seiford and Tone (2007) or Coelli *et al.* (2005) provide a comprehensive treatment of the methodology. A pedagogical guide about DEA is provided by Huguenin (2012, 2013a, 2013b).

DEA is a non-parametric method. Inputs and outputs are used to compute, using linear programming methods, a hull to represent the best-practice frontier.

Each school's efficiency score is calculated relative to the best-practice frontier. This frontier consists of a series of linear segments connecting the schools that maximize output given a set of inputs (or minimizes input given a set of outputs).

Schools located on the frontier have an efficiency score of 1 (or 100%). Schools operating beneath the frontier have an efficiency score inferior to 1 (or 100%) and hence have the capacity to improve future performance. Efficiency measures include (Taylor, 2010, p. 208):

- Technical efficiency: schools are technically efficient when it is not possible to increase outputs without increasing inputs (or when it is not possible to reduce inputs without reducing outputs) for a given proportion of inputs and outputs.
- Scale efficiency: schools are scale efficient when there are no productivity gains from changing the scale at which the school operates (in other words, the size of the school).
- Allocative efficiency: schools are allocatively efficient when they use inputs in optimal proportion given their respective prices.

As described below in the data section, the inputs and outputs are formulated as ratios. In such a case, a DEA variable returns to scale model (VRS) is required (Hollingsworth & Smith, 2003). As Coelli *et al.* (2005, p. 172) point out, the use of the VRS model permits the calculation of technical efficiency devoid of the scale efficiency effects. In other words, a 'pure' technical efficiency is calculated. The retained model in the current study is a VRS model with a multi-stage treatment of slacks (Coelli, 1998). The model is input oriented, meaning that it minimizes input for a given level of output.

Following the notation adopted by Johnes (2004, pp. 630-637), it is assumed there are data on s outputs and m inputs for each of n primary schools to be evaluated (n = 90). y_{rk} is the quantity of output r produced by school k. x_{ik} is the quantity of input i consumed by school k. u_r is the weight of output r. v_i is the weight of input i. θ_k represents the measure of VRS efficiency of school k (i.e. 'pure' technical efficiency free from any scale inefficiency). λ_j represents the associated weighting of outputs and inputs of entity j.

The VRS efficiency of the k[th] school is calculated by solving the following linear problem:

Minimize θ_k (1)

$$\text{Subject to} \quad y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} \le 0 \quad r = 1, \dots, s$$

$$\theta_k x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} \ge 0 \quad i = 1, \dots, m$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \ge 0 \quad \forall j = 1, \dots, n$$

Note that the above model does not take slacks into account. The interested reader will refer to Coelli (1998) for a comprehensive treatment of slacks and to Johnes (2004, pp. 634-635) for the equations of the above model including slacks.

The value of θ obtained is the efficiency score of the k[th] school. This value varies between zero and one ($\theta \le 1$). A value of 1 indicates a school on the best-practice frontier (and hence a technically efficient school). The linear programming problem must be solved n times, once for each school in the dataset. A value of θ is then obtained for each school.

Second stage

In the second stage, the efficiency scores are regressed against the environmental (i.e. non-discretionary or exogenous) variables. As shown in the next section, Tobit regression, as developed by Tobin (1958), is used in the majority of studies dealing with efficiency in the education sector (20 out of 27), since efficiency scores seem to be truncated from below at one[12]. However, recent studies have shown that Ordinary Least Squares (OLS) regression is sufficient or even more appropriate to model the efficiency scores. Hoff (2007, p. 434) conclude that Tobit regression is a mis-specification of DEA scores and that OLS regression performs at least as well as Tobit regression (and two other models also tested –Papke-Wooldridge and unit-inflated beta). McDonald (2009, p. 795) argues that efficiency scores are not censored but are fractional data. Tobit estimation is therefore inappropriate. McDonald (2009) demonstrates that "OLS is a consistent estimator, and, if White's heteroskedastic-consistent standard errors are calculated, tests can be performed which are valid for a range of disturbance distribution assumptions" (p. 797). OLS is, therefore, the method of choice in the ensuing study[13].

The coefficients of the environmental variables, estimated by the regression, can be used to model the efficiency scores to correspond to an identical condition of environment (usually the average condition).

[12] Alexander and Jaforullah (2004, p. 19) do not share this point of view. The authors observe that, by definition, scores cannot exceed 1 or be lower than 0. Therefore data are not truly censored at 1 or 0 and OLS seems quite appropriate.

[13] The debate between OLS and Tobit (and even truncated regression) continues. See Simar and Wilson (2011) for discussion.

5. Two-stage DEA in the education sector : a litterature review

27 studies using a two-stage DEA approach in the education sector have been reviewed[14]. They are presented in Table 1. These studies cover kindergarten, primary schools, lower secondary schools, upper secondary schools, universities and school boards[15]. 13 countries are concerned with these studies, among which includes Switzerland (Diagne, 2006; Olivares & Schenker-Wicki, 2010). Ten studies (37%) concern the United States. Only two studies focus specifically on primary schools (Mancebón & Mar Molinero, 2010; Burney, Johnes, Al-Enezy & Al-Musallam, 2011).

[14] Ray (1991) is the first one to apply this approach to district schools in Connecticut, USA.

[15] This review focuses on schools as decision-making units (DMUs). As a result, it does not include studies which consider regions as DMUs, as in Sibiano and Agasisti (2012).

Table 1
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
			Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Agasisti (2013)	651 lower secondary schools Italy	Tobit	*Results of the third Tobit model tested*			
			Location Central Italy	- **	Location in small city	-
			Location South Italy	- **	Location in large city	-
			Location Isles	- **	Class size	-
			Academic school	+ **	Percentage of girls	-
			Vocational school	+ **		
			Private school	- **		
			School size	+ *		
			Parental pressure	- **		
			Number of schools in the region - competition	+ **		
Alexander and Jaforullah (2004)	324 lower and upper secondary schools	OLS	State-owned school	- *	School with grades 1 to 13	-
	New Zealand		School with grades 7 to 13 only	- *	All-boys school	+
			All-girls school	+ *	Teacher qualification	-
			Location secondary urban	+ *		
			Location minor urban	+ *		
			Location rural	+ *		
			Underprivileged socioeconomic background of pupils	- *		
			Number of pupils	+ *		
			Number of pupils squared	- *		
			Teacher experience	+ *		

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
			Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Alexander, Haug and Jaforullah (2010)	324 lower and upper secondary schools	Truncated	State-owned school	- **	School with grades 1 to 13	+
	New Zealand		School with grades 7 to 13 only	- **	Location secondary urban	+
			All-girls school	+ **	Number of pupils squared	-
			All-boys school	+ **		
			Location minor urban	+ **		
			Location rural	+ **		
			Underprivileged socioeconomic background of pupils	- **		
			Number of pupils	+ **		
			Teacher experience	+ **		
			Teacher qualification	+ **		
Borge and Naper (2006)	426 lower secondary schools	Tobit	Share of students with special needs	- (level not mentioned)	Parental level of education	-
	Norway		School size	+ (level not mentioned)	Share of minority students	-
			School size squared	- (level not mentioned)	Location rural	+
			Population size	+ (level not mentioned)	Municipal revenue	-
			Political fragmentation of local council	- (level not mentioned)	Centralized budgetary procedure	-
			Share of socialists	- (level not mentioned)	School choice	-

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
			Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Bradley, Johnes and Little (2010)	188 upper secondary schools (Further Education) England	Tobit	*Results for all Further Education (FE) providers (efficiency scores)*			
			Percentage of female students	+ **	Percentage of students of Afro-Caribbean origin	+
			Percentage of students of Pakistani or Bangladeshi origin	+ *	Percentage of students of Indian origin	+
			Percentage of students aged 19 or more	- **	Percentage of students of origin other than Pakistani, Bangladeshi, Afro-Caribbean, Indian or white	+
			Percentage of students born outside the UK	+ *	Percentage of students with learning disabilities	-
			Unemployment rate in the Local Authority District (LAD) in which the college is located	+ **	Percentage of the workforce without qualifications in the LAD in which the college is located	+
			Percentage of teaching staff on permanent or fixed term contracts	+ **	Average age of teaching workforce	+
			Number of teachers / number of support staff	- **	Average age squared	-
			Number of students / number of teachers	+ **	Percentage of teachers of Pakistani or Bangladeshi origin / percentage of students of Pakistani or Bangladeshi origin	-
					Percentage of teachers of Afro-Caribbean origin / percentage of students of Afro-Caribbean origin	-
					Percentage of teachers of Indian origin / percentage of students of Indian origin	+
					Percentage of teachers of other origin / percentage of students of other origin	+
					Number of teachers / number of managers	-
					Sixth form college	-
					Specialist college	-

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency): Variable	Statistically significant variables (impact on efficiency): Sign and significance at the 1% (**) and 5% (*) levels	Not statistically significant variables (impact on efficiency): Variable	Not statistically significant variables (impact on efficiency): Sign
Bradley, Johnes and Millington (2004)	2657 lower secondary schools England	Tobit	*Results for 1998*			
			Number of non-selective schools within 1 km radius	+ **	Number of selective schools within 1 km radius	-
			Number of non-selective schools between 1-2 km radius	+ **	Number of selective schools between 1-2 km radius	-
			Number of non-selective schools between 2-3 km radius	+ **	Number of selective schools between 4-5 km radius	-
			Number of non-selective schools between 3-5 km radius	+ **	Voluntary controlled school	+
			Number of selective schools between 2-3 km radius	- *	All-boys school	+
			Number of selective schools between 3-4 km radius	- *	Expenditure on books and materials	+
			Secondary modern school	- **	Population density	+
			Voluntary assisted school	+ **		
			Grant maintained school	+ **		
			Special agreement school	+ *		
			All-girls school	+ **		
			Unemployment rate	+ **		
			Share of professional and managerial workers	+ **		
			School size	+ **		
			Expenditure on teachers	+ **		
			Pupil-teacher ratio	- **		

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency): Variable	Statistically significant variables (impact on efficiency): Sign and significance at the 1% (**) and 5% (*) levels	Not statistically significant variables (impact on efficiency): Variable	Not statistically significant variables (impact on efficiency): Sign
Burney, Johnes, Al-Enezy and Al-Musallam (2011)	170 kindergarten schools Kuwait	OLS	*Results for 2004-2005*			
			Region Al-Aasimah	+ *	Region Hawally/Mubarak	+
			Region Al-Ahmedi	+ *	Region Al-Farwaniya	-
			Teacher salary	+ *		
			Proportion of teaching staff who are Kuwaiti nationals	- *		
	203 primary schools Kuwait	OLS	Region Al-Aasimah	+ *	Region Hawally/Mubarak	-
			Teacher salary	+ *	Region Al-Farwaniya	-
					Region Al-Ahmedi	-
					Proportion of teaching staff who are Kuwaiti nationals	-
					All-boys school	-
	156 lower secondary schools Kuwait	OLS	Teacher salary	+ *	Region Al-Aasimah	+
					Region Hawally/Mubarak	-
					Region Al-Farwaniya	-
					Region Al-Ahmedi	-
					Proportion of teaching staff who are Kuwaiti nationals	-
					All-boys school	-
	114 upper secondary schools Kuwait	OLS	Teacher salary	+ *	Region Al-Aasimah	+
			Proportion of teaching staff who are Kuwaiti	- *	Region Hawally/Mubarak	-
			All-boys school	- *	Region Al-Farwaniya	-
					Region Al-Ahmedi	-

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
			Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Chakraborty, Biswas and Lewis (2001)	40 school districts Utah, USA	Tobit	*Efficiency estimates (Tobit models residuals) are presented. The significance of non-controllable variables used in the second stage Tobit regression is not mentioned.*			
Denaux, Lipscomb and Plumly (2011)*	326 high schools Georgia, USA	Tobit	*Results of the first Tobit model tested ("Awba")*			
			Percentage of people residing in the county who recognize their race as white but not "Spanish/Latino/Hispanic"	+ **	Urban schools	+
			Percentage of students that are HOPE scholarship eligible	+ *	County schools (not in a city)	-
			Percentage of adults residing in the county school district with at least a bachelor's degree	+ *	High school adequate yearly progress during the 2006-2007 academic year	+
					Real income per capita by each county	+
					Federal, State and Local contribution per pupil expenditure at the school district level	-
					Unemployment rate	-
Diagne (2006)	27 upper secondary schools Switzerland	OLS, Tobit	*Results based on the first DEA model, valid both for the OLS and the Tobit regressions*			
			Teacher qualification	+ *	Proportion of students with financial aids	+
			Teacher with indefinite duration contracts	- *		

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

			Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
Authors	Units analyzed	Type of regression	Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Duncombe, Miner and Ruggiero (1997)	585 school districts New York, USA	Tobit	Number of students enrolled in private schools	- *	Number of schools within a district	-
			No referendum about school budget	- *	School density	+
			Wealth ratio	- *	Elementary school size	+
			Proportion of households with school age children	- *	Percentage of property value in commercial and industrial property	-
			Percentage of expenditures on staff salaries and benefits	- *	Proportion of owner-occupied housing	-
			Proportion of adults with a college degree	+ *	Percentage of tenured teachers	-
Grosskopf and Moutray (2001)	61 upper secondary schools Illinois, USA	OLS	*Results based on the Malmquist productivtiy index (1989-1994)*			
			Percentage change in personal expenditures per student	- **	Percentage change in the percentage of white students	+
					Percentage change in adm./teacher ratio	+
					Time	+

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency): Variable	Sign and significance at the 1% (**) and 5% (*) levels	Not statistically significant variables (impact on efficiency): Variable	Sign
Jeon and Shields (2005)	49 school districts Michigan, USA	Tobit	*Results based on the fourth DEA model*			
			Percentage of students who do not qualify for free or reduced lunch	+ *	Percentage of the school district's population living in urban areas	-
					Median value of housing in the district	-
					Median household income in the district	+
					Percentage of students in the school district enrolled in private school	+
Kantabutra and Tang (2006)*	456 upper secondary schools Thailand	Tobit	Class size	+ * for urban schools		
			School size	+ ** for urban schools		
			Class size	- ** for rural schools		
			School size	+ ** for rural schools		
Kirjavainen and Loikkanen (1998)*	291 upper secondary schools Finland	Tobit	*Results of the three Tobit model tested based on the third DEA model (3)*			
			Class size (from 11 students)	+ (level not mentioned)	School size	-
			Parental level of education	+ (level not mentioned)	Share of female students	+
			Private schools	- (level not mentioned)	Heterogeneity of students in the school	-
					Urban schools	-
					Dense schools	-
					Grant ratio	- or +

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
			Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Kounetas, Anastasiou, Mitropoulos and Mitropoulos (2011)	18 university departments Greece	Tobit	*Results based on the sixth DEA model*			
			Ownership of a building for its department	+ *	School to which the deparment belongs	-
					Age of department	-
					Number of staff in the departement	+
Lovell, Walters and Wood (1994)	530 to 585 high schools	OLS	*Results based on the first DEA model*			
						-
	USA		Elite private schools	+ *	Catholic schools	-
			School enrollment	+ **	Rural schools	-
			Percentage of tenth-grade students taking remedial reading classes	- **	Schools with separate tax district	
						+
					Schools with unionized teachers	-
					Schools with program for talented students	+
					Teacher absenteeism	
McCarty and Yaisawarng (1993)	27 school districts New Jersey, USA	Tobit	Socioeconomic background of pupils	+ *		

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency): Variable	Statistically significant variables (impact on efficiency): Sign and significance at the 1% (**) and 5% (*) levels	Not statistically significant variables (impact on efficiency): Variable	Not statistically significant variables (impact on efficiency): Sign
McMillan and Datta (1998)*	45 universities Canada	Tobit	*Results based on the fourth DEA model*			
			Total student enrollment in universities within 200 km	+ *	Undergraduate FTE enrollment per undergraduate degree awarded	-
			Specialization among undergraduate programs	+ *	Class size	+
			Total full-time equivalent students	+ *	Part-time student enrollment divided by total student enrolment	+
					Proportion of full-time faculty eligible for MRC and/or NSERC grants	
					Percentage change in total enrollment 1990-1991 to 1992-1993	+
					Percentage change in total revenue 1989-1990 to 1992-1993	-
Mancebon and Mar Molinero (2000)	176 primary schools Hampshire, England	Logistic	Church of England non aided school	+ *	Church of England aided school	+
			Percentage of fixed period exclusions of pupils	- *	Percentage of parents that strongly agree that the school enables their child(ren) to achieve a good standard of work	+
			Percentage return rate to the parental survey	+ *		

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
			Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Olivares and Schenker-Wicki (2010)	12 universities Switzerland	Tobit	*Results for universities as a whole (uni-total)*			
			Student-faculty ratio	+ **	Cantonal matriculation quota	-
			Proportion of professors per scientific personnel	+ **	Year of university foundation	-
			Years of studying	- **	Cantonal GDP per capita	+
			Number of undergraduate and postgraduate students	+ **	Universities offering specifically study programmes	+
					Time trend	+
					Universities operating a hospital	-
					Proportion of scientific personnel per personnel in total	+
					Proportion of students enrolled in Bachelor and Master's programmes as a proportion of all undergraduate students	-
Ouellette and Vierstraete (2005)	142 school boards Québec, Canada	Tobit	Percentage of the population in the school board's region with less than a ninth grade education	- *		
			Percentage of the population in the school board's region who do not speak either official language at home	- *		
			Percentage of the population in the school board's region who do not speak either official language at home squared	+ *		
			Population density in the school zone	+ *		
			Proportion of pupils who obtain a diploma	- *		

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

			Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
Authors	Units analyzed	Type of regression	Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Ramanathan (2001)	41 lower secondary schools Netherlands	OLS	Number of pupils	+ **	Public schools	-
			Grammar schools	+ **	Private schools	-
			Roman Catholic and/or Protestant Christian schools	+ *	Schools located in The Hague	+
Rassouli-Currier (2007)	354 school districts Oklahoma, USA	Tobit	*Results of the first Tobit model tested*			
			Percentage of minority students	- *	Poverty rate	-
			Percentage of students eligible for reduced cost or free lunch	- *	Average daily membership (number of students) squared	+
			Average household income	+ *		
			Assessed value of property within the district boundaries	- *		
			Percentage of adults aged 20+ with education beyond high school diploma	+ *		
			Percentage of students in special education	- *		
			Average salary per full-time equivalent teacher	- *		
			Average daily membership (number of students)	- *		
			Student/teacher ratio	+ *		

Table 1 (Continued)
A review of two-stage data envelopment analysis in schools

Authors	Units analyzed	Type of regression	Statistically significant variables (impact on efficiency)		Not statistically significant variables (impact on efficiency)	
			Variable	Sign and significance at the 1% (**) and 5% (*) levels	Variable	Sign
Ray (1991)	122 school districts Connecticut, USA	OLS	*Predicted and adjusted predicted technical efficiency scores are estimated. The significance of non-controllable variables used in the second stage OLS regression is not mentioned.*			
Ruggiero and Vitaliano (1999)	520 school districts New York, USA	Tobit	Teacher salary index	- *	Student enrollment	+
			Poverty rate	+ *		
			Percentage of households with school-age children	+ *		
			Percentage of single parent households	- *		
Waldo (2007)	365 lower secondary schools Sweden	Tobit	*Results of the three Tobit model tested based on the first DEA model*			
			Socialist majority since 1991 in the municipal council	- **	Share of students in the municipality attending private schools in 1999	+
			Share of teachers with formal pedagogical training	- **	Conservative majority since 1991 in the municipal council	+
			Share of votes in the last election on either the Social Democratic party or the left party	- **	Average distance in kilometres between municipal citizens	-
					Population	-
					Socialist or conservative majority of more than 60% in the last election	+
					Share of the population over 65 years	-

* The dependent variable in these studies is the inefficiency score (and not the efficiency score). The signs of the coefficients displayed in this table have been adjusted in order to reflect the influence on efficiency (and not

inefficiency). For instance, McMillan and Datta (1998) show that the number of full-time equivalent students negatively influences inefficiency. The sign associated with this variable is negative in their study, but reported as positive in Table 1, as a negative impact on inefficiency corresponds with a positive one on efficiency.

As the levels of the education system, the types of efficiency and the choice of inputs and outputs differ in the first stage, a straight-forward comparison of the determinants of efficiency across the studies under review could provide misleading results. However, variables influencing efficiency issues can be grouped into categories, including the socioeconomic status of students, types of schools, school location, political context, competition, teacher characteristics and size effects. Within these categories, the impact of specific variables on efficiency can be contradictory. It is therefore difficult to conclude, beyond reasonable doubt, that specific variables will have the same impact on efficiency in every empirical case.

As no straightforward conclusion about a specific variable can be drawn, it is highly necessary to test the influence of environmental variables in every particular case, as is done in the current study for the primary schools in the State of Geneva. The fact that one particular variable influences efficiency of primary schools in Kuwait (as, for instance, teacher salary in Burney *et al.,* 2011) does not necessarily mean that the same variable will influence efficiency of primary schools in Geneva.

The different categories are presented and commented on hereafter:

- **Socioeconomic status of students**

  A higher proportion of disadvantaged students reduces school efficiency. This finding is consistent across studies and appears almost unchallenged. This is the case when socioeconomic status of students is captured either by a composite score (Alexander & Jaforullah, 2004; Alexander, Haug & Jaforullah, 2010; McCarty & Yasawarng, 1993) or by single variables such as the percentage of students eligible for reduced cost or free lunches (Rassouli-Currier, 2007), the percentage of single parent households (Ruggiero & Vitaliano, 1999), the share of professional and managerial workers (Bradley, Johnes & Millington, 2001), the percentage of students who do not qualify for free or reduced lunches (Jeon & Shields, 2005) or the percentage of the population in the school board's region who do not speak either official language at home (Ouellette & Vierstraete, 2005). Another single variable reflecting the socioeconomic status of students is the educational level of parents or population in the school area. Duncombe, Miner and Ruggiero (1997), Kirjavainen and Loikkanen (1998), Ouellette and Vierstraete (2005) and Rassouli-Currier (2007) observe that a better educational level is associated with higher school efficiency. This is not surprising, as educational level is linked to productivity and, hence, to individual salary, as pointed out by the human capital theory (Mincer, 1958; Schultz, 1961; Becker, 1964). Rassouli-Currier (2007) also shows that a higher average household income is associated with higher school efficiency. Finally, Borge and Naper (2006) and Rassouli-Currier (2007) show that schools with a higher share of students with special needs or in Special education are less efficient than others.

  In the 27 studies under review, three variables produce seemingly counterintuitive results:

  - First, Bradley *et al.* (2001) and Bradley, Johnes and Little (2010) find a positive impact of the local unemployment rate on school efficiency. Bradley *et al.* (2001) suspect that this is the consequence of the DEA (mis)-specification chosen for the study (p. 561). Bradley *et al.* (2010) gives another explanation:

    > A high unemployment rate may encourage students to stay on, rather than drop out, because opportunities in the labour market are scarce (a discouraged worker effect), and

it may lead to higher attainment in so far as students work harder to secure a job once they complete FE (Further Education) (p. 13).

- Second, Rassouli-Currier (2007) shows that the assessed value of property within the district boundaries is negatively linked with school efficiency. Because the value of property includes all types of commercial, industrial as well as residential properties in the school districts, districts with high property valuation could actually be populated by low income families (Rassouli-Currier, 2007, p. 138). A similar finding occurs in Duncombe *et al.* (1997). The authors identify a negative link between a combined wealth ratio (composed by a mix of 50% property wealth and 50% adjusted gross income) and school efficiency. This result is explained by arguing that "incentives for efficiency may be lower for wealthier districts or districts whose composition of taxable property permits greater tax exporting because easier financial constraints diminish political pressure for efficiency" (p. 13). For instance, districts with commercial and industrial companies located on their territories will be associated with a high wealth ratio but will also face tax from exporting.
- Third, Ruggiero and Vitaliano (1999) observe a positive relationship between the poverty rate and school efficiency. The explanation of this counterintuitive result is not quite clear. The authors mention that "poverty may be an index of local fiscal capacity and thus represent a budget constraint that compels districts to economize resources" (p. 326).

A few studies show that variables which can be associated with the socioeconomic status of pupils are not statistically significant (Borge & Naper, 2006, for the level of parental education and the share of minority students; Diagne, 2006, for the proportion of students with financial aids; Kirjavainen & Loikkanen, 1998, for grant ratio; Rassouli-Currier, 2007, for poverty rate).

- **Type of school**

12 studies define various school types (or categories) and test their impact on efficiency. Depending on the study, school type could refer to private versus public school, all-girls versus all-boys school, specialized versus general school, and so on. The only conclusion that can be drawn is that the type of school can matter, sometimes positively, sometimes negatively.

Academic or vocational schools are associated with higher efficiency (Agasisti, 2013). Private schools are associated with lower efficiency according to Agasisti (2013) and Duncombe *et al.* (1997) but with higher efficiency according to Lovell, Walters and Wood (1994). Note that Waldo (2007) and Ramanathan (2001) find that private schooling is not a statistically significant variable. Alexander and Jaforullah (2004) and Alexander *et al.* (2010) find that state-owned schools are associated with lower efficiency. Schools specialized in 7^{th} to 13^{th} grade are also less efficient (Alexander & Jaforullah, 2004; Alexander *et al.*, 2010) but schools with grade 1 to 13 do not provide significant results. Universities with specialization among undergraduate programmes are associated with higher efficiency (McMillan & Datta, 1998).

All-girls schools are found to have high efficiency in Alexander and Jaforullah (2004), Alexander *et al.*, (2010) and Bradley *et al.* (2001). All-boys schools are associated with higher efficiency in Alexander *et al.* (2010) but with lower efficiency of upper secondary schools in Burney *et al.* (2011). All-boys schools are not significant in Alexander and Jaforullah (2004), Bradley *et al.* (2001) and Burney *et al.* (2011) for primary and lower secondary schools. Secondary modern schools, voluntary assisted schools, grant maintained schools and special agreement schools positively impact efficiency (Bradley *et al.*, 2001), as Church of England non aided schools (Mancebón & Mar Molinera, 2000), grammar schools and Roman Catholic and/or Protestant

Christian schools (Ramanathan, 2001). Note that Catholic schools are not significant in Lovell *et al.* (1994). Voluntary controlled schools (Bradley et al., 2004), Church of England aided schools (Mancebón & Mar Molinero, 2000) and universities operating a hospital (Olivares & Schenker-Wicki, 2010) are identified as not significant.

- **School location**

  As for school type, school location can matter when it comes to efficiency. Evidence has been found to suggest that the geographical region of a school can either negatively (Agasisti, 2013) or positively (Burney *et al.*, 2011) impact efficiency. In Burney *et al.* (2011) some regions are not statistically significant. Being located in a rural area or in a minor urban area is associated with higher efficiency (Alexander & Jaforullah, 2004; Alexander *et al.*, 2010). Ouellette and Vierstraete (2005) show that population density in the school zone is associated with higher efficiency. Large city (Agasisti, 2013), rural location (Borge & Naper, 2006; Lovell *et al.*, 1994; Denaux, Lipscomb & Plumly, 2011), population density (Bradley *et al.*, 2004), urban and dense schools (Kirjavainen & Loikkanen, 1998), and schools located in the city of The Hague, Netherlands (Ramanathan, 2001) are not significant variables in these studies.

- **Political context**

  Two studies (Borge & Naper, 2006; Waldo, 2007) include the political context as explanatory variables in the second stage. Both of them demonstrate that a higher share of socialists in the local council is associated with lower school efficiency. Borge and Naper (2006) demonstrate that a politically fragmented local council is associated with lower school efficiency. Waldo (2007) shows that schools located in municipalities where a socialist majority holds in the municipal council since 1991 have a lower efficiency. A conservative majority since 1991 and a socialist or a conservative majority of more than 60% in the last election are not significant.

- **Competition**

  Five studies test the impact of competition on efficiency. Bradley *et al.* (2001) find that the number of competitors (non-selective schools) in the immediate proximity or in the wider area of a school impacts positively on its efficiency. The result for selective schools is not consistent: the number of selective schools between 2-3 and 3-4 kilometres radius are associated with lower efficiency, but the number of selective schools within 1 kilometre radius and between 1-2 and 4-5 kilometres radius is not significant. Duncombe *et al.* (1997) approximate the degree of competition by considering the number of students enrolled in private schools. The authors find a negative association with efficiency. In his third Tobit model, Agasisti (2013) approximates competition by the number of schools in the region. The impact on school efficiency is positive.

  However, Borge and Naper (2006) show that school choice is not a statistically significant variable. Jeon and Shields (2005) consider the percentage of students in the school district enrolled in private schools. This variable is not statistically significant.

- **Teachers characteristics**

  Duncombe *et al.* (1997), Rassouli-Currier (2007) and Ruggiero and Vitaliano (1999) find that the coefficient for teacher salary or expenditure on staff is negative. Conversely, Burney *et al.*

(2011) and Bradley *et al.* (2001) find a positive impact of teacher salary on school efficiency, although the value of the coefficient is almost zero in the latter study (0.002).

Teacher experience is associated with higher school efficiency in Alexander and Jaforullah (2004) and Alexander *et al.* (2010) but teacher experience, measured as the average age in Bradley *et al.* (2010), is not found to be significant. Whith regards to teacher qualification, Diagne (2006) finds that a greater proportion of teachers with a master degree or a doctorate increases school efficiency. Alexander *et al.* (2010) show that the proportion of teachers who have at least second year university qualifications increases school efficiency. However, it seems that a greater proportion of teachers with formal pedagogical training is associated with lower school efficiency (Waldo, 2007). Olivares and Schenker-Wicki (2010) show that a higher proportion of professors per scientific personnel is associated with higher university efficiency.

An original result is presented by Diagne (2006) who shows that a greater share of teachers with indefinite duration contracts negatively impacts school efficiency. But the same variable is positive in Bradley *et al.* (2010). And it is not statistically significant in Duncombe *et al.* (1997).

Unionized teachers and teacher absenteeism are two variables that are not significant in Lovell *et al.* (1994).

Finally, Burney *et al.* (2011) test the teacher citizenship on school efficiency. The authors show that in Kuwait, the coefficient with respect to the proportion of teaching staff who are Kuwaiti nationals is negative.

- **Size effects (school and class)**

A clear picture emerges regarding the positive impact of school size, as measured by the number of pupils or students, on school efficiency (Agasisti, 2013; Alexander & Jaforullah, 2004; Alexander *et al.*, 2010; Borge & Naper, 2006; Bradley *et al.*, 2001; Kantabutra & Tang, 2006; Lovell *et al.*, 1994; McMillan & Datta, 1998; Olivares & Schenker-Wicki, 2010; Ramanathan, 2001). This finding is valid across countries and levels of the educational system. Nonetheless, Duncombe *et al.* (1997), Kirjavainen and Loikkanen (1998) and Ruggiero and Vitaliano (1999) find that school size is not significant.

Class size also positively impacts school efficiency (Kirjavainen & Loikkanen, 1998). This finding is confirmed by Kantabutra and Tang (2006), but only for schools located in urban areas, as class size has a negative impact in schools located in rural areas. Class size is not significant in McMillan and Datta (1998).

- **Other**

Other variables, not included in the above categories, have a statistically significant impact on efficiency.

For instance, Bradley *et al.* (2010) show that the percentage of female students and the percentage of students of Pakistani or Bangladeshi origin positively influence school efficiency. The authors also show that the teachers/support staff ratio negatively impacts efficiency, meaning that increasing the number of administrative staff (and thus reducing the teacher/support staff ratio) will increase efficiency.

Kounetas, Anastasiou, Mitropoulos and Mitropoulos (2011) show that university departments which own their own buildings are more efficient than departments which do not.

The literature review examines determinants of school efficiency and identifies that schools which operate on several locations (or sites) has never been tested as an explanatory variable. As far as the author is aware, neither has it been tested as a determinant of pupil performance. This is probably explained by the fact that the number of sites a school comprises is not information contained in the PISA school questionnaire[16]. Most studies are precisely based on PISA to identify the variables that influence student achievement. As a result, this variable is not tested in economics of education studies. In this study, the number of sites on which schools operate is known. It is therefore a truly original variable to be tested.

In Switzerland, schools operate in a context of school mergers imposed by the State authority. Small schools located in neighboring villages or in city neighborhoods were used to offer schooling covering the entire obligatory education, even with a very low number of pupils per class. Alongside the merger process, small schools are grouped into a unique administrative unit, becoming school sites. These school sites specialize themselves in only a part of the obligatory education. As a result, the pupils often have to be transported daily from their home town to the appropriate school site; headteachers have to distance manage the different sites; and teachers have to work on several sites, meaning that they sometimes have to move from one site to another during the same day. Headteachers estimate that managing a multi-sites school needs more resources than managing a single-site school (Observatory on Primary Education, 2010).

Note that in related fields such as health care delivery, the multi-site problem is also underreasearched. For instance, it is entirely absent in hospital efficiency studies using either non-parametric methods (Mathiyazhagan, 2007; Chang, 1998) or parametric methods (Procházková & Šťastná, 2011; Zuckerman, Hadley & Lezzoni, 1994). Readers interested in hospital efficiency studies will find a comprehensive review of the literature in Hollingsworth (2008).

6. Data and model

Database

At the State of Geneva level, information about school input and output are divided into various databases belonging to different administrative units. Public access to these databases is denied, making information about school processes unknown and opaque. Partial access to selected data concerning the 2010-2011 school year and the 90 public primary schools has been secured for this study. It includes pupils' standardized test results (aggregated at school level), number of full-time equivalent staff and various environmental variables. Data had to first be gathered from the different administrative units and second be organized in order to be workable.

The disadvantage of cross-sectional data (2010-2011) is that the analysis cannot capture how one or several variables can influence another variable with a time lag. Ideally, time series data would be needed to include lagged explanatory variables in the second stage model.

[16] Downloadable data about PISA, including the school questionnaire, are available at: http://pisa2009.acer.edu.au/downloads.php.

First stage

Three outputs and three inputs are considered. These variables are all under the control of headteachers. They are aggregated over schools.

Outputs include three composite scores (standardized on a scale with a maximum of 100) purely reflecting the quality of the education process. The first one is composed of pupils' results in French and mathematics standardized tests at the end of the second grade (SCORE2). The second one is composed of pupils' results in French, German and mathematics standardized tests at the end of the fourth grade (SCORE4). Finally, the third one is composed of pupils' results in French, German and mathematics standardized tests at the end of the sixth grade (SCORE6).

The outputs can be considered as high quality data considering that test scores are totally standardized in the State of Geneva, from the design (by civil servants external to classes and schools) to the evaluation. As a result, test results provide perfectly comparable information over time and across schools.

Several studies focus specifically on standardized test scores as outputs. Among those are Bessent and Bessent (1980), Bessent, Bessent, Kennington and Reagan (1982), Bradley *et al.* (2001), Chalos (1997), Chalos and Cherian (1995), Demir and Depren (2010), Kirjavainen and Loikkanen (1998), Mizala, Romaguera and Farren (2002), Ray (1991), Ruggiero (1996, 2000) and Sengupta (1990).

The number of pupils is often used as an output measure, as in Abbott and Doucouliagos (2003), Ahn and Seiford (1993), Avkiran (2001), Coelli *et al.* (2005) or Essid, Ouellette and Vigeant (2013). However, this variable is not included as an output in the model for two reasons:

- First, the three composite scores used as outputs are built from school average test scores in different subjects. As these averages are ratios (test scores divided by number of pupils), the information about the size of the school is already lost. It implies that the assessment of scale efficiency does not make sense, and that 'pure' technical efficiency is the only workable information. In such a case, a DEA variable returns to scale model is required (Hollingsworth & Smith, 2033). As a result, it is more valuable to consider, in the current study, the number of pupils as an explanatory variable in the second stage.
- Second, every school in the State of Geneva is assigned to a pupil catchment area based on a school map. As a result, headteachers do not control the number of pupils – their school must accept every single pupil coming from the catchment area. The number of pupils must therefore be considered as a non-discretionary variable (and thus not be included in the first stage).

Although equity is one criterion of school performance in the State of Geneva, this model does not include the inverse standard deviations values of composite scores as outputs[17]. Including standard deviations could result in allocatating a 100% technical efficiency score to schools where all pupils fail to pass the test but where the standard deviation is very small. Such a situation is, of course, undesirable.

Inputs include *(1)* the number of full-time equivalent (FTE) teaching staff (TEACHER), *(2)* the number of FTE administrative and technical staff (ADMIN) and *(3)* the school budget in Swiss francs – excluding staff salaries and capital expenditure (BUDGET). The three inputs are expressed by pupils to be coherent with the formulation of the outputs. Note that BUDGET consists of a (relatively) small financial amount received by schools according to the number and the types of

[17] Standard deviation is an undesirable output (Scheel, 2001). The greater the value, the worse the performance is. The inverse value should therefore be considered.

classes it runs. It can be used to finance teachers conducting further tasks (i.e. tasks which do not appear in their contracts) or to buy school materials, support cultural activities, etc.

In 2010, according to the Swiss Federal Statistical Office, the first two inputs (TEACHER and ADMIN) corresponded to 94.9% of the public education operating expenses of the State of Geneva (State and local authorities – municipalities)[18]. They are formulated in FTE as opposed to monetary terms given that schools are not responsible for the age pyramid of their teachers and other staff. Taking into account the wages of the employees (which automatically grow higher alongside seniority) would unfairly alter efficiency of a school with a greater proportion of senior staff.

Other traditional inputs such as capital, energy, materials and services could be included in the first stage analysis. Unfortunately, no data were available for such inputs for this study.

The inputs used in this study are very similar to those used by Arcelus and Coleman (1997) – FTE teachers, FTE support staff, operating expenses and library expenses – although BUDGET is a feature of this study. The number of teachers and the number of administrative staff are classical inputs (Abbott & Doucouliagos, 2003; Avkiran, 2001; Grosskopf & Moutray, 2001), as are the overhead expenses (Ahn & Seiford, 1993; Beasley, 1990; Chalos & Cherian, 1995; Engert, 1996).

Descriptive statistics of outputs and inputs are reported in Table 2. On average, a pupil obtains 78.8 points (out of 100) at the end of grade 2, 77.3 points at the end of grade 4 and 76.7 points at the end of grade 6. The teacher/pupil ratio is 0.0582, meaning that there are 0.0582 teachers per pupil (or 5.82 FTE teachers per 100 pupils). The administrative and technical staff/pupil ratio is 0.0035, meaning that there are 0.0035 administrative and technical staff per pupil (or 0.35 FTE administrative and technical staff per 100 pupils). Finally, the school budget allocates 20.2 Swiss francs per pupil.

Table 2
Statistical summary of output and input variables included in the first stage DEA model (sample size = 90 primary schools)

	Mean	SD	Minimum	Maximum
Outputs				
SCORE2 (points/pupil)	78.8082	4.4956	64.9589	91.9591
SCORE4 (points/pupil)	77.2733	3.8718	68.0930	87.3654
SCORE6 (points/pupil)	76.7382	4.5361	64.7010	85.5275
Inputs				
TEACHER (FTE/pupil)	0.0582	0.0043	0.0520	0.0689
ADMIN (FTE/pupil)	0.0035	0.0005	0.0026	0.0052
BUDGET (CHF/pupil)	20.1643	5.8233	8.8186	48.2835

Source: General Direction of Primary Schools, Education Department, State of Geneva.

[18] These statistics are available at : http://www.bfs.admin.ch/bfs/portal/fr/index/themen/15/02/data/blank/01.html.

The correlation matrix of the variables included in the first stage is presented in Table 3.

Table 3
Correlation Matrix for the first stage variables

	TEACHER	ADMIN	BUDGET	SCORE2	SCORE4	SCORE6
TEACHER	1.00					
ADMIN	0.29	1.00				
BUDGET	0.08	-0.10	1.00			
SCORE2	-0.22	-0.09	0.07	1.00		
SCORE4	-0.46	-0.01	-0.07	0.33	1.00	
SCORE6	-0.49	-0.09	0.05	0.30	0.49	1.00

Correlations between input variables (TEACHER, ADMIN and BUDGET) are positive but very weak[19]. Correlations between output variables (SCORE2, SCORE4 and SCORE6) are positive but very weak between SCORE2 and SCORE 4 (0.33) and between SCORE2 and SCORE6 (0.3) and weak between SCORE4 and SCORE6 (0.49). Correlations between the two labour inputs (TEACHER and ADMIN) and the output variables are negative and very weak (TEACHER and SCORE2; ADMIN and SCORE2, SCORE4, SCORE6) or weak (TEACHER and SCORE4, SCORE6). Correlations between BUDGET and the output variables are positive or negative but very weak. This finding is coherent with Hanushek (2006) who, based on a meta-analysis, shows that school resources are weakly associated with school performance.

In the first stage analysis, a DEA input oriented variable returns to scale model is applied. It is run by using the 'twin' DEA software free package DEAP/Win4DEAP[20].

Second stage

The database contains eight explanatory and non-discretionary variables. They are divided into two groups: school characteristics and environmental variables.

School characteristics

- SITE: this variable indicates whether a school is located on one site or several. It is set up as a dummy variable, which takes the value of 1 if a school is located on more than one site. The expected sign of SITE is negative, as a greater number of site locations should complicate school organization and alter technical efficiency. As mentioned earlier in the literature review, this variable has never been tested before in two-stage DEA models. SITE is of paramount importance in the context of increasingly merging schools (schools located in small towns are grouped together into a common administrative unit).
- SPECIAL: this variable indicates whether special education for special needs pupils is available at a particular school. It is set up as a dummy variable, which takes the value of 1 if a school provides

[19] Correlation coefficients are considered as perfect between 1 and 0.98 (or -1 and-0.98), strong between 0.97 and 0.8 (or -0.97 and -0.8), moderate between 0.79 and 0.6 (or -0.79 and -0.6), weak between 0.59 and 0.35 (or -0.59 and -0.35) and very weak between 0.34 and 0 (or -0.34 and 0).

[20] As DEAP is a DOS program, a user friendly Windows interface has been developed for it (Win4DEAP). DEAP was developed by Timothy Coelli (Coelli Economic Consulting Services) and Win4DEAP by Michel Deslierres (University of Moncton).

special education. The expected sign of SPECIAL is negative (Borge & Naper, 2006; Rassouli-Currier, 2007) as *(1)* school organization with special education is more restrictive than without it and *(2)* schools with special education mostly admit disadvantaged pupils into special education classes.

- RECEPTION: this variable indicates whether special reception classes for immigrant pupils are available at a particular school. It is set up as a dummy variable, which takes the value of 1 if a school offers special reception classes. The expected sign of RECEPTION is negative because special reception classes are populated by allophone pupils. Ouellette and Vierstraete (2005) show that the percentage of the population in the school board's region who do not speak either official language at home is associated with lower efficiency.
- URBAN: this variable indicates whether a school is located in an urban area[21]. This is the case for 69 schools (out of 90). It is set up as a dummy variable, which takes the value of 1 if a school is located in an urban area. The expected sign of URBAN is negative, as urban schools tend to be less efficient than rural ones (Alexander & Jaforullah, 2004; Alexander *et al.*, 2010; Duncombe *et al.*, 1997).
- CLASS: this variable refers to the number of classes within a school. As the maximum number of pupils per class is regulated by law, this variable is outside of the control of the headteacher and should be included in the second stage analysis. The expected sign of CLASS is negative, as a greater number of classes could be due to a smaller number of pupils per class[22]. Class size is positively associated with school efficiency (Kirjavainen & Loikkanen, 1998; Kantabutra & Tang, 2006).

Environmental variables

- PUPIL: this variable refers to the number of pupils in a school. The expected sign of PUPIL is positive, as efficiency tends to grow with school size (Alexander & Jaforullah, 2004; Alexander *et al.*, 2010; Borge & Naper, 2006; Bradley *et al.*, 2001; Kantabutra & Tang, 2006; McMillan & Datta, 1998; Olivares & Schenker-Wicki, 2010; Ramanathan, 2001)[23].
- SOCIO: this variable represents the percentage of pupils (per school) whose parents are blue-collar workers or unqualified workers (category # 9 of the International Standard Classification of Occupations). It reflects the socioeconomic status of pupils. The expected sign is negative (Alexander & Jaforullah, 2004; Alexander *et al.*, 2010; McCarty & Yasawarng, 1993).
- ALLO: this variable represents the percentage of allophone pupils (per school). The expected sign is negative, based again on the results of Ouellette and Vierstraete (2005) showing that the

[21] In Switzerland, the Swiss Federal Statistical Office considers a city as a local entity with at least 10,000 people (Schuler, Dessemontet & Joye, 2005, p. 149). A city is considered to be an urban area. In 2011, the State of Geneva counts 12 cities, all of which are part of the agglomeration of the city of Geneva (the number of inhabitants is indicated in parentheses): (city of) Geneva (188,234), Vernier (33,237), Lancy (28,723), Meyrin (21,729), Carouge (20,004), Onex (17,637), Thônex (13,478), Versoix (12,942), Le Grand-Saconnex (11,759), Chêne-Bougerie (10,337), Veyrier (10,289) and Plan-les-Ouattes (10,196). These statistics are available at: http://www.bfs.admin.ch/bfs/portal/fr/index/regionen/02/key.html.

[22] For instance, consider two schools, each with 100 pupils. Assume that the first school has four classes, each with 25 pupils, and that the second school has five classes, each with 20 pupils. The greater number of classes in the second school is a result of the smaller number of pupils per class.

[23] Our database also contains the number of classes per school. As the number of pupils per class is regulated by law, this variable is outside of the control of the headteachers and should be included in the second stage analysis. However, preliminary results show that the number of classes and the number of pupils suffer from multicolinearity. As a result, one of these two variables (number of classes and number of pupils) has to be dropped from the model.

percentage of the population in the school board's region who do not speak either official language at home is associated with lower efficiency.

Descriptive statistics school characteristics and environmental variables are reported in Table 4. On average, a school has 381 pupils. 37% of them are disadvantaged; 41% are allophone. A school has an average of 20 classes. Schools are mostly located on more than one site and outside the city of Geneva. A minority of schools provide special education and special reception classes.

Table 4
Statistical summary of variables included in the second stage DEA model (sample size = 90 primary schools)

	Mean	SD	Minimum	Maximum
School characteristics				
SITE (dummy*)	0.64			
SPECIAL (dummy*)	0.23			
RECEPTION (dummy*)	0.41			
URBAN (dummy*)	0.79			
CLASS	19.69	6.18	9.00	38.00
Environmental variables				
PUPIL	381.38	116.52	157.00	726.00
SOCIO (%)	37.43	13.73	11.00	64.00
ALLO (%)	41.38	14.46	11.08	70.21

* For dummy variables, the mean value gives the proportion of schools in that class. For instance, 64% of schools are located on more than one site.

Source: General Direction of Primary Schools, Education Department, State of Geneva.

Correlations between the explanatory variables are checked before estimating the regression model. The correlation matrix is presented in Table 5.

Table 5
Correlation Matrix for the explanatory variables

	SITE	SPECIAL	RECEPTION	URBAN	CLASS	PUPIL	SOCIO	ALLO
SITE	1.00							
SPECIAL	-0.19	1.00						
RECEPTION	-0.09	0.07	1.00					
URBAN	-0.27	0.29	0.21	1.00				
CLASS	0.40	0.28	0.28	-0.01	1.00			
PUPIL	0.47	0.06	0.17	-0.12	0.96	1.00		
SOCIO	-0.16	0.30	0.29	0.54	0.23	0.08	1.00	
ALLO	-0.18	0.30	0.46	0.64	0.19	0.03	0.81	1.00

Note that other variables not tested in this study have demonstrated their impact on pupil performance in previous economics of education studies. These variables include:

- The degree of school autonomy (Hindriks, Verschelde, Rayp & Schoors, 2010; Clark, 2009; Woessmann, 2007);

- Teacher characteristics (Rivkin, Hanushek & Kain, 2005; Rockoff, 2004; Woessmann, 2003);
- Accountability systems (Woessmann, 2007; Hanushek & Raymond, 2005);
- Family environment (Rothstein, 2010; Currie & Goodman, 2010; Fuchs & Woessmann, 2004);
- Resources consumption (Hanushek, 2006);
- Competition (Woessmann, 2007; Sandström & Bergström, 2005; Björklund, Edin, Fredriksson & Krueger, 2004; Levacic, 2004; Hoxby, 2003; Bradley & Taylor, 2002; Chubb & Moe, 1990);
- Peer effects (McEwan, 2003; Zimmer & Toma, 2010; Hoxby, 2000);
- School size (Leithwood & Jantzi, 2009; Slate & Jones, 2005).

For a review of these variables, see Huguenin and Soguel (2013). In this study, resources consumption is included in the first stage analysis. Family environment and school size are covered by explanatory variables in the second stage analysis. As the 90 schools of the State of Geneva have the same degree of autonomy, are subject to the same accountability system and face the same competition from private schools, these determinants of pupil performance do not need to be included as explanatory variables. It would have been interesting to test the influence of teacher characteristics and peer effects on school efficiency but, unfortunately, no data about these variables were available for this study.

Multicollinearity

Three correlations are above 0.6. As expected, the correlation between the number of classes and the number of pupils is positive and strong (0.96); the correlation between the percentage of disadvantaged pupils and the percentage of allophone pupils is also positive and strong (0.81); and the correlation between schools located in an urban area and the percentage of allophone pupils is positive and moderate (0.64). None of the other correlations are larger than 0.54. They can be considered as weak (between 0.35 and 0.6 or –0.35 and –0.6) or very weak (between 0.349 and –0.349).

To test for potential multicollinearity in the data set, the variance inflation factors are assessed.

A regression model containing all the explanatory variables mentioned above is run. The variance inflation factors (VIF) of the number of classes, the number of pupils, the percentage of disadvantaged pupils, the percentage of allophone pupils and the URBAN variable are equal to 54.41, 45.88, 3.26, 4.10 and 1.84 respectively[24]. The mean VIF for all the explanatory variables is equal to 14.51. It is therefore likely that the results are distorted by multicollinearity (Bowerman & O'Connell, 1990; Myers, 1990).

CLASS and PUPIL are the two variables with the highest VIF. As an objective of this model is to test the effect of school size, the variable for the number of pupils is kept in the model, as it is a more accurate reflection of school size compared to the number of classes. As a result, CLASS is removed from the model, which is left with seven explanatory variables. The new mean VIF, once the number of classes has been removed from the model, is equal to 2.04[25]. Therefore, it can be concluded that the results of this new model are unlikely to be distorted by multicollinearity.

Out of 27 studies under review, five test for multicollinearity (Agasisti, 2013; Bradley *et al.*, 2010; Burney *et al.*, 2011; Denaux *et al.*, 2011; Ray, 1991).

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[24] The VIF values of the other variables are the following: SPECIAL = 3.29, RECEPTION = 1.77 and SITE = 1.53.

[25] The VIF values of the variables are the following: ALLO = 4.05, SOCIO = 2.98, URBAN = 1.81, SITE = 1.45, PUPIL = 1.43, RECEPTION = 1.37 and SPECIAL = 1.18.

The OLS model takes the following form:

$$TE_k = \alpha_0 + \alpha_1 SITE_k + \alpha_2 SPECIAL_k + \alpha_3 RECEPTION_k + \alpha_4 URBAN_k + \alpha_5 PUPIL_k$$
$$+ \alpha_6 SOCIO_k + \alpha_7 ALLO_k + e_k$$

TE_k is the efficiency score, derived from the first stage analysis, of the k_{th} school and e_k is an error term satisfying the usual conditions for ordinary least squares estimation. This model is run by using the data analysis and statistical software Stata ®.

In order to identify the functional form of the OLS regression, three Box-Cox models have been run. In the first model, the Box-Cox transformation is applied only to the dependent variable. In the second model, the Box-Cox transformation is applied only to the independent variables. In the third model, the Box-Cox transformation is applied both to the dependent and independent variables. As the variables should only contain strictly positive data, URBAN, SITE, RECEPTION and SPECIAL have been excluded from the second and third model.

In the first model, the maximum likelihood is maximized with a theta value of 6.752. The theta coefficient fits in the 95% interval $4.092 < \theta < 9.413$. However, the three null hypothesis ($\theta = -1$; $\theta = 0$; $\theta = 1$) are all rejected at the 1% level, meaning that all possible specifications are rejected (reciprocal, logarithmic and linear specification respectively).

In the second model, the maximum likelihood is maximized with a lambda value of 2.912. The lambda coefficient fits in the 95% interval $1.836 < \lambda < 3.989$. However, the three null hypothesis ($\lambda = -1$; $\lambda = 0$; $\lambda = 1$) are all rejected at the 1% level, meaning that all possible specifications are rejected (reciprocal, logarithmic and linear specification respectively).

In the third model, the maximum likelihood is maximized with a lambda value of 2.967. The lambda coefficient fits in the 95% interval $2.075 < \lambda < 3.859$. However, the three null hypothesis ($\lambda = -1$; $\lambda = 0$; $\lambda = 1$) are all rejected at the 1% level, meaning that all possible specifications are rejected (reciprocal, logarithmic and linear specification respectively).

Results show that the best specification is unclear. The skewness/kurtosis tests are performed on TE. The results show that the hypothesis of a normal distribution is rejected at the 1% level. Several alternative functional forms (cubic, square, square root, 1 / (square root), 1 / square, 1 / cubic) are tested in order to identify a transformation that would convert TE into a normally distributed variable. All of them are rejected at the 5% level.

As a result, the linear form is retained as *(1)* no clear indication points to another specification and *(2)* all Box-Cox models display the lowest chi-square value for the $\theta = 1$ and the $\lambda = 1$ null hypothesis.

Heteroskedasticity

The presence of heteroskedasticity in the second stage is considered. Out of 27 studies under review, four test for heteroskedasticity (Alexander & Jaforullah, 2004; Mancebon & Mar Molinero, 2010; Rassouli-Currier, 2007; Waldo, 2007). A Breusch-Pagan / Cook-Weisberg test for heteroskedasticity is performed. It tests the null hypothesis (Ho) that the error variances are all equal versus the alternative that the error variances are a multiplicative function of one or more variables. If Ho is accepted, it indicates homoskedasticity; if it is rejected, it indicates heteroskedasticity.

The χ^2 of the Breusch-Pagan / Cook-Weisberg test is equal to 15.64 with a p-value of 0.0001. As the p-value is smaller than 0.05, the null hypothesis is rejected and there is significant evidence of heteroskedasticity. Following this result, the White correction is applied to the model to correct for heteroskedasticity. An OLS regression with robust standard errors is run.

Endogeneity

Endogeneity remains a significant issue in two-stage DEA analysis. Ruggiero (1998) concludes his article by mentioning that the use of two-stage DEA analysis opens the door for known problems in regression analysis, such as endogeneity. His call has mostly remained unaddressed. Out of the 27 studies under review, only Waldo (2007) tests for endogeneity and only for one explanatory variable. Using two instruments (educational level in the municipality and private day-care), Waldo (2007) tests the endogeneity between the share of students in the municipality attending private schools (explanatory variable) and efficiency scores (dependent variable)[26]. No endogeneity is found.

Identifying endogeneity in the second stage appears challenging as *(1)* the efficiency scores themselves are usually unknown from school stakeholders before the DEA analysis is run[27] and *(2)* the efficiency scores are, in fact, built on multiple outputs and multiple inputs[28]. As a result, loops of causality (or simultaneity) are to be identified between any of the outputs and/or inputs used in the first stage and the independent variables. Except for Waldo (2007), instrumental variables have not yet been identified in the context of two-stage DEA analysis focused on education.

In the retained model, it could be argued that simultaneity occurs between the following variables:

- The number of school sites increases where the quantity of teaching and administrative staff increases, and therefore SITE is endogenous to school efficiency. The quantity of staff is used as an input in the first stage. All other things being equal, increasing the number of staff reduces efficiency. In such a case, local authorities decide to increase the number of sites because more staff are working[29].
- Special education is provided where pupil performance is poor and therefore SPECIAL is endogenous to school efficiency. Pupil performance (measured by standardized tests) is used as an output in the first stage. All other things being equal, poor performance reduces efficiency. In such a case, the State authority will provide special education in schools.
- Reception classes are provided where pupil performance is poor, and therefore RECEPTION is endogenous to school efficiency. Pupil performance (measured by standardized tests) is used as an output in the first stage. All other things being equal, poor performance reduces efficiency. In such a case, the State authority will provide reception classes in schools.
- The proportion of disadvantaged pupils increases where pupil performance is poor, and therefore SOCIO is endogenous to school efficiency. Pupil performance (measured by standardized tests) is used as an output in the first stage. All other things being equal, poor performance reduces efficiency. In the State of Geneva, school catchment areas are defined by the State authority. As a result, the parents' residential address determines which school will be attended by their children. However, it could be argued that some parents develop school catchment area evasion strategies.

[26] One of the instruments (level of education) is also used as an input in the first stage.

[27] Unknown efficiency scores means that a loop of causality (i.e. efficiency scores explaining the independent variables and not the other way round) is improbable, precisely because efficiency scores are unknown.

[28] Moreover, the weighting of inputs and outputs used by DEA to compute efficiency scores differ for each school. For instance, the weight of TEACHER used to calculate the efficiency score of school#1 is different than the weight of the same input used to calculate the efficiency score of school#2. If an omitted variable impacts TEACHER, this impact would probably vary in terms of endegoneity according to the assigned weights.

[29] In the State of Geneva, school infrastructure is financed by local authorities. Teachers' salary is financed at State level.

The objective is to enroll their children into high performance schools (and, as a result, to avoid low performance schools), thus parents may strategically move to another catchment area. As the State of Geneva faces a continuous housing crisis, with very limited housing available and high rental rates, only privileged parents can afford to move into these areas. As a result, such moves would increase the proportion of remaining disadvantaged pupils[30].

- The proportion of allophone pupils increases where pupil performance is poor, and therefore ALLO is endogenous to school efficiency. Pupil performance (measured by standardized tests) is used as an output in the first stage. All other things being equal, poor performance reduces efficiency. In this case, French-speaking parents move to other neighbourhoods because their childrens' schools have a low performance. This move increases the proportion of allophone pupils.

Endogeneity is solved by using instrumental variables. Instruments are identified following the procedure used by Waldo (2007): first, the instruments have to correlate with the potential endogenous variables; second, they cannot have any explanatory power on efficiency scores if they are to be used as independent variables alongside the potential endogenous variables.

27 variables are tested in order to identify instruments. These variables are all measured at the municipality level in which schools are located[31]. Correlation coefficients between potential endogenous variables and instruments are presented in Table 6. For presentation purposes, only correlation coefficients over |0.5| are listed.

Table 6
Correlation Matrix over |0.5| between potential endogenous variables and instruments

	SOCIO	ALLO
Social assistance rate (%)	0.60	0.63
Agricultural area (%)		-0.60
Habitat and infrastructure area (%)		0.58

[30] For instance, Noreisch (2007) studies the school catchment area evasion in the city of Berlin, Germany. The results show that the higher the percentage of non-German speaking pupils that are enrolled in a school, the more German children avoid it. Although priviledged parents do not know the performance of a particular school, they consider the presence of a large proportion of minority pupils "as a hindrance for the cognitive, personal and social development of their children" (van Zanten, 2003, p. 109).

[31] The 27 variables are as follows: population (2011), population density per km^2,(2011), proportion of the population (2011) between *(1)* 0 and 19 years old, *(2)* 20 and 64 years old, *(3)* over 64 years old, area in km^2 (1992/1997, last data available), habitat and infrastructure area (%), agricultural area (%), wooded area (%), unproductive area (%), total number of jobs (2008, latest data available), number of jobs in the primary sector, number of jobs in the secondary sector, number of jobs in the tertiary sector, total number of companies (2008, latest data available), number of companies in the primary sector, number of companies in the secondary sector, number of companies in the tertiary sector, number of newly built apartments (2010), social assistance rate (2011), share of votes in the last federal election on the left parties (2011), tax burden for married people with two children and an annual revenue of 100,000 CHF (State, municipal and religious tax, in % of gross labour income) (2011), budget surplus (excess revenue) (2011), gross debt (2011), taxable wealth of natural persons (2008, last data available), taxable income of natural persons (2008, last data available), taxable profit of corporations (2009, last data available).
These statistics are available at:
http://www.bfs.admin.ch/bfs/portal/fr/index/regionen/02/key.html.
http://www.estv.admin.ch/dokumentation/00075/00076/00720/01253/
index.html?lang=fr.
http://www.ge.ch/statistique/domaines/18/18_02/tableaux.asp.

Social assistance rate (BENEFIT) is positively correlated with SOCIO and ALLO. The proportion of agricultural area (AGRI) is negatively correlated with ALLO and the proportion of habitat and infrastructure area (HABIT) is positively correlated with ALLO.

To measure the explanatory power of BENEFIT, AGRI and HABIT, two additional models are run. The first one includes BENEFIT and the second one includes BENEFIT, AGRI and HABIT alongside SITE, SPECIAL, RECEPTION, URBAN, PUPIL, SOCIO and ALLO. BENEFIT, AGRI and HABIT are not statistically significant in any of the models. In the first model, BENEFIT has a coefficient value of 0.0052273 (t value of 1.21). In the second model, BENEFIT, AGRI and HABITAT have coefficient values of 0.0028614 (0.54), –0.0003065 (–0.41) and –0.0000121 (–0.02). As a result, BENEFIT can be considered as an instrumental variable for SOCIO and BENEFIT, AGRI and HABIT can be considered as instrumental variables for ALLO.

First, the model tests SOCIO as a potential endogenous variable, using BENEFIT as an instrument. A Durbin-Wu-Hausman test is performed. The null hypothesis (Ho) states that endogeneity is not present in the model. If Ho is accepted, it indicates the absence of endogeneity; if it is rejected, it indicates that endogeneity exists within the model. The χ^2 value of the Durbin-Wu-Hausman test is equal to 1.60211 with a p-value of 0.2056. As the p-value is larger than 0.05, the null hypothesis is accepted. No endogeneity is found.

Second, the model tests ALLO as a potential endogenous variable, using BENEFIT, AGRI and HABIT as instruments. The χ^2 value of the Durbin-Wu-Hausman test is equal to 0.21047 with a p-value of 0.6464. As the p-value is larger than 0.05, the null hypothesis is accepted. No endogeneity is found.

This is not surprising. In this study, SOCIO is assumed to be the cause of SCORE2, 4 and 6. If information about pupil performance (measured by standardized tests) was public knowledge, it could potentially encourage parents to move into catchment areas of better schools. However, there is strong information asymmetry is strong relating to school data. Information about school quality (pupil performance) and resource consumption are computed at State level and is unknown by parents. Therefore, parents cannot base their move on rational data and it is unlikely that SOCIO and ALLO are endogenous.

Unfortunately, no correlation coefficients over |0.5| were found for SITE, SPECIAL and RECEPTION. Those potential endogenous variables are therefore not tested for endogeneity. However, it is unlikely that these variables are endogenous for the following reasons:

- Considering a principal-agent approach to educational production (Wössmann, 2005), asymmetric information about school data between the principal (i.e. the parents) and the agent (i.e. the headteacher) appears to be strong in the State of Geneva. Information about school quality (pupil performance) and resource consumption are computed at State level. This is not public knowledge, probably not even for local authorities. Efficiency scores have never been measured before this study. As a result, it is unlikely that the variable SITE is endogenous.
- The provision of special education and reception classes does not depend on the State office of compulsory education but on the State office of special education. The presence of special education and reception classes in schools appears to be due to heritage rather than a rational decision based on efficiency analysis. As a result, it is unlikely that the variables SPECIAL and RECEPTION are endogenous.

7. Results

Technical efficiency scores (first stage)

The mean variable returns to scale technical efficiency score, VRSTE (also called ‘pure’ efficiency) is equal to 0.93 (or 93%). This means that schools could proportionately reduce all their inputs by 7% (100 – 93) whilst maintaining the same quality of pupil performance (outputs). As the calculation of VRSTE is devoid of scale effect, the 7% capacity for improvement resides with school management. VRSTE scores are presented in Table 7.

Table 7
Variable returns to scale technical efficiency scores

School	Technical efficiency	School	Technical efficiency
30	1.00	16	0.95
40	1.00	74	0.95
44	1.00	55	0.94
56	1.00	39	0.94
59	1.00	57	0.94
60	1.00	49	0.94
61	1.00	52	0.94
62	1.00	41	0.93
63	1.00	29	0.93
64	1.00	37	0.93
65	1.00	47	0.93
66	1.00	67	0.92
70	1.00	28	0.92
71	1.00	32	0.92
77	1.00	23	0.91
78	1.00	51	0.91
84	1.00	22	0.91
87	1.00	31	0.91
88	1.00	13	0.91
90	1.00	75	0.91
68	1.00	43	0.90
53	1.00	26	0.90
82	1.00	3	0.89
80	0.99	83	0.89
25	0.99	50	0.89
86	0.99	79	0.89
72	0.98	20	0.89
81	0.98	18	0.88
69	0.98	15	0.88
76	0.98	4	0.88
73	0.98	5	0.87
58	0.98	2	0.86
54	0.97	35	0.85
38	0.97	21	0.85
24	0.96	19	0.83
42	0.96	6	0.82
36	0.96	12	0.81
46	0.96	7	0.81
89	0.96	10	0.81
33	0.95	11	0.80
34	0.95	1	0.79
85	0.95	8	0.78
45	0.95	17	0.76
48	0.95	9	0.76
27	0.95	14	0.76

22.2% of schools have a score of 1. These schools lie on the efficiency or best-practice frontier. All of the other schools are beneath the frontier with respective scores of less than one. 25.6% of schools have a score between 0.999 and 0.95, 24.4% have a score between 0.949 and 0.9, 14.4% have a score between 0.899 and 0.85, 6.7% have a score between 0.849 and 0.8 and 6.7% have a score between 0.799 and 0.75. The lowest score registered is 76%.

Sensitivity analysis (first stage)

Sensitivity analysis aims to identify the impact on school efficiency and ranking when certain parameters are modified in the model. First, the efficiency frontier may be partially modelled with respect to outlier schools. Removing these outliers could result in different efficiency scores and ranks. Second, testing different combinations of inputs and outputs in different first stage DEA models may also provide different efficiency scores and ranks.

A jackknifing procedure is used to deal with potential outlier schools. Such a procedure is used by Borge (2006), Bradley *et al.* (2001), Hu, Zhang and Liang (2009), Kirjavainen and Loikkanen (1998) or Waldo (2007). It tests the sensitivity (also called stability or robustness) of DEA results regarding outlier schools. In this procedure, efficient schools (i.e. located on the frontier) are removed one at a time from the analysis. In this study, 20 schools are 100% efficient. That means that 20 additional models are run, each removing a different efficient school. The similarity of *(1)* school efficiency scores and *(2)* school ranking between the original model and the models where efficient schools are removed one at a time is then tested using Pearson and Spearman rank correlations. Results of this analysis are presented in Table 8.

Table 8
Sensitivity analysis regarding outlier schools

	Mean	Min	Max
VRSTE original model	0.9321	0.7604	1.0000
VRSTE iterated models*	0.9393	0.9286	0.9469
Pearson**	0.9958	0.9553	1.0000
Spearman**	0.9936	0.9497	1.0000

* For each additional model run, a mean is calculated. The mean value indicated in this table refers to the mean of the models' means. The minimum value corresponds to the minimum mean identified within the additional models. The maximum value corresponds to the maximum mean identified within the additional models.

** For each additional model run, a Pearson and a Spearman correlation is calculated with the original model. The mean value indicated in this table refers to the mean of the correlation coefficients observed. The minimum value corresponds to the minimum correlation coefficient observed. The maximum value corresponds to the maximum correlation coefficient observed.

The Pearson and the Spearman mean correlations are positive and considered as perfect (0.9958 for Pearson and 0.9936 for Spearman). The efficiency scores correlation (Pearson) and school ranks correlation (Spearman) range from 0.9553 to 1 and from 0.9497 to 1 respectively. These correlation coefficients are significant at the 1% level. The results show that the efficiency scores and the school ranking are not sensitive to outlier schools.

The efficiency scores and rankings of schools may also vary when different combinations of inputs and outputs are considered and must therefore be tested (Abbott & Doucouliagos, 2000; Burney *et al.*, 2011; Martin, 2006). Beside the original model containing three inputs and three outputs, six additional models are run. In each of them, a different variable is removed. Table 9 describes these six models. For instance, model 3 contains two inputs (TEACHER and ADMIN) and three outputs (SCORE2, SCORE4 and SCORE6). The variable BUDGET has been removed from this model.

Table 9
Additional DEA models

	Inputs			Outputs		
	TEACHER	ADMIN	BUDGET	SCORE2	SCORE4	SCORE6
Model 1		X	X	X	X	X
Model 2	X		X	X	X	X
Model 3	X	X		X	X	X
Model 4	X	X	X		X	X
Model 5	X	X	X	X		X
Model 6	X	X	X	X	X	

The similarity of *(1)* school efficiency scores and *(2)* school ranking between the original model and the models where input and output variables are removed one at a time is then tested using Pearson and Spearman rank correlations. Results of this analysis are presented in Table 10.

Table 10
Sensitivity analysis regarding input and output variables

	Mean	Min	Max
VRSTE original model	0.9321	0.7604	1.0000
VRSTE iterated models*	0.9127	0.8433	0.9298
Pearson**	0.9413	0.7477	0.9950
Spearman**	0.9414	0.7884	0.9930

* For each additional model run, a mean is calculated. The mean value indicated in this table refers to the mean of the models' means. The minimum value corresponds to the minimum mean observed within the additional models. The maximum value corresponds to the maximum mean observed within the additional models.

** For each additional model run, a Pearson and a Spearman correlation is calculated with the original model. The mean value indicated in this table refers to the mean of the correlation coefficients observed. The minimum value corresponds to the minimum correlation coefficient observed. The maximum value corresponds to the maximum correlation coefficient observed.

The Pearson and the Spearman mean correlations are positive and strong (0.9413 for Pearson and 0.9414 for Spearman). The efficiency scores correlation (Pearson) and school ranking correlation (Spearman) range from 0.7477 to 0.995 and from 0.7884 to 0.993 respectively. These correlation coefficients are significant at the 1% level. The minimum correlation coefficients (0.7477 for Pearson and 0.7884 for Spearman) are observed between the original model and model 1. In model 1, the input variable TEACHER is removed. In this case, the correlation is considered as moderate, but still significant at the 1% level. This result is not surprising: pupil performance as an output of administrative staff and monetary budget is likely to vary when the input of teachers is added. As teachers represent the most important input variable in a school, it stands to reason that it should be retained within the model. As a result, model 1 can be excluded. Relatively small differences in efficiency scores and school ranks are observed. These results show that, with the exception of model 1, the efficiency scores and the efficiency rankings are not sensitive to the removal of inputs and outputs.

Determinants of school efficiency (second stage)

SITE, SPECIAL, RECEPTION, URBAN, PUPIL, SOCIO and ALLO explain 68% of technical efficiency scores (R^2 = 67.89). Three variables are significant at the 1% level: SITE, PUPIL and SOCIO. One variable is significant at the 5% level: SPECIAL. Detailed results are presented in Table 11[32].

Table 11
Determinants of school efficiency: results from the OLS regression

	Coefficient	t-statistic
Constant	1.0205	69.89 **
School characteristics		
SITE	-0.0349	-3.20 **
SPECIAL	-0.0239	-2.08 *
RECEPTION	-0.0081	-0.84
URBAN	0.0097	0.88
School environment		
PUPIL	0.0002	5.60 **
SOCIO	-0.0032	-6.29 **
ALLO	-0.0007	-1.30

** Significant at the 1% level; * Significant at the 5% level

All the variables have the expected sign, with the exception of URBAN which shows a positive sign. However, as URBAN is not statistically significant, it cannot be concluded that this result contradicts Alexander and Jaforullah (2004), Alexander *et al.*, (2010) and Duncombe *et al.* (1997)[33].

[32] Three alternative models were also run: first, a Tobit regression with the same variables; second, an OLS regression in which the VRSTE scores were replaced by the inefficiency scores (1 minus VRSTE) as the dependant variable, OLS-INEFF; third, a log-linear OLS regression containing the same variables as in the linear OLS model. Concerning the log-linear model, note that Ruggiero (2004), using simulated data, demonstrates that linear versus log-linear results produce similar results.
Results of the three alternative models are very similar to the original OLS models. They are mentioned below.
The coefficients values and the levels of significance of the Tobit model are as follows (pseudo R^2 = - 1.0509): - 0.0464338** for SITE; - 0.0260671* for SPECIAL; - 0.0089017 for RECEPTION; - 0.000249 for URBAN; 0.0003039** for PUPIL; - 0.003932** for SOCIO; - 0.0007593 for ALLO; 1.045769** for the constant.
The coefficients values and the levels of significance of the OLS-INEFF model are as follows (R^2 = 67.94): 0.0355405** for SITE; 0.0236371* for SPECIAL; 0.0078518 for RECEPTION; - 0.0100752 for URBAN; - 0.0002259** for PUPIL; 0.0032218** for SOCIO; 0.0007279 for ALLO; - 0.02032** for the constant.
The coefficients values and the levels of significance of the log-linear OLS model are as follows (R^2 = 67.22): - 0.03834** for SITE; - 0.0285165* for SPECIAL; - 0.0088994 for RECEPTION; 0.0136607 for URBAN; 0.0002514** for PUPIL; - 0.0035971** for SOCIO; - 0.0008015 for ALLO; 0.0230547** for the constant.

[33] Note that an additional regression model was run in which the variable URBAN was removed and replaced by a dummy variable (GENEVA) accounting for the location of schools only in the city of Geneva. In this additional model, the coefficient of GENEVA is also positive and not statistically significant. Results concerning all other variables remain valid. Ramanathan (2001) tests the impact of the location of schools in the city of The Hague (Netherlands). As for the location in the city of Geneva, the direction of influence is positive but not significant.

SITE is negative and significant at the 1% level. Technical efficiency is negatively influenced by the fact that a school is located on several sites. The movement of SITE from 0 (one site) to 1 (several sites) generates a –0.0349 unit change in the VRSTE score. For instance, school # 6 is located on more than one site. It has a VRSTE score of 0.8152. All other things being equal, the VRSTE of school # 6 would improve to 0.8501 (0.8152 + 0.0349) if it was located on only one site. School # 82 has a VRSTE score of 0.9955 and is located on only one site. All other things being equal, the VRSTE of school # 82 would decrease to 0.9606 (0.9955 – 0.0349) if it was located on several sites[34].

SPECIAL is negative and significant at the 5% level. Technical efficiency is negatively influenced by the fact that a school provides special education. This result is in line with Borge and Naper (2006) and Rassouli-Currier (2007). The movement of SPECIAL from 0 (no special education) to 1 (with special education) generates a –0.0239 unit change in the VRSTE score. For instance, school # 17 provides special education and has a VRSTE score of 0.7604. All other things being equal, the VRSTE of school # 17 would improve to 0.7843 (0.7604 + 0.0239) if it did not provide special education. School # 46 has a VRSTE score of 0.9598 and does not provide special education. All other things being equal, the VRSTE of school # 46 would decrease to 0.9359 (0.9598 – 0.0239) if it provided special education.

PUPIL is positive and significant at the 1% level. Technical efficiency is positively influenced by school size. This result is in line with Alexander and Jaforullah (2004), Alexander *et al.* (2010), Borge and Naper (2006), Bradley *et al.* (2001), Kantabutra and Tang (2006), McMillan and Datta (1998), Olivares and Schenker-Wicki (2010) and Ramanathan (2001). The value of the coefficient is close to zero. A one unit change in the number of pupils generates a 0.0002 unit change in the VRSTE score. For instance, school # 17, the smallest school with 157 pupils, has a VRSTE score of 0.7604. All other things being equal, the VRSTE of school # 17 would improve to 0.8052 (0.7604 + (0.0002 * (381 – 157))) if it had a number of pupils equal to the mean (381 pupils).

SOCIO is negative and significant at the 1% level. Technical efficiency is negatively influenced by the proportion of disadvantaged pupils. This result is coherent with Alexander and Jaforullah (2004), Alexander *et al.* (2010), Bradley *et al.* (2001), Duncombe *et al.* (1997), Kirjavainen and Loikkanen (1998), McCarty and Yasawarng (1993), Ouellette and Vierstraete (2005), Rassouli-Currier (2007) and Ruggiero and Vitaliano (1999). A one unit change in the proportion of disadvantaged pupils generates a 0.0032 unit change in the VRSTE score. For instance, school # 14 has the highest percentage of disadvantaged pupils (64%) and a VRSTE score of 0.7604 (as does school # 17). All other things being equal, the VRSTE of school # 14 would improve to 0.8468 (0.7604 + (– 0.0032 * (37 – 64))) if it had a proportion of disadvantaged pupils equal to the mean (37%).

The case of school # 14 is emblematic as it embodies a 'worst case' situation. It is a small school (296 pupils) with a high proportion of disadvantaged pupils (64%), located on more than one site and providing special education. All other things being equal, if this school held the mean number of pupils (381), the mean proportion of disadvantaged pupils (37%), was located on one site only and did not provide special education, it would have an efficiency score of 0.8766 instead of 0.7604.

[34] Note that an additional regression model was run in which the dummy variable SITE was removed and replaced by a discrete variable (NSITE) accounting for the number of sites on which schools are located (from 1 up to 5 sites, with a mean of 1.87 and a standard deviation of 0.85). In this other model, the coefficient of NSITE is negative and not significant. PUPIL (positive) and SOCIO (negative) remain significant at the 1% level. SPECIAL is not significant (but still negative). These results show that being located on one site or on several sites, rather than the number of sites itself, matters.

The variables RECEPTION and ALLO have the expected negative sign but are not significant. It is therefore not possible to draw any reliable explanations about these variables.

The coefficients of the OLS regression allow the efficiency scores of schools to be adjusted to common levels of statistically significant non-discretionary variables. In this study, the efficiency scores are adjusted to the following level of statistically significant non-discretionary variables:

- It is assumed that all schools are considered located on several sites (indeed the majority of schools are located on several sites);
- It is assumed that none of the schools provide special education (indeed the majority of schools do not provide special education);
- It is assumed that all schools have the same number of pupils (the mean value of 381.3 pupils);
- It is assumed that all schools have the same proportion of disadvantaged pupils (the mean value 37.43%).

Due to the adjustment of the efficiency scores for the statistically significant non-discretionary variables, the maximum value predicted by the OLS model is slightly higher than one[35]. This occurs in the case of relatively efficient schools operating in a relatively unfavourable environment.

Table 12 compares the unadjusted VRSTE and the adjusted VRSTE scores. For instance, school # 21 has an unadjusted score of 0.85. Once this score is corrected to take into account the influence of the significant variables as defined above, school # 21 has an adjusted score of 0.93. The mean efficiency of the unadjusted and the adjusted scores is equal to 0.9321 and 0.9252. 40 schools out of 90 have an adjusted score higher than their unadjusted score.

[35] Two schools have an adjusted efficiency score higher than one: school # 30 (1.04) and school # 25 (1.01). See Table 12.

Table 12
Adjusted variable returns to scale technical efficiency scores

School	VRSTE	Adjusted VRSTE	School	VRSTE	Adjusted VRSTE
30	1.00	1.04	16	0.95	1.00
40	1.00	0.96	74	0.95	0.94
44	1.00	0.96	55	0.94	0.93
56	1.00	0.97	39	0.94	0.94
59	1.00	0.94	57	0.94	0.94
60	1.00	0.94	49	0.94	0.93
61	1.00	1.00	52	0.94	0.91
62	1.00	0.94	41	0.93	0.91
63	1.00	0.95	29	0.93	0.97
64	1.00	0.90	37	0.93	0.94
65	1.00	1.00	47	0.93	0.94
66	1.00	0.95	67	0.92	0.93
70	1.00	0.94	28	0.92	0.93
71	1.00	0.91	32	0.92	0.93
77	1.00	0.92	23	0.91	0.89
78	1.00	0.91	51	0.91	0.90
84	1.00	0.94	22	0.91	0.98
87	1.00	0.90	31	0.91	0.93
88	1.00	0.93	13	0.91	0.94
90	1.00	0.93	75	0.91	0.88
68	1.00	0.95	43	0.90	0.87
53	1.00	0.97	26	0.90	0.94
82	1.00	0.93	3	0.89	0.95
80	0.99	0.94	83	0.89	0.90
25	0.99	1.01	50	0.89	0.90
86	0.99	0.92	79	0.89	0.86
72	0.98	0.94	20	0.89	0.94
81	0.98	0.92	18	0.88	0.91
69	0.98	0.94	15	0.88	0.89
76	0.98	0.95	4	0.88	0.93
73	0.98	0.93	5	0.87	0.89
58	0.98	0.90	2	0.86	0.88
54	0.97	0.93	35	0.85	0.87
38	0.97	0.96	21	0.85	0.93
24	0.96	0.95	19	0.83	0.87
42	0.96	0.95	6	0.82	0.89
36	0.96	0.98	12	0.81	0.85
46	0.96	0.96	7	0.81	0.86
89	0.96	0.90	10	0.81	0.87
33	0.95	0.94	11	0.80	0.83
34	0.95	0.95	1	0.79	0.87
85	0.95	0.90	8	0.78	0.84
45	0.95	0.97	17	0.76	0.86
48	0.95	0.92	9	0.76	0.83
27	0.95	0.96	14	0.76	0.89
			Mean	0.9321	0.9252

The unadjusted scores are positively correlated with the adjusted scores (Pearson correlation = 0.6963, significant at the 1% level). The unadjusted ranks are also positively correlated with the adjusted ranks (Spearman correlation = 0.5948, significant at the 1% level). The Pearson correlation is considered as moderate and the Spearman correlation as weak.

8. Further analysis

This study could be extended by several means. They are discussed hereafter.

- As advocated by Badillo and Paradi (1999), the measurement of efficiency by the use of a quantitative method could advantageously be complemented by a qualitative survey. For instance, Mancebón and Bandrés (1999) interview headteachers of efficient schools in order to identify the best practices that characterize efficient schools. The qualitative survey could be extended to teachers and eventually to school board members, pupils and parents.
- Referring to the KLEMS input framework (OCDE, 2001), inputs involved in the first-stage DEA model of the current study could also include variables which adequately reflect capital, energy, materials and services used by schools. Such variables are unfortunately either unavailable or unavailable disaggregated at school level in the State of Geneva. However, the model used includes three inputs, two of which measure the use of labour and correspond to 94.9% of the public education operating expenses in the State of Geneva and therefore adequately reflect the range of resources.
- Outputs involved in the first-stage DEA model of this study reflect quality (pupils' results) and not quantity (such as the number of pupils). As test scores are measured as an average per pupil, information about size effect is lost. To ensure consistency in how inputs and outputs are defined, inputs are also defined per pupil. As a result, scale efficiency cannot be measured in the first stage. In order to be able to measure scale efficiency, further studies could consider output as the multiplication between the average test scores and the number of pupils (instead of average test scores)[36]. This could, in some way, bypass the ratio form of the average test scores. It would also allow the inclusion of the number of pupils as a full output. In this study, the number of pupils is kept as an explanatory variable of school efficiency in the second stage.
- Outputs could also include variables reflecting other aspects of human capability (and not only test scores)[37]. Unfortunately, in the State of Geneva, such other aspects are either not defined or, if defined, not measured.
- Explanatory variables could include variables reflecting teacher characteristics and peer effects. These two elements have demonstrated their influence on pupil attainment. It would be interesting to know if they also influence school efficiency.
- Techniques have been developed in order to derive confidence intervals for the calculated efficiency scores, such as the bootstrap procedure (initially proposed by Simar & Wilson, 1998) or more recently the method proposed by Zervopoulos (2012), which is based on random data generation procedures. For instance, four studies out of the 27 under review use a bootstrap procedure (Agasisti, 2013; Alexander *et al.*, 2010; Borge & Naper, 2006; Olivares & Schenker-Wicki, 2010). Re-sampling using the bootstrap procedure is particularly appropriate when data on the full population of schools is unavailable or when there is a small sample set. In three out of four studies, the original sample had to be reduced for various reasons (from 394 to 324 in Agasisti, 2013; from 779 to 651 in Alexander *et al.*, 2010; from 434 to 426 in Borge & Naper,

[36] Lovell *et al.* (1994) measure outputs as the average number of maths, science, vocational and foreign language classes multiplied by enrolment, but not the average test scores multiplied by enrolment as proposed in this paper.

[37] David Broddy, chairman of the Society of Heads, made the following statement at the Society of Heads' annual meeting in 2013 (Paton, 2013): "What part have we played in allowing that only academic success is a measure of human capability? That a definition of a "good" school is one that rises to the top of exam league tables and the definition of a "bright" pupil is one that gets A* grades?"

2006). In the fourth study (Olivares & Schenker-Wicki, 2010), the sample set consists of 12 units (universities). In the current study, as the full population of schools is available and large enough, bootstrapping makes little sense.

- Other methods have been developed in order to identify the determinants of school efficiency. Various three-stage models have been proposed, as by Ruggiero (1998) or Fried, Lovell, Schmidt and Yaisawarng (2002). In Ruggiero (1998), the first and the second stages are similar to the two-stage method. Based on the second stage results, Ruggiero (1998) constructs an index of environmental influence. In the third stage, this index is introduced in a modified DEA model in order to re-evaluate efficiency scores. Fried *et al.* (2002) use a stochastic frontier analysis in the second stage. In the third stage, either outputs or inputs (depending on the model orientation) are adjusted for the environmental effect and statistical noise.

  Muñiz, Paradi, Ruggiero and Yang (2006) compare various three-stage models. The authors conclude that the Ruggiero (1998) model performs best overall. However, Ruggiero (2004), using simulated data, compares the second-stage model and his own three-stage model (Ruggiero, 1998). He concludes that the second-stage model performs better than the three-stage one. The added-value of three-stage models is therefore not convincing.

  Fried, Schmidt and Yaisawarng (1999) develop a four-stage model. The first stage measure efficiency scores using DEA. In the second stage of this model, slacks are regressed upon environmental variables. Parameters estimated in the second stage are used to adjust variables of the first stage. Last, efficiency scores are re-estimated using DEA in the fourth stage. The four-stage model has only been applied once in the education sector (Sav, 2013).

  Note that the three- and four-stage models are sophisticated models in terms of methodology and in terms of computation. Yang and Pollitt (2009) compare the two-, three- and four-stage models in the specific case of coal-fired power plants with undesirable outputs. The authors conclude that, in this particular case, the three- and four-stage models are superior to the two-stage model because they make better use of information contained in the input slacks. This result needs to be confirmed by further studies, especially when simulated data are used and when undesirable outputs are not included.
- No instrumental variables were identified for the potential endogenous variables SITE, SPECIAL and RECEPTION. These potential endogenous variables have therefore not been tested for endogeneity.

9. Conclusion

The mean variable returns to scale technical efficiency of schools in the State of Geneva is equal to 93%. By improving the operation of schools, 7% (100 – 93) of inputs could be saved, representing 17'744'656.2 Swiss francs in 2010.

Using a two-stage data envelopment analysis, determinants of school efficiency are identified.

School location in an urban area, the provision of reception programmes for immigrant pupils and the proportion of allophone pupils are not statistically significant.

On the other hand, school size (measured by the number of pupils), the proportion of disadvantaged pupils, the provision of special education and schools operating on several sites are statistically significant.

School size positively influences efficiency, whilst the proportion of disadvantaged pupils, the provision of special education and schools operating on several sites negatively influences efficiency.

Technically, these variables are outside of the control of the headteachers. However, it is still possible to either boost the positive impact or curb the negative impact. Actions can be taken at State, school and class level.

To tackle the difficulty of managing multi-sites schools, the State of Geneva and the local authorities could invest in information and communication technology (ICT). Selwood and Visscher (2008) advocate the use of school information systems for enhancing school improvement. The use of ICT could be used for distance learning and distance management (for instance the use of video conferencing or dematerialized school record) in order to reduce the necessity for teachers and managers to systematically move physically from one site to the other. For instance, pupils could carry a smartcard which would register their presence as soon as they enter the school perimeter, even if there were no administrative staff present on a particular school site. In case of absence, headteachers and parents would be automatically informed by SMS and/or e-mails.

Positive discrimination is often advocated to correct the negative influence of disadvantaged pupils on school performance. It generally results in allocating more resources to disadvantaged schools. Unfortunately, positive discrimination does not seem to improve pupil performance in neither Europe (Demeuse, Frandji, Greger & Rochex, 2008) nor in the State of Geneva (Souci & Nidegger, 2010). The impact of positive discrimination on school efficiency is therefore negative: inputs increase without any output improvement. As a result, other actions need to be taken in order to correct the negative influence of disadvantaged socioeconomic status on school performance.

In order to define these actions, one has to identify the social-class differences which explain why disadvantaged children underperform. Through a review of the literature, Rothstein (2010) sums up these differences. The author demonstrates that childrearing and literary practices, health characteristics, housing stability and economic security influence pupil achievement. Children with a low socioeconomic status are disadvantaged in all these areas. For instance, less-educated parents read to young children less often and less consistently; disadvantaged children are in poorer health – mental health, asthma, acute illness, etc. (see also Currie and Goodman, 2010, for a review about the impact of health on education achievement)[38]; they are confronted with housing instability; they suffer from parents confronted with unemployment. Evidence shows that these variables impair skill acquisition. Rather than allocating more resources to schools, policymakers should therefore focus on related social policies. For instance, they could define pre-school, family, health, housing and benefits policies in order to improve the conditions for disadvantaged children. In Switzerland, Abrassart (2009) proposes that global family policies should be taken into account. He advocates that language courses could be systematically offered to immigrant parents. Speaking the language of the host country would allow them to be better involved in their childrens' schooling. However, recent studies, such as Melhuish, Belsky and Leyland (2010), show that positive discrimination actions implemented in related social policies generate mixed effects but also non-effects, especially with regard to children's development.

Special education is mainly provided in separate classes, meaning that pupils with special needs are grouped into specific classes. In the State of Geneva, a new law ruling the integration of children and

[38] Rothstein (2010, p. 152) and Curie (2010, p. 159) mention that nutrition may play a significant role in a child's cognitive development. Disadvantaged pupils suffer from poor nutrition. For instance, a recent survey in the UK led by the Association of Teachers and Lecturers (ATL, 2013) reveals that 45% of school staff questioned thinks that attendance at a school breakfast club is the only way some pupils get access to a meal in the morning. School staff believes that offering breakfast to pupils has a positive impact on their concentration (77%), their ability to learn (71%), their behaviour (58%) and their social skills (60%).

young people with special needs or disability came into force in 2010. It states that integrative solutions are preferred to separative solutions. A move towards integrating pupils with special needs or disabilities into regular classes could increase school efficiency, although this assumption remains untested.

Finally, further analysis should be conducted in order to measure scale efficiency. It should especially determine if there is a size at which school efficiency starts to decline (rather than continuing to increase). Depending on the results of this analysis, a reflection about merging schools facing increasing returns to scale, splitting schools facing decreasing returns to scale, or modelling catchment areas should be undertaken.

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