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# A two-stage double-bootstrap data envelopment analysis of efficiency differences of New Zealand secondary schools

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## Abstract

We conduct a two-stage (DEA and regression) analysis of the efficiency of New Zealand secondary schools. Unlike previous applications of two-stage semi-parametric modelling of the school "production process", we use Simar and Wilson's double bootstrap procedure, which permits valid inference in the presence of unknown serial correlation in the efficiency scores. We are therefore able to draw robust conclusions about a system that has undergone extensive reforms with respect to ideas high on the educational agenda such as decentralised school management and parental choice. Most importantly, we find that school type affects school efficiency and so too does teacher quality.

**Keywords:** efficiency, productivity, double boot-strapping, school finance

# A two-stage double-bootstrap data envelopment analysis of efficiency differences of New Zealand secondary schools

There is considerable evidence that improved school quality can have a strong positive impact on economic performance (Hanushek 2005). New Zealand has, since 1989, been at the leading edge internationally of reforming its school system in line with liberal economic thinking that tightly controlled centralised bureaucratic systems inevitably produce inferior outcomes to systems based on decentralised management with accountability, parental choice and inter-school competition (Fiske and Ladd 2000). We do not focus here, though, on comparing schools before and after the reforms, for which detailed quantitative data are lacking, but rather on explaining, post-reform, what factors drive variations in efficiency across New Zealand secondary schools. Thus, our results are able to provide lessons both for New Zealand and other countries as to the determinants of school performance in what is now a very decentralised system.

In order that we may have confidence in our results, we adopt recently developed statistical techniques that overcome the principal shortcomings of previous analyses of school, as well as other types of firm, efficiency (Simar and Wilson 2000, 2003, 2007). Our analysis is in two stages. At the first stage, we undertake a Data Envelopment Analysis (DEA) using a tightly defined set of quantitative inputs. We envisage these basic inputs being transformed into quantifiable success in terms of pupil qualifications. From this DEA we derive an estimate of the efficiency with which each school handles this process. We conceive of the initial generation of efficiency scores as the result of a simple productive process transforming inputs into outputs and avoid other variables (environmental or managerial) that might affect efficiency at this stage of the analysis. In the second, regression, stage of the analysis we take into account all the other factors that we can measure. Simar and Wilson (2007) have pointed out that previous studies involving such two-stage semi-parametric models of production processes fail to describe a coherent data-generating process and are invalid because of the complicated nature of serial correlation among the estimated efficiencies. We use Simar and Wilson's (2007) suggested double bootstrap procedure to permit valid inference and to improve statistical efficiency.

Our approach offers a theoretically justifiable way both of measuring efficiency and of highlighting and measuring the effects of environmental or managerial factors that contribute to efficiency differences. Our principal findings are: that single-sex schools out-perform co-educational schools; that teacher quality, measured in terms of both qualifications and experience, has important positive effects on efficiency; that state schools do not perform as well as their counterparts in the semi-private sector (known in New Zealand as integrated schools); that country schools have demonstrably higher efficiencies than urban schools; that, up to the size of the largest New Zealand schools, roll size positively affects efficiency; and that the lower the socio-economic status of a school's neighbourhood, the lower the school's efficiency.

In Section 1 of the paper we provide background on the New Zealand secondary school system. Section 2 describes our method. In Section 3 we present details of the data used. Sections 4 presents our findings and Section 5 concludes.

# 1. The New Zealand secondary school system

A range of reforms known as "Tomorrow's Schools" came into force in New Zealand at the end of 1989 and now provide the basis for the current system where funding is disbursed from the centre but responsibility for use of that funding devolves to the school level to an elected Board of Trustees (Fiske and Ladd 2000). The New Zealand Government provides funds to schools by means of "Operational Funding, which does not include the salaries of entitlement teachers, property or other large capital items" (New Zealand Ministry of Education 2003d, page 5). Operational funding is paid directly to each Board of Trustees quarterly in a bulk grant and, although the overall amount is arrived at by looking at a large number of components, each Board is free to decide how the grant is spent. The most important components in the calculation of a schools' bulk grant include: base funding, designed to compensate small schools for diseconomies of scale; per-pupil funding, which makes up the largest part of the grant; and targeted funding for educational achievement, which is based on the school's roll and its socio-economic rating.

A government agency, the Education Review Office, visits schools on a three or four yearly cycle and writes publicly available reports on its findings relating to the quality of processes and educational outcomes (Education Review Office 2003). The New Zealand Qualifications Authority, another government agency, compiles and publishes statistics on each school's performance in national qualifications in all subjects of the curriculum (New Zealand Qualifications Authority 2003).

It is clear, then, that the system is one of school-based management but with a high degree of accountability and transparency, both of which serve to inform parent choice. With the exception of some popular schools in the main urban areas which have found it necessary to introduce geographic zones to limit their intake, parents are free to send their children to whatever school they choose. Schools are not permitted to select pupils on academic criteria, or indeed on any other criteria, except in the case of those schools founded by particular religious denominations that may require a commitment to the ethos of the establishment.

In New Zealand, compulsory education begins customarily on each child's fifth birthday when she/he enters a 'new entrants' class. After that class, time spent in which varies considerably, pupils usually spend one calendar year at each of year levels 1 to 13, typically turning 6 during year 1 and 18 during year 13. New Zealand secondary school pupils study in schools that differ along a number of dimensions. Schools vary according to the range of ages of pupils for which they cater. They also vary by location (urban or rural), ownership type, and by whether they cater for boys only, girls only or both boys and girls (co-educational).

The traditional main type of secondary school in New Zealand teaches pupils in years 9 to 13. There are, however, significant numbers of schools that cover years 7 to 13, some of these formed by merger of traditional secondary schools with Intermediate (years 7 and 8) schools, and some which have always existed to serve rural locations with smaller population bases. Secondary pupils are also sometimes taught, especially in more isolated districts, in Area or Composite schools covering years 1 to 13.

There are three different types of school ownership. The predominant type is State-owned. The second most common type of school is known as 'Integrated'. Integrated schools were previously privately owned and operated, although they did attract some degree of state subsidy. Following the passage of the Private Schools Conditional Integration Act in 1975 (New Zealand Institute of Economic Research 2003, page 5), it became possible for a private school to integrate into the state system, while still retaining its own special character. This special character usually relates to some sort of religious belief. Integrated schools must follow state curriculum requirements, but their buildings and land remain the property of the private owners and costs of property maintenance and development are their responsibility. All other operational expenses, including teacher salaries, are met by the Government at the same level of funding per pupil provided to State schools. The third and final type of school ownership is private or Independent. These are the few schools that have chosen not to integrate into the state system. We have not included Independent schools in our analysis since they are not financially accountable to the Ministry of Education in the same way as State or Integrated schools so that no data are available to us. The system of State and Integrated schools covers about 93% of secondary school enrolments (Minister of Education 2003, Table A11).

Many of the older established secondary schools in New Zealand cater for only boys or only girls, while others are co-educational. This factor may affect educational outcomes according to a good deal of recent evidence. For example, in the New Zealand context, Woodward, Fergusson and Horwood (1999), having controlled for school selection processes, find that children attending single-sex schools tend to perform better than their co-educated peers.

Whether a school is located in a main urban area or in a less densely populated area may affect its scale of operations and/or its ability to attract teaching staff. In addition, different types of community may be more or less supportive of a local school. For example, rural communities may see the school as a focus of community involvement.

The system of school qualifications has just finished undergoing considerable change, but the data we have used relates to the 2001 school year because that is the only year, so far, covered by teacher census data. In that year, the long-established qualification system based on School Certificate (SC), Sixth Form Certificate (SFC) and University Bursaries (UBS) in years 11, 12 and 13, respectively, was still in place. School Certificate and University Bursaries were predominantly examination-based qualifications, while Sixth Form Certificate was internally (school-based) assessed, although grades awarded were moderated using school cohort performance in the previous year's School Certificate examinations.

## 2. Methods

Given that costs of school resources are quite easily quantified in terms of dollars, the main difficulty in assessing school performance comes down to measuring outputs. This issue is usually practically resolved by using the only data that are readily available and these most often relate to scores on some form of tests or examinations. Whatever the limitations of such data, they are derived from national qualification systems that attract a good deal of effort from both educators and bureaucrats and which are valued by the community at large.

Taking each school as the unit of observation, we measure inputs in terms of New Zealand dollars spent on administration and learning resources, numbers of teachers employed and students taught. These are conceived of as the raw materials that are transformed into outputs, which are to be measured by success in gaining various formal qualifications. Note that, at this first stage of our analysis, there are multiple inputs and multiple outputs. One approach to handling multiple outputs would be to decide on weightings for each output to produce a single composite output. This approach is appealing if the outputs have clearly defined market values (prices). In the educational setting this is certainly not the case so that, inevitably, there will be disagreement about the weightings. A school with low measured output can reasonably object that the weightings chosen do not reflect its particular objectives. Data Envelopment Analysis (DEA) is a linear programming technique that permits evaluation of the relative efficiency of decision-making units (DMUs, in this case, schools) without imposing *a priori* weights on the inputs and outputs.

Lewin and Minton (1986, page 259) set out in some detail the desirable features of the DEA approach to efficiency measurement. Worthington (2001) provides a very clear explanation of DEA along with a review of those empirical studies that have applied the technique to schools. Most studies, including Engert (1996), Ruggiero (1996), Bates (1997), Chalos (1997), Duncombe, Miner and Ruggiero (1997) and Grosskopf, Hayes, Taylor and Weber (2001), perform their analyses at the level of school district (in the United States) or local education authority (United Kingdom), although Mizala, Romaguera and Farren (2002), Bradley, Johnes and Millington (2001) and Kirjavainen and Loikkanen (1998) use data at school level in Chile, England and Finland, respectively, in the context of situations where individual schools are permitted a good degree of decision making authority. Simar and Wilson (2007, page 32) provide a very long list of studies that have taken a two-stage (DEA and regression) approach to the measurement and subsequent analysis of efficiency in a range of settings. Unfortunately, almost all of these studies, including those on schools, suffer from a problem that arises because the DEA efficiency estimates are serially correlated. Two papers that did attempt to correct for the serial correlation problem made use of a naïve bootstrap method which is "inconsistent in the context of non-parametric efficiency estimation" (Simar and Wilson 2007, page 33). Oliveira and Santos (2005) appear to be the first to implement some of Simar and Wilson's (2000) suggestions in the context of schooling. However, their data relate to a cross-section sample of only 42 Portugese public schools and they are therefore unable to implement double bootstrapping to correct for bias in the estimates of the efficiency scores. We follow the double bootstrapping method set out by Simar and Wilson (2007) in order both to bias-adjust the efficiency scores and to conduct consistent inference.

For the DEA approach, we choose an input orientation so that input efficiency is measured for a given level of output. We use Farrell's (1957) definition of efficiency. The efficiency score of a school is measured by the radial distance, keeping fixed the direction of the input vector to an estimated production frontier. We assume constant returns to scale so that the boundary is a conical hull. DEA is a non-parametric method in the sense that no specific functional form is assumed for the production function. Linear programming is used to estimate the true but unobservable frontier, conditional on data for the observed schools. The efficiency score ranks a school's performance relative to the estimated frontier. In other words, the score measures the relative reduction of inputs that is feasible and needed in order to achieve efficiency.

Kneip, Park and Simar (1998) state all required statistical assumptions needed to derive consistency and convergence speeds of Farrell's estimated efficiency scores for the multivariate case with multiple inputs and multiple outputs. The rate of convergence of the efficiency scores is low and depends on the degree of smoothness of the true frontier and the number of inputs and outputs. The greater the number of inputs and outputs, the slower the convergence rate. Also, the efficiency measure is sensitive to sampling variation and is upward biased by construction. Unfortunately, analytical results for the asymptotic distribution and for bias-correction are not available for the multivariate case due to the complexity involved.

In order to study the properties of the DEA estimator, a data generating process (DGP) must be defined, i.e., a statistical model must be chosen. Simar (1996) and Simar and Wilson (1998) formulate a set of assumptions to achieve this. Simar and Wilson (2007) suggest a bootstrap method in order to approximate the asymptotic distribution and to bias-correct estimates of efficiency scores, within a two-stage DEA.

The second step in the analysis is to carry out a regression analysis to determine the influence of environmental variables on the bias-corrected efficiency scores. Simar and Wilson (2007) describe a statistical model (i.e. a DGP) that is logically consistent with regressing non-parametric DEA efficiency estimates in a second stage regression on covariates (environmental variables) that are different from the inputs in the first stage. They spell out the separability conditions that allow for a two-stage procedure. The DGP that they describe is appropriate for the two-stage approach and accounts for the censoring of the dependent variable (the estimated efficiency scores) that is due to lumpiness (many values of 1). The second stage regression involves a generated dependent variable but, more importantly, the estimated efficiency scores are serially correlated in an unknown fashion. Standard inference is therefore not appropriate. Also, an ordinary (naïve) bootstrap is inconsistent.[1] Simar and Wilson (2007) propose instead a double bootstrap based on a well-specified statistical model that successfully deals with the described problems in the two-stage DEA with environmental variables.

We use the software package FEAR 1.0 of Wilson (2007) in order to carry out the DEA estimations. FEAR is based on the statistical package R. Efficiency is measured in terms of Shephard's (1970) input distance function, which is the reciprocal of Farrell's measure. Shephard's measure is hence one or larger. The results of Kneip, Park and Simar (1998) can be translated into Shephard's distance measure in a straightforward manner leading to a downward bias for the efficiency-score estimate instead of an upward bias found for Farrell's measure. The simplex method of Hadley (1962) is used in order to calculate the distance function estimates.

We program the double bootstrap following Algorithm #2 in Simar and Wilson (2007). First, we apply the DEA procedure in FEAR in order to estimate Shephard's efficiency scores for the schools in our sample. Second, we carry out a truncated normal regression with the maximum likelihood method, regressing estimated efficiency scores that are larger than one on the environmental variables. We use the "trunc.reg" command in FEAR for this purpose. Third, we program a bootstrap, drawing 100 samples each of size 324 from the truncated empirical normal distribution of the estimated efficiency scores. We use the random deviates generated with "rnorm.trunc" in FEAR.[2] Fourth, we calculate bias-corrected efficiency scores with the bootstrap results. Fifth, we use the bias-corrected efficiency scores to re-estimate the marginal effects of the environmental variables in the second stage regression. Sixth, we apply a second (double) bootstrap based on the empirical distribution of the bias-corrected second-stage regression. We obtain 2,000 replications for each parameter estimate of the marginal effect of environmental variables.[3] Last, we construct bootstrap-based p-values for each parameter estimate.

# 3. Data

The main source of information on New Zealand secondary schools is a census of schools carried out by the Data Management Unit of the Ministry of Education as at 1 July each year (New Zealand Ministry of Education 2003b). We have been fortunate to obtain the co-operation of the Ministry in accessing this data for a number of recent years.[4] Unfortunately, the school census does not collect information on teacher experience and qualifications. In 2001, the Ministry undertook a Teacher Census (New Zealand Ministry of Education 2003a) that collected quite detailed information from all teachers including actual subjects taught and qualifications in those subjects. Confidentiality issues prevented us from accessing this survey at the unit record level, but the Data Management Unit did construct for us two summary measures at school level, one of teacher experience and one of subject-specific qualifications, to supplement the school census and pupil qualification data of 2001. Consequently, we focus in this study on data for the 2001 school year.

## DEA outputs

At each of the year levels 11, 12 and 13 we have available to us various measures of school qualifications gained by pupils. In our DEA model we have used the three output variables detailed below.

At Year 11, until the recent introduction of the new National Certificate of Educational Achievement, New Zealand pupils (aged approximately 16) sat their first national examination, known as School Certificate. The Ministry of Education collated results at school level in a number of summary measures. The most detailed of these is simply the sum of all marks gained in all papers over all subjects sat (SCM). Other data provided to us include indicators based on marks and grades, but we decided to use the finest measure of a school's performance available to us. We also adopted this practice in choosing other variables.

In Year 12, until recently, the award was known as Sixth Form Certificate. This qualification was internally assessed. That is, there was no national examination, but an individual school's assessment of its students was moderated by the performance of the same group of students in the School Certificate examinations of the previous school year. The variable we use at this level is 6FC, being the number of year 12 students gaining this qualification.

In year 13, until 2004, pupils were able to sit the University Bursaries Examination. On the basis of performance in this examination, students scoring over 299 marks in five subjects were awarded an 'A' Bursary, those scoring between 250 and 299 marks a 'B' Bursary. We use a variable UBS at this level, being the number of students gaining four Cs (46% to 55%) or better which is the standard that qualifies a student for entrance to university.

## DEA inputs

In our DEA model, we have considered 11 input variables. We obtained data on school expenditures, excluding teacher salaries, broken down by five different categories. Each of these categories was entered into the DEA as a separate variable. These variables are: administration expenses (ADM), expenditure on learning resources (LRS), depreciation expenses (DPR), expenditure for raising local funds (LCL) and property management expenses (PRP). All of these variables are measured in New Zealand dollars. The other input variables we used are teachers, teacher aides and students at various levels of study. We measure teachers not in dollar terms but by the number of Full Time Teacher Equivalents (FTT). Other direct teaching staff consists of teacher aides, who are employed in many schools to assist in the classroom with children with special educational needs. Teacher aide data (ADS) are available only on a body count basis, not in full-time equivalents. The final input variables are the number of pupils at each of the year levels 11, 12 and 13 and all other school years combined, which are denoted, respectively, by Y11, Y12, Y13 and OTH. The variable OTH is included because, although qualifications are only gained at years 11 to 13, it is not possible to separate out school resources used by year level.

Table 1 summarises the variables used in the DEA stage of the analysis, together with their means and standard deviations.

*Table 1 about here*

## Data for the regression analysis

There are a number of categorical variables relating to school type or location that need to be present in any regression explaining school efficiency. All of the schools in our sample are either State-owned or Integrated into the State system. We set up a dummy variable, STA, which takes the value 1 if a school is State-owned and 0 otherwise. Given public perceptions of league table examination performances and indications that the 'special character' of an integrated school may create a supportive community of interest, we hypothesise that the variable STA will have a negative coefficient.

Traditionally, secondary education has been in schools that cater for the 14-18 year age group (years 9 to 13). We use this type of school as the basis of constructing dummy variables for two other types of school catering for differing age ranges. These types are: 7UP (catering for children from year 7 upwards) and 1UP (catering for all children from new entrants upwards). The former incorporates two further years of education that are often undertaken in separate intermediate schools. The latter is common in less heavily populated areas. We have no priors as to the likely signs on these dummy variables.

With a population of only about four million, a main urban area in New Zealand is defined as one with a population of over 30,000, while minor urban areas range from 1,000 to 9,999 in population. Secondary urban areas have populations intermediate between these two definitions. Taking schools in the main urban areas as a base type, we construct a set of dummy variables to capture schools in secondary urban (SEC), minor urban (MIN) and rural (RUR) areas. These are the standard classifications of New Zealand centres of population used by Statistics New Zealand and adopted by the Ministry of Education for classifying schools. We have no strong priors as to the likely signs on these dummy variables, although once we account for school size it might well be thought that smaller communities offer a more supportive framework for their schools as well as being freer from some of the social pressures associated with living in more densely populated districts.

In the light of our earlier discussion on the relative performance of boys and girls, we constructed one final set of dummy variables related to whether the school caters for boys only, girls only or is co-educational. The variable BYS takes the value 1 for a school catering for boys only, and 0 otherwise. Similarly, GRS takes the value 1 for single sex girls' schools and 0 otherwise. Therefore, both BYS and GRS take the value 0 in the case of a co-educational school. We expect to find that both of these variables turn out to have positive coefficients, providing evidence of a school-level gender effect although it does not allow us to say anything about the more general issue of girls' superior academic performance relative to boys.

Considering school students as an input to a school's production process, it is clear that their quality must matter. Ideally, one would like to assess a school's efficiency in terms of the value it adds to its students. If a school selects students for entry at year 9 on the basis of high academic performance to date, then it can evidently enjoy greater success in terms of examination results in year 12. There is, in fact, some evidence (Jesson 2000) to suggest that non-selective schools add more value. Unfortunately, no detailed national data on students leaving primary school are collected in New Zealand. Instead, we consider a proxy for student quality in terms of the socio-economic status of the community in which each school is located. For the purposes of school funding, the Ministry of Education allocates each school a decile rating based on the extent to which it draws its students from low socio-economic conditions. A decile 1 school has the highest proportion of students from low socio-economic communities, while a decile 10 school has the lowest proportion of such students. This decile rating is based on a more detailed index that runs from 0 to 599 with 599 indicating a school with the highest proportion of poor students. It is calculated from data on a number of dimensions, including the proportion of households in the school's catchment in the bottom 20% of an equivalised income scale (which makes adjustments for household size and composition when comparing incomes), the proportion of parents with no qualifications, the proportion of parents in elementary occupations and the proportion of parents receiving a welfare benefit, as well as measures of household crowding and the proportion of students from disadvantaged ethnic minorities (New Zealand Ministry of Education 2003c). We use this more detailed index of socio-economic deprivation (denoted by SES) in our regression analysis. We expect that a higher value of this index will have a negative impact on school efficiency.

School size could potentially affect efficiency both positively and negatively. It can be argued that there are certain economies of scale in school operations. For example, it would be difficult for the students of a very small school to perform well in national examinations if the school found it not within its means to employ teachers sufficiently qualified in all specialist subjects. A critical mass of teachers qualified in important subject areas may also produce synergistic effects in terms of quality of lesson preparation and so on. However, too large a school may suffer from difficulties caused by unwieldy administration or other diseconomies of scale. To capture these sorts of possibilities, we enter the variables ROL (the total number of pupils enrolled) and RLS (the square of the same quantity) into the regression analysis. Our expectations are of finding a positive coefficient on ROL but a negative coefficient on its square.

While the educational literature surprisingly often finds little impact of teacher quality on student performance (Hanushek 2003), it certainly does not seem reasonable to dismiss such variables from consideration here without testing. From the teacher census of 2001, the Ministry of Education released to us two summary measures of teacher quality useful for our purposes. The first of these is a measure of teacher experience (TEX), defined as the proportion of teachers in a school with five or more years' experience. The other is a measure of teachers' qualifications (TQL). This is the proportion of teachers teaching in the core subject areas

(Mathematics, Science, English and Social Studies) who have at least second year university qualifications in one of these subject areas. We would have preferred more subject area specificity with respect to this variable. As the variable is currently defined, a teacher with a degree in Mathematics might well be teaching English, or vice versa. However, we are currently unable to obtain greater detail due to confidentiality issues surrounding the teacher census data.

There are, of course, other variables that one would ideally like to see incorporated in the regression analysis. Apart from finer measures of both teacher and student quality, as already mentioned, class size may be a factor, but data availability inevitably constrains any more detailed analysis.

## Regression model

The regression equation takes the following form:

$$EFF_i = \alpha_0 + \alpha_1 STA_i + \alpha_2 7UP_i + \alpha_3 1UP_i + \alpha_4 BYS_i + \alpha_5 GRS_i + \alpha_6 SEC_i + \alpha_7 MIN_i + \alpha_8 RUR_i + \alpha_9 SES_i + \alpha_{10} ROL_i + \alpha_{11} RLS_i + \alpha_{12} TEX_i + \alpha_{13} TQL_i + e_i \quad (1)$$

$EFF_i$ is Farrell's bias-corrected efficiency score of the ith school derived from the earlier part of the analysis. The right hand side variables are as described above.

## Description of the sample

The sample of schools provided to us by the Ministry of Education contained data on 394 schools. Once we eliminated those schools for which some of the data we needed, as described above, were missing or miscoded or inconsistent in some way, the sample size was reduced to 324. The schools omitted from the sample range from quite small to relatively large by New Zealand standards and we can detect no systematic reasons for the missing data in terms of school type. Table 2 presents some descriptive statistics of the variables used in the regression analysis of this sample of 324 schools. The schools in the sample vary considerably both in size and socio-economic status, but they tend not to vary much along the dimensions of teacher experience and qualifications. Both of these latter variables cluster strongly around the 82% level, indicating that, in most schools, the vast majority of teachers have at least five years' experience and at least second year university qualifications in some core subject. State schools dominate the sample, with only 21% of the schools being Integrated schools. Traditional secondary schools, catering for years 9 to 13 make up 69% of the sample. Schools in main urban areas constitute 70% of the sample, as do Co-educational schools.

*Table 2 about here*

# 4. Results

The cumulative distribution of the bias-adjusted efficiency scores is shown in Figure 1. They have a mean of 0.7377 and a standard deviation of 0.2025. The lowest efficiency score is 0.2134 and 39 of the 325 schools (12%) are 100% efficient.

*Figure 1 about here*

Now, suppose we rank schools of various types according to their average estimated bias-adjusted efficiency score. We find that, from highest to lowest, the ranking is: integrated girls' schools (86% mean efficiency), state boys' schools (82%), state girls' schools (81%), integrated boys' schools (80%), integrated co-educational schools (73%) and state co-educational schools (70%). On this basis there is *prima facie* evidence that single-sex schools out-perform co-educational schools. However, the 95% confidence intervals for some of these categories of schools would overlap substantially and, moreover, there are other factors that have not been controlled for here; for example, SES score and teacher qualifications.

Figure 2 is based on some selected summary statistics concerning the efficiency scores. It displays the average efficiency score for schools of the six types just mentioned relative to the overall average efficiency score. Similarly, it displays the average teacher qualification percentage for each of the six types of school as a proportion of the average over all schools; and, again similarly for the average SES (socio-economic deprivation index). Clearly, the picture is not as obvious as that suggested by the simple left-to-right ranking according to efficiency scores in Figure 1, so we turn now to the regression results.

*Figure 2 about here*

Table 3 reports the results of estimating equation (1). The coefficients are corrected for bias using the methods described above. The p-values are those derived from the boot-strapping technique, also described above.

*Table 3 about here*

The coefficients of the dummy variables are directly interpretable as shifts in the percentage efficiency scores. Six out of eight of these coefficients have p-values of 0.001 or less and are therefore highly statistically significant. We consider each of them in turn.

Integrated schools are more efficient than State schools, all other things being equal, by almost 8 percentage points. This is in keeping with expectations that these formerly private schools still maintain an edge over the rest of the schools in the state system. Some efforts to understand in what way their management practices differ could pay dividends for State school managers, although the effect that is being captured may relate in part to the supportive nature of a strong community of interest derived from the special character or ethos of such schools.

The traditional Year 9-13 secondary school is more efficient than a Year 7-13 school, all other things being equal, by nearly 5 percentage points. We had no prior expectation of any significant difference between these two types of school and it is not at all clear to us why this should be the case as it seems unlikely that the existence of a group of younger students in the secondary school environment should have a negative impact on outcomes at the senior levels of a school. One might speculate that the presence of younger students occasioned by a merger with an Intermediate (years 7-8) school might also imply the presence of a number of Primary-trained teachers without university qualifications. However, this factor ought to be picked up in the teacher qualification data. Since we have also controlled for location (urban or rural) it seems likely that this result is driven primarily by lower efficiency of Year 7-13 schools in urban areas. Closer examination of what distinguishes the practices of typical Year 7-13 schools would appear to be worthwhile. There appears to be no significant difference in efficiency between Year 1-13 and Year 9-13 schools, which only adds to the difficulty of interpreting the significantly negative coefficient for Year 7-13 schools.

Girls' schools are, all other things being equal, more efficient than Co-educational schools by almost 7 percentage points. This finding is supportive of the view that girls perform academically more strongly in the absence of boys. The estimate of the coefficient on BYS is also positive but of a smaller magnitude to that on GRS. Boys' schools are about 4.6 percentage points more efficient than Co-educational schools.

There is no statistically significant difference in efficiency between schools in Secondary and Main Urban areas. However, schools in Minor Urban locations and Rural locations are almost 7 percentage points and more than 11 percentage points more efficient, respectively, than those in Main Urban Areas. Further study of how the larger urban environments negatively affect school efficiency therefore has the potential to improve outcomes.

The coefficients of the continuous variables are not as directly interpretable as those on the dummy variables, but we offer examples of their meaning. The estimate of the coefficient on the variable SES is –0.000450 and it is highly statistically significant. Holding all other variables equal, it can be interpreted as suggesting that a one point rise in this variable (which represents a decrease in socio-economic status) lowers percentage efficiency by about 0.05 percentage points. Thus, for example, a school with the average measured value of this variable (282) would be (*ceteris paribus*) a little more than 12 percentage points less efficient than a school with the best measured value of this variable (10), a very substantial effect from socio-economic status alone. Such a finding, at face value, might seem to lend support to the preferential funding of poorer schools. However, a low efficiency as measured by DEA can come about as the result of low output values or high input values. If a school in a poorer area finds it hard to raise student outcomes (has low output values) in spite of the preferential funding it receives (high inputs) its efficiency may look low indeed. One could possibly improve such a school's apparent efficiency score by removing the preferential funding if there were little effect on student performance. The policy implication of finding a significant effect of SES is therefore not at all clear. The most we can say with certainty is that SES affects outcomes but differential funding programmes to address disadvantage need to be carefully assessed for effectiveness.[5]

The estimates of the coefficients on the two variables controlling for overall school size (ROL and RLS) have the correct signs, but the squared term is not statistically significant. Within the range of school sizes in New Zealand, there is therefore no evidence of diseconomies of scale.[6] Consider an increase in school size by the amount of a typical secondary school class of approximately 30 students. The resulting change in efficiency is an increase of about two-thirds of a percentage point.

The coefficient on the teacher experience variable (TEX) is positive and statistically significant at better than 0.1%. *Ceteris paribus*, each one percent lift in the percentage of teachers in a school with five or more years of experience raises efficiency by 0.719 percentage points. For example, if a school could increase its proportion of staff with five or more years experience by 1 standard deviation on the existing distribution of experience, it could expect a rise in efficiency of more than 5 percentage points.

The coefficient on the teacher qualification variable (TQL) is also positive and highly statistically significant. Each one percent rise in the proportion of qualified teachers in a school raises efficiency by 0.184 percentage points. Consequently, a school that increases its proportion of staff qualified at this level by 1 standard deviation of the existing distribution of teacher qualification could achieve a rise in efficiency of almost 2 percentage points.

# 5. Conclusion

The New Zealand secondary school system is a relatively homogeneous one in the sense that it is predominantly state-funded and each school has many obligations placed upon it by a national system of qualifications. Nevertheless, schools do vary along a number of dimensions that have the potential to affect their efficiency. Most importantly, each school has a very high degree of control over decision making with respect to employment of its resources, making outcomes from the New Zealand context of relevance to educational policy makers everywhere who are interested in reforms focussed on decentralising decision making.

DEA provides a way of assigning weights to outputs that places each school in the best light amongst its peers. In this study we have used DEA as the first of two stages in analysing secondary school efficiency. We then used these efficiency scores in the second stage of our analysis, consisting of a regression model to explain the efficiency scores in terms of environmental and other variables that are, to a greater or lesser degree, subject to possible policy manipulation. Given that previous work in this area is subject to a number of serious analytical flaws, we used the procedures recently developed by Simar and Wilson (2007) to provide valid statistical inference.

In summary, we find that integrated (formerly private) schools have an efficiency advantage over state schools, as do year 9-13 schools over year 7-13 schools. Girls' schools and boys' schools also have an efficiency advantage over co-educational schools and the same is true for schools in rural and minor urban areas compared to their main urban area counterparts.

Further study of all of these differences could be rewarding if factors could be identified that explained the differences and could be applied to changing management practices. We also find that socio-economic deprivation is, not unexpectedly, negatively related to efficiency. Since schools cannot change the socio-economic background of their students, funding decisions need to be made in the light of accepting the additional challenges less favoured schools face. However, care needs to be taken that additional funding for disadvantage does not perpetuate apparent inefficiency by ensuring that the outcomes of increased funding are regularly evaluated. In the New Zealand context where no school is very large by some international standards, schools need not concern themselves with becoming too large to manage, since they can make modest efficiency gains with some growth in roll size, contingent on appropriate funding. Finally, we find significant positive effects from both teacher experience and qualification levels.

Perhaps the most promising way to improve on this study would be to obtain more detailed data on both teachers and students. Unfortunately, the best source of teacher data is to match information collected for payroll purposes with other data. Confidentiality issues currently preclude this. The current absence of a national assessment system at the end of primary schooling prevents our controlling for student input quality other than by the blunt proxy for socio-economic status. Although such a system may soon emerge from the political process, it would be a minimum of seven years before useful data would follow.

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**Table 1 Variables used in the DEA stage**

| Variable name | Variable description | Mean | Standard deviation |
|---|---|---|---|
| **Outputs** | | | |
| UBS | Number of students passing bursary with minimum 4C or better grade | 32.9 | 40.5 |
| SCM | Sum of marks of students passing school certificate examination | 34290 | 29405 |
| 6FC | Number of students leaving school with a 6th Form certificate | 96.2 | 76.9 |
| **Inputs** | | | |
| FTT | Number of fulltime equivalent teachers | 48.2 | 25.6 |
| ADS | Number of teacher aides | 15.0 | 13.9 |
| Y13 | Year 13 student roll | 88.4 | 72.7 |
| Y12 | Year 12 student roll | 123 | 95.3 |
| Y11 | Year 11 student roll | 146 | 101 |
| OTH | Number of students in other years | 375 | 211 |
| ADM | Administration expenses (NZ$) | 310,700 | 260,240 |
| LRS | Expenditure on learning resources (NZ$) | 3,110,730 | 1,656,240 |
| DPR | Depreciation expenses (NZ$) | 146,720 | 100,340 |
| LCL | Expenditure for raising local funds (NZ$) | 301,110 | 347,260 |
| PRP | Property management expenses (NZ$) | 334,050 | 221,660 |

## Table 2 Variables used in the regression stage

| Variable name | Variable description | Mean | Standard deviation |
|---|---|---|---|
| SES | Socio-economic environment index | 282 | 120 |
| ROL | School size | 732 | 451 |
| RLS | School size squared | 738961 | 950694 |
| TEX | Percentage of teachers with 5 or more years of teaching | 82.3 | 7.34 |
| TQL | Percentage of teachers teaching core subjects with at least 2nd year university qualifications | 82.7 | 10.8 |
| STA | State-owned school | 0.79 | |
| 1UP | Composite school (yrs 1-13) | 0.07 | |
| 7UP | Secondary school (yrs 7-13) | 0.24 | |
| SEC | Secondary urban school | 0.10 | |
| MIN | Minor urban school | 0.21 | |
| RUR | Rural school | 0.09 | |
| BYS | Boys' school | 0.13 | |
| GRS | Girls' school | 0.17 | |

Note: For dummy variables, the mean value gives the proportion of schools in that class.

**Table 3 Regression explaining efficiency scores (EFF)**

| Variable | Estimated coefficient | p-values from bootstrap distribution |
|---|---|---|
| STA | -0.0793 | ≤0.001 |
| 7UP | -0.0470 | ≤0.001 |
| 1UP | -0.0493 | 0.112 |
| BYS | 0.0455 | ≤0.001 |
| GRS | 0.0689 | ≤0.001 |
| SEC | 0.0428 | 0.176 |
| MIN | 0.0695 | ≤0.001 |
| RUR | 0.114 | ≤0.001 |
| SES | -0.000450 | ≤0.001 |
| ROL | 0.000222 | ≤0.001 |
| RLS | -0.0000000280 | 0.902 |
| TEX | 0.00719 | ≤0.001 |
| TQL | 0.00184 | ≤0.001 |

*Figure 1 Cumulative distribution of efficiency scores*

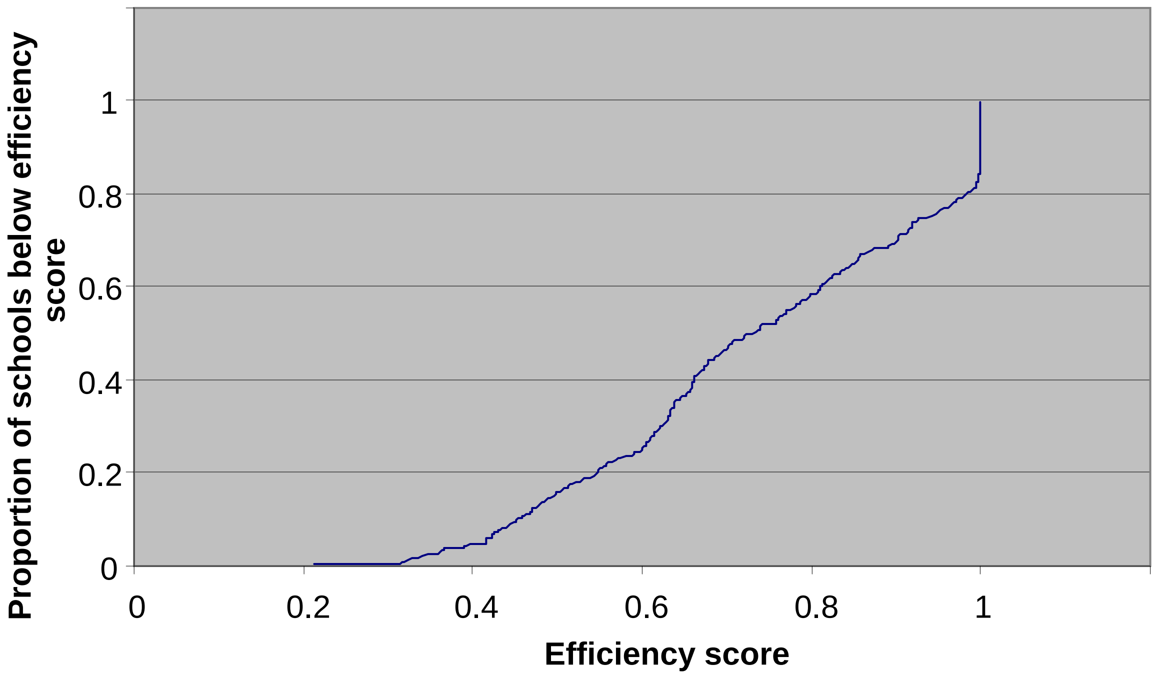
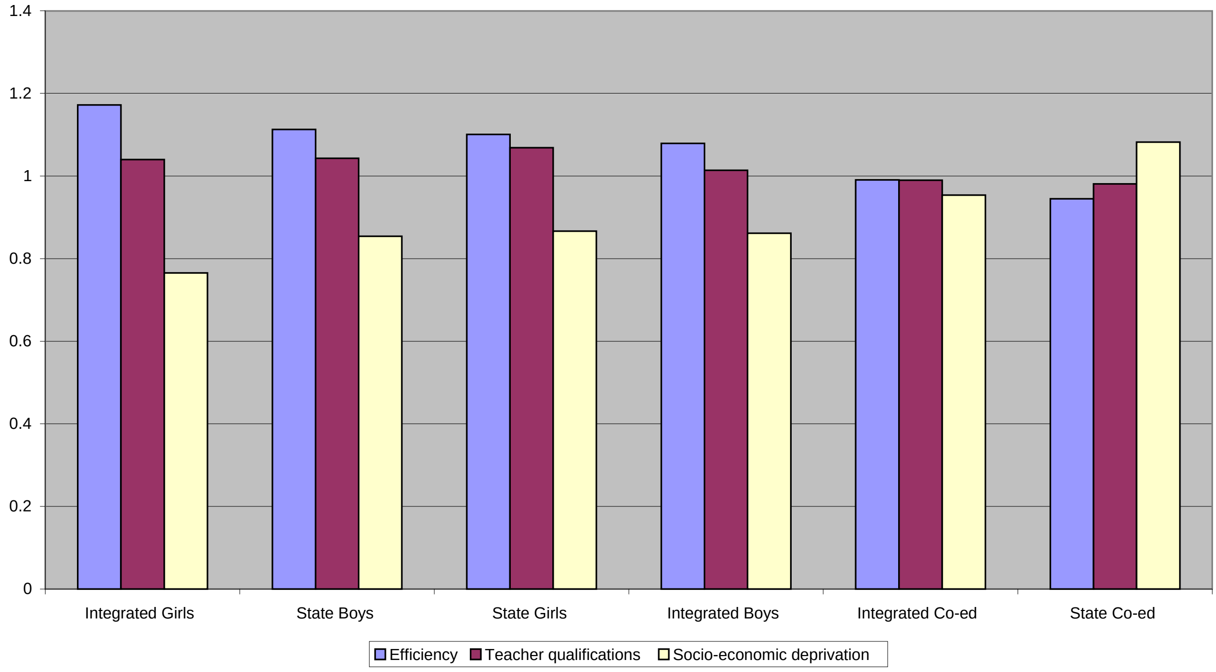


*Figure 2 Average for selected school types as a proportion of overall average*




Note: Values above (below) 1 on the vertical scale indicate an average score for that type of school which is above (below) the average for all schools on the variable indicated.

[1] See Simar and Wilson (1999a, b, 2000) and Kneip, Simar and Wilson (2003).

[2] Simar and Wilson (2007, page 14) state that 100 replications are "typically sufficient." We experimented with 500 instead of 100 replications but found no improvements.

[3] We attempted 5,000 and 10,000 replications; however, regressions converged for about only half the replications.

[4] The authors would like to express their thanks to the staff of the Data Management Unit of The New Zealand Ministry of Education, especially Cheryl Remington and Amanda Borich, as well as to Senior Policy Analyst Martin Connelly, for their assistance.

[5] Because of the different possible ways they can be interpreted, our results do not allow us to suggest either increasing or decreasing preferential funding.

[6] The average school roll in our sample is only 732 and schools of over 2000 students are very rare.