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Explaining efficiency differences of New Zealand secondary schools*

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Abstract

The New Zealand Secondary School system is characterized by centrally provided government funding for almost all schools, yet responsibility for use of that funding has been devolved right down to the school level. The central provision of funding has resulted in consistent collection of data across the system including, for one recent year (2001), a census of teachers. We use this data in a two-stage analysis of school efficiency. Data envelopment analysis is employed at the first stage to derive a score for each school representing the efficiency with which it transforms basic inputs into outputs. At the second stage of the analysis, to explain variations in efficiency, we regress the efficiency scores on a range of environmental and school type variables, some of which are controllable by schools and some of which are not. We find that school type, defined along a number of dimensions, matters. So too do the socio-economic status of the community from which the school draws its pupils, school size and teacher experience, although not teacher qualifications. **JEL classification code:** JEL 121

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1. Introduction

There would be few who would disagree that, "Improving achievement outcomes for all students lies at the heart of what schools do" (Minister of Education 2003, p.12). However, there are many possible achievement outcomes, including results as measured by examination success, engagement and excellence in cultural and sporting pursuits and the development of life-long learning and coping skills. Any method of assessing the performance of schools across such multiple objectives is necessarily controversial, but whatever the perceived limitations, interested parties (principally parents) want some information on how schools rate. In addition, governments insist on accountability for public funding. In many countries, examination league tables are published and agencies of government make and publish assessments of schools' processes. In the context of New Zealand secondary schools, the New Zealand Qualifications Authority (NZQA) publishes information about each school's students' success in national examinations (NZQA 2003), while the Education Review Office (ERO) publishes reports outlining its first hand scrutiny of each school's performance once every three or four years (ERO 2003). Apart from this, a lot of the information available about schools is anecdotal or self-promotional.

Following the reforms of the 1989, known as Tomorrow's Schools, the New Zealand secondary school system offers an interesting example of a centrally funded system with accountability devolved to the school level (NZCER 2003). The governance of each school is in the hands of a Board of Trustees elected by parents and guardians of the schools' pupils. That Board is responsible for appointment of a school Principal and for financial management of the school. The Principal, working under the Board's direction, is responsible for the day-to-day running of the school, including the appointment of teaching and other staff. Thus, deployment of resources is decided at school level. However, funding for staffing and school operational expenses is overwhelmingly provided through a state bureaucracy, the Ministry of Education. This applies to the vast majority of secondary schools. There remain very few truly independent schools (Minister of Education 2003, Table A14) with most classified as "State" or "Integrated". The latter are state-funded but retain something of their "special character", most often a religious affiliation

While a good deal of decision-making power has been devolved, central government funding has required schools to provide information to the Ministry of Education in a standardized form. Therefore, in studying this system we have available to us detailed comparable data including, for one particular year (2001), a census of teachers, which provides a unique snapshot of teacher experience and qualifications (NZ Ministry of Education 2003a). While the literature surprisingly often finds little impact of teacher quality on student performance (Hanushek 2003) it is hard to justify *a priori* omitting such information.

We have two main objectives in this paper: (a) measuring the efficiency with which each school transforms inputs into outputs, and (b) explaining the variation in efficiency across schools by identifying its determinants. Therefore, our analysis is in two stages.

At the first stage of the analysis we propose to undertake a Data Envelopment Analysis (DEA) using a tightly defined set of quantitative inputs, namely measures of financial expenditures as well as teacher and pupil numbers. We envisage these basic inputs being transformed into quantifiable success in terms of pupil qualifications. From such a DEA we derive an estimate of the efficiency with which each school, or decision-making unit (DMU), handles this process. Efficiency, by definition, varies from 0 to 1 (or 0% to 100%). It can be defined in two ways: either in terms of inputs or in terms of outputs. We set up the model in input oriented form. The input oriented efficiency of a DMU is the minimum observed input level used to produce a given output, divided by the actual input level used[1]. DEA concludes that a particular DMU is *relatively* inefficient if there is some other DMU (or combination of DMUs) that can produce more output while not using any more input (Sengupta 1989, p. 63)[2].

Were we to leave the analysis at the first stage, one could reasonably object that a particular school might have achieved a lower efficiency rating than another by virtue of any one of a

[1] Output oriented efficiency is the actual output produced from a given level of input divided by the maximum output level observed to be produced by that input level.
[2] Fare, Grosskopf and Lovell (1994) provide full algebraic and graphical presentations of a wide range of DEA models, while Kirjavainen and Loikkanen (1998) provide concise model details in the context of measuring school efficiency.

large range of factors of which we have failed to take account in the DEA. For example, we could hypothesise that pupils' socio-economic background might affect school efficiency, or perhaps the general environment in a large urban school might affect educational progress in a different way to that of a smaller rural school. To take account of such considerations, we take the efficiency scores from the DEA stage and try to explain them in a multivariate regression framework, where the regressors chosen are guided by previous educational literature, as well as by data availability. In this way, having taken into account only what we might consider raw quantifiable inputs in arriving at an efficiency score, we then check to see what sort of factors influence that efficiency. Taking the examples given above, *a priori* we might expect, *ceteris paribus*, schools with a greater proportion of high socio-economic status pupils to achieve higher efficiency scores, while we might expect that, at least up to a point, school size *per se*, might be a positive factor but that an urban environment might not be.

In section 2 of the paper we provide additional background on the New Zealand secondary school system, including more detail on school types and on formal means of student assessment. Section 3 describes the two-step DEA and regression method we use to measure and then study the determinants of school efficiency. In section 4 we present details on the data and models used. Sections 5 and 6 present the results from the DEA and regression analyses, respectively. Section 7 concludes.

2. The New Zealand secondary school system

As noted in the introduction, a range of reforms known as "Tomorrow's Schools" came into force in New Zealand at the end of 1989 (NZCER 2003)[3] 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 a Board of Trustees elected by parents and guardians of pupils. Before 1989 District Education Boards, responsible for schools in each region allocated

[3] The link given in this reference describes the extensive programme of surveys and educational research undertaken by the New Zealand Council for Educational Research into monitoring the effects of these reforms.

funds to schools tied to very specific purposes. In the case of Primary Schools, these Boards actually appointed teachers to fill vacancies notified to them by schools, although Secondary schools had long had greater say over teacher appointments. Now, each school's Board of Trustees is responsible for financial management of operational funding provided by the Ministry of Education and for choosing teaching staff who are then paid salaries on a single national pay scale by the Ministry.

A separate government agency, the Education Review Office (ERO), 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 (ERO 2003). The New Zealand Qualifications Authority, a government agency, compiles and publishes statistics on each school's performance in national examinations (NZQA 2003).

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 (January to December) 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 for which they cater. They also vary by ownership type, by whether they cater for boys only, girls only or are co-educational, as well as by location.

The traditional main type of secondary school in New Zealand teaches pupils in years 9 to 13. There are, however, significant numbers of schools which 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, mainly in rural locations. 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 (NZIER 2003, p.5), it became possible for a private school to integrate into the state system, while still retaining its own special character. This special character generally relates to some sort of religious or philosophical belief[4]. Integrated schools must follow state curriculum requirements. 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 not taken the opportunity to integrate into the state system. They attract subsidies at rates that have varied from 17% to 40% of State school per pupil funding at various year levels over the period 1996-2001 (NZIER 2003, p.6). It would be fair to say that the more leftward leaning politically the government of the day, the more likely it is that independent school subsidies are lower. 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. The system of State and Integrated schools (the latter sometimes known as State-Integrated schools since they are part of the broader State system) 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, Fergusson and Horwood (1997), find that girls outperform boys academically at all levels of the school system, whether measured by standardized tests or teacher ratings or qualifications on leaving school and that the difference is not explainable by IQ but, largely, by behavioural factors. Woodward, Fergusson and Horwood (1999), focusing on the secondary school level and

[4] Preference for entrance to many of these Integrated schools is given to children of families who can demonstrate affiliation with a particular religious denomination.

controlling for school selection processes, find that children attending single-sex schools tend to perform better than their co-educated peers. The latest descriptive data on this phenomenon can be found in Table A2 of Minister of Education (2003), which shows girls outperforming boys, and pupils in single sex schools doing better than those in co-educational schools, in years 11, 12 and 13 assessments across all learning areas, although boys do tend to narrow the gap in mathematics and science by year 13.

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.

Currently the system of school qualifications is undergoing considerable change. The new system, which will be completely phased in by the end of 2004 involves a National Certificate in Educational Achievement (NCEA) at three levels (NZQA 2003). Levels 1, 2 and 3 are intended for students at years 11, 12 and 13 respectively. These qualifications are gained by a combination of national examinations at the end of each of these year levels and nationally moderated school-based assessment. Levels 1, 2 and 3 of the NCEA replace, respectively, the older qualifications School Certificate (SC), Sixth Form Certificate (SFC) and University Bursaries (UB). School Certificate and University Bursaries were predominantly examination-based qualifications, while Sixth Form Certificate was internally (school-based) assessed. Since the data we have available from the teacher census covers only 2001 we intend to measure school outputs in terms of pupil success in SC, SFC and UB. Further details of the measures we use are in section 4 below. We note here that in 2001, about 17% of school leavers had no formal qualifications under this system, about 20% left school with SC as their highest award, 27% with SFC and 18% with UB. The remainder left from year 13 with a lesser award than a pass in UB (Minister of Education 2003, Table A3).

3. Methods

As discussed in the introduction, there is inevitably controversy over how best to measure educational inputs and outputs. Given that costs 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, not least pupils, parents and employers.

Taking each school as the unit of observation, we measure inputs in terms of dollars spent, teachers employed and students taught. These are conceived of as the "raw materials" that are transformed by whatever goes on in the school into outputs, which are to be measured by success in gaining various formal qualifications. In addition to these inputs and outputs, one must also control for other factors that affect the process of transforming these inputs to outputs. Such factors include, but are not limited to, the socio-economic background of the school's pupils, the school's type (urban/rural, single sex/co-ed, state/integrated), the school's size and the quality of its teachers.

The basis of the approach that we propose here is to tackle this problem in two stages. At the first stage we examine the efficiency of each school in transforming what we have referred to as "raw materials" (inputs) to outputs. In the second stage we examine the extent to which the "other" factors that were not taken into account in the first stage can explain variations in school efficiency.

Note that, at the first stage of this 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. Worthington (2001) provides a very clear explanation of the DEA technique along with a review of those empirical studies that have applied the technique to schools[5] and universities.

The essence of the DEA technique is to solve, for each DMU, a linear programming problem involving maximizing outputs given the levels of the inputs (or minimizing inputs given the levels of outputs). In simultaneously solving such a problem for the entire sample of DMUs the weightings are chosen that maximize the relative efficiency of each DMU. It is not therefore possible to argue that a school could obtain a better efficiency score by a more judicious choice of weights. This is a very attractive feature of DEA[6].

Of course, it *can* reasonably be argued that a factor such as the socio-economic status of pupils is an important input to the process. Indeed any variable that takes on numerical values could be treated as part of a DEA and Cooper, Park and Yu (1999) even show how to extend the technique to handling imprecise data. However, the more such factors are incorporated into a DEA, the more DMUs will appear to have relative efficiencies of 100%. This is because DEA sets up a production frontier in such a way as to identify groups of “peer” DMUs. Peers are those DMUs that can reasonably be compared in the sense that they are “similar enough” with respect to their mix of inputs and outputs. Clearly, if one goes far enough in identifying “other” factors one can place each school in a peer group of one! Practically speaking, then, we propose not influencing the efficiency scores we obtain by any factor other than a strictly measurable and economically meaningful input or output. The “other” factors, which are of

[5] Kirjavainen and Loikkanen (1998) use a similar approach and data to our study at school level. Most other studies, including Engert (1996), Ruggiero (1996), Bates (1997), Chalos (1997) and Duncombe, Miner and Ruggiero (1997), perform their analyses at the level of school district (in the US) or local education authority (UK).

[6] Lewin and Minton (1986, p. 259) set out the desirable features of this approach to efficiency measurement.

vital importance in explaining variations in school performance, we incorporate into our analysis at a second stage, once these efficiency scores are in hand.

At the second stage of our approach we consider as many factors as we can to explain schools' efficiency scores using standard multiple regression analysis. Following the discussion of the data below we outline both the DEA and regression model that we implement.

4. Data and models

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 (NZ 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. Unfortunately, the school census does not collect information on teacher experience and qualifications. In 2001, the Ministry undertook a Teacher Census (NZ 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. Consequently, we focus in this study on data for the 2001 school year.

DEA inputs

School expenditures, excluding teacher salaries, for the 2001 year were provided, broken down by five different categories. Each of these categories was entered into the DEA as a separate variable. These variables are: administration expenses (ADMIN), expenditure on learning resources (LRES), depreciation expenses (DEPR), expenditure for raising local funds (LOCAL) and property management expenses (PROP). All are measured in dollars. We measure teachers not in dollar terms but by the number of Full Time Teacher Equivalents (FTTE). 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 (TAIDES) 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: YR11ROLL, YR12ROLL, YR13ROLL, OTHERS[7].

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.

At Year 11, until the recent introduction of NCEA, New Zealand pupils (aged approximately 16) sat their first national examination, known as School Certificate. The Ministry of Education collates results at school level in a number of summary measures. The most detailed of these[8] is simply the sum of all marks gained in all papers sat (SCMKS).

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[9].

[7] Although qualifications are only gained at years 11 to 13, it is not possible to separate out inputs by year level. It is therefore necessary to include inputs at other levels.
[8] Other data provided to us include indicators based on marks and grades. Where possible we prefer to use a finer measure with as much variation as possible.
[9] Strictly speaking, all students receive a grading in each subject for this certificate but there is a threshold over four subjects that is traditionally regarded as a pass.

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 300 marks in five subjects were awarded an “A” Bursary, those scoring between 250 and 299 marks a “B” Bursary and those scoring at least four C grades were deemed to be qualified to matriculate at a New Zealand University; that is, they qualified for University entrance, although some Universities required a higher standard for admission to some courses. We use a variable UB at this level, being the number of students gaining four Cs or better[10].

Before we consider the model in which these inputs and outputs are used, to avoid any confusion it is worth noting that it is indeed total roll and total marks (or successes) at each year level that are used, respectively, as inputs and outputs. The DEA model accounts for differing levels of inputs by expecting different levels of outputs; that is marks ought not to be divided by the number of candidates. This approach has the incidental advantage of not inflating the apparent performance of schools that do not have their less able candidates attempting some national qualifications[11].

DEA model

DEA[12] identifies “peer” schools for an individual school and then estimates the efficiency of the school by comparing its performance with that of the “best-practice” schools chosen from its peers. Note that the idea here of “best practice” is not some theoretical and possibly unattainable concept, but the school (schools) performing best amongst its (their) peers, which is assigned an efficiency score of 1 or 100%.

[10] This is the standard that qualifies a student for entrance to university.

[11] Some schools offer alternative courses that are, no doubt, more appropriate for the less academically able, but it is not possible to be sure whether all schools apply the same standards in pre-selecting students for such courses.

[12] Charnes, Cooper and Rhodes (1978) is the seminal work in DEA, while Hanushek (1986) details its application to schooling.

DEA involves solving a linear programming problem for each school. The solution to the linear programming (LP) problem consists of information about the peers of the school and the efficiency of the school relative to its peer group. In order to formulate the LP problem for a school, suppose that there are *n* schools each producing *m* outputs by using *p* inputs and the objective of a school is to minimise inputs given an output level. The input oriented LP problem of the ith school is to

$$\min_{\phi_i, \mathbf{z}} \phi_i$$

$$\text{s.t.} \quad -\mathbf{y_i} + \mathbf{Yz} \geq \mathbf{0}$$
$$\phi_i \mathbf{x_i} - \mathbf{Xz} \geq \mathbf{0}$$
$$\mathbf{z} \geq \mathbf{0}$$

where **Y** is an $m \times n$ matrix of outputs with element y_{ij} representing the quantity of the ith output of the jth school, **X** is a $p \times n$ matrix of inputs with element x_{kj} representing the quantity of the kth input of the jth school, $\mathbf{y_i}$ is an $m \times 1$ vector of ith school's outputs, $\mathbf{x_i}$ is a $p \times 1$ vector of the ith school's inputs, **z** is an $n \times 1$ vector of weights and ϕ_i is a scalar that indicates the efficiency of the school. The value of ϕ_i varies between zero and one. A value of one implies that the school is one hundred per cent efficient and a value of less than one (although 0 can never actually occur) implies the school is $(100)\phi_i$ per cent efficient relative to the "best practice" school.

A DEA model can be estimated under the alternative assumptions of constant (CRS) and variable returns to scale (VRS). The model presented above incorporates the CRS assumption. Since we intend to incorporate variables to capture school size in the second (regression) stage of our analysis, we impose the CRS assumption at the DEA stage. Not to do so would result in a greater number of schools attaining 100% efficiency by virtue of being placed in peer groups of comparable size. This is a good particular example of the more general point about method raised in the previous section. We want to ensure that the efficiency scores we use in the regression analysis do not already take into account factors other than those which can strictly be described as inputs and outputs. This is because the regression stage of the analysis is designed to measure the effect of these "other" factors. Table 1 summarises the variables used in the DEA stage of the analysis, together with their means and standard deviations.

Data for the regression analysis

The output from the first phase of the analysis is an efficiency score for each school in the data set. These efficiency scores then become the dependent variable in a multiple regression model that uses "other" factors to try to explain efficiency.

We have available to us a range of information about each school that could plausibly affect its efficiency score. To take the most obvious example from the educational literature, it is widely held that the socio-economic background of pupils is probably the best predictor of academic success at the school level. Fergusson and Woodward (2000) provide some New Zealand evidence on this point relating to progression to university education, while the Education Review Office (ERO 1998) looks in some detail at the differing performance of high and low decile schools. The most up to date descriptive data is provided in table A1 of Minister of Education (2003) and shows strikingly different outcomes across schools for years 11 to 13 when schools are classified by decile rating (which is based on a measure of socio-economic status described below). From the data available we have chosen a range of categorical and measurable variables that are available on a consistent and reliable basis for all the schools in our sample.

There are a number of categorical variables relating to school type or location that need to be entered as controls in any regression explaining school efficiency. In our sample there are no Independent schools as defined in section 2 above. All of the schools are either State-owned or Integrated into the State system. We choose *INTEGRATED* as the reference class and set up a dummy variable, STATE, 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 STATE 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, *YRS9*-13, as a reference class in constructing dummy variables for two other types of school catering for differing age ranges. These types are: YRS7-13 and YRS1-13. 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 *MAINURBAN* as the reference class, we construct a set of dummy variables to capture schools in secondary urban (SECURBAN), minor urban (MINURB) and rural (RURAL) 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 (see below) 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 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 BOYS takes the value 1 for a school catering for boys only, and 0 otherwise. Similarly, GIRLS takes the value 1 for single sex girls' schools and 0 otherwise. This leaves co-educational schools as the reference class. We expect to find that both of these variables turn out to have positive coefficients.

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[13], 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 (Ministry of Education 2003c). We use this more detailed index (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 impact 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 subjects 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. To capture these sorts of possibilities we enter the variables ROLL (the total number of pupils enrolled) and ROLLSQ (the square of the same quantity) into the regression analysis. Our expectations are of finding a positive coefficient on ROLL but a negative coefficient on its square.

As mentioned earlier, some of the educational literature fails to find the expected positive effect of measured teacher quality on school outputs. However, 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

[13] Such a scale makes adjustments for household size and composition when comparing incomes.

quality useful for our purposes. The first of these is a measure of teacher experience (TEXP), defined as the proportion of teachers in a school with five or more years' experience. The other is a measure of teachers' qualifications (TQUAL). 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.

Regression model

The regression equation takes the following form:

$$EFF_i = \alpha_0 + \alpha_1 STATE_i + \alpha_2 YRS7\text{-}13_i + \alpha_3 YRS1\text{-}13_i + \alpha_4 BOYS_i + \alpha_5 GIRLS_i$$
$$+\alpha_6 SECURBAN_i + \alpha_7 MINURBAN_i + \alpha_8 RURAL_i + \alpha_9 SES_i + \alpha_{10} ROLL_i$$
$$+ \alpha_{11} ROLLSQ_i + \alpha_{12} TEXP_i + \alpha_{13} TQUAL_i + e_i$$

EFF_i is the efficiency score of the ith school derived from the DEA stage of the analysis. The right hand side variables are as described in the previous section and e_i is an error term, which is assumed to satisfy the usual conditions for ordinary least squares (OLS) estimation.

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. Table 2 presents some descriptive statistics of the variables used in the regression analysis of this sample of 324 schools[14]. 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.

5. The efficiency scores

The output from the DEA analysis consists of an efficiency score for each school in the sample[15]. The efficiencies of individual schools range from 0.3170 to 1, with a mean of 0.8597 and a standard deviation of 0.1486. Table 3 presents some summary statistics of these efficiency scores. On the face of it the most obvious deduction one might make from this table is that the average efficiency of Integrated schools is higher than that of State schools, so too is the average efficiency of Single sex schools relative to Co-educational schools. Differences in average efficiency amongst types of school classified by the year levels they teach or their locations are less striking.

[14] Table 1 gave descriptive statistics covering the same sample for the variables used in the DEA stage.
[15] The DEA analysis was performed using DEAP version 2.1 (Coelli 1996).

It is well known, however, that it is extremely risky to draw conclusions from such two dimensional cross-tabulations. Simpson (1951) draws attention to the need for care in the interpretation of cross-tabulated data in the presence of interaction amongst variables of interest. Inferences drawn may be invalid by virtue of omitting to consider other relevant factors. The problem is analogous to regression with an omitted relevant variable. In the present case, for example, it could be that the variable SES (socio-economic status) interacts strongly with the form of school ownership.

Nevertheless, within a group of schools that it is accepted are similar in most respects, it would no doubt be of considerable interest to a particular school to know how it rates. For example, our sample contains 29 Integrated Girls Schools. Table 4 ranks these schools by efficiency scores and presents their data on teacher experience and teacher qualifications[16]. We can see that there is some variability in even this restricted sample's efficiency scores, although many of them score 100% efficiency.

Such exercises as the one just presented would be of interest in identifying "best practice" schools amongst a particular peer group of schools or, perhaps more importantly, outliers in a negative sense. Further investigation of what sort of management practices might have led to this situation could well allow recommendations for change in the under-performing schools, although a case for special circumstances can often be made by considering other variables[17].

This sort of information is, of course, only useful to those who can identify the schools involved. No information allowing such identification can be published. In any case, our focus is rather on seeing if we can explain variations in efficiency scores using the other factors identified in a multiple regression framework.

[16] More extensive data, including school size, are not presented in order to prevent possible identification of individual schools.

[17] In this regard, it is interesting to note that the school with the lowest efficiency score is an outlier in spite of scoring as highly as possible on measures of teacher experience and qualification. Other data that could possibly explain this apparent anomaly cannot be presented, again to avoid identification of the school concerned.

6. Explaining the efficiency scores

We estimated the regression equation in section 4 above by OLS. Because of the fact that the dependent variable, EFF_i, is constrained to lie in the interval [0,1] and, in practice lies in (0,1] since an efficiency score of 0% never occurs, it could be considered that OLS is inappropriate because of the apparently censored nature of the data. If this argument is accepted, one should use a TOBIT model. However, 100% efficiency (or 0% inefficiency) is a valid score and no higher (or lower) score is possible, by definition. In this sense, the data are not truly censored at 1 (or 0). OLS is, therefore, quite appropriate.

In estimating the regression model, we tested for heteroskedasticity of the error variance, suspecting that the considerable variability in school size would cause a problem. On the assumption that the error variance is related to the school roll size, i.e., the variable ROLL, we performed three tests: Breusch-Pagan, Glesjer and Harvey-Godfrey. The assumed relationship between the error variance and the ROLL variable under each of these three tests is specified in Table 5. All three tests indicate, at the 5% or better significance level, that the error variance is heteroskedastic. Therefore, the OLS estimates are not BLUE. To improve the efficiency of the estimates we corrected for heteroskedasticity, estimating the regression equation in section 4 by the maximum likelihood method under each of the three assumptions relating to the structure of heteroskedasticity. As can be seen in Table 5, the strongest rejection of heteroskedasticity was obtained under the assumption of the Breusch-Pagan model, that the error variance is linearly related to the school roll size. These results of estimation using the Breucsh-Pagan correction are reported in Table 6[18].

Of the 13 estimated coefficients of the independent variables, 10 are significant at the 5% level or better, while 3 are not significantly different from 0. All but one of the coefficients have the expected signs (if any prior expectations were held) and that is the coefficient on TQUAL, which is unexpectedly negative, although it is not significant. While it may be disappointing to confirm some of the previous literature that teacher qualifications appear not to matter, it is

[18] Regression results obtained under the other two assumptions were very similar. They are not reported here, but can be made available to the interested reader.

worth noting the limited informational content of this variable as discussed above. For entry to secondary teacher training a university degree, while not mandatory, is usual. Therefore the percentage of teachers who end up teaching the core subjects who do not have at least second year university qualifications in one of those subjects is likely to be quite small. In our sample this figure drops below 70% in only 11% of schools and is below 80% in less than 30% of schools.

The coefficients of the dummy variables are directly interpretable as shifts in the percentage efficiency scores. Six of these coefficients are significant and they suggest that: Integrated schools are more efficient than State schools, all other things being equal, by 8.3%. 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 to the supportive nature of a strong community of interest derived from the special character of such schools.

(1) The traditional Year 9-13 secondary school is more efficient than a Year 7-13 school, all other things being equal, by 5.7%. 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[19]. Closer examination of what distinguishes the practices of typical Year 7-13 schools would appear to be worthwhile, although 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.

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[19] 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.

(2) Girls' schools are, all other things being equal, more efficient than Co-educational schools, by 4.0%. This finding is supportive of the view that girls perform academically more strongly in the absence of boys. The estimate of the coefficient on BOYS is also positive and of a similar order of magnitude to that on GIRLS, but does not come close to statistical significance at any conventional level.

(3) Schools in locations other than Main Urban Areas are, all other things being equal more efficient by 5.8% (Secondary Urban), 7.7% (Minor Urban) and 10.1% (Rural). Further study of how the larger urban environments negatively affect school efficiency has the potential to improve outcomes.

The coefficients of the continuously measured variables are not so directly interpretable but we offer below examples of their everyday meaning:

(1) The estimate of the coefficient on the variable SES, a measure of socio-economic status, is –0.000481 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%. Thus, for example, a school with the average measured value of this variable (282) would be (*ceteris paribus*) 13% 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 lends support to the preferential funding of poorer schools.

(2) The estimates of the coefficients on the two variables controlling for overall school size (ROLL and ROLLSQ) have the correct signs and are both statistically significant, the former at 1% and the latter at 5%. The effect of a change in school size can be illustrated by considering an increase in school size by the amount of a typical secondary school class of approximately 30 students. The change in percentage efficiency as a result of such an increase can be computed directly using the estimated coefficients by considering a change of 30 in ROLL (900 in ROLLSQ) or by calculating the elasticity of efficiency with respect to school size evaluated at means. The former calculation indicates that an increase in school size by a typical class raises school efficiency by about 0.53%. If the elasticity at

means (of about 0.10) is applied to an increase in ROLL of 30 from its mean value, the mean value of efficiency would rise from 85.96 to 86.32, an increase of 0.36%, very much of the same order of magnitude.

(3) The teacher experience variable (TEXP) is positive and significant at the 5% level. Each one percent lift in the percentage of teachers in a school with five or more years experience raises efficiency by 0.193%. For example, if a school moved from the average observed value of teacher experience of 82.29% to a staff all of whom had five or more years of experience, it could expect a rise in efficiency of about 3.4%.

7. 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, such as the socio-economic backgrounds of their students, the form of school ownership and organisation and, of course, the quality of their teaching staff. It is very difficult to assess the efficiency of secondary schools because of their multiple inputs and outputs and lack of agreement over which outputs are most important. Even restricting attention to outputs consisting of traditional measures of academic success, we still face the problem of weighting the various measures appropriately.

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 New Zealand secondary school efficiency. Restricting the DEA stage to a parsimonious set of inputs and outputs allowed us to construct an efficiency score for each school that indicates how that school transforms basic inputs (funding, teachers and pupils) into outputs in terms of academic successes in the final three years of schooling. 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.

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 over co-educational schools and schools in non-main urban areas over their main urban counterparts. Further study of all of these differences could be rewarding if factors could be identified that explained them and could be applied to changing management practices. We also find that higher socio-economic status is, not unexpectedly, positively related to higher 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. In the New Zealand context, most schools need not concern themselves with becoming too large to manage, since most can make modest efficiency gains with some growth in roll size, contingent on appropriate funding. It may seem surprising that we find no positive effect of teacher qualifications, although teacher experience is found to be a significantly positive factor. It may well be that the measure of qualifications available to us lacks sufficient detail to expect it to explain much since it amounts to a fairly minimal threshold level that most teachers surpass. On the other hand, we could interpret these results concerning the teacher variables to indicate that more effort directed toward in-service training would reap greater benefits than raising teacher entry standards.

Perhaps the most promising way to improve on this study would be to obtain more detailed data on teachers. Unfortunately, the best source of such data is to match information collected for payroll purposes with other data. Confidentiality issues currently preclude this. Alternatively, if it is thought that teacher quality really does not matter, it ought to be possible to investigate changes in school efficiency over time using a model that omits all measures of teacher quality.

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Table 1 Variables used in the DEA stage

Variable name	Variable description	Mean	Standard deviation
Outputs			
UB	Number of students passing bursary with minimum 4C or better grade	32.85	40.50
SCMKS	Sum of marks of students passing school certificate examination	342890	29405
6FC	Number of students leaving school with a 6th Form certificate	96.19	76.92
Inputs			
FTTE	Number of fulltime equivalent teachers	48.23	25.59
TAIDES	Number of teacher aides	14.95	13.86
YR13ROLL	Year 13 student roll	88.44	72.65
YR12ROLL	Year 12 student roll	122.85	95.26
YR11ROLL	Year 11 student roll	146.28	101.03
OTHERS	Number of students in other years	374.65	211.05
ADMIN	Administration expenses ($)	310,700	260,240
LRES	Expenditure on learning resources ($)	3,110,730	1,656,240
DEPR	Depreciation expenses ($)	146,720	100,340
LOCAL	Expenditure for raising local funds ($)	301,110	347,260
PROP	Property management expenses ($)	334,050	221,660

Table 2 Variables used in the regression stage

Variable name	Variable description	Mean	Standard deviation
SES	Socio-economic environment index	282.02	119.99
ROLL	School size	732.23	451.04
ROLLSQ	School size squared	738960.5	950694.3
TEXP	Percentage of teachers with 5 or more years of teaching	82.29	7.34
TQUAL	Percentage of teachers teaching core subjects with at least 2nd year university qualifications	82.67	10.84
STATE	State-owned school	0.79	
YRS1-13	Composite school (yrs 1-13)	0.07	
YRS7-13	Secondary school (yrs 7-13)	0.24	
SECURB	Secondary urban school	0.10	
MINURB	Minor urban school	0.21	
RURAL	Rural school	0.09	
BOYS	Boys' school	0.13	
GIRLS	Girls' school	0.17	

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

Table 3 Average efficiencies by school type

Type of school	Efficiency
State	0.85
Integrated	0.91
Composite (yrs 1-15)	0.88
Secondary (yrs 7-15)	0.85
Secondary (yrs 9-15)	0.86
Main urban	0.86
Secondary urban	0.89
Minor urban	0.84
Rural	0.85
Boys	0.91
Girls	0.92
Co-educational	0.84
All schools	**0.86**

Table 4 Ranking of Integrated Girls Schools by efficiency score, showing teacher experience and qualification variables

	EFFICIENCY	TEXP	TQUAL
	0.389	100	100
	0.662	90	84.211
	0.708	81.818	89.474
	0.728	80.9524	84.615
	0.838	94.444	68.421
	0.892	90.9091	87.5
	0.904	93.75	85.714
	0.904	89.655	78.947
	0.921	91.667	64.286
	0.938	96.2963	94.737
	0.942	95.745	88.462
	0.947	78	100
	0.95	89.744	86.364
	0.986	90.3226	94.118
	1	86.047	86.957
	1	83.019	80
	1	83.333	72.727
	1	95.455	90
	1	69.565	83.333
	1	90	83.333
	1	100	78.571
	1	85.185	86.667
	1	75	87.5
	1	90	77.778
	1	85.4167	96.296
	1	90	86.364
	1	93.548	76.19
	1	93.478	100
	1	87.5	100
average	*0.92*	*88.65*	*85.95*
sd	*0.1390*	*7.0877*	*9.1677*

Table5 Tests for heteroscedasticity

Test	**Assumed form of heteroscedasticity**	**Test statistic ($LM = nR^2$)**
Breusch-Pagan	$\sigma_i^2 = \beta_0 + \beta_1 ROLL + u_i$	13.38*
Glesjer	$\sigma_i = \beta_0 + \beta_1 ROLL + u_i$	13.15*
Harvey-Godfrey	$\ln\sigma_i^2 = \beta_0 + \beta_1 ROLL + u_i$	5.7996**

Note: * indicates null hypothesis rejected at 1% level; ** null rejected at 5%.

The test statistic is Lagrange multiplier, distributed as χ^2 with one degree of freedom.

Table 6 Regression explaining efficiency scores (EFF)

Variable	Reference class	Estimated coefficient	Asymptotic t
CONSTANT		0.0190	12.7
STATE	INTEGRATED	-0.0829	-3.43
YRS7-13	YRS9-13	-0.0574	-2.79
YRS1-13	YRS9-13	-0.00872 [ns]	0.273
BOYS	CO-ED	0.0230 [ns]	1.11
GIRLS	CO-ED	0.0397	1.96
SECURBAN	MAINURBAN	0.0585	2.47
MINURBAN	MAINURBAN	0.0771	3.50
RURAL	MAINURBAN	0.101	2.96
SES		-0.000481	-8.40
ROLL		0.000177	4.33
ROLLSQ		-0.0000000382	-3.30
TEXP		0.00193	2.00
TQUAL		-0.00120 [ns]	-1.60

Note: [ns] indicates estimated coefficient not significantly different from zero at the 5% level; all other estimates are significant at 5% or better based on a one-sided asymptotic t-test; all estimates are presented to three significant figures.