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**Scale and pure efficiencies of New Zealand secondary schools** *

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**Scale and pure efficiencies of New Zealand secondary schools**


**Abstract**

The scale efficiency of schools is a controversial matter. Government quite naturally wants to capture such scale efficiencies as are available, while parents and educators often favour smaller schools because of their perceived quality advantages that are not easily measurable. We use data envelopment analysis to calculate three different measures of the efficiency with which New Zealand secondary schools transform basic inputs into outputs. There is considerable variation across schools on all three measures: scale, pure and overall efficiencies. We more closely examine our sample broken down by ownership type, by single-sex/co-educational and by location. All of these factors influence the efficiency measures, with scale disadvantages evident in rural versus urban schools, Integrated schools generally outperforming State schools and single-sex schools outperforming co-educational ones, especially in pure efficiency terms. We then present evidence that higher socio-economic status of a school's community confers both scale and pure efficiency advantages and use regression analysis to quantify the effects at work.



**JEL classification codes:** C20, C21, C24, C61, H52, I21, I22.

## 1. Introduction

Over the next decade it is projected that school rolls will decline in New Zealand, especially in regions outside the main population centres (New Zealand Ministry of Education 2003a). In fact, the last few years have seen numerous school closures in areas of declining younger populations. Community pressure and political reality have recently resulted in a five-year moratorium on further closures (Mallard 2004). However, the debate over how best to utilise limited resources to achieve the best possible educational outcomes will continue and, at least in large part, is centred on the issue of scale. Schools most likely to be threatened with closure are those that seem to be too small to capture economies of scale.

Interestingly, following over half a century of spectacular growth in average school size, there is a growing movement in the United States that advocates the advantages of smaller schools (Irmscher 1997). The small school movement highlights that there are potential diseconomies as well as economies of scale.

Our aim in this paper is to examine the scale and pure efficiencies of New Zealand secondary schools in respect of one important aspect of their output, the capacity to produce academic qualifications for their students. Not that academic achievement is the only aspect of schools worthy of study, but it is one of importance both to students and parents and it is easier to measure than attitudes, social behaviours or cultural and sporting participation.

We measure efficiency using Data Envelopment Analysis (DEA), which allows us to produce measures of scale, pure and overall efficiencies for each school. DEA is a mathematical linear programming technique that constructs an empirical best-practice benchmark against which to compare actual schools. The method does not compare a school against some theoretical ideal of best-practice, but only against its peers. Motivated by the specific details of the New Zealand school system we also look at whether efficiency varies according to a number of factors that potentially constrain a school's ability to operate at optimal scale and/or directly affect efficiency. These factors include school ownership (State or Integrated), school type (co-educational or single sex) and school location (from main urban to rural).

Because of the complexity of the way these various factors may be related to each other we use regression analysis to quantify the various effects at work.

The outline of the remainder of this paper is as follows. In Section 2 we explain how DEA can be used to measure scale, pure and overall efficiencies. Section 3 briefly outlines some institutional details of the New Zealand secondary school system as well as the data we have available to us. It also discusses why scale might be important. Section 4 presents the results and Section 5 concludes.

## 2. Measuring efficiency

The use of linear programming to measure efficiency is usually attributed to Charnes, Cooper and Rhodes (1978) although others had applied linear programming techniques to input-based efficiency measurement in the 1960s (Boles 1966). Worthington (2001) provides a thorough survey of frontier efficiency measurement techniques, including DEA, as applied to educational institutions. Also in the educational context, Barnett *et al.* (2002, p.296) explain how DEA can be used "to simultaneously construct an empirical best practice frontier (or a set of benchmarks) and measure each school's observed performance relative to this frontier." Barnett *et al.* (2002) emphasise the importance of taking school size into account in assessing measures of efficiency. Size is, of course, intimately related to the issue of scale efficiency. In the present paper, we decompose the overall efficiency of New Zealand secondary schools into measures of scale and pure efficiency.

Following Fare, Grosskopf and Lovell (1985), it is possible to define input oriented efficiency measures satisfying three different types of scale behaviour. These measures are constant returns to scale (CRS) efficiency, variable returns to scale (VRS) efficiency and non-increasing returns to scale (NRS) efficiency, which we will denote by $\lambda_c$, $\lambda_v$ and $\lambda_n$, respectively. Each of these efficiency measures is the solution of a mathematical programming problem as set out below.

Let $\boldsymbol{Y}$ be an ($M \times N$) matrix of outputs for New Zealand secondary schools with elements $y_{ij}$ representing the quantity of the i$^{th}$ output produced by the j$^{th}$ secondary school. Let $\boldsymbol{X}$ be a ($P \times N$) matrix of inputs with elements $x_{kj}$ representing the quantity of the k$^{th}$ input used by the j$^{th}$ school in producing its outputs. $\boldsymbol{z}$ is an ($N \times 1$) vector of weights to be defined. The vector $\boldsymbol{y}^j$ is the ($M \times N$) vector of outputs and $\boldsymbol{x}^j$ is the ($P \times 1$) vector of inputs of the j$^{th}$ school.

The CRS input measure of efficiency for the j$^{th}$ New Zealand secondary school is calculated as the solution to the following problem:

$$\lambda_c^j = \min_{\lambda,\mathbf{z}} \lambda \tag{1}$$

$$\text{s.t.} \quad \mathbf{y}^j \le \mathbf{Yz}$$

$$\mathbf{Xz} \le \boldsymbol{\lambda}\mathbf{x}^j$$

$$\mathbf{z} \in R_+^N$$

$\lambda$ is a scalar value representing a proportional reduction in all inputs such that $0 \le \lambda \le 1$, and $\lambda_c^j$ is the minimised value of λ so that $\lambda_c^j.\mathbf{x}^j$ represents the vector of efficient inputs for the j$^{th}$ school. Maximum efficiency is achieved when $\lambda_c^j$ is equal to unity. In other words, according to the DEA results, when $\lambda_c^j$ is equal to unity, a school is operating at best-practice and cannot, given the existing set of observations on inputs and outputs, improve on this performance.

We regard $\lambda_c$, the CRS measure of efficiency, as a measure of *overall* efficiency.

The VRS input measure of efficiency for the j$^{th}$ New Zealand secondary school is calculated by solving the following problem:

$$\lambda_v^j = \min_{\lambda,\mathbf{z}} \lambda \tag{2}$$

$$\text{s.t.} \quad \mathbf{y}^j \le \mathbf{Yz}$$

$$\mathbf{Xz} \le \boldsymbol{\lambda}\mathbf{x}^j$$

$$\mathbf{lz} = 1 \quad \text{where } \mathbf{l} \text{ is a } (1 \times N) \text{ vector with all elements 1}$$

$$\mathbf{z} \in R_+^N$$

We regard $\lambda_v$ as a measure of *pure* efficiency. Since the VRS assumption is less restrictive than CRS, $\lambda_v$ is necessarily at least as large as $\lambda_c$. It is free from any scale inefficiency affecting $\lambda_c$.

The input oriented *scale* efficiency measure, $S^j$, for the j[th] school is defined as:

$$S^j = \lambda_c^j / \lambda_v^j \tag{3}$$

Since $\lambda_v^j \geq \lambda_c^j$ it follows that $S^j \leq 1$. If $S^j = 1$ then the school is 100% scale efficient. If $S^j < 1$, the school is scale inefficient. There are two possible reasons for scale inefficiency. The school could be operating under increasing returns-to-scale (IRS) and therefore be of sub-optimal scale. Alternatively, the school could be operating under decreasing returns-to-scale (DRS) and therefore be of supra-optimal scale. To determine which of these is the case we calculate one further measure of efficiency.

The NRS input measure of efficiency, $\lambda_n^j$, for the j[th] New Zealand secondary school is calculated as the solution to the following mathematical programming problem:

$$\lambda_n^j = \min_{\lambda,\mathbf{z}} \lambda \tag{4}$$

$$\begin{aligned} \text{s.t.} \quad & \mathbf{y}^j \leq \mathbf{Yz} \\ & \mathbf{Xz} \leq \boldsymbol{\lambda}\mathbf{x}^j \\ & \mathbf{lz} \leq 1 \\ & \mathbf{z} \in R_+^N \end{aligned}$$

If $S^j < 1$ and $\lambda_c^j = \lambda_n^j$ then scale inefficiency is due to IRS and the school is of sub-optimal size. On the other hand, if $S^j < 1$ and $\lambda_c^j < \lambda_n^j$ then input scale inefficiency is due to DRS and the school is of supra-optimal size.

Corresponding to the three measures of efficiency above are three measures of inefficiency defined in the obvious way, namely $1-\lambda_c$, $1-\lambda_v$ and 1-S. Thus, *overall* *inefficiency*, 1-$\lambda_c$, can be thought of as being attributable to *scale inefficiency*, 1-S, and *pure inefficiency*, 1-$\lambda_v$, the latter sometimes referred to as *controllable, managerial* or *X-inefficiency*. Two points are worthy of note here.

First, identifying pure inefficiency as controllable is overstating the case since there are aspects of the operating environment that are not controllable. For example, a school cannot control its geographical location or the socio-economic status of its students.

Second, the relationship $1-\lambda_c = (1-\lambda_v)+(1-S)$ does not strictly hold. In fact, it is easily shown that $1-\lambda_c = (1-\lambda_v)+(1-S)-(1-\lambda_v)(1-S)$. However, the term $(1-\lambda_v)(1-S)$, typically being the product of two small numbers, is very small. Therefore, imagining *overall* inefficiency as roughly the sum of *pure* inefficiency and *scale* inefficiency is an intuitively appealing and reasonable first approximation.

In summary, pure inefficiency is attributable to managerial (controllable) and environmental (uncontrollable) factors. Scale inefficiency is attributable to operating with IRS (at sub-optimal scale) or with DRS (at supra-optimal scale).

## 3. The New Zealand secondary school system

The New Zealand Ministry of Education had, until recently, an active programme of what it called 'network reviews' underway (New Zealand Ministry of Education 2003a). Given demographic changes driven by falling birth rates and internal, as well as external, migration, the educational needs of all regions of the country are constantly changing. New schools have to be built in regions of strong population growth while, in other areas, falling enrolments can lead to under-utilised schools. A network review is the process by which the Ministry seeks to identify how resources in a particular area are being used and to recommend change. Although the "main purpose of any school merger or closure is to improve educational opportunities for students" (New Zealand Ministry of Education 2003a, p.12), perceived scale inefficiency is often an issue and small rural schools and urban schools in areas of population decline are frequently affected. Thus, community anxiety around a network review inevitably focuses on school mergers and closures. In opposing the closure of small schools, parent groups in New Zealand, particularly in rural areas, often rely on arguments that place the school at the centre of their community, conferring benefits beyond the strictly educational. Ministry of Education analysis tends to focus solely on cost effectiveness in terms of expenditure per student. Naturally, this measure not only fails to address non-educational matters, but it also does not measure outcomes, even in strictly academic terms.

The quite substantial evidence on the relationship between school size and various aspects of schooling is reviewed by Cotton (1996), who identifies research relating school size to various outcomes, including academic achievement, attitudes, behavioural problems, extra-curricular participation, feelings of belongingness or isolation, interpersonal relations, attendance, dropout rates and students' self-concept. All of these outcomes are important and, in many cases, it is not possible *a priori* to be sure of the effect of school size on them so that one needs to examine the weight of empirical evidence. For example, it seems reasonable to argue that a larger school can offer a broader curriculum and more specialist teaching, yet the evidence does not indicate any simple relationship between school size and even variety of subjects on offer. Cotton cites evidence to suggest that a 1% increase in enrolment yields only about 0.17% increase in variety of courses offered and that only a small percentage (5% to 12%) of students actually avail themselves of the extra courses offered. In terms of extra-curricular participation, the proportion of students involved actually falls with roll size as children polarise into two groups: participants and non-participants. Advocates of smaller schools in the US, such as Lawrence *et al.* (2002) catalogue the higher crime, vandalism and drop-out rates in large schools.

Our objective in this paper is quite modest. We focus only on academic achievement as measured by national qualification outcomes in the senior years of secondary education. Our measure of efficiency tells us something about how effective schools are in this one area. Any differences in efficiency amongst different types of school that we find have to be weighed against other possible benefits that might be seen as compensatory. To make clear what it is we are measuring, the rest of this section sets out some details about New Zealand school types and qualifications.

*New Zealand school types*

As described in Section 2, we can obtain various measures of school efficiency/inefficiency but these will all be affected to some degree by uncontrollable environmental factors. New Zealand secondary schools differ along a number of dimensions that potentially affect their efficiency. Schools vary by ownership, by whether they cater for boys only or girls only or are co-educational, by geographical location as well as by the socio-economic status of the community for which they cater.

There are three different types of school ownership in New Zealand. 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 for Economic Research 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[1]. Integrated schools must follow state-prescribed 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. 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 do not form part of the

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

available data set. The system of State and Integrated schools[2] covers about 93% of secondary school enrolments (Minister of Education 2003, Table A11). In many cases, one of the conditions imposed on Integrated schools is a cap on their enrolments so that they may suffer from being unable to expand to optimal size. On the other hand their special character may confer managerial efficiencies.

In many New Zealand population centres the older established traditional secondary schools cater for only boys or only girls. Typically, such schools exist in pairs, one for girls and the other for boys. According to a good deal of recent evidence, whether children are in a single-sex or a co-educational environment may affect academic outcomes. 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 controlling for school selection processes, find that children attending single-sex schools tend to perform better than their co-educated peers. This sort of evidence motivates the splitting of our sample into single sex and co-educational schools.

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. Thus, rural schools may suffer from scale inefficiencies relative to urban schools, but their environment may contribute to reduction in X-inefficiency. Our sample can be split into schools in *main* urban, *secondary* urban, *minor* urban and *rural* areas.

*New Zealand school qualifications*

[2] Integrated schools are sometimes referred to as State-Integrated schools, since they are part of the broader State system, while State schools are referred to as State-Not Integrated schools.

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 (New Zealand Qualifications Authority 2003). 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 relates to the 2001 school year, we intend to measure school outputs in terms of pupil success in SC, SFC and UB. 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). Further details of the measures we use are outlined below under the heading *DEA outputs*.

*DEA inputs*

The inputs we use to estimate the models outlined in Section 2 consist of expenditures in dollars, teaching staff and students. School expenditures, excluding teacher salaries, for the 2001 year were provided to us by the Ministry of Education, 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 New Zealand 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[3].

*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 that can be used as outputs in estimating the models in Section 2.

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 collated results at school level in a number of summary measures. The most detailed of these[4] 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[5].

In year 13, until 2004, pupils were able to sit the University Bursaries Examination. On the basis of performance in this examination, students scoring 300 marks or more in five subjects were awarded an 'A' Bursary, those scoring between 250 and

[3] 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.

[4] 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.

[5] 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.

299 marks a ‘B’ Bursary and those scoring at least four C[6] grades were deemed to be qualified to matriculate at a New Zealand university; that is, they qualified for university entrance, although some universities require 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.

We have been fortunate to obtain the co-operation of the New Zealand Ministry of Education in providing to us the most complete data relating to the variables discussed above for the 2001 school year. This original data set contained information 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. Summary statistics of the input and output variables are presented in Table 1. The results of our DEA analysis, comprising three efficiency measures for each school, are discussed in the next section.

**4. Results**

Each of the models described in Section 2 was implemented using the computer program DEAP version 2.1 (Coelli 1996). Table 2 summarises the results from the full sample of 324 schools. Approximately one third of the inefficiency of the average New Zealand secondary school is attributable to scale with the remaining two thirds due to pure inefficiency. Of the schools operating at non-optimal scale, the vast majority are of sub-optimal scale. Such schools are in the ratio of 11:2 to schools of supra-optimal scale. Their average roll size is only 606, compared with an average roll of 843 in scale efficient schools and 1046 in supra-optimal scale schools. Although these summary results do not take into account uncontrollable environmental factors, they do support the view that few New Zealand secondary schools are so large as to suffer diseconomies of scale.

[6] A C grade is between 46% and 55%.

Table 3 is a first attempt to explore how efficiency scores are related to various school types. It shows the approximate breakdown of overall inefficiency into pure inefficiency and scale inefficiency when schools are classified according to ownership (Integrated or State), gender (Co-educational or Single-sex) and location (Main urban or the rest of the country).

Notwithstanding the higher inefficiency of State schools, both Integrated and State schools suffer pure and scale inefficiencies in about the same ratio (2:1). The indications are that most of the 6 percentage point overall efficiency advantage of Integrated over State schools is due to pure rather than scale efficiency. Moreover, Integrated schools do not suffer scale inefficiency relative to State schools as might be expected because of caps on rolls, which are common in integration agreements. It should be noted, however, that a greater proportion of Integrated schools is located in main population centres[7].

Single sex schools are more efficient than co-educational schools on all measures. Overall, the gap in efficiency is about 7 percentage points with nearly two-thirds of that gap attributable to pure rather than scale inefficiency. The breakdown of inefficiency for each school type separately does indicate, however, very similar proportions of inefficiency due to pure and scale reasons for both school types, albeit with co-educational schools displaying much greater inefficiency.

By location, we can see very little difference in any type of efficiency. Both overall and scale inefficiencies are the same to the nearest whole percent and pure inefficiencies differ by only one percentage point. But there are variations not evident in the two-way classification of location as presented. For example, rural schools suffer a 3 percentage point disadvantage in scale terms compared to main urban schools, not surprising given the population bases they serve. However, they outperform main urban schools by 2 percentage points in pure efficiency, leaving only a 1 percentage point overall deficit. By contrast, schools in minor urban areas

[7] Location and ownership type, as well as other factors in the analysis, potentially interact. We explore this issue further in the regression analysis below.

seem not to suffer in comparison with those in main urban areas on a scale basis but lag by 3 percentage points in pure efficiency terms. Schools in secondary urban areas are ahead of all others on all efficiency measures.

To go further in analysing efficiency differences amongst these various groups of schools, we need a more formal means of testing differences than we can get from the sort of breakdowns in Table 3. Since it is most unlikely that the efficiency scores generated by DEA are normally distributed[8] (Grosskopf 1996, p. 196), to go beyond simply noting that descriptive statistics differ, we need a non-parametric and distribution-free way of comparing the various distributions of efficiency scores. The Kolmogorov-Smirnov (KS) test, which makes no assumptions about the distribution of the data, computes the maximum vertical deviation (D statistic) between the empirical distribution functions[9] of a pair of samples (Banker 1993), along with a p-value appropriate for testing the null hypothesis that the two distribution functions are the same. The lower is the p-value, the more likely it is that the two distributions in question differ, with D indicating the maximum difference. The KS test also allows computation of confidence intervals of the mean efficiency scores.

Table 4 breaks our sample of schools into State and Integrated and presents the means, standard deviations and 95% confidence intervals for the three different types of efficiency, along with D-statistics and corresponding p-values. There is strong evidence that the distributions of efficiencies of all three types differ by school ownership type, with the highest p-value being only 2.6%. For all types of efficiency, the empirical distribution function for Integrated schools in fact lies above that of State schools across practically all efficiency scores. In other words, for almost any given efficiency score, a greater proportion of Integrated schools than State schools exceeds that score. Moreover, for measures of both overall and

[8] In fact, formal testing rejects that the distribution of any type of efficiency score is normally or log-normally distributed.
[9] An empirical distribution function (or cumulative fraction function) is analogous to the cumulative distribution function (cdf) of a random variable. In this case, graphically it would appear as the cumulative fraction of efficiency scores (on the vertical axis) less than or equal to a given efficiency (on the horizontal axis).

pure efficiency, the 95% confidence interval for the mean efficiency of Integrated schools lies entirely to the right of the corresponding confidence interval for State schools. For scale efficiency, the two confidence intervals do overlap but that for Integrated schools extends far to the right of that for State schools. We conclude that Integrated schools are more efficient than State schools, more particularly in terms of pure than scale efficiency.

Table 5 breaks down the sample of schools into Co-educational, Boys' and Girls' schools. The KS test indicates that both Boys' and Girls' schools outperform Co-educational schools in terms of all types of efficiency. The gap is greater in terms of pure rather than scale efficiency. There is no significant difference between the distribution for Boys' and Girls' schools, even though the average efficiency of Girls' schools is higher than Boys' schools across all efficiency types.

Table 6 splits the sample by school location (Rural, Minor Urban, Secondary Urban and Main Urban). There is no evidence of differences in the distributions of any type of efficiency between rural and minor urban areas. However, there is some difference between every other pair of school types, with schools in secondary urban areas more efficient than schools in main urban areas and those in main urban areas more efficient than those in minor urban areas. The efficiency difference between schools in secondary urban and rural areas is to do with scale because there is no significant difference in the distributions of pure efficiency. There is a significant difference in overall efficiency between schools in secondary and minor urban areas, but neither pure nor scale efficiency gaps are sufficient on their own for significance, only in combination do they become significant. Schools in main urban areas and rural areas significantly differ in both pure and scale efficiency terms, with the rural schools ahead on pure efficiency and the urban schools ahead on scale efficiency. Main urban schools also differ significantly from schools in both secondary and minor areas in all types of efficiency. Secondary urban areas are more efficient in all respects with their location evidently not a constraint on attaining relative scale efficiency. In the case of schools in minor urban areas most of their overall lower relative efficiency is due to scale inefficiency.

It is not entirely clear whether one should attempt to draw policy conclusions from these results. For example, the most clear-cut finding above is that Integrated schools outperform State schools in both pure, scale and overall efficiency terms. If one attributed the whole of the pure efficiency difference to *controllable* or *managerial* factors, then a close study of these factors could be rewarded with an improvement in State school efficiency. However, this assumes that all other things are equal. In particular, the efficiency scores as calculated have made no allowance for the quality of inputs available to schools. 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 13. Unfortunately, no detailed national data on students leaving primary school are collected in New Zealand. The best we can do is to 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 socio-economic status indicator 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[10], 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 2003b).

[10] An equivalised income scale is one which makes adjustments for household size and composition when comparing incomes.

To get some idea of how socio-economic status affects the efficiency scores we consider the values of Spearman's rho presented in Table 7. This statistic measures the degree of association between the ranks of each school on two variables. The variable SES is the socio-economic status indicator calculated by the Ministry of Education and the other variables are our various measures of efficiency, overall, pure or scale. For all values of rho in Table 7, a formal test of the null hypothesis that the two variables are independent is rejected at a p-value of less than 0.00005[11]. SES is highly significantly negatively correlated with all of the measures of efficiency, meaning that the higher the socio-economic status of the school's community the higher the efficiency score.

To the extent that SES interacts with any of our categorical variables (school ownership, etc.) the more care we need to take in interpreting the differences in distributions of efficiency in the Tables 4, 5 and 6[12]. To enable us to consider the effect of these categorical variables simultaneously, as well as SES and other potentially confounding variables, we propose estimating a regression model of the following form:

$$EFF_i = \alpha_0 + \alpha_1 INT_i + \alpha_4 BYS_i + \alpha_5 GRS_i + \alpha_2 7UP_i + \alpha_9 ISO_i + \alpha_{10} ISS_i + \alpha_9 SES_i$$

$$+ \alpha_{10} ROL_i + \alpha_{11} RLS_i + \alpha_{12} TEX_i + \alpha_{13} TQL_i + e_i \qquad (5)$$

$EFF_i$ is the efficiency score (which could be pure, scale or overall efficiency) of the ith school derived from the DEA stage of the analysis and $e_i$ is an error term. The right hand side variables are set up to capture the different school types already described and to control for other factors. These variables are summarised in Table 8.

[11] The various measures of efficiency are also strongly correlated with each other. As one would expect, the lowest value of rho is between the pure and scale efficiency scores which measure different aspects of efficiency.

[12] The complexity of relationships between pairs of types of schools is already difficult to clearly articulate in Table 6 without even considering other potential influencing factors.

INT is a dummy variable which captures whether a school is Integrated or State[13]. BYS and GRS are dummy variables for single-sex boys' and girls' schools, respectively, so that for a co-educational school both BYS and GRS are set to zero. The variables 7UP, ISO and ISS are used to capture school location. Together they provide a finer classification of schools by area than would a set of dummy variables based on the Main Urban, Secondary Urban, Minor Urban and Rural classification system. ISO is an isolation index constructed by the Ministry of Education based on a school's distance from the population centres of 5000, 20 000 and 100 000. The higher the value of this index the more isolated is the school. ISS is the square of the isolation index, which we include to capture the possibly non-linear effect of isolation which is suggested by the results in Table 6. It appears that lower efficiency may be associated with schools in both rural and main urban areas (as opposed to secondary and minor urban areas), so that efficiency rises with isolation at first but then starts to fall again as isolation becomes greater. The variable 7UP is a dummy which is set to 1 if schools cater for children in years 7 to 13. The more traditional New Zealand arrangement is for secondary schools to cater for years 9 to 13 but there are secondary schools that start at year 7 and Composite or Area schools that cater for children in all years (1 to 13), although this latter type is in rural areas so that it is already captured by the isolation index.

SES is the socioeconomic status index already discussed. Recall that it is higher if the community in which a school is located is of lower socio-economic status so that we conjecture that the estimated coefficient on SES will be negative.

[13] INT=1 if the school is Integrated and 0 otherwise.

School size could potentially affect efficiency both positively and negatively. It can be argued that there are certain economies of scale in school operations 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, at least in the case of scale efficiency, are of finding a positive coefficient on ROL but a negative coefficient on its square. In the case of pure as opposed to scale efficiency, we would expect to find no effect of school size because the measure of pure efficiency should have stripped out any scale effects.

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.

Table 9 presents the results of estimating equation (5) by OLS over our sample of schools with the dependent variable being scale efficiency, pure efficiency and overall efficiency in turn.

It is clear that, even after controlling for other factors, including socio-economic status, that Integrated schools are more efficient than State schools. *Ceteris paribus*, an Integrated school has an overall efficiency score more than 8 percentage points higher than a comparable State school, with most of the difference attributable to pure rather than scale efficiency. This generally confirms the findings of Table 4, testing the distributions of efficiency by school type but, interestingly, the regression analysis does not confirm the apparent advantage of single-sex over co-educational schools reported in Table 5. Once other factors are controlled for, as in Table 9, we find no significant difference between the efficiency scores of either boys' or girls' schools and co-educational institutions.

The use of the isolation index, rather than a set of location dummies, allows us to quantify the effect of location. Isolation does have the predicted effect on both scale and overall efficiency, with efficiency low at first (in main urban schools) then rising with isolation to a peak at 2.28 on the index for scale efficiency and 3.24 for overall efficiency and then falling again[14] Isolation seems to have no statistically significant impact on pure efficiency. The position of schools catering for years 7 to 13 is negative with respect to the rest of the sample, having accounted for isolation as well as all of the other factors in the model. *Ceteris paribus*, such a school is nearly 6 percentage points lower in pure efficiency and nearly 5 percentage points lower in overall efficiency, although there is no significant scale efficiency difference. We are not clear as to why these schools should be less efficient than more traditional secondary schools, or indeed Area Schools, but this finding is worthy of further investigation.

The estimated coefficient on SES is, as expected, negative and statistically significant across all types of efficiency measure. The elasticity of efficiency with respect to SES is about -0.05 for scale efficiency and -0.13 for pure efficiency, with these effects summing to approximately -0.19 in overall efficiency. A 0.13% drop in pure efficiency for a 1% drop in socio-economic status is a sizeable effect and it may be that the perception amongst the public that higher socio-economic status schools have such an advantage partly drives roll growth in these schools and their consequent scale advantage.

School size has the postulated quadratic relationship with scale efficiency with an implied turning point at a roll size of 1587. The average total roll in the sample of 324 schools in 732, with only 18 schools exceeding a roll of 1587 so that diseconomies of scale do not set in until quite a high level.

[14] The average of the isolation index is 0.87 with all schools in main urban areas having an index in the range of 0.10 to 0.35. Only 26 schools have an isolation index higher than 2.28 and only 11 over 3.24.

Neither the coefficient on the teacher experience variable nor on the teacher qualification variable attains statistical significance in any of the regressions. This may seem surprising, but it may well be that these measures simply lack much variation in the sample. In particular, the teacher qualification variable lacks sufficient detail to expect it to explain much since it amounts to a fairly minimal threshold level that most teachers surpass.

This finding, or rather lack of finding, concerning the teacher experience and qualification variables leads us to be cautious about any policy implications of our results. However, it is fairly clear that, controlling for those factors we are able to, including socio-economic status, Integrated schools do appear to have a substantial efficiency edge over State schools. This is especially true of pure as opposed to scale efficiency. Although we would prefer to replicate our findings with finer measures of teacher qualifications, this result seems clear enough to recommend closer study of Integrated and State schools matched as closely as possible on other variables to see if managerial factors affecting the efficiency differential can be identified.

## 5. Conclusion

This paper has examined the scale efficiency of New Zealand secondary schools with respect to the output 'academic qualifications'. Using DEA we have calculated measures of overall, pure and scale efficiencies/inefficiencies for each of the 324 schools in a data set provided to us by the Ministry of Education for which data were complete. Schools' efficiency scores cluster quite tightly but there is sufficient variation in performance to draw some conclusions, which we summarise here:

(1) Very few New Zealand secondary schools exceed optimal scale with sub-optimal scale schools far more common than supra-optimal ones. Very few schools indeed exceed the point at which efficiency is harmed by size.

(2) Integrated schools outperform State schools in all types of efficiency, with a striking 6 percentage point advantage in pure efficiency, even controlling for other factors.

(3) Rural schools suffer more from scale inefficiency relative to urban schools but almost compensate for this in terms of pure efficiency. Some degree of isolation from the pressures of the main urban environment helps efficiency but too much isolation is harmful.

(4) All types of efficiency rise with socio-economic status, with the greatest difference in pure rather than scale efficiency terms.

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*Table 1 Inputs and outputs used in the DEA*

| *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 Summary measures of efficiency in full sample*

| *Efficiency measure* | *Overall* | *Pure* | *Scale* |
|---|---|---|---|
| Average efficiency (%) | 85.97 | 90.63 | 94.90 |
| Standard deviation | 14.86 | 13.03 | 9.33 |
| Minimum observed efficiency (%) | 31.70 | 45.10 | 31.70 |
| Average inefficiency (%) | 14.03 | 9.37 | 5.10 |
| Number [%] of fully efficient schools | 99 [31%] | 164 [51%] | 113 [55%] |
| | | Number [%] of sup-optimal scale schools | 179 [35%] |
| | | Number [%] supra-optimal scale schools | 32 [10%] |

*Table 3: Inefficiency breakdowns by school type*

| *Inefficiency* | *Overall* | | *Pure* | | *Scale* |
|---|---|---|---|---|---|
| Integrated | 9% | ≈ | 6% | + | 4% |
| State | 15% | ≈ | 10% | + | 5% |
| Co-ed | 16% | ≈ | 11% | + | 6% |
| Single sex | 9% | ≈ | 6% | + | 3% |
| Main urban | 14% | ≈ | 9% | + | 5% |
| Rest | 14% | ≈ | 10% | + | 5% |

*Table 4: Tests of differences of distribution of efficiencies by school ownership type*

| ***Type of school*** | ***State*** | ***Integrated*** |
|---|---|---|
| **Overall efficiency** | | |
| *Mean* | 0.847 | 0.906 |
| *SD* | 0.153 | 0.121 |
| *95% CI* | (0.828,0.866) | (0.877,0.936) |
| *D (v Integrated)* | 0.206 | |
| | (0.017) | |
| **Pure efficiency** | | |
| *Mean* | 0.896 | 0.944 |
| *SD* | 0.137 | 0.0930 |
| *95% CI* | (0.879,0.913) | (0.922,0.967) |
| *D (v Integrated)* | 0.301 | |
| | (0.001) | |
| **Scale efficiency** | | |
| *Mean* | 0.946 | 0.960 |
| *SD* | 0.0948 | 0.0870 |
| *95% CI* | (0.934,0.958) | (0.939,0.981) |
| *D (v Integrated)* | 0.196 | |
| | (0.026) | |

Note: The p-value below the D-stat is for the test of $H_0$: the two distributions are the same.

*Table 5: Tests of differences of distribution of efficiencies (Co-ed vs single-sex schools)*

| *Type of school* | *Co-educational* | *Boys* | *Girls* |
|---|---|---|---|
| **Overall efficiency** | | | |
| *Mean* | 0.837 | 0.905 | 0.920 |
| *SD* | 0.153 | 0.129 | 0.118 |
| *95% CI* | (0.817,0.857) | (0.865,0.945) | (0.888,0.953) |
| *D (v Boys)* | 0.316 | | |
| | (0.001) | | |
| *D (v Girls)* | 0.329 | 0.151 | |
| | (0.001) | (0.620) | |
| **Pure efficiency** | | | |
| *Mean* | 0.891 | 0.938 | 0.948 |
| *SD* | 0.139 | 0.114 | 0.0849 |
| *95% CI lower* | (0.873,0.909) | (0.903,0.973) | (0.925,0.972) |
| *D (v Boys)* | 0.347 | | |
| | (0.001) | | |
| *D (v Girls)* | 0.316 | 0.132 | |
| | (0.001) | (0.779) | |
| **Scale efficiency** | | | |
| *Mean* | 0.940 | 0.965 | 0.973 |
| *SD* | 0.0974 | 0.0697 | 0.0865 |
| *95% CI* | (0.928,0.953) | (0.944,0.987) | (0.950,0.997) |
| *D (v Boys)* | 0.248 | | |
| | (0.021) | | |
| *D (v Girls)* | 0.238 | 0.130 | |
| | (0.011) | (0.794) | |

Note: The p-value below the D-stat is for the test of $H_0$: the two distributions are the same.

*Table 6: Tests of differences of distribution of efficiencies by location*

| ***Type of school*** | ***Rural*** | ***Minor Urban Area*** | ***Secondary Urban Area*** | ***Main Urban Area*** |
|---|---|---|---|---|
| **Overall efficiency** | | | | |
| *Mean* | 0.852 | 0.841 | 0.891 | 0.862 |
| *Std dev* | 0.119 | 0.147 | 0.140 | 0.154 |
| *95% CI* | (0,806,0.898) | (0.805,0.877) | (0.841,0.941) | (0.840,0.884) |
| *D (v Minor)* | 0.117 | | | |
| | (0.936) | | | |
| *D (v Sec)* | 0.359 | 0.340 | | |
| | (0.030) | (0.009) | | |
| *D (v Main)* | 0.301 | 0.270 | 0.291 | |
| | (0.018) | (0.001) | (0.013) | |
| **Pure efficiency** | | | | |
| *Mean* | 0.925 | 0.883 | 0.923 | 0.909 |
| *SD* | 0.0960 | 0.133 | 0.120 | 0.134 |
| *95% CI* | (0.888,0.962) | (0.851,0.916) | (0,880,0.966) | (0.890,0.928) |
| *D (v Minor)* | 0.194 | | | |
| | (0.406) | | | |
| *D (v Sec)* | 0.140 | 0.221 | | |
| | (0.908) | (0.201) | | |
| *D (v Main)* | 0.464 | 0.398 | 0.444 | |
| | (0.001) | (0.001) | (0.001) | |
| **Scale efficiency** | | | | |
| *Mean* | 0.921 | 0.950 | 0.964 | 0.950 |
| *SD* | 0.0853 | 0.0649 | 0.0798 | 0.104 |
| *95% CI* | (0.888,0.954) | (0.934,0.966) | (0.936,0.993) | (0.935,0.965) |
| *D (v Minor)* | 0.222 | | | |
| | (0.249) | | | |
| *D (v Sec)* | 0.343 | 0.206 | | |
| | (0.043) | (0.273) | | |
| *D (v Main)* | 0.357 | 0.327 | 0.337 | |
| | (0,003) | (0.001) | (0.002) | |

Note: The p-value below the D-stat is for the test of $H_0$: the two distributions are the same.

*Table 7: Spearman's rho for SES and efficiency measures*

| | *overall* | *pure* | *scale* |
|---|---|---|---|
| *SES* | -0.535 | -0.339 | -0.373 |
| *scale* | 0.740 | 0.262 | - |
| *pure* | 0.745 | - | - |

*Table 8: Variables used in the regression analysis*

| *Variable name* | *Variable description* |
|---|---|
| INT | 1 if school Integrated, 0 if State school |
| BYS | 1 if Boys' school, 0 otherwise |
| GRS | 1 if Girls' school, 0 otherwise |
| 7UP | Secondary school (yrs 7-13) |
| ISO | Isolation index |
| ISS | Square of the isolation index |
| SES | Socio-economic environment index |
| ROL | School size |
| RLS | School size squared |
| TEX | Percentage of teachers with 5 or more years of teaching |
| TQL | Percentage of teachers teaching core subjects with at least $2^{nd}$ year university qualifications |

*Table 9: Regression explaining efficiency scores (EFF)*

| *efficiency* | *scale* | | *pure* | | *overall* | |
|---|---|---|---|---|---|---|
| | **Coefficient** | **Elasticity** | **Coefficient** | **Elasticity** | **Coefficient** | **Elasticity** |
| **INT** | 0.0306 (0.051) | 0.0306 | 0.0583 (0.004) | 0.0583 | 0.0824 (<0.0005) | 0.0824 |
| **BYS** | 0.00134 (0.920) | - | 0.0164 (0.455) | - | 0.0178 (0.414) | - |
| **GRS** | 0.0149 (0.177) | - | 0.0180 (0.267) | - | 0.0312 (0.097) | - |
| **7UP** | 0.00875 (0.396) | - | -0.0590 (<0.0005) | -0.0590 | -0.0496 (0.004) | -0.0496 |
| **ISO** | 0.0643 (0.002) | 0.0592 | 0.0247 (0.285) | - | 0.0875 (0.001) | 0.0889 |
| **ISS** | -0.0141 (0.002) | -0.0227 | 0.000852 (0.877) | - | -0.0135 (0.025) | -0.0242 |
| **SES** | -0.000181 (0.003) | -0.0537 | -0.000409 (<0.0005) | -0.127 | 0.000569 (<0.0005) | -0.187 |
| **ROL** | 0.000188 (0.007) | 0.145 | 0.0000245 (0.670) | - | 0.000141 (0.043) | 0.120 |
| **RLS** | -0.0000000592 (0.018) | -0.0461 | 0.0000000331 (0.158) | - | 0.0000000198 (0.427) | - |
| **TEX** | 0.00127 (0.263) | - | 0.000563 (0.557) | - | 0.00171 (0.132) | - |
| **TQL** | -0.000740 (0.238) | - | -0.000564 (0.490) | - | -0.00116 (0.301) | - |
| **CONST** | 0.848 (<0.0005) | - | 1.05 (<0.0005) | - | 0.900 (<0.0005) | - |
| **F** | 5.13 (<0.00005) | | 7.78 (<0.00005) | | 19.6 (<0.00005) | |
| **$R^2$** | 0.206 | | 0.246 | | 0.392 | |

Notes: Estimation is by OLS with robust standard errors (corrected for heteroskedasticity); p-values are in parentheses; elasticity only calculated if coefficient significant at 5% level or better; in the case of dummy variables, the marginal effect is reported rather than elasticity.