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Efficiency measurement of Australian public sector organisations

The case of state secondary schools in Victoria

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Abstract *The growth in importance of performance assessment in education over recent years has been linked with a concern to ensure that the service represents "value for money". Increasing concern over funding of schools by government and the limitation on the resources available to the education sector has given rise to demands for greater efficiency and public accountability. These concerns reflect the need for comprehensive techniques to assess the degree to which school management practices and the education industry structure promote efficiency in education. An additional problem has been that, whilst there are many different desirable outcomes which are appropriate for education authorities to pursue, conventional models handle these one at a time.*

1. Introduction

The problem of evaluating the performance of organisations, whether in the private or public sector, has been an ongoing concern of practitioners and researchers. In the private sector it has been assumed that, in the long run, the discipline of the market place motivates the firm to strive for cost efficiencies and maximisation of profits. While it is true that private firms pursue multiple goals and that goals often are not sufficiently well-defined, the market system does provide economic (as distinct from social) indicators of performance through such measures as profits, rates of return on investment, market share and so forth. The public sector lacks both an analog for profit seeking behaviour and an adequate feedback system for learning about quality of decisions. As a result, the problem of evaluating performance of public sector organisations and the development of insights to guide performance improvement has been much more difficult.

This paper provides a review and an illustration of a new methodology for measuring the relative efficiency of public sector organisations where comparisons can be made to a reference group of other organisations

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performing similar tasks. The paper will focus on measuring the relative technical efficiency of State secondary schools in a geographical region in the Australian State of Victoria. It recognises that state secondary schools like other non-profit making organisations produce multiple outcomes by combining alternative discretionary and non discretionary inputs. This paper aims at providing a contribution to State secondary school performance evaluation in Victoria.

2. Measuring relative efficiency of organisations performing similar tasks

The concept of relative performance evaluation through the use of appropriate comparisons or reference points is not new. The concept of a reference group was introduced by Hyman (1942), developed by Merton (1957) and applied to goal formulation and goal attainment in various studies. In general, when the criteria of desirability are ambiguous, or when cause and effect relationships cannot be specified with precision, organisations utilise (social) reference groups in goal setting and performance evaluation. It has been argued in various studies including Lewin and Morey (1981) that attempts in utilising comparative approaches to performance evaluation have encountered difficulties involving lack of acceptable aggregate performance measures, and problems associated with combining multiple measures and relating them to the utilisation of multiple inputs. A new analytical technique, data envelopment analysis (DEA – a methodology widely employed in evaluating relative technical efficiency on an ex post basis) seems appropriate for assessing efficiency of public sector organisations. This is because amongst other characteristics:

- DEA has the ability to handle multiple outputs simultaneously. This is important for non-profit making organisations like secondary schools whose operations are characterised by multiple outputs;
- DEA does not require a pre-specification of a mathematical form for the production function, where a single set of parameters links all efficient input and output levels; and
- DEA does not require commensurate inputs and outputs. In other words, it does not require input prices or output values.

3. The DEA approach

DEA is an approach used in comparing the efficiency of organisational units such as local authority departments, schools, hospitals, shops, bank branches and so forth where there is a relatively homogeneous set of organisational units. (For an overview of the DEA approach see the Appendix.)

In the simplest case where a process or organisational unit has a single input and a single output, efficiency is defined as:

$$Efficiency = output/input \qquad (1)$$

More typically processes and organisational units have multiple incommensurate inputs and outputs and this complexity can be incorporated in an efficiency measure by defining the efficiency as:

$$\textit{Efficiency} = \textit{weighted sum of outputs}/\textit{weighted sum of inputs} \qquad (2)$$

Equation (2) requires a set of weights to be defined and this can be difficult, particularly if a common set of weights to be applied across the set of organisational units is sought. This problem can be resolved be arguing that individual units may have their own particular value systems and therefore may legitimately define their own peculiar set of weights. Charnes *et al.* (1978) introduced a conceptual model that generalised equation (1) to equation (2).

Figure 1 shows a hypothetical example to demonstrate the DEA approach to efficiency evaluation. This example represents an attempt to evaluate the efficiency of secondary schools relative to a maximum production possibility frontier. In this example, x_1 and x_2 represent two different inputs used in the production of a school output. Each observation represents the combination of x_1 and x_2 that a particular school uses in the production of a given amount of school output, AO[1]. Each school in the sample uses a different input mix[2], but produces the same amount of school output.

Isoquant AO_1 represents the production frontier defined as the locus of all observations that minimise the combinations of x_1 and x_2 required to produce a constant product AO. It can be argued that in theory, schools on the frontier for student achievement are producing no other outputs. Levin (1976) noted that the production of other outputs in this situation, is assumed to be derived from the production of different levels of student achievement. He also mentioned that, it is likely that there is a socially minimal level of other outputs that all schools produce. In this case, the schools that appear to be on the achievement frontier are on a "modified frontier" which assumes a socially minimal level of other outputs.

All observations to the northeast of are AO_1 of "inefficient" schools that are using higher input levels to produce the same output[3]. Each inefficient school in this example has an efficiency rating above 1.0 while each school located on

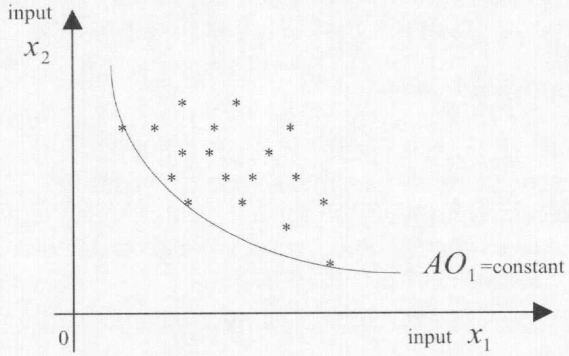

Figure 1.
Frontier production isoquant for student achievement

the frontier has an efficiency rating of 1.0. In view of the objective of this study, relationships representing maximum output that can be produced with the inputs used will be the main focus. This study will therefore, adopt an "output oriented" rather than an "input oriented" approach in measuring the technical efficiency of a state secondary school.

4. Selection of inputs and outputs

Inputs and outputs selected in this paper (see Table I) are relevant to the operations of state secondary schools in Victoria. These inputs and outputs are measures understood and regularly used by school administrators and the Directorate of School Education (DSE). Reasons why we are unable to select other variables relevant to the school production process include the fact that data on these inputs and outputs are not available. The following are the inputs and outputs selected for the evaluation and subsequent analysis of State secondary school relative technical efficiency[4].

5. Results

5.1 Output tables and interpretation

Problem (a2) in the Appendix is applied to a sample of State secondary schools. For confidential reasons, schools are represented by codes. An objective of this paper is to attempt to address the question, that is, given the factors both under and beyond a school's control, how efficient is the school? The relative efficiency of each school in each sample is calculated by re-running the linear programming problem (a2) once for each school. When DEA is applied to a sample of secondary schools, an efficiency (relative not absolute) rating equal to 1.0 is provided to schools that are DEA efficient. On the other hand, an efficiency rating greater than 1.0 represents sources of inefficiency. The rating 1.0 is a relative measure of efficiency obtained from a piecewise linear production frontier. This frontier is made up of the most efficient schools in each sample. This does not imply that these schools are absolutely efficient.

	Source of data
Input under control of schools	
I1 Staff pupil ratio	DSE, Victoria (1996)
Non-discretionary input	
I2 Adjusted special learning needs (SLN) index	DSE, Victoria (1996)
Outputs	
O1 Proportion (of students) with tertiary entrance rank (TER) scores of 50 and above	VTACSCHL.SYS, System Wide Data, VTAC, 1996/1997
O2 Year 12 apparent retention rate	DSE, Victoria (1996)

Note: ABS (1997) and DSE (1993) define the apparent retention rate as, the number of year 12 students expressed as a proportion of the year 7 enrolment five years earlier. In other words, of the students who commence secondary schooling in year 7, the proportion who continue to year 12 represent the apparent retention rate (Steering Committee, 1997)

Table I.
Inputs and outputs used in this paper

The DEA assessment of a school merely establishes that this school is efficient in comparison with other schools in the sample.

5.2 Efficiency rating of inefficient schools

For each inefficient school, DEA identifies a reference set of efficient schools. In general, it provides a framework within which performance targets can be set for the school so that it may improve its efficiency. The reference set of an inefficient school consists of schools having an efficiency rating of 1.0. These corresponding efficient schools are readily identified by the fact that they have positive λ values associated with the optimal solution to problem (a2) in the Appendix. For a school $j = k$, let $x_k = (x_{1k}, \ldots, x_{mk})$ represent the vector of known inputs and $y_k = (y_{1k}, \ldots, y_{sk})$ represent the vector of known outputs. Also defined u_r as output weights for each output ($r = 1, \ldots, s$), and v_i as input weights for each input ($i = 1, \ldots, m$)[5]. The output-oriented projection $(X_k, Y_k) \longrightarrow (X_k, \phi_k^* Y_k)$ underlying the approach used in this paper, yield boundary points which are efficient (technically) only if for all optimal λ^*[6]:

$$\phi_k^* Y_k = \sum_{j=1}^{n} y_{rj}\lambda_j^* \qquad r = 1, \ldots, s; \tag{3}$$

and

$$X_k = \sum_{j=1}^{n} x_{ij}\lambda_j^* \qquad i = 1, \ldots, m; \tag{4}$$

The point $(\sum_{j=1}^{n} x_{ij}\lambda_j^*, \ \sum_{j=1}^{n} y_{rj}\lambda_j^*)$, is a linear combination of inputs on one hand, and outputs on the other, of efficient schools that lie on a facet of the envelopment surface. It follows from equations (3) and (4) that:

- Schools for which $\phi_k^* = 1$ are relatively efficient. Such schools are said to be operating on the boundary of the efficient surface[7].
- Schools for which $\phi_k^* > 1$ are relatively inefficient. Such schools are said to be operating in the interior to the production possibility set and could increase outputs proportionally by $\phi_k^* - 1$, given their inputs if they were operating efficiently (Fare *et al.*, 1989).

Following Charnes *et al.* (1986), the set of boundary schools can be partitioned into three classes, namely: E, E', and F:

(1) E consists of schools sometimes referred to as strongly efficient. These schools are located at the vertices (extreme points) of the efficient surface.

(2) E' consists of efficient schools not located at the vertices, i.e. these schools can be expressed as linear combinations of schools in E with $\lambda_j \geq 0, \ j = 1, \ldots, n$.

(3) F consists of schools sometimes referred to as weakly efficient.

The identification of the reference set of an inefficient school will prove very useful in practice. Comparing an inefficient school with efficient schools in its reference set indicates areas where the former's performance is weak. The relevance of this comparison is presented in Table II and section 5.3. Table II shows the performance of some schools when compared with other schools across the State. Information from this kind of comparison is useful in seeking an improved understanding of the performance of the schools concerned.

5.3 Analysis of information in Table II

The following schools j = S18, S21 and S22 for which $\phi_j^* = 1$ and equations (3) and (4) hold, are sometimes referred to as strongly efficient (Charnes *et al.*, 1986). These schools have a set of multipliers (weights) = $\mu^* = (\mu_1^*, \mu_2^*)$ and $\nu^* = (\nu_1^*, \nu_2^*)$ which are of maximal dimension (Seiford and Thrall, 1990). A total of 46 percent of the schools are properly enveloped. For S16, the optimal solution to the envelopment form after applying problem (a2) is, $\lambda^*_{21} = 0.8074$, $\lambda^*_{22} = 0.4667$ and $\lambda^*_j = 0$ (otherwise), with the input slacks in problem (a2) in the Appendix equal to zero. Output slacks in problem (a2) are as follows:

- $s_r^{+*} = 0$, r = proportion (of students) with TER score of 50 and above; and
- $s_r^{+*} = 30.06$, r = Year 12 apparent retention rate.

It can be argued that on this facet of the envelopment surface, there exists input-output vectors (X_j, Y_j) for any school j and (X_{16}, Y_{16}) and for j = S18, S21 and S22, (X_j, Y_j) dominates (X_{16}, Y_{16})[8]. It follows from equations (3) and (4) that using the above optimal solution would yield a boundary point (for the second output) made up of a linear combination of outputs of S21 and S22. S16 is output inefficient but may be said to be weakly input efficient (Seiford and

Number of schools in sample = 27	Inefficient school S16	Reference set of efficient schools S18	 S21	 S22
DEA efficiency rating	1.01	1.00	1.00	1.00
Inputs				
Staff pupil ratio	0.11	0.08	0.09	0.08
Adjusted SLN index	1.82	1.46	1.26	1.72
Outputs				
Proportion (of students) with TER scores of 50 and above	0.52	0.32	0.4	0.43
Year 12 apparent retention rate	70.37	85.29	79.63	78.48

Note: Reference set of efficient schools, represents schools whose performances were compared to the performance of S16. Values have been rounded to two decimal places. Adjusted SLN index represents the inverse of the original SLN index value

Table II. Inputs and outputs of S16 and schools in its reference set

Thrall, 1990)[9]. We will discuss in section 5.4 how adjustments to outputs might make inefficient schools efficient. Issues to be discussed in this section are applicable in this case to S16. Alternatively, taking account of the output slack , $s^{+*}_r = 30.06$, S16 could further increase the second output proportionally by $\phi^*_{16} - 1$ of its current output level without consuming additional inputs.

For each of j = S18, S21 and S22, the λ^*_j value associated with the optimal solution to problem (a2) is unity. We recall that efficiency scores computed in this paper are relative to the schools concerned and should be interpreted accordingly. In Table II, S16 is identified as relatively inefficient, with S18, S21 and S22 as efficient schools in its reference set. S18, S21 and S22 are operating on the efficiency frontier and lie on the facet defined by the hyperplane:

$$y_1 + 130.5y_2 - 1058.5x_1 - 29x_2 = 0 \qquad (5)$$

of the envelopment surface. With $\phi^*_{16} > 1$, it can be argued that S16 is operating in the interior of the production possibility set (Fare *et al.*, 1989). As will be discussed in section 5.4, S16 could increase outputs proportionally by $\phi^*_{16} - 1$ of its current output levels. This in effect will change the mix of S16's outputs. These possible adjustments will project S16 onto the efficiency frontier. In general, for each input $i = 1,2$ with $\alpha_i > 0$ and for each output type $r = 1,2$ with $\beta_r > 0$, an input or output hyperplane for each basis school j can be written as:

$$\text{input:} \qquad \alpha_i x_i = C_j - \sum_{p \neq i} \alpha_p x_p \qquad (6)$$

$$\text{output:} \qquad \beta_r y_r = C_j - \sum_{q \neq i} \beta_q y_q \qquad (7)$$

where, $\alpha > 0$ and $\beta > 0$ are $(1 \times m)$ and $(1 \times s)$ row vectors respectively.

The input and output hyperplanes defined by equation (5) have negative slopes as shown in (i) and (ii) below. Furthermore, from equation (5) we obtain the following marginal rates of substitution (trade offs between inputs on one hand and outputs on the other):

(i) $\frac{\partial x_1}{\partial x_2} = -0.027 < 0$ (input trade off)

(ii) $\frac{\partial y_2}{\partial y_1} = -0.008 < 0$ (output trade off)

As schools perform "well" in an attempt to deliver "quality" educational service to students, on the frontier of "best practice" defined by the most efficient secondary schools in the sample, inputs trade off with other inputs while outputs trade off with other outputs. For example, schools on the facet defined by equation (5) face the situation where a drop in the retention rate (a result of the departure of a student) will have to be compensated by an increase of 0.8 percent in the number of students with a TER score of 50 and above. For each input $i = 1{,}2$ with $\alpha_i > 0$ and for each output type $r = 1{,}2$ with $\beta_r > 0$, using equations (6) and (7) we obtain:

$$\text{(a)}\quad \beta_r y_r = \sum_{i=1}^{2} \alpha_i x_i - \sum_{q \neq r} \beta_q y_i; \quad \text{and}$$

$$\text{(b)}\quad \frac{\partial y_r}{\partial x_i} = \frac{\alpha_i}{\beta_r} > 0$$

We recall that on the efficiency frontier of the envelopment surface, schools are producing maximum outputs given the inputs available to them. It follows from (a) and (b) above, that on the facet of the efficiency frontier defined by equation (5), an increase in say the staff pupil ratio, all else being the same, will lead to an increase in the number of students with TER scores of 50 and above. Similar analysis can be applied to other facets of the envelopment surface. A multiplier for input *i*, is assigned a zero value if the rates of substitution of that input with other inputs in the facet tended to be non-negative. This condition would occur if the input *i* did not trade off with other inputs or if there is a zero or negative correlation between input *i* and the outputs. This is not the case in this paper because all the inputs selected are positively correlated with the outputs.

The comparison of S16 with S18, S21 and S22 (efficient schools in its reference set) not only provides a better understanding of the performance of the schools concerned, but also helps in setting performance targets for S16. It is worth noting that a school with a low adjusted SLN index indicates that this school is at a relative disadvantage when compared to a school with a high-adjusted SLN index. It is an indication that the former school has a large number of students with relatively low socioeconomic characteristics. Such students are described by the DSE as "students at educational risk" whose achievement is adversely affected by these characteristics. Table II shows that the adjusted SLN indexes for S18, S21 and S22 are lower than the adjusted SLN index for S16. This implies that the former schools are at a relative disadvantage when compared to the latter school. It means the former schools have students who, because of their socioeconomic characteristics, are at a relative disadvantage when compared to students at the latter school. This analysis suggests that S16 is not getting the output levels expected for the resources committed, and that, S18, S21 and S22 appear to be achieving more with the given level of inputs.

It might be useful for management at S16 to consider and possibly adopt some of the teaching practices at S18, S21 and S22 (where there is evidence that such practices have contributed to higher output levels). Staff contribution to the school production process is important in improving:

- student learning outcomes; and
- the performance of State secondary schools.

Feldhusen (1992) argued that the use of effective teaching techniques allowed students to build on previous experiences. He maintained that such practices created active learning situations contributing to improvement in student performance. Views expressed in several studies including Carnoy (1995) and Feldhusen (1992) in part, reflect the need for efficient and inefficient State secondary schools to adopt practices necessary to enhance student performance. It is also an indication that the State secondary schools analysed in Table II are capable of increasing the selected outputs with an effective and efficient use of their staff. The approach adopted in this paper allows schools to compare themselves with "peer" group of schools with and without the same size. It is an approach consistent with policies of the DSE in that a range of performance measures will assist schools in making informed judgements about their performance.

5.4 Adjustments necessary to classify inefficient schools efficient

Apart from a reference set of efficient schools, the DEA assessment of an inefficient school also yields the values of inputs and outputs which, in principle, the school ought to be able to achieve. It is important to recall that our measure of technical efficiency uses an output orientation. This means schools attempt to increase their outputs proportionally given their level of inputs. Consequently, the efficiency score is at least 1.0. If a school is technically efficient, its efficiency score is equal to 1.0. If, this school is not technically efficient, its efficiency score is greater than 1.0.

At this point we note that at an optimum, the conditions $\phi_k^* > 1$ and/or $s^{+*}_r > 0$ or $s^{-*}_i > 0$ in problem (a2) in the appendix represent sources of inefficiency. Consequently, adjustments to the inputs and/or outputs of an inefficient school would mean that, in principle, that school would get a relative efficiency rating of 1.0. However, the adjusted values cannot be used in general as targets of achievement for the school concerned. Some adjustments may not be feasible in practice. However, where possible, improvement in efficiency rating can be achieved in one of three different ways. First, a school can reduce its inputs while holding outputs constant. Second, a school can increase its outputs while holding inputs constant, and third, a school can adjust its inputs and outputs. A school's objective may be to select and implement a set of changes to inputs and/or outputs in order to increase efficiency ratings. Input and output "value if efficient" might be useful for planning purposes if transformed into forms commonly used by analysts and managers involved in the school planning process. Recall that in Table II, S16 was found to be inefficient in the sample of State secondary schools in Region 31. Table III demonstrates how the adjustment of the outputs of this school might help make it efficient.

5.5 Analysis of information in Table III

Results from the application of problem (a2) in the Appendix to the sample of schools in region 31 indicate that S16 is properly enveloped. Hence for k = S16, $s^{+*}_r = 0$ and $s^{-*}_i = 0$. As noted in Section A.2 in the Appendix, efficiency can be attained if we apply the following results to the original data in the form:

DEA efficiency rating S16 = 1.006	Actual values S16	Slack/excess S16	Projected values if efficient S16
Inputs			
Staff pupil ratio	0.11	0	0.11
Adjusted SLN index	1.82	0	1.82
Outputs			
Proportion (of students) with TER score of 50 and above	0.52	0	0.52
Year 12 apparent retention rate	70.37	0	100.92

Notes:
Projected values refer to values necessary to make S16 efficient. Values have been rounded to two decimal places. Adjusted SLN index represents the inverse of the original SLN index value
Sample size = 27 schools

Table III.
A set of input and output values sufficient to classify S16 efficient

(i) input reduction $\hat{x}_{ik} = x_{ik} - s^{-*}_{i}$ $i = 1, 2,$ and
(ii) output augmentation $\hat{y}_{rk} = y_{rk}\phi^{*}_{k} + s^{+*}_{r}$ $r = 1, 2$

In other words, adjusting the original x_{ik} and y_{rk} observations for k = S16 to obtain new values $\hat{x}_{ik}$ and $\hat{y}_{rk}$ would render S16 efficient. Table III indicates that the following adjustments of outputs might be necessary to make S16 efficient:

School: S16
Efficiency value: $\phi^{*}_{k} = h^{*}_{k} = 1.006$
Proportion (of students) with TER scores of 50 and above = (0.52) × (1.006) + 0 = 0.52
Year 12 apparent retention rate = (70.37) × (1.006) + 0 = 100.92

In cases where changes in outputs are controllable, the new adjusted values provide targets to be achieved, perhaps over a period of time. However, when the school faces such a situation, most, if not all outputs, are beyond the control of that school. Special programs directed towards preventing dropouts in some State secondary schools can be considered as a means of improving efficiency at these schools. Such programs will assist in improving retention rates. As shown above, part of the adjustment needed to make S16 efficient is the need for S16 to increase the retention rate by 6.7 percent of the current level. Consequently, one course of action for S16 would be to study the operating practices of, say, S18, S21 and S22 in Table II. As noted earlier, not all adjustments may be feasible in practice. Thanassoulis *et al.* (1987) also voice this view.

In practice:

(1) some State secondary schools administer an aptitude test as part of their selection criteria to admit students who transfer from other schools; and

(2) some State secondary schools might also "advise" some of their Victorian Certificate of Education (VCE) students who are "performing poorly" not to continue with the VCE studies or might arrange for such students to undertake Technical And Further Education (TAFE). In this case, the number of students who will be advised to leave might be replaced with an equal number of new students who meet the school's entry requirements as cited in (1) above.

In this way, such State secondary schools admit or retain students expected to perform well in the VCE. Management at inefficient State secondary schools may adopt any of these practices to allow trade offs between the selected outputs, if this would enable such schools to maintain or make further improvements to their technical efficiency levels. Such trade offs might also allow schools to accommodate any changes in their adjusted SLN index (changes in the adjusted SLN index will result from changes in student composition). Practices of the types cited in (1) and (2) above may also prove useful to "poorly" performing or inefficient State secondary schools. This point is demonstrated in the following.

For example, in Table II, S18 is found to be efficient relative to the schools in the sample. S18 has a total enrolment of 858 students and 140 of the VCE students had TER scores. Of the number of students who had TER scores, there were 45 with TER scores of 50 and above (32.14 percent). If for reasons of poor performance, management at S18 "advise" ten of the VCE students not to proceed with the VCE, then the number of VCE students who had TER scores in that year would drop to 130. This might bring down the retention rate. In this way, the 45 students with TER score of 50 and above (now from a cohort of 130) will bring the proportion (of students) with TER of 50 and above to 0.35 (35 percent). However, a school might choose to replace these ten students with ten new students expected to perform well in the VCE. This latter decision will result in the proportion (of students) with TER of 50 and above being greater than 0.35 (35 percent).

Assuming the results presented in Table II are reasonable, operating practices at any of the efficient State secondary schools can assist management at inefficient State secondary schools. This will enable such State secondary schools to improve their efficiency performance. Furthermore, it will enable them to determine if the inefficiency is justifiable, or due to factors that can be controlled and/or managed.

5.6 Sensitivity to input-output model specification

The inputs selected in this study represent relevant factors of the school production process in Victoria. Because the true production relationships are often not known, alternative input-output specifications could be used to assess the sensitivity of a school's efficiency rating. An indicator of such sensitivity is the extent to which the omission of just one input or output would render the school inefficient. It is not possible to generalise the effect of such alternative measures. However, it is worth re-running DEA evaluations for alternative samples of measures to observe how different input-output specifications affect the results. We therefore tested the sensitivity of our results by replacing the inputs and re-assessing the efficiency of the schools in the sample.

5.6.1 Using expenditure per pupil as the only input. The following approach was employed in testing the sensitivity of the efficiency ratings:

- Stage 1: the relative technical efficiency of schools in region code 31 was assessed using the staff pupil ratio and the adjusted SLN index as inputs.
- Stage 2: expenditure per pupil was used as the only input in assessing the relative technical efficiency of these schools.

The following outputs were used in both stages:

- Proportion (of students) with TER scores of 50 and above; and
- Year 12 apparent retention rate.

Table IV will report on the results of stages 1 and 2 relating to schools in a non-urban geographical location in Victoria (regional code 31). As will be discussed in sub-section 5.7, analysis of the performance of schools in this region will provide further insight into the performance of such schools. Efficient and inefficient schools may adopt practices of schools located in this region which might contribute to the improvement of school performance. Such comparisons of school technical efficiency performance will assist schools to identify wider areas of achievement and areas for improvement.

Table IV reports on any changes in the efficiency ratings of the schools in region 31. For the purposes of our discussion, Table IV will report only on schools found to be:

- efficient in stage 1, but inefficient in stage 2;
- inefficient in stage 1, but efficient in stage 2; and
- efficient in both stages 1 and 2.

Schools found to be inefficient in both stages are not reported in Table IV.

Region code 31 Number of schools in sample = 26	State secondary schools S5[a]	S14[b]	S16[b]	S18	S21[a]	S24[b]
Stage 1 DEA efficiency rating	1.00	1.00	1.01	1.00	1.00	1.17
Stage 2 DEA efficiency rating	1.14	1.74	1.00	1.00	1.00	1.00

Notes:
[a] S5, S14 and S21 (actual efficiency rating is 1.003) were found to be inefficient in stage 2
[b] S16 and S24 were found to be efficient in stage 2
Values have been rounded to two decimal places. Adjusted SLN index represents the inverse of the original SLN index value

Table IV.
Effects on school efficiency

5.7 Analysis of information in Table IV

Information contained in Table IV will prove useful in seeking an improved understanding of the performance of S5, S14 and S21. Such information will assist in setting performance targets for these inefficient schools. Exclusion of the staff pupil ratio and the adjusted SLN index inputs had an adverse effect on the efficiency rating of these schools. Their resulting low performance may be justified as long as there is reason to believe that staff pupil ratio and the socioeconomic characteristics of their pupils contribute to their technical efficiency performance.

Analysis of results in stage 1. Refer to section 5.3 for an analysis of stage 1 results.

Analysis of results in stage 2:

(1) *Administrative implications of expenditure analysis*. Analysis of the expenditure per pupil of schools in region 31 shows the following: S5 ($4,629.81), S14 ($8,263.71), S18 ($4,589.23), S21 ($4,985.93) and S24 ($4,521.14). S14 spends nearly twice as much on a pupil when compared to S18 and S24, but the latter schools have respectively 38 percent and 52 percent more students with TER scores of 50 and above. This analysis indicates that S18 and S24 appear to be accomplishing more with less expenditure per pupil input. It also indicates that S14 should be able to achieve outputs specified if efficient because S18 and S24 in the same geographical location but with less expenditure per pupil (relative) are able to achieve more outputs. This form of comparison is intended to illustrate how DEA results could be used for policy formulation in resource allocation to schools.

(2) *Implications of excluding staff pupil ratio and adjusted SLN index*. Of the State secondary schools in Table IV, S14 and S21 have relatively low SLN index values, which is an indication of the state of relative disadvantage of their students. Considering that stage 2 does not account for the socioeconomic status of the students, we are of the view that schools identified as "inefficient" in stage 2 of the analysis, may not, in fact, exhibit "waste" and "mismanagement". Rather, they may face a more difficult task in converting inputs to outputs given the factors (the socioeconomic characteristics of their students) largely outside their control. To the extent that low socioeconomic status is associated with conditions that make learning more difficult, schools with low socioeconomic status pupils may be identified as being inefficient when in fact, they are not engaging in "operations" that can be described as inefficiency. For S21, output slacks in problem (a2) in the Appendix are as follows:

- $s^{+*}_{r} = 0$, r = proportion (of students) with TER scores of 50 and above; and
- $s^{+*}_{r} = 0$, r = Year 12 apparent retention rate.

Projected values of S21 if efficient:

- The current input level is equal to the projected input level if efficient[10].
- For r = Year 12 apparent retention rate, the current output level is equal to the projected output level if efficient[11].
- For r = proportion (of students) with TER scores of 50 and above, S21 could further increase this output proportionally by $\phi_{21}^* - 1$ of its current output level without consuming additional inputs.

It follows from equations (5) and (6) that for j = S21, using the λ_j^* values associated with the optimal solution to problem (a2) in the Appendix would yield a boundary point (for the second output) made up of a linear combination of outputs of S16 and S24. S21 is output inefficient but can also be said to be weakly input efficient (Seiford and Thrall, 1990). A similar analysis and discussion is applicable to S5 and S14.

Our results in section 5.7 show that assessment of school relative efficiency performance with and without adjustments for the socioeconomic characteristics of pupils in these schools affects the DEA rating of these schools. The results also indicate that schools for which output levels show considerable inefficiency in resource utilisation, when adjustments are made for the socioeconomic disadvantages, such schools did not appear to be "significantly" less efficient than other schools. In part, information in Table IV and the foregoing, suggest that further investigations outside the DEA context are necessary in order to gain insight into operating practices at respective schools. The Pearson's correlation coefficient between the efficiency ratings obtained in stages 1 and 2 of Table IV for State secondary schools in region 31 is 0.66. This is significantly different from zero at the 95 percent confidence level. Our analysis in stages 1 and 2 of Table IV produce similar results for State secondary schools in region 31 in the sense that the DEA efficiency ratings obtained in both stages are positively and significantly correlated.

Analysis of our DEA results in sections 5.2 through 5.6, suggests that, when DEA was applied to any new set of input-output specifications, DEA was found in this study to:

- be able to locate relatively inefficient schools given that inputs and outputs are correctly specified;
- indicate the magnitude of inefficiency;
- indicate a reference set of efficient school(s) against which the performance of inefficient schools are compared;
- indicate alternative sets of adjustments to inputs and outputs to increase the level of efficiency of an inefficient State secondary school.

Furthermore, information contained in sections 5.2 through 5.6 indicates that the use of alternative input and output specifications does affect the efficiency ratings. Data availability determined the inputs and outputs used in this study on State secondary school technical efficiency. It may be argued that there are outputs from the school production process other than those used in this study. Schools that rated low in our analysis may be diverting more resources to other less tangible outputs. Conversely, if we have included an output in our analysis which might be considered secondary, or indeed irrelevant, then the analysis may have unduly favoured schools who performed well on that output. Interpretation of the DEA efficiency ratings in this study should be done with reference to the specific sets of inputs and outputs used. This is important when alternative input and output specifications are used in testing the sensitivity of the efficiency ratings. It is also important to check the results of efficiency evaluations with a reliable source of information regarding the actual performance levels of these schools.

6. Validity checks and reliability of DEA results

Based on the reactions of "experts" in the education industry to the results, the following issues require further analysis:

- lack of a large enough sample of efficient schools against which the secondary schools rated as inefficient can be compared; and
- monitoring the performance of an individual school over time relative to itself and to other schools.

This paper will not address the issue of whether DEA isolates a large enough percent of inefficient secondary schools. However, if DEA is reliable with respect to schools identified as inefficient, then the question is whether the advantages are sufficient to warrant the use of DEA relative to alternative techniques.

6.1 Validity

We contend that the approach adopted in this paper is a valid way of comparing State secondary schools for reasons including the following:

- DEA, the basis of the results obtained in this paper has been applied and found useful in many situations; and
- alternative methods of comparing State secondary schools in Victoria such as those presented in DSE (1996), rely on a number of different performance indicators (e.g. expenditure per pupil) considered separately. These indicators may be intuitively easier to understand but frequently fail to give a clear overall "picture" of technical efficiency as that provided in this paper.

6.2 Usefulness

The results obtained in this paper provoke insight into issues outside the DEA context as to why certain State secondary schools perform "well" or "poorly" in terms of technical efficiency and how their performance can be improved.

7. Conclusion

State secondary schools are an important component of human capital formation. They are also a major expenditure component for taxpayers. The efficiency by which hired inputs produce desired outputs is thus an important public policy issue. Moreover, with increased competition between private and State secondary schools for students, the efficiency of State secondary schools has become a national issue.

In this paper, DEA was used to estimate technical efficiency for a sample of State secondary schools using 1996 data. A number of different measures of outputs and inputs associated with the State secondary school system were used. It is apparent that among other factors, in any school performance evaluation, it is important that roles and objectives, which characterise the operating practices at these schools, are taken into account. As decision-making units, a consistent measurement of the important inputs and outputs of these schools is required for a more informed judgement to be made on a school's performance.

This paper suggests that an appropriate measure of efficiency is necessary to assist State secondary schools to monitor and improve their performance. Efficiency measures are also important for policy formulation, resource allocation, improvement in school retention rates, proportion of students who exit, proportion of students with higher TER scores and so on. This paper provides State secondary schools in Victoria with such a measure.

The technical efficiency results suggest that State secondary schools analysed in this study are operating at a fairly high level of efficiency relative to each other, although there is room for improvement in several State secondary schools. One key finding of the study is that, most schools are in a position to increase their outputs through a more efficient use of their available resources (such as the school global budget, school teaching and non-teaching staff, school facilities and so on). At the end of each school year, the DEA results will show whether school objectives achieved are as expected and whether increments in school inputs previously approved by school authorities have been efficiently used.

The analysis indicates that, when the socioeconomic status of students at various schools is taken into account, schools which appear to be "inefficient" may not, in fact, exhibit "waste" and "mismanagement". Rather, they may face a more difficult task in converting inputs into outputs given the factors (the socioeconomic characteristics of their students) largely outside their control. To the extent that low socioeconomic status is associated with conditions that make learning more difficult, schools with low socioeconomic status pupils may be identified as being inefficient when in fact, they are not engaging in "operations" that can be described as inefficient. This conclusion suggests that issues relating to the operations of these schools outside the DEA context are as important as the DEA results if improvement in school performance should be sustained.

Comparable secondary schools could adopt "similar" operating practices. In this case, inefficient schools with low retention rates, high proportion of students who exit, relatively high expenditure per pupil will have to adopt measures applicable to efficient comparable schools that will assist to improve their performance. One option could be for such inefficient schools to administer dual accreditation aimed at giving VCE students, the options of proceeding with the VCE and/or pursuing Technical And Further Education (TAFE). This system of accreditation, currently in practice in a number of State secondary schools in Victoria has been identified as a "driver" to increasing retention rates.

This paper concludes that DEA has considerable potential in measuring the relative technical efficiency of State secondary schools. In addition, DEA is found to provide useful insights into issues concerning technical efficiency for management not available with:

- the current Framework of the Directorate of School Education; and
- some of the alternative analytical techniques used to date in Victoria in evaluating school performance.

Further research is needed into the State secondary school system in Victoria. Non-parametric techniques can be applied to panel data to shed light on changes in efficiency over time, as well as total factor productivity and technical change. The use of disaggregate data will enable comparisons to be made between State secondary schools over any specified period of time.

Notes

1. Refer to Mante (1998) for detailed discussion of outputs to the school production process.
2. This refers to different proportions of factors affecting the school production process. In practice, it is necessary that the outputs and inputs considered in any performance evaluation are those of interest and importance to the education sector and that the inputs are those utilised to produce the outputs.
3. In computing measures of comparative efficiency, it is necessary that the number of schools compared in the analysis exceed the total number of inputs plus outputs.
4. Efficiency of a school in this case is generally interpreted to be a measure of its success in producing the maximum output(s) given a set of inputs.
5. In Charnes *et al.* (1979), non-negativity conditions for the virtual weights u_r and v_i were replaced by strict positivity conditions.
6. In the DEA literature, this condition is usually stated as the sum of the slacks for these constraints is zero for every optimal λ^*. See Chapter 3 of Mante (1998). Also see Charnes *et al.* (1978).
7. See Shephard (1970, pp. 13, 180) for a discussion of efficient sub-sets of the boundary with $\phi_k^* = 1$ and the sum of the slacks is zero. Also see Seiford and Thrall (1990).
8. For any two input-output vectors (X', Y') and (X'', Y''), we say that (X', Y') dominates (X'', Y'') if $X' \leq X''$ and $Y' \geq Y''$.
9. The first output value is a boundary point. See also Charnes *et al.* (1986).
10. See equation 4. The input value is a boundary point.
11. See equation 3. The output value is a boundary point.

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Appendix

A.1 Overview of data envelopment analysis (DEA)

Charnes *et al.* (CCR, 1978) introduced a conceptual model that generalised equation (1) to equation (2) (see Charnes *et al.*, 1978, 1994). They assumed there are n decision-making units (DMUs) to be evaluated where each DMU uses varying amounts of m different inputs to produce s different outputs. They defined DMU_k as the $k-th$ DMU whose efficiency is being assessed. For this particular DMU, $x_k = (x_{1k}, \ldots, x_{mk})$ represents the vector of known inputs and $y_k = (y_{1k}, \ldots, y_{sk})$ represents the vector of known outputs. They also defined u_r as output weights for each output $(r = 1, \ldots, s)$, and v_i as input weights for each input $(i = 1, \ldots, m)$ (in Charnes *et al.*, 1979, non-negativity conditions for the virtual weights u_r and v_i were replaced by strict positivity conditions). The ratio of weighted outputs to weighted inputs for this particular DMU in question is maximised subject to the condition that similar ratios for every DMU be less than or equal to unity. In this manner, CCR argued that the efficiency of each DMU is computed relative to other DMUs in the reference set. The ratio measure of relative efficiency for DMU_k is given by problem (a1):

$$\max h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad j = 1, \ldots, n;$$

$$u_r > 0, \qquad r = 1, \ldots >, s;$$

$$v_i > 0, \qquad i = 1, \ldots >, m.$$

In problem (a1), the x_{ij} and y_{rj} (all positive) are known inputs and outputs respectively of the $j-th$ DMU. Charnes *et al.* (1978) stated that these usually represent observations from past decisions on inputs and the outputs that were produced. $r = k$ in the functional designates that the latter is being rated. They argued that the weights u_r and v_i are objectively determined to obtain a (dimensionless) scalar measure of efficiency (scaling and invariance properties are discussed in Rhodes, 1978). This approach means the choice of weights is determined directly from observational data subject only to the constraints set forth in problem (a1). Under these observations and constraints, they argued that no other set of common weights will give a more favourable rating relative to the reference set of DMUs. They also reported that because the ratio in the functional form also appears in the constraints, it implies that max $h_k = h_k^* \leq 1$, and $h_k^* = 1$ if and only if DMU_k is efficient.

A.2 Reduction to linear programming form

Studies by Charnes *et al.* (1978) and Charnes *et al.* (1981) argued that by utilising the theory of linear fractional programming with corresponding transformation of variables (see also Charnes and Cooper, 1961, 1962, pp. 181-85), problem (a1) may be solved by an ordinary linear programming problem. This paper will not repeat that development here, however, we will replace problem (a1) by the following:

$$\max \phi_k = \left\{ h_k + \varepsilon \left(\sum_{i=1}^{m} s_i^- \right) + \varepsilon \left(\sum_{r=1}^{s} s_r^+ \right) \right\} \tag{a2}$$

subject to

$$h_k y_{rk} + s_r^+ - \sum_{j=1}^{n} \lambda_j^T y_{rj} = 0 \qquad r = 1, \ldots, s;$$

$$\sum_{j=1}^{n} \lambda_j^T x_{ij} + s_i^- = x_{ik} \qquad i = 1, \ldots, m;$$

$$s_i^- \geq 0, \qquad i = 1, \ldots, m;$$

$$s_r^+ \geq 0, \qquad r = 1, \ldots, s;$$

$$\lambda_j^T \geq 0, \qquad j = 1, \ldots, n;$$

h_k is unconstrained in sign.

The results of problem (a2) indicate that, the DMU under examination with j index ($j = k$) is efficient if, and only if, $h_k^* = 1$ with $\{s_i^-\}$ and $\{s_r^+\}$ all equal zero. The reference set for the ($j = k$)-th unit in this evaluation is the subset of units $j = 1, \ldots k, \ldots, n$; for which $\lambda_j^* > 0$ in (a2). To assess the relative efficiency of each of the n units (a2) must be solved n times, each time suitably modified for the unit being assessed. In Bessent *et al.* (1982), it is noted that at an optimum, the conditions $\phi_k^* > 1$ and/or $s^{+}{}_r^* > 0$ or $s^{-}{}_i^* > 0$ in (a2) represent sources of inefficiency. Efficiency can be attained if we apply these results to the original data in the form:

$$\hat{x}_{ik} = x_{ik} - s^{-}{}_i^* \qquad i = 1, \ldots, m;$$

$$\hat{y}_{rk} = y_{rk} \phi_k^* + s^{+}{}_r^* \qquad r = 1, \ldots, s;$$

In other words, adjusting the original x_{ik} and y_{rk} observations to obtain new values $\hat{x}_{ik}$, $\hat{y}_{rk}$ would render the DMU being assessed efficient. It is important to note that although in principle the adjustments to the inputs and outputs of an inefficient unit would give a relative efficiency rating of 1, some adjustments may not be feasible in practice.

A.3 Previous studies on school efficiency

There is considerable published research on production functions for educational institutions (see Hanushek, 1979, pp. 351-88; 1986, pp. 1141-77). Most of these studies have only a single output. Some, however, estimate multiple output production technologies via simultaneous equation models. These studies include Levin (1970), Michelson (1970), Boardman *et al.* (1973), and Brown and Saks (1975). In these cases, comparing actual and predicted output levels provide estimates of comparative efficiency.

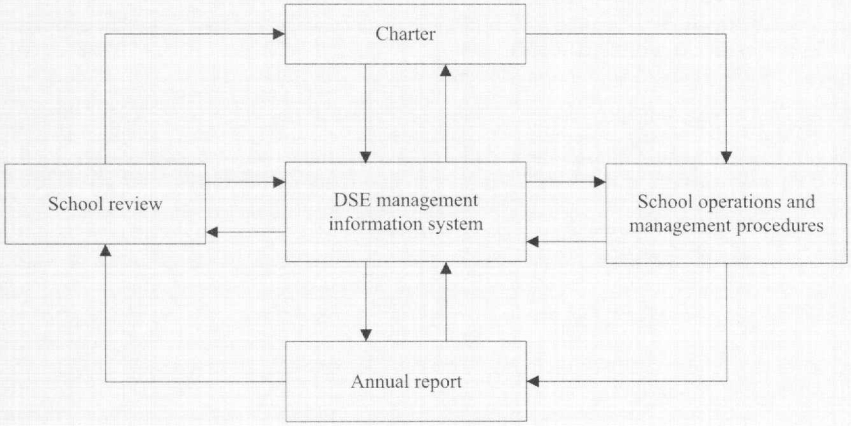
Studies measuring technical efficiency in State schools have used a variety of empirical techniques to identify technically efficient schools and to compare them with technically inefficient schools. In a number of studies including McCarthy and Yaisawarng (1993), it is reported that these studies have in common the fact that they focus attention on schools that produce the maximum output(s) given their inputs. In other words, these studies focus on schools on the production frontier.

A.4 Studies in Victoria

A search for ways to improve the delivery of education is motivated by the general view that the learning environment is an important aspect of the multidimensional educational process (Thomas, 1990). McKenzie and Keeves (1982) argue that the distribution of educational resources is one of the most significant problem areas for executive decision making. These resources, they state include distribution of available space, utilisation of staff in their area of expertise and the use of funds along budget priority lines. All bear on the issue of achieving institutional goals.

In 1993, the Victorian Directorate of School Education (DSE) released a policy document entitled *A Quality Provision Framework for Victorian Schools*. (A detailed review of the objectives of this framework can be found in the Report of the Auditor-General (1995).) As a result, a "quality provision" taskforce was charged with the responsibility of providing advice on a more effective use of educational resources in State schools. This policy was promulgated to enable schools to become viable "Schools of the Future" (DSE, 1993, p. 7).

The DSE's policy had three aspects namely, quality curriculum, quality facilities and school consolidation, and was based on a notion of sufficient threshold enrolments to provide sufficiently broad curriculum. (This was based on the premise that larger schools (rather than small schools) are better able to provide quality education and are more cost-effective to operate.) This was in line with the Auditor-General's Report (1995), which pointed out that structural change was a necessary precondition for quality outcomes of students. Three other frameworks designed to provide quality teaching and learning in State schools were: the accountability framework, curriculum and standards framework, and the professional recognition program. Figure A1 is a diagrammatic representation of the accountability framework. This has been considered in much greater detail in Mante (1998).



Source: DSE Guidelines for Developing a School Charter (1995)

Figure A1. The accountability framework

While improvement in student learning is seen as a prime focus of all school activities, school effectiveness and cost containment rather than technical efficiency have been the major thrust of these programs. To date, a shortcoming of these programs is that no technical efficiency benchmarks are provided for schools to evaluate their performance relative to other schools. This applies whether the schools have similar or dissimilar characteristics.

It is important to note that to date, studies that attempt to measure performance in school education in Victoria, have measured effectiveness of school and school systems using student learning outcomes. (In McKenzie and Keeves (1982), school systems are defined as government primary and secondary schools administered by the State Department of Education in Australian States.) As noted by the Steering Committee (1995, pp. 199-290), "student learning", "social" and "equity" objectives provided a basis for the development of performance indicators addressing the effectiveness of school systems. (Here effectiveness indicators focus on the outcomes of each school system and not individual schools. Social objectives emphasise the role of schooling in relation to student experiences in school, pathways through life and social responsibility.) None of these studies into school performance in Victoria made any judgements on technical efficiencies in State secondary schools.

Tables AI and AII indicate that there is low positive correlation between the inputs and low positive correlation between the outputs. None of the correlation coefficients were found to be significantly different from zero at a 5 per cent level of significance.

Table AI.
Pearson's correlation coefficient between inputs

Schools in region 31 Number of schools = 26	Staff pupil ratio	Adjusted SLN index
Staff pupil ratio	1	0.007
Adjusted SLN index	0.007	1

Note: Adjusted SLN index represents the inverse of the original SLN index value

Table AII.
Pearson's correlation coefficient between outputs

Schools in region 31 Number of schools = 26	Proportion (of students) with TER of 50 and above	Year 12 apparent retention rate
Proportion (of students) with TER of 50 and above	1	0.238
Year 12 apparent retention rate	0.238	1

Note: Year 12 apparent retention rate is defined as the number of Year 12 students expressed as a proportion of the Year 7 enrolment five years earlier (ABS, 1997 and DSE, 1993).