DOCUMENT RESUME

ED 437 500 CE 078 701

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TITLE Technical and Scale Efficiency of Vocational Education and Training Institutions: The Case of the New Zealand Polytechnics.
INSTITUTION Monash Univ., Clayton, Victoria (Australia). Centre for the Economics of Education and Training.
SPONS AGENCY Australian National Training Authority, Melbourne.
REPORT NO CEET-WP-22
PUB DATE 1999-03-00
NOTE 22p.
AVAILABLE FROM Center for the Economics of Education and Training, Faculty of Education, Monash Univ., Clayton, Victoria, Australia 3168 (Free). Tel: 61-3-9905-9157; Fax: 61-3-9905-9184; Web site: http://www.education.monash.edu.au/centres/CEET.
PUB TYPE Reports - Research (143)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Case Studies; Comparative Analysis; *Cost Effectiveness; Delivery Systems; Educational Improvement; Educational Needs; *Efficiency; Foreign Countries; Needs Assessment; *Program Effectiveness; Resources; Statistical Analysis; *Technical Institutes; Two Year Colleges; *Vocational Education
IDENTIFIERS Australia (Victoria); *New Zealand; *Polytechnics; TAFE (Australia)

ABSTRACT

Data envelopment analysis, which is designed to assist in identifying best practice performance in the use of resources among a group of like organizations, was used to estimate the technical and scale efficiency of vocational education and training in 25 New Zealand polytechnics serving a total of 94,201 students. The polytechnics' efficiency was also compared to that of a sample of technical and further education (TAFE) institutes in Victoria, Australia. The average level of technical efficiency in the New Zealand polytechnics was high in 1995 and rose slightly in 1996. In terms of scale efficiency, only 4 polytechnics operated with constant returns to scale in 1995, 9 were producing too much output relative to the optimal scale, and 10 were producing too little output. In 1996, 6 of the polytechnics operated with constant returns to scale, 14 were producing too little output, and 1 was producing too much output. Compared with Victoria's TAFE institutes, the New Zealand polytechnics were somewhat less efficient but nevertheless performed relatively well. Although New Zealand's polytechnics have numerous opportunities for improving efficiency, further research is needed before policies attempting to address the problems of technical and scale efficiency are implemented. (Contains 5 tables, 3 figures, and 27 references.) (MN)

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CENTRE FOR THE ECONOMICS OF EDUCATION AND TRAINING

TECHNICAL AND SCALE EFFICIENCY OF VOCATIONAL EDUCATION AND TRAINING INSTITUTIONS: The Case of the New Zealand Polytechnics

Malcolm Abbott and Chris Doucouliagos*

March 1999
WORKING PAPER NO. 22

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Technical and Scale Efficiency of Vocational Education and Training Institutions: The Case of the New Zealand Polytechnics

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Keywords: Data Envelopment Analysis, technical efficiency, scale efficiency, economies of size.

JEL Classifications: I21 Analysis of Education. I28 Education: government policy. J45 Public sector labour markets.

Abstract: *In recent years vocational education and training has been recognised as having a crucial impact on worker productivity, enterprise performance and the overall performance of the New Zealand economy. The importance of vocational education and training gives rise to the issue of the efficient operation of educational institutions. In this paper Data Envelopment Analysis is used to derive estimates of technical and scale efficiency. Comparisons are also made with Victorian TAFE institutes. The results indicate the existence of significant technical and scale inefficiency and that there is scope to improve efficiency and to take advantage of economies of size within the sector.*

* The views expressed in this paper are those of the authors and not necessarily those of their employers.

Technical and Scale Efficiency of Vocational Education and Training Institutions: The Case of the New Zealand Polytechnics

During the 1980s and 1990s there has been a great deal of concern expressed amongst policy makers about the relatively slow growth rate of the New Zealand economy. In response to these concerns the New Zealand Government embarked upon an ambitious program of macroeconomic and microeconomic reform designed to help raise the rate of New Zealand's productivity growth. This involved, amongst other things, the floating of the New Zealand dollar, financial market deregulation, a gradual reduction of industry and agricultural protection, the privatisation of major government utilities and finally in the early 1990s reform of the labour market. Reform of the provision of tertiary education also occurred as it began to be perceived that education and training had a crucial role to play in the restructuring of the New Zealand economy (see for instance Hawke, 1988; *Education in the 21st Century*, 1995; *Tertiary Education Review Green Paper,* 1997).

Education and training is perceived as being an 'essential requirement' of creating the skilled and adaptable workforce necessary to achieve increased levels of adaptability and productivity, which in turn will help to create international levels of competitiveness (*Education in the 21st Century,* 1995; Smith, 1991; for the United States see Bartel 1994; National Center on Education and the Economy, 1990; for the United Kingdom see Bosworth et. al. 1996; CBI Taskforce, 1989; and for Australia see Maglen 1993). In response to this perception that the New Zealand work-force requires a development of its skill base the New Zealand Government has funded a steady increase in the numbers of students enrolled in tertiary level institutions, including the polytechnics. One of the major concerns of education policy makers in New Zealand in recent times has been to continue this expansion of the polytechnics, while at the same time avoiding too great a strain on the finances of the government.

One way of responding to the problem of expanding tertiary education with limited resources is to consolidate the polytechnics into larger institutions in order to reap economies of scale.[1] This strategy is based on the assumption that average unit costs per student will be lower for larger sized institutions (assuming no change in the quality of the education provided). Although a great deal of work has been conducted on this phenomena for American tertiary institutions (for a summary of American work see Brinkman and Leslie, 1986; Cohn, Rhine and Santos, 1989) and for various other countries little work has been conducted in New Zealand.

An alternative way to reduce the costs of tertiary education is to improve efficiency. Measuring the efficiency of tertiary education providers like the polytechnics can help to identify possibilities for improving institutional performance. The issue of efficiency has also not been explored for New Zealand's tertiary education institutions.

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[1] Related to this proposal is the one to amalgamate polytechnics with universities which is designed also partially to make cost efficiencies by reaping economies of size and scope. See for instance the proposal to merge the Wellington Polytechnic with Massey University (Minister of Education, 31 October 1997, Media Release).

In this paper Data Envelopment Analysis (DEA) will be used to derive estimates of the technical and scale efficiency of New Zealand's polytechnics. In New Zealand, polytechnics provide the bulk of vocational education and training courses. As such they concentrate on sub-degree level courses, enrol a large number of part-time students and put little emphasis on research. This makes them dissimilar to universities and therefore it seems appropriate to only include polytechnics in this study.

DEA is an analytical technique that can be used to assist in identifying best practice performance in the use of resources among a group of like organisations. Such identification can highlight where the greatest gains can be made from improvements in efficiency and help institutions to achieve their full potential. Measurement tools like DEA are useful in situations where government bodies operate in markets, which are distorted by regulated prices, subsidies and a lack of contestability. In these situations DEA provides a comparative performance monitoring that identifies variations and hence provide encouragement and direction for performance improvement.

The purpose of this paper is to use DEA to investigate the efficiency (technical and scale) of the New Zealand polytechnics. Section one provides an account of the data used in this study as well as a discussion of the use of DEA. In the second section DEA is used to explore the technical and scale efficiency of the 25 New Zealand polytechnics, for 1995 and 1996. Separate efficiency estimates are provided for the polytechnics as a whole and for individual divisions within the polytechnics. In the third section, the efficiency of New Zealand's polytechnics is explored relative to a sample of Australia's technical and further education (TAFE) institutes. The TAFE institutes are educational institutions, which like the New Zealand polytechnics concentrate on the provision of post-secondary vocational education and training programs. In the fourth section, the existence of economies of size[2] is explored and in the final section some conclusion are made.

1. Data and Methodology

Typically government organisations operate in markets which lack prices and costs determined under competitive conditions. Moreover, these markets tend to be distorted by regulations, subsidies and the exercise of monopoly power. In these cases, the usual market indicators of performance like profitability and rates of return can not be used to gauge an institution's economic performance accurately. Despite this, governments and the general public are still concerned that these institutions operate in an efficient manner. The dearth of input and output prices means that it is not possible to draw reliable inference on issues such as allocative efficiency. However, it is possible to use data on inputs and outputs to analyse technical and scale efficiency. Technical efficiency is a relevant measure of performance in polytechnics because it offers information on the links between the inputs purchased by a polytechnic and the outputs generated by those inputs. The maximisation of output subject to a fixed budget is a central objective of education institutions (see Coelli *et al* 1998, pp. 22-23). Moreover, Pestieau and Tulkens (1993) argue that productive efficiency is probably the only meaningful measure of the performance of public enterprises.

[2] Economies of scale refer to the case where output is increased without changing the ratio of inputs. As educational institutions grow in size however it is likely that the relative share of inputs will change. Thus, it is important to explore also economies of size.

1.1 *Technical and Scale Efficiency*

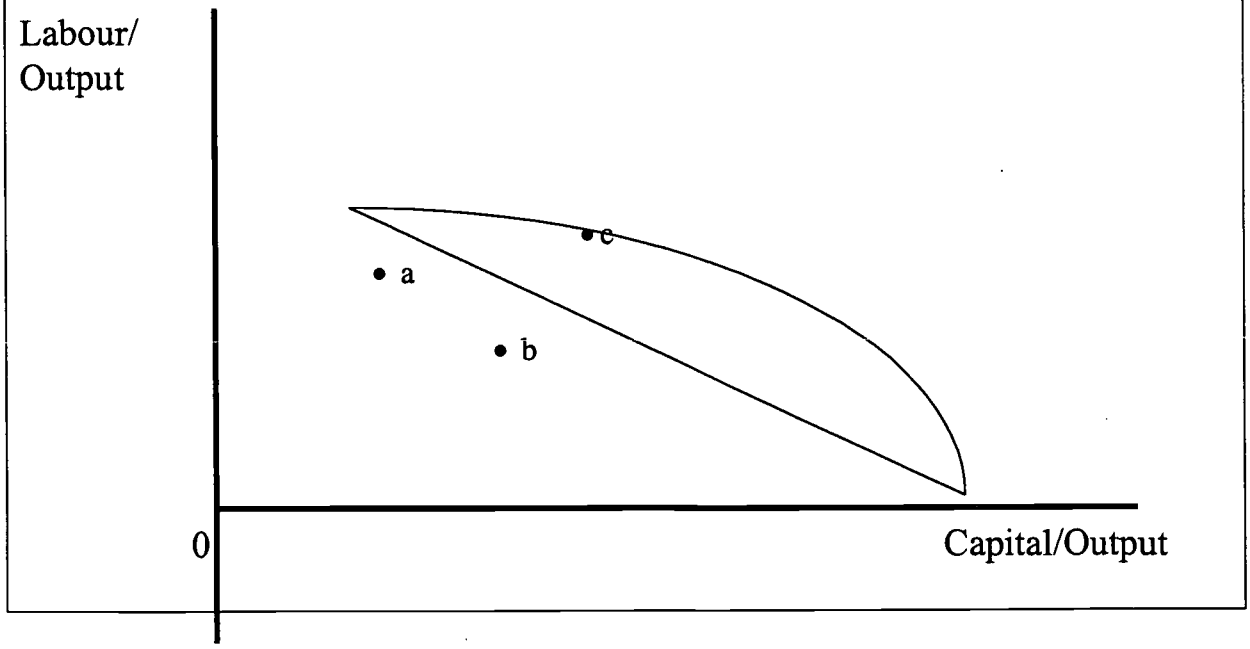
Technical efficiency is a valid performance measure, as the provision of education and training to the maximum number of students possible at a given level of quality, within resource restraints is a major objective of tertiary education institutions. Some authors argue that, next to the delivery of quality training and learning, technical efficiency is probably the only valid measure of performance of tertiary institutions (see Pestieau and Tulkens, 1993). Even if a polytechnic is not concerned with technical efficiency, the pursuit of other objectives would have consequences for technical efficiency. Information on the opportunity cost of not considering technical efficiency is important to both the teaching and policy communities.

Technical efficiency is determined by the difference between the observed ratios of output to inputs and the ratio achieved by the best practice decision making units. It can be expressed as the potential to increase the quantity of outputs from given quantities of inputs, or the potential to reduce the quantities of inputs used in producing given quantities of output. Technical efficiency is affected by factors including the size of the operations, managerial practices, ownership structure and the regulatory environment. Technical efficiency can be defined independently of costs and prices.

The concept of technical efficiency is depicted graphically in Figure 1, which plots different combinations of two input-to-output ratios, labour-to-output and capital-to-output, required to produce a given output (in the case of polytechnics this output is the number of students enrolled; EFTS). This curve is known as the unit isoquant or best practice frontier. If a decision making unit is producing on the unit isoquant (for example at points **a** and **b**) then it is regarded as technically efficient. DEA estimates the best practice isoquant based upon the information on outputs and inputs. Decision making units operating to the right of the unit isoquant (for example at point **c**) are considered to be operating with a degree of technical inefficiency.[3]

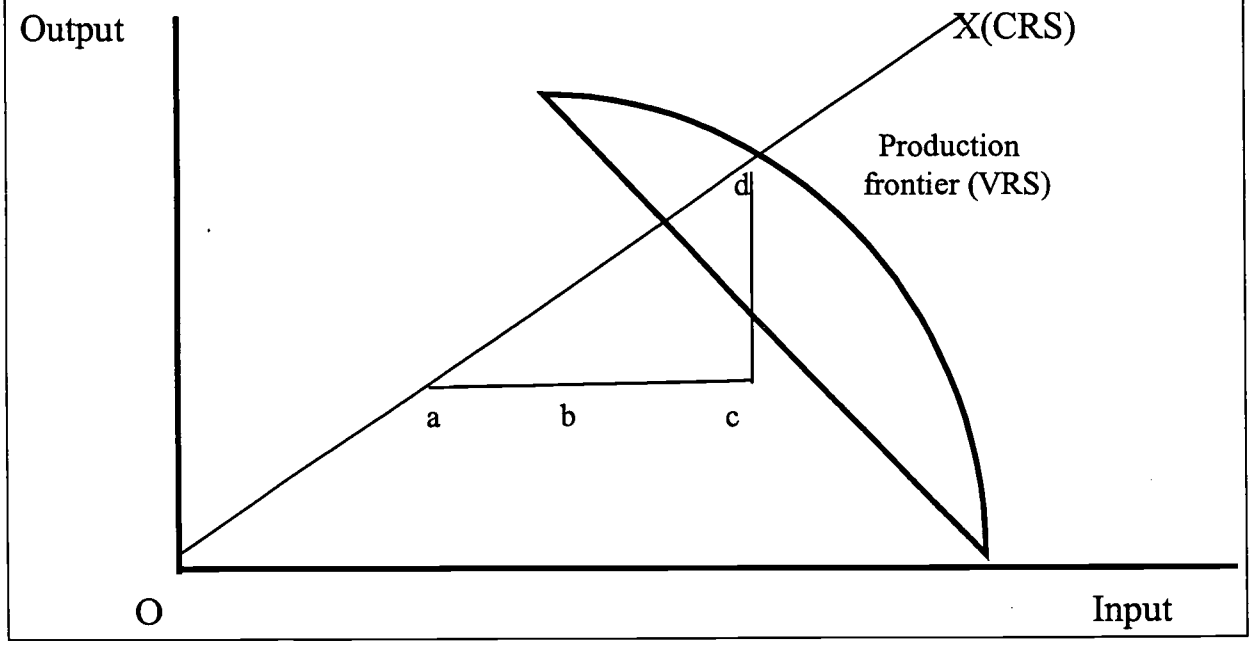
[3] Knowledge of factor prices would allow the identification of which decision making unit, for example, **a** or **b** in Figure 2, or some other, is allocative efficient - using the appropriate mix of inputs.

Figure 1: Illustration of Technical Efficiency Concept.



A polytechnic may be 100 percent technically efficient in that it generates the maximum output from the available inputs, but it need not be scale efficient. Scale efficiency is the extent to which a decision making unit can take advantage of returns to scale by altering its size towards the optimal scale (defined as the region in which there are constant returns to scale in the relationship between outputs and inputs). This is demonstrated for the simple case of a one input and one output decision making unit in Figure 2.

Figure 2: The Production Frontier and Returns to Scale.



The constant returns to scale production frontier is the straight line from the origin (O-X). The variable returns to scale frontier (VRS) passes through the points where the decision making unit have the highest output to input ratios, given their relative sizes.[4] The scale efficiency of a decision making unit can be determined by comparing the technical efficiency scores of each decision making unit under constant returns to scale and variable returns to scale. The distance from the respective frontier determines technical efficiency under each assumption. The distance between the constant returns and the variable returns frontiers determines the scale efficiency component. Technical efficiency resulting from factors other than scale is determined by the distance from the variable returns frontier. Thus when efficiency is assessed under the assumption of variable returns, the efficiency scores for each organisation indicate only technical efficiency resulting from non-scale factors (Steering Committee, 1997).

It is important to separate technical and scale efficiency, as they provide different types of information. For example, decision making unit **c** (in Figure 2), is technically inefficient, as measured by the difference between **b** and **c**. Unit **c** could produce the same volume (and quality) of output with less input (move from **c** to **b**), or it could produce more output with the same input (move from **c** to **d**). Unit **b** is technically efficient, as it lies on the VRS frontier. However, unit **b** is scale inefficient (measured by the distance **a** to **b**).

1.2. Data Envelopment Analysis

DEA is a set of non-parametric programming techniques which assists with identifying the subset of a set of decision making units, which are considered to be best practice. DEA has been explored productively in many areas, particularly financial institutions, as well as public organisations such as educational institutions, health and correctional services. The notion of technical efficiency relating to the generation of maximum output given inputs, suggests that there is some upper or outward boundary or production possibilities frontier which can be estimated. Alternatively, it can be thought of as the existence of some sort of best practice. DEA is one technique for estimating what is best practice. Best practice decision making units are given a ranking of 1 and efficiency scores are assigned to other units by comparing them to best practice units.[5] DEA was pioneered by Charnes et al (1978) who were influenced by Farell (1957). There are now many texts offering a detailed discussion on DEA, including the algorithms used (see, for example, Lovell and Schmidt (1988), Färe, Grosskopf and Lovell (1985) and Coelli, Rao and Battese (1998)). The term decision making unit can apply to various organisations whose efficiency an analyst is concerned with. The set of decision making units to be analysed should be chosen with some caution, so that valid comparisons can be made. For this reason is has been decided in this study to include only the polytechnics and omit the other tertiary institutions (universities, colleges of education, private providers and wananga) as their inclusion in the analysis might lead to biased estimates of efficiency, because of differences in ownership structure, nature of operations, type of output provided and the quality of inputs.

DEA is the most common technique used in the analysis of efficiency of public sector organisations. Because it is a non-parametric technique, DEA has the advantage of avoiding the need to make assumptions regarding the functional form of the best practice frontier (eg. Cobb-Douglas or translog), as well as avoiding the need to make distributional assumptions

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4 The VRS allows for first increasing, then constant and then decreasing returns to scale.

5 All the calculations were performed using the program DEAP (see Coelli 1996).

regarding the residuals in the regression analysis. DEA can readily incorporate multiple inputs and be used to calculate technical and scale efficiency as it only requires information on output and input quantities. An alternative to DEA is the use of stochastic production frontiers (see Coelli *et al* 1998).

There are some limitations in using DEA. Firstly DEA identifies two or more decision making units that operate at best practice. This may be a significant problem in that within any sample it is likely that all units will be inefficient to some degree. An additional problem is that it is not possible to undertake tests of statistical significance with DEA scores as is possible with regression analysis.

Secondly a common practice with DEA is to derive efficiency scores using only those inputs managers control, and then use information on the non-included inputs to assess their impact. However, detailed data on all inputs may not be available. Ideally, data is needed on non-physical inputs, such as experience, information and supervision. Most importantly, there is the issue of the quality of the output. In the case of the New Zealand polytechnics focusing on outputs (students enrolled) without considering the quality of education provided might bias the efficiency scores in favour of high output and low quality institutions (if they exist). A lack of quality adjusted data for output levels necessitates the abstraction from the issue of quality. The lack of quality of data is not limited to DEA, it exists equally for stochastic production frontiers, as it does for more simpler methods of performance comparison, such as simple output-to-labour ratios.

These limitations aside, analysis of the sort presented in this paper is important in that it sheds some light on an important field of study. Policy makers and the general public are concerned with the issues of efficiency and the human capital formation process, and information on this process is important.

1.3. Data

In this paper, we have the number of full-time equivalent enrolments as the output measure and three inputs; the number of equivalent full-time (EFT) teaching staff, the number of EFT non-teaching staff and the value of fixed assets as a proxy for capital. We would prefer to use student contact hours as the measure of output and the number of teaching and non-teaching *hours* as inputs, but this data is not available.[6] Twenty-three provided data for 1995 and twenty-one for 1996.

By design and tradition New Zealand polytechnics provide a wide variety of academic, vocational and professional programs and cover an increasing number of subjects at various levels of specialisation. In 1997 there were 25 polytechnics operating in New Zealand with 46,647 full-time students and 94,201 in total (full time and part time*) (Tertiary Education Statistics* 1997).

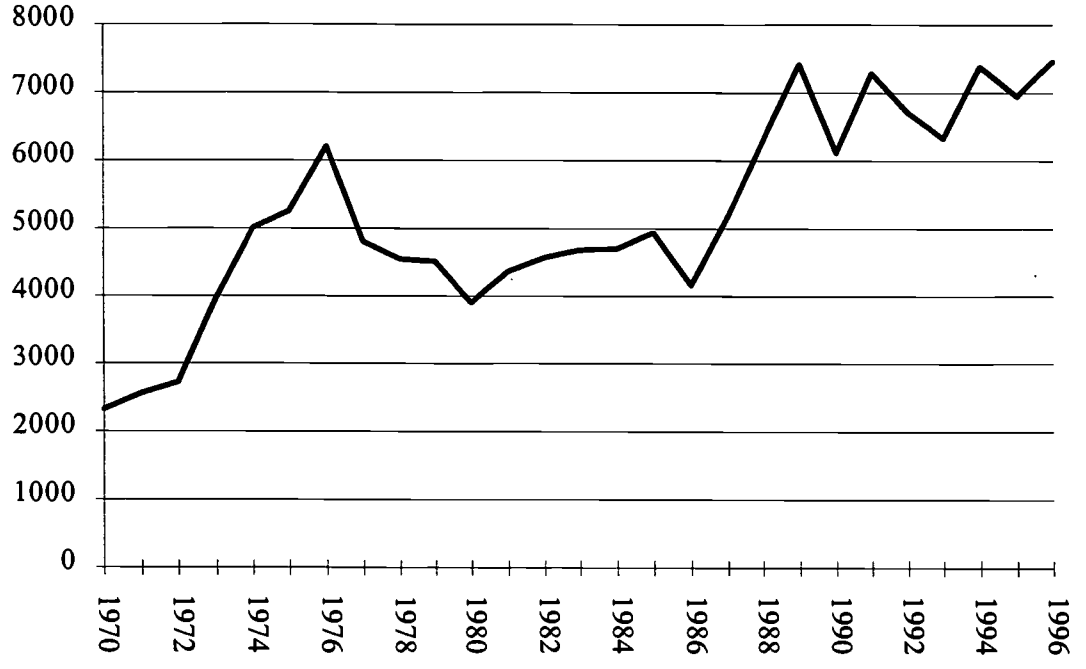
The polytechnics range in size from the Telford Rural Polytechnic with only 143 students in 1997 to the Auckland Institute of Technology with 11,207 and the Open Polytechnic with 17,865 *(Tertiary Education Statistics, 1977)*. By world standards many of the polytechnics are of relatively small size and therefore there have been calls for their number to be

[6] There is also a dearth of data on the composition of the output produced, in the form of different types of course enrolments.

rationalised in order to achieve economies of size. There have also been suggestions that some polytechnics might merge with universities (*Media Release* 31 October 1997).
Throughout the 1970s and 1980s student numbers in the polytechnics rose as did the level of real spending per student (full-time equivalent) which has heightened the need to operate the polytechnics at a higher level of efficiency (Figure 3).

The autonomy of the polytechnics was granted under the Education Amendment Act of 1990 when the Department of Education ceased to administer them. Today each is granted an annual allocation of funds from which it pays its staff and pays for its own buildings and within the limits of its Charter and the funds available, plans its own destiny. The polytechnics are governed by councils made up of members representing industry, local authorities, universities, staff and are compelled by law to issue Annual Reports which include statistical data on staff numbers, recurrent and capital expenditure and a range of performance indicators. It is this data that is used as the basis for the analytical work in this paper. In most cases however, the reported data relates only to overall institution activities;. Only some of the polytechnics reported data on their separate departments or centres.[7]

Figure 3: Real Expenditure per Student (equivalent full-time student) in New Zealand Polytechnics, 1970-1996, 1989/90 $.



Source: New Zealand, Dept. Of Education, *Annual Report. Education Statistics of New Zealand.*

[7] Moreover, some data anomalies can be found in the Annual Reports, which reduces the number of polytechnics which can be reliably included in the analysis.

2. Efficiency of New Zealand's Polytechnics

2.1. Efficiency Results

The technical and scale efficiency scores for the New Zealand polytechnics in 1995 and 1996 are presented in Table 1.[8] A polytechnic that is 100 per cent efficient is indicated by a score of 1. For scale efficiency, 'crs' denotes constant returns to scale, 'drs' denotes decreasing returns to scale and 'irs' denotes increasing returns to scale.

The average level of technical efficiency was high in 1995 and rose slightly in 1996. Scale efficiency was higher in both years, although there was a slight decline in 1996. Several of the polytechnics were identified to have a technical efficiency score of 1 and are hence identified as best practice. Aoraki, Auckland, Telford and Waiariki were best practice in both years. In terms of technical efficiency there appears a wide dispersal of results, indicating that there is scope for improving technical efficiency.

In terms of scale efficiency, in 1995 only four of the polytechnics operated with constant returns to scale. Nine of the polytechnics operated with decreasing returns to scale, indicating that they were producing *too much* output, relative to the optimal scale. The remaining ten polytechnics operated with increasing returns to scale, indicating that they were producing too little output. In 1996, six of the polytechnics operated with constant returns to scale, most (14) operated with increasing returns to scale and only one operating with decreasing returns to scale. It is clear that there is a scale problem in the New Zealand polytechnic system. Waiariki Polytechnic was the only polytechnic that was both technically and scale efficient in both years, although Aoraki and Auckland are effectively best practice institutions.[9] This suggests that there are opportunities for improving efficiency.

[8] In order to test the sensitivity of the results, DEA was also undertaken using only a one output and two input specification, with the two inputs being only the labour inputs. The results were substantially the same as those presented in Table 1 above. These results are available from the authors.

[9] This does not mean that these institutions are 100 percent efficient. Since input price data are not available, allocative efficiency cannot be measured. It is possible for an organisation to be both technically and scale efficient, but also allocatively inefficient, in that it does not use the appropriate input combination.

Table 1: Technical and Scale Efficiency of New Zealand Polytechnics, 1995 and 1996

Polytechnic	*Technical Efficiency 1995*	*Scale Efficiency 1995*	*Technical Efficiency 1996*	*Scale Efficiency 1996*
Aoraki Polytechnic	1.000	1.000 (crs)	1.000	0.990 (irs)
Auckland IT	1.000	0.948 (drs)	1.000	1.000 (crs)
Bay of Plenty Polytechnic	0.762	0.997 (irs)	0.881	0.999 (irs)
Central IT	0.919	0.999 (irs)	0.794	0.999 (irs)
Christchurch Polytechnic	0.861	0.929 (drs)	0.856	1.000 (crs)
Hawke's Bay Polytechnic	1.000	1.000 (crs)	0.840	0.992 (irs)
Hutt Valley Polytechnic	0.661	0.984 (irs)	0.714	0.994 (irs)
Manawatu Polytechnic	0.768	0.997 (drs)	0.831	0.996 (irs)
Manukau IT	1.000	0.932 (drs)	na	na
Nelson Polytechnic	0.740	0.997 (drs)	0.761	0.996 (irs)
Northland Polytechnic	0.889	0.980 (irs)	0.870	0.997 (irs)
Otago Polytechnic	0.807	0.968 (drs)	0.806	0.997 (irs)
Southland Polytechnic	0.793	0.983 (drs)	na	na
Tairawhiti Polytechnic	0.668	0.978 (irs)	0.789	0.984 (irs)
Tai Poutini Polytechnic	1.000	0.922 (irs)	0.986	0.782 (irs)
Taranaki Polytechnic	0.858	0.979 (drs)	0.735	0.991 (irs)
Telford Rural Polytechnic	1.000	0.817 (irs)	1.000	0.988 (irs)
Open Polytechnic of NZ	1.000	0.992 (drs)	na	na
Unitec IT	na	na	1.000	1.000 (crs)
Waiariki Polytechnic	1.000	1.000 (crs)	1.000	1.000 (crs)
Waikato Polytechnic	1.000	1.00 (crs)	0.895	1.000 (crs)
Wairarapa Community Polytechnic	1.000	0.745 (irs)	0.897	0.901 (irs)
Wanganui Regional Community Polytechnic	0.769	0.992 (irs)	1.000	1.000 (crs)
Wellington Polytechnic	na	na	1.000	0.997 (drs)
Whitireira Community Polytechnic	0.580	0.981 (irs)	na	na
Arithmetic Average	0.873	0.962	0.895	0.934
Median	0.889	0.983	0.895	0.996

* known as the Eastern Institute of Technology in 1996

2.2. The Performance of Individual Centres

Unfortunately, most of the polytechnics do not report their operations on a centre by centre basis in sufficient detail. From the limited information available six different groupings were constructed - Arts, Commerce, Health, Science and Engineering, Maori and Other. Separate DEA estimates of efficiency were made for each centre. However, the sample sizes are small and may not necessarily represent efficiency throughout the New Zealand polytechnics - they represent only the status for those institutions which provide the sufficient data. The output measure is still the number of students (EFTS) but the input measures are total expenditure on teaching related expenses and total expenditure on administration. Only a handful of the polytechnics provide details on the number of staff at the division level, so that for this analysis it is necessary to use expenditure as the labour input proxy.

The efficiency scores for 1996 are presented in Table 2. Technical efficiency appears to be lowest for the science and engineering centres. While these centres can be expected to be more demanding in terms of inputs – requiring as they do sophisticated technical equipment - it should be noted that the scores relate to the relative efficiency of science and technology course delivery in the 13 polytechnics which reported the necessary data. Thus, it is valid to compare the different centres. Substantial scale inefficiency also exists across each of the centres.

Table 2: Efficiency of Individual Centres of New Zealand's Polytechnics, 1996

Centre	*Number of Polytechnics*	*Average Technical Efficiency*	*Average Scale Efficiency*
Arts	11	0.69	0.83
Commerce	14	0.73	0.77
Health	10	0.73	0.72
Science & Engineering	13	0.51	0.89
Maori studies	6	0.92	0.78
Other	9	0.74	0.88

Care should be exercised in comparing across centres. While Science and Engineering centres appear to be the least technically efficient, it is possible that the best practice frontier in these educational areas is shifting rapidly so that a number of institutions may not have caught up with best practice. This situation would drive down the average technical efficiency score. In the Maori centres the best practice frontier may not be shifting rapidly. This suggests the need for an in-depth analysis of shifts in the production possibilities frontier in the different centres over time.

3 New Zealand's Polytechnics in an International Context

In the previous section, the analysis identified best practice purely in terms of the New Zealand polytechnics. It is also useful to compare similar institutions in other countries, as the identification of best practice partners need not be confined to a national boundary. Moreover, markets for education and training are becoming international. Hence, education institutions are finding that they are increasingly forced to compete with institutions from overseas.

For the purpose of this comparison we have used the TAFE institutes in the Australian State of Victoria. In Australia, the main providers of post-secondary vocational education and training are the government administered technical and further education institutes, which are known as TAFE institutes. Like the New Zealand polytechnics, Australian TAFE institutes provide a wide variety of courses including vocational training for apprenticeships, diploma courses in applied science, technology, engineering, business, building, general education and leisure and art courses. Like the New Zealand polytechnics the Australian TAFE institutes evolved out of technical schools and colleges that were common in both countries. There are a few differences between the Australian TAFE institutes and the New Zealand polytechnics. In the TAFE institutes the proportion of students that that are enrolled as part-time students (80-85 per cent) is higher than in the polytechnics. In recent years some of the polytechnics have been allowed to offer degree courses, a right that has been denied the Australian TAFE institutes.

Australian TAFE institutes come under the jurisdiction of state governments and thus operate in a different fashion from state to state. TAFE institutes have operated over the last few years as autonomous institutions, like in New Zealand only in the State of Victoria. In New South Wales and Queensland TAFE institutes are administered on a departmental basis which means that some of the costs incurred in their operation are subsumed into the general expenses of the two states' relevant departments of vocational education and training. In recent years TAFE institutes in South Australia, Tasmania and Western Australia have been going through a process of reorganisation from a department basis to an autonomous basis. These differences make comparisons with New Zealand polytechnics problematic.

As the Victorian TAFE institutes are the only ones that have operated throughout the 1990s on similar basis to those in New Zealand this paper limits itself to these institutes. Data relates to the year 1995 only. In this year the value of fixed assets for New Zealand were revalued using the exchange rate prevailing between the two countries. The two labour inputs are similar in definition - teaching staff and non-teaching staff. The output measure presents more problems. The Victorian TAFE institutes publish data on the number of annual student contact hours (SCH) but unfortunately similar data is not available for the New Zealand polytechnics. Thus, in order to ensure comparability the measure of output used for the Victorian TAFE institutes is also the number of full-time equivalent students.[10]

Because the pool of institutions to be compared is broadened by the inclusion of the Victorian TAFE institutes, the technical and scale efficiency scores may differ from those reported in Table 1. For example, it is possible that New Zealand's polytechnics operate with a high degree of technical efficiency relative to the best practice frontier constructed using only New Zealand institutions but when compared with Australian institutions their relative performance may be lower, or higher.

The efficiency scores derived from applying DEA to the combined New Zealand and Victorian data are presented in Table 3. Both the median technical and scale efficiency scores are lower for New Zealand's polytechnics, with a greater difference in the technical efficiency scores. However, the differences are not substantial. This suggests that New Zealand's polytechnics are performing well relative to the Victorian institutions.

The technical efficiency scores presented in Table 3 are lower in many cases than those presented in Table 1, and suggest even greater scope for improving technical efficiency. That is, when the best practice frontier is constructed using only New Zealand institutions, the individual New Zealand institutions emerge in a more favourable light. The simple correlation between the technical efficiency scores presented in Table 1 (for 1995) and those presented in Table 3 is 0.86. In the light of international comparison, six polytechnics emerge as best practice institutions with respect to technical efficiency, regardless of the level of analysis - Auckland, Tai Poutini, Telford Rural, The Open, Waiariki and Wairarapa Community.

[10] An alternative measure is to use the total number of enrolments. However, this generates very low efficiency scores for New Zealand, because of the large number of part-time enrolments in Victorian TAFE. These results are available from the authors. The use of *full-time equivalent students* for both New Zealand and Victoria is the best measure of output available, for international comparisons to be made.

Table 3: The Efficiency of New Zealand's Polytechnics Relative to Australian (Victorian) TAFE Institutes

Polytechnic	*Technical Efficiency 1995*	*Scale Efficiency 1995*
Aoraki Polytechnic	0.72	0.88
Auckland IT	1.00	0.71
Bay of Plenty Polytechnic	0.56	0.90
Central IT	0.78	0.99
Christchurch Polytechnic	0.53	1.00
Hawke's Bay Polytechnic	0.93	0.94
Hutt Valley Polytechnic	0.41	0.91
Manawatu Polytechnic	0.60	1.00
Manukau IT	0.61	0.96
Nelson Polytechnic	0.54	0.98
Northland Polytechnic	0.87	0.95
Otago Polytechnic	0.49	0.99
Southland Polytechnic	0.54	0.90
Tairawhiti Polytechnic	0.55	0.91
Tai Poutini Polytechnic	1.00	0.55
Taranaki Polytechnic	0.60	0.93
Telford Rural Polytechnic	1.00	0.56
The Open Polytechnic	1.00	0.94
Waiariki Polytechnic	1.00	1.00
Waikato Polytechnic	0.87	0.84
Wairarapa Community Polytechnic	1.00	0.66
Wanganui Regional Community Polytechnic	0.60	0.95
Whitireira Community Polytechnic	0.37	0.86
MedianNew Zealand Polytechnics	0.61	0.93
Median Victorian TAFE institutes	0.69	0.96
Median All Institutions	0.68	0.94

The distribution of technical and scale efficiency scores is highlighted in Table 4. It is clear, that the inclusion of the Victorian TAFE institutes reduces the recorded technical efficiency of New Zealand's polytechnics, and also to a smaller degree, scale efficiency.

Table 4: Distribution of Technical and Scale Efficiency Scores

Efficiency Score	*Technical Efficiency Percent of Polytechnics*	*Scale Efficiency Percent of Polytechnics*	*Relative Technical Efficiency Percent of Polytechnics*	*Relative Scale Efficiency Percent of Polytechnics*
0.30 < 0.40	0%	0%	4%	0%
0.40 < 0.50	0%	0%	9%	0%
0.50 < 0.60	4%	0%	22%	9%
0.60 < 0.70	9%	0%	17%	4%
0.70 < 0.80	22%	4%	9%	4%
0.80 < 0.90	17%	4%	9%	13%
0.90 < 0.95	4%	17%	4%	30%
0.95 < 1.00	0%	57%	0%	26%
1.00	43%	17%	26%	13%

4. Economies of Size

An important issue for policy makers is whether there is a link between the size of a polytechnic (measured as the number of students full-time equivalent) and the average cost of operating the polytechnic (measured as operating expenses divided by the number of students). The scale efficiency measures presented in Table 1 and 3 relate to cases where all inputs are varied by the same proportion. Equally important is the case where the size of an institution is varied, with inputs allowed to change in varying proportions. This is known as economies of size.

The existence of economies of size in the polytechnics is highlighted in Table 5, for 1995 and 1996. Several output intervals are presented together with the associated average cost of servicing students. It is clear from both the unweighted and the weighted averages, that there are benefits in terms of costs in expanding the size of New Zealand's polytechnics.[11]

The simple correlation coefficients between the number of students enrolled and average costs was -0.20 in 1995 and -0.38 in 1996, indicating an expected negative association between cost and the size of output. This suggests that, all else equal, expanding the size of the polytechnics should result in reductions in the average costs of operating these institutions.

It is pertinent also to ask whether there are any links between technical and scale efficiency and economies of size. For 1995, the simple correlation coefficient is -0.13 between average cost and technical efficiency, indicating that higher levels of technical efficiency are associated with lower average costs. There is a large negative correlation between average cost and scale efficiency; -0.27. Thus, increasing technical and scale efficiency can be expected to result in reductions in average costs.

These conclusions are based on the assumption that the quality of output - the education, training and learning processes - are not adversely affected in the process of increasing size (or scale). Policy needs to be sensitive to the fundamental tasks of the polytechnics and prevent any changes to the operating environment of the polytechnics from jeopardising these responsibilities. Thus, it is important that any measures designed to increase the size or scale of the polytechnics consider fully all of the implications of doing so.

[11] Some of the cells have only a small proportion of polytechnics, so that little emphasis should be placed on them, see for example, the cell in the 2,500 to 4,500 for 1995 and the cell 5,000 to 5,500 for 1996.

Table 5: Economies of Size in New Zealand Polytechnics, 1995 and 1996

Output Interval	*Proportion of Polytechnics 1995*	*Average Cost ($000) 1995*	*Proportion of Polytechnics 1996*	*Average Cost ($000) 1996*
0 < 500	12%	10.13 (9.85)	13%	10.76 (10.49)
1000<1500	32%	8.53 (8.57)	25%	8.89 (8.94)
1500 < 2000	16%	7.32 (7.26)	17%	11.20 (11.26)
2000 < 2500	12%	9.27 (9.24)	13%	9.36 (9.29)
2500 < 4500	4%	2.65 (2.65)	8%	9.56 (9.53)
4500< 5000	8%	8.51 (8.51)	8%	8.83 (8.83)
5000 < 5500	8%	6.88 (6.87)	4%	7.94 (7.94)
5500 plus	8%	7.81	13%	7.69 (7.84)

Figures in brackets are weighted averages.

5. Summary

The provision of vocational education and training is likely to gain in importance over the next few years as New Zealand's economic development becomes increasingly dependent upon technology and knowledge. New Zealand polytechnic's will come under increased pressure to provide vocational education and training in a cost efficient manner. So far there has been little empirical analysis of the performance of the polytechnics in New Zealand. DEA is a useful technique for analysing the technical and scale efficiency of government owned institutions that operate in market where price and cots are distorted. In this paper data envelopment analysis has been used to analyse the technical and scale efficiency of the polytechnics and economies of size. The results indicate that in terms of technical efficiency there is a fairly wide dispersal and therefore there are opportunities for improving the technical efficiency (modifying the input-output ratios). There is also potential for increased scale efficiency within the system as a whole. To the extent that the Victorian and New Zealand are valid comparison partners - and we believe they are - New Zealand polytechnics appear to be less efficient. Moreover, the issue of operational efficiency has become very important in Victoria and several initiatives have been undertaken to improve efficiency. Thus, it is likely that the performance differences will change over time.

Further research is needed on the issue of technical and scale efficiency in New Zealand's polytechnics. In particular, the use of panel data, would enable analysis of changes in efficiency over time. Moreover, it seems pertinent to compare New Zealand's polytechnics with those from countries such as Canada, South Africa and the United Kingdom. Such analysis would draw more refined measures of the performance of New Zealand's polytechnics.

Finally many of the polytechnics appear to be too small to capture all of the economies associated with scale and size. The majority of the institutions therefore could substantially lower average costs by expanding their activities. This does not necessarily mean that the appropriate response is to merge institutions in order to create larger sized units as has been attempted in the Australian higher education system over the past ten years (see for instance Gregory, 1995; Lloyd et.al. 1993). The appropriate response may simply be to freeze the number of polytechnics and expand enrolments in those institutions where there is the greatest scope for achieving economies of size and scale and lower average costs through expansion.

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