Estimation of Cost Efficiency in Australian Universities

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EXTENDED ABSTRACT

Various studies have been carried out on estimation of cost functions for Australian universities, for example, Throsby (1986) and Heaton and Throsby (1997, 1998), and Lloyd et al (1993). While estimating a cost function with different purposes, all of the studies have estimated an aggregate cost function in the sense that the sampled institutions were assumed to have the same cost function. The present study differs from the previous studies in two aspects; first, it employs the stochastic frontier analysis for the specification of a cost function for Australian universities, which allows for the estimation of cost efficiency for each university. Secondly, a panel data set is utilised which enables not only comparisons of cost efficiency between universities, but also hypothesis-testing of assumptions about university cost functions. The data set for the present study are comprised of student, staff and expenditure statistics for 36 Australian universities over the period 1995-2002, obtained from the Department of Education, Science and Training (DEST). The student statistics enable a breakdown of student numbers by field of study and mode of attendance. Research expenditure has been excluded so the cost efficiency estimated in the study only reflects how efficiently resources were used for teaching. The findings from the study contribute to the formulation of an equity-efficiency based policy on university-financing. The main conclusion reached is that the hypothesis that universities are operating at minimum cost efficiency is rejected over the sample period 1995-2002. The period encompasses the peak of the debate on reform of higher education, including conflicting views on this dimension of university performance. The main direction of further research is to extend the model to include factors that explain the efficiency rankings and thereby provide scope for universities to strengthen their absolute and relative performance over time.

1. Introduction

The purpose of this paper is to quantify the efficiency with which Australian universities utilise their existing resources. The study estimates the cost efficiency of Australian universities over the period 1995-2002 using stochastic frontier analysis. Stochastic frontier analysis has been used extensively in other areas of economics such as airlines (Cornwell, et al, 1990) and the manufacturing sector (Hay and Liu, 1997**)** but it is the first time that the methodology has been applied to estimating cost efficiency of universities. The findings also provide input into recent policy debate on the scope for accommodating recent cutbacks in government funding to universities through increasing efficiency and other mechanisms.

There is no shortage of empirical studies of the cost function of the higher education sector in Australia (see Throsby, 1986; Lloyd, Morgan and Williams, 1993; Heaton and Throsby, 1997). The methodology used in these studies is to estimate either an aggregate output or multiple output cost function. The main finding of this literature is to demonstrate the existence of internal economies-of-scale with minimum average and marginal costs of around $11, 500 per EFTSU load in 1996 dollars. However, these studies assume that the cost function of each university lies along the efficiency frontier. The empirical methodology used in the present study provides a means of testing the null hypothesis of optimal cost efficiency and rejects it.

A relatively small empirical literature has examined the technical efficiency (defined as the ability to minimise input use for a given output) of universities; see Coelli (1996) for Australia and McMillan and Datta (1998) for Canada. Restriction to technical rather than cost efficiency avoids the imposition of behavioural assumptions such as cost minimisation. Both studies use the non-parametric methodology of data envelopment analysis (DEA) based upon linear programming techniques. An advantage of DEA analysis is that it avoids potential problems involved in arbitrary specification of cost or production functions. But a major shortcoming is its inability to provide statistical tests of parameter estimates.

At a policy level, the issue of university efficiency has not been addressed in any systematic way but did receive attention in the 2001 Senate Inquiry as well as policy discussion papers preceding the new reforms (see Commonwealth of Australia, 2001; Department of Education, Science and Training, 2002). These documents give conflicting views, reflecting the different definitions of efficiency and lack of empirical evidence. For example, at the Senate Inquiry, policymakers argued that further efficiency gains might be achieved while universities felt that this scope was exhausted.

Further understanding of the scope for efficiency gains is of considerable interest for policymakers at a government and university level. But the issue extends beyond this interest: if scope exists for further efficiency gains, less adjustment is borne by other variables such as student fees for meeting present and projected funding gaps.

The major contribution of this study is to help fill this gap in information on a key dimension of university performance, namely by estimating cost efficiency. Two qualifications to the findings deserve mention at the outset, the issue of quality and the factors behind difference in efficiency across universities. The perception of declining quality of higher education dominates much of the debate and affects the interpretation of any cost and efficiency estimates insofar as a relatively high ranking may reflect a fall in the quality of education rather than a more effective use of resources. We attempt to control for quality by introducing university-specific data on staff/student ratios as a separate variable affecting university costs. But any inferences that are drawn are subject to the problem of the reliability of this measure in capturing quality changes.

The remainder of the paper examines in more detail the above issues. Section II discusses the issue of cost efficiency in the context of the debate on financing of Australian universities. Sections III and IV discuss the empirical methodology used in the analysis, estimation results and their interpretation. Section V presents the policy implications, main conclusions and directions for future research.

2 Background and issues

The changes in financing sources of Australian universities over the sample period (1995-2002) are given in Table 1 and need to be viewed within the context of longer-term trends in government financing of higher education (see Marginson, 2001). Government expenditure on higher education has halved as a percentage of GDP since its peak of 1.5 in 1976-77. Over the same period, student numbers increased by a multiple of three with a rise of one third recorded in the past decade.

Given the size of the government cutbacks, a key policy issue is how these changes are being accommodated at a university level. A number of variables may bear the burden of adjustment, including student numbers, revenue and costs.
On the cost side, the composition remained fairly stable, reflecting the dominant share of wage costs: the share of the staff wage bill fell from 63.6 percent in 1995 to 58.7 percent of total costs in 2002. But given the retrenchments that have taken place in the past few years and the pressure placed on universities from inadequate wage indexation to allow for enterprise bargaining, there is little scope for significant further reduction.

Table 1. Revenues and expenditures of Australian universities, 1995-2002(in percent)

Revenues	**1995**	**2002**
Common. Govt. grants	57.2	40.1
HECS	12.0	15.8
Fees and charges	11.7	21.2
Investment income	4.0	1.8
State govt.	1.4	4.0
Other	13.8	17.1
	100.0	100.0
Costs		
Salaries	63.6	58.7
(academic)	(33.1)	(31.2)
Other	36.4	27.5
	100.0	100.0
Memorandum items		
Average real revenue per EFTSU (in $)	7,535	11,614
Average real costs per EFTSU (in $)	15,069	15,677
EFTSUs	544,146	626,749
Student/staff ratio	15.3	21.4

Source: DEST Selected Higher Education Statistics

This leaves one further option, increasing efficiency. The concept and measurement of efficiency depend upon the definition used (see below). The only available empirical evidence for Australia is based upon a multi-stage DEA study by Coelli (1996) of technical efficiency for 36 universities in 1994. This study is, however, restricted to an analysis of administrative efficiency and found a relatively high average efficiency score of 0.8 against a benchmark of unity. An empirical gap still exists on identifying changes in technical and cost efficiency of teaching (and research) output and the scope for further increases in efficiency.

3 Methodology

The analytical framework of the present study is based upon cost frontier analysis, which defines cost inefficiency as the ratio of estimated cost frontier to observed cost (Kumbhakar and Lovell, 2000). Two approaches have been used to estimate a cost frontier; stochastic frontier analysis (SFA) and data envelopment analysis (DEA) (for surveys, see Lovell, 1993; Coelli et al (1998)). A major drawback of DEA is that it does not allow hypothesis testing and assumes that every observation unit operates under the same technology. In the context of a panel data set, DEA virtually treats individual differences as fixed, ignoring the possibility of them being random. As noted above, the Australian tertiary education sector has undergone substantial changes during the past decade, it is expected that the environment under which a university operates may be different from university to university. Hence, it is advisable to subject such individual differences to a formal screening process. SFA allows statistical hypotheses testing with regard to differences in university cost frontiers and is therefore chosen over DEA for the present study.

It is conjectured that universities have different cost frontiers, C_i, for given vectors of output and factor prices, Y_i and P_i, respectively, where i indexes the university. The C_i may be represented by a function such as, $C_i = f(Y_i, P_i)$, where $f(\bullet)$ characterises the underlying technology. The observed cost (nominal expenditure) for Y_i is denoted by E_i which equals $P_i' X_i$, where X_i is a vector of input factors (P_i and X_i are conformably dimensioned).

To take into account random shocks to the cost frontier, a stochastic component, ε_i, is included in the cost frontier, namely,

$$C_i = f(Y_i, P_i, \varepsilon_i) \qquad (1)$$

Assuming a Cobb-Douglas functional form for the $f(\bullet)$ and omitting P_i since factor prices (salaries of academic and non-academic staff) facing Australian universities are similar (Lloyd et al, 1993), (1) is written as,

$$C_i = \alpha_{i0} \prod_j Y_{ij}^{\beta_{ij}} \varepsilon_i \qquad (2)$$

where Y_{ij} is the jth element of Y_i, α_{i0} (intercept term) and β_{ij} s (university cost responsiveness to output change) are parameters to be estimated. (2) represents the stochastic cost frontier for University i.

It follows by definition that $E_i = P_i' X_i \geq C_i = f(Y_i, P_i, \varepsilon_i)$, which implies that cost inefficiency has led to University i to overspend by an amount of $E_i - C_i$ (the difference between observed and estimated minimum cost).

Denote cost inefficiency by $u_i (\geq 0)$ and follow Kumbhakar and Lovell (2000), the university expenditure function is written as:

$$E_i = \alpha_{i0} \prod_{j=1}^{k} q_{ij}^{\beta_{ij}} \varepsilon_i \, e^{u_i} \qquad (3)$$

so that the cost efficiency (CE) can be measured by the ratio of C_i to E_i,

$$CE_i = \exp(-u_i) \, . \qquad (4)$$

(3) can be rewritten in the following panel data model specification,

$$\ln E_{it} = \ln \alpha_{i0} + \sum_j \beta_{ij} \ln Y_{ijt} + v_{it} + u_i$$

$$\text{or } e_{it} = \beta_{i0} + \sum_j \beta_{ij} y_{ijt} + v_{it} + u_i \qquad (5)$$

where the lower case letters denote logarithms, subscript t indexes time period and v is a white noise.

Estimation of the inefficiency component depends on whether (5) is specified as a random or fixed effects model. A random effects model suggests that inefficiency differences between the universities are independent of differences in university attributes, that is, the u_i s, are independent of the y_{ijt} s. A fixed effects model, however, is indicative of the u_i s being conditional on the y_{ijt} s. Since the sample period spans only eight years, such a difference in model specification has a significant impact on coefficient estimates (Hsiao, 2003, p. 37), which, in turn, affect estimation of cost inefficiency. This gives rise to the use of a specification test, such as Hausman (1978) to select one of the two model specifications.

(5) indicates that cost inefficiency is different between universities but remains unchanged over time. To overcome this limitation, the procedure proposed by Cornwell et al (1990) is followed, which assumes that cost inefficiency evolves over time according to

$$u_{it} = \delta_{i0} + \delta_{i1} t + \delta_{i2} t^2 \qquad (6)$$

where δ_{i0}, δ_{i1} and δ_{i2} are cost-time variant university-specific parameters to be estimated. There are two steps involved in estimation of the δ_{i0}, δ_{i1} and δ_{i2}. In the first step, (5) is either estimated by a least squares dummy variable estimator if a fixed effects model specification is accepted, or by an estimated generalised least squares estimator (EGLS) if a random effects model specification is accepted. In the second step, the estimated residuals in step one are regressed on t and t^2 to obtain the estimates of the δ_{i0}, δ_{i1} and δ_{i2}, denoted by $\hat{\delta}_{i0}$, $\hat{\delta}_{i1}$ and $\hat{\delta}_{i2}$. Thus, the estimates of the u_{it} are computed by $\hat{u}_{it} = \hat{\delta}_{i0} + \hat{\delta}_{i1} t + \hat{\delta}_{i2} t^2$, which are consistent estimators when both the numbers of time period and panel units are large (Greene, 1993).

To ensure the non-negativeness of the inefficiency component (ruling out the possibility that observed cost lies below minimum cost) requires a normalisation of the $\hat{u}_{it}$ s, which amounts to re-defining inefficiency as $\hat{u}_{it} - \hat{u}_{\min t}$, where $\hat{u}_{\min t}$ is the smallest $\hat{u}_{it}$ for period t. For example, suppose university A's inefficiency at time t is $\hat{u}_{At} = 0.8$ and university B's is $\hat{u}_{Bt} = -0.6$, then, the $\hat{u}_{\min t}$ will be $\hat{u}_{Bt} = -0.6$, namely, university B is the most efficient university since its cost efficiency is 100% ($\hat{u}_{Bt} - \hat{u}_{\min t} = -0.6 - (-0.6) = 0$), and using (4) gives $CE_B = \exp[-(\hat{u}_{Bt} - \hat{u}_{\min t})] = 1$). The estimation procedure allows for time-varying costs and, hence, the possibility that the most efficient university may alter over the sample period.

4 Estimation and Empirical Results

The data set for the present study are comprised of student, staff and expenditure statistics for 36

Australian universities over the period 1995-2002, obtained from the Department of Education, Science and Training (DEST). The student statistics enable a breakdown of student numbers by field of study and mode of attendance. As noted above, a number of studies have been conducted to estimate cost functions for the Australian tertiary sector, including Throsby (1986), Heaton and Throsby (1997, 1998), and Lloyd et al (1993). A commonality among these studies is that costs are assumed to be a function of student numbers only since universities face similar factor prices (staff salaries are more or less identical across universities).

The cost determinant variables that appear on the right hand side of (5) include the following: (a) postgraduate students (PG); (b) undergraduates (UG); (c) share of science-engineering students (SE); (d) share of business students (SB) and (e) share of other students (SO). To reflect the influence of teaching quality on cost formation, a sixth variable, student-staff ratio (SR) is added. Staff data by institution from 1995 to 1999 were not available and therefore were estimated by applying staff growth rates at the national level to existing staff numbers.

The six cost determinants listed above do not include research output; research costs are measured by the difference between total expenditure and research expenditure. Data on research costs are not published either by DEST or Australian Bureau of Statistics (ABS). However, shares of research income by institution from 1995 to 1999 and total research expenditures by all the universities from 1995 to 2002 are available at DEST and ABS, respectively. It is assumed that the share of research income at an institution is positively correlated with its share of research expenditure. Thus, research expenditure for each university is estimated by applying its share of research income (expenditure) to the total research expenditure.

The estimated random effects panel data model is as follows,

$$\begin{aligned} e_{it} &= \beta_{i0} + \beta_{i1}\ln PG + \beta_{i2}\ln UG \\ &\quad + \beta_{i3}\ln SE + \beta_{i4}\ln SB \\ &\quad + \beta_{i5}\ln SO + \beta_{i6}\ln SR + v_{it} + u_i \end{aligned} \tag{7}$$

where i =1 to 36, t =1995 to 2002.

The first step in the analysis is to test if each of the universities has a different cost function. This amounts to conducting an F-test for the following hypotheses.

$$H_0 : \beta_{1,0} = \cdots = \beta_{36,0}; \beta_{1,k} = \cdots = \beta_{36,k}; k = 1 \, to \; 6$$
$$H_1 : at\ least\ one\ of\ the\ \beta s\ is\ different.$$

The F-test indicates that the above null hypothesis should be rejected, which vindicates use of a panel data modelling approach. Further F-tests are conducted to find out whether the universities share the same intercept or the same slope coefficients. Such tests reveal that the universities share the same slope coefficient, namely, $\beta_{1,k} = \cdots = \beta_{36,k} = \beta_k; k = 1 \, to \; 6$. This implies that the universities have the identical "technology" to produce students of various fields in terms of cost elasticity of student. However, the universities do have a different intercept coefficient, namely, the null hypothesis $H_0 : \beta_{1,0} = \cdots = \beta_{36,0}$ is rejected. This is followed by a Hausman test, which gives rise to a random effects specification for the panel model. This implies that university cost inefficiency is exogenous to student numbers. The estimated model (by the EGLS procedure) is given below with the asymptotic t-ratios in the parentheses.

$$\begin{aligned} \hat{e}_{it} &= \underset{(11.1485)}{7.9291} + \underset{(2.9080)}{0.1213}\ln PG_{it} + \underset{(7.0404)}{0.4785}\ln UG_{it} \\ &\quad + \underset{(3.3625)}{0.6351}\ln SE_{it} + \underset{(2.9215)}{0.3674}\ln SB_{it} + \\ &\quad \underset{(1.8280)}{0.3747}\ln SO_{it} - \underset{(-2.6375)}{0.0721}\ln SR_{it} \end{aligned} \tag{8}$$

$$R^2 = 0.49 \quad F = 45.66 \quad Hausman\ test = 0.0001$$

The t-ratio of the variable, $\ln SO_{it}$, is insignificant at a 5 percent level, which suggests that students of fields other than science/engineering and business have an insignificant impact on university cost, *ceteris paribus*. All other independent variables, including the quality variable are significant at a 5 percent level; each coefficient measures the cost elasticity response. For example, the estimates show that a 10 percent increase in undergraduates increases costs for all universities by the same amount, almost 5 percent. Increasing the relative share of business students has a smaller effect on costs compared to non-business students. The elasticity of university costs in response to the proportion of science to business students is almost double that of business students alone while the cost elasticity of undergraduates is four times that of postgraduates. Quality of teaching has a small but significant negative impact on costs: a rise in the student/staff ratio of 1 percent reduces costs by less than 0.1 percent.

Table 2. Efficiency estimates (ratio of minimum feasible cost to actual cost)

Year	1995	1996	1997	1998	1999	2000	2001	2002
ACU	0.58	0.58	0.59	0.60	0.58	0.52	0.46	0.40
CQU	0.85	0.80	0.75	0.71	0.65	0.56	0.47	0.39
CSU	0.69	0.66	0.64	0.65	0.64	0.60	0.56	0.53
CUT	0.58	0.55	0.52	0.51	0.48	0.43	0.38	0.33
DU	0.56	0.55	0.54	0.53	0.50	0.44	0.38	0.31
ECU	0.57	0.55	0.54	0.55	0.53	0.49	0.45	0.40
GU	0.61	0.58	0.55	0.54	0.51	0.45	0.39	0.34
JCU	0.58	0.60	0.61	0.63	0.62	0.57	0.50	0.44
LTU	0.55	0.57	0.58	0.59	0.56	0.49	0.41	0.33
MQU	0.64	0.66	0.67	0.67	0.63	0.54	0.45	0.35
MOU	0.52	0.50	0.49	0.48	0.45	0.40	0.35	0.30
MDU	0.87	0.85	0.82	0.81	0.77	0.68	0.59	0.50
NTU	0.80	0.86	0.89	0.92	0.87	0.76	0.63	0.49
QUT	0.58	0.56	0.54	0.54	0.52	0.47	0.43	0.39
RMIT	0.54	0.56	0.57	0.57	0.53	0.46	0.37	0.29
SCU	0.96	0.96	0.94	0.94	0.89	0.79	0.69	0.57
SUT	0.81	0.87	0.89	0.89	0.81	0.66	0.50	0.35
ANU	0.19	0.20	0.21	0.22	0.22	0.20	0.17	0.15
FU	0.90	0.90	0.91	0.97	1.00	1.00	1.00	1.00
UAD	1.00	0.87	0.79	0.76	0.72	0.68	0.65	0.63
UML	0.56	0.60	0.62	0.64	0.61	0.53	0.44	0.35
UNE	0.56	0.57	0.58	0.60	0.58	0.52	0.46	0.39
NSW	0.47	0.50	0.52	0.55	0.55	0.50	0.45	0.38
UNC	0.68	0.69	0.70	0.71	0.67	0.60	0.51	0.42
UQ	0.76	0.72	0.68	0.65	0.58	0.49	0.41	0.32
USD	0.36	0.41	0.45	0.49	0.49	0.45	0.39	0.32
UWA	0.92	0.78	0.69	0.66	0.63	0.59	0.56	0.55
UB	0.98	1.00	1.00	1.00	0.93	0.80	0.66	0.51
UC	0.85	0.83	0.81	0.81	0.77	0.70	0.62	0.54
USA	0.60	0.58	0.57	0.59	0.57	0.54	0.50	0.45
USQ	0.91	0.82	0.77	0.77	0.75	0.71	0.69	0.67
UTAS	0.77	0.77	0.77	0.78	0.75	0.67	0.59	0.50
UTS	0.61	0.62	0.63	0.64	0.61	0.55	0.48	0.40
UWS	0.55	0.55	0.54	0.55	0.54	0.49	0.45	0.39
UW	0.74	0.72	0.71	0.72	0.71	0.67	0.62	0.58
VUT	0.67	0.69	0.69	0.69	0.64	0.56	0.46	0.36

In interpreting the results, it is recalled that the normalisation procedure estimates university efficiency relative to the most efficient university (benchmark) in a given year. The benchmark is endogenously determined and hence, can change over time as shown in the Table. It appears that the non-Go8 universities have dominated the top 10 places in terms of cost efficiency. Only the University of Adelaide and the University of Western Australia are in the top 10 throughout the sample period. The most efficient universities are the University of Ballarat and Flinders University with the latter outpacing the former in recent years. The least efficient in every year is ANU. There is no discernible pattern of an increase in cost efficiency (increase in ratio) over time. Further, the results suggest scope for increasing cost efficiency: in 2002, the average cost efficiency is below 0.5.

5. Policy implications and conclusions

Three main policy issues arise from the empirical findings: the scope for efficiency adjustment in response to government funding cutbacks, the use of efficiency rankings as performance criteria for government funding of teaching resources and measures to increase relative efficiency.

An earlier study by Heaton and Throsby (1997) examined the policy implications of estimated university cost functions of Australian universities, including the effects of cuts in government funding. The main finding of this study is that universities are not operating efficiently, as measured by cost efficiency and in relative terms. But on average the size of efficiency gaps is below 0.5 suggesting scope for further gains in cost efficiency.

A second issue concerns the potential policy use of the efficiency rankings in allocating government funding of teaching resources. Unlike research funding which is based upon a competitive set of performance criteria, the current system of block operating grants and its successor (Commonwealth Grant Scheme) are input based having little or no effect on government funding for teaching. The efficiency rankings provide quantitative measurement of one dimension of university output that might be used together with other criteria such as undergraduate degree completions and quality control benchmarks. A third issue follows from the second: if the rankings are to be of operational use, what measures are within university control to improve relative efficiency, especially in relation to the findings of scale effects of cost studies? Statistical support for the random effects model implies that student numbers are exogenous to efficiency.

The main conclusion reached is that the hypothesis that universities are operating at minimum cost efficiency is rejected over the sample period 1995-2002. The period encompasses the peak of the debate on reform of higher education, including conflicting views on this dimension of university performance. The main direction of further research is to extend the model to include factors that explain the efficiency rankings and thereby provide scope for universities to strengthen their absolute and relative performance over time.

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Table 3. Rankings of universities by cost efficiency (most efficient to least efficient).

1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
UAD	**UB**	**UB**	**UB**	**FU**	**FU**	**FU**	**FU**
UB	**SCU**	**SCU**	**FU**	**UB**	**UB**	**USQ**	**USQ**
SCU	**FU**	**FU**	**SCU**	**SCU**	**SCU**	**SCU**	**UAD**
UWA	**SUT**	**SUT**	**NTU**	**NTU**	**NTU**	**UB**	**UW**
USQ	**UAD**	**NTU**	**SUT**	**SUT**	**USQ**	**UAD**	**SCU**
FU	**NTU**	**MDU**	**MDU**	**UC**	**UC**	**NTU**	**UWA**
MDU	**MDU**	**UC**	**UC**	**MDU**	**MDU**	**UC**	**UC**
CQU	**UC**	**UAD**	**UTAS**	**UTAS**	**UAD**	**UW**	**CSU**
UC	**USQ**	**USQ**	**USQ**	**USQ**	**UTAS**	**UTAS**	**UB**
SUT	**CQU**	**UTAS**	**UAD**	**UAD**	**UW**	**MDU**	**UTAS**
NTU	**UWA**	**CQU**	**UW**	**UW**	**SUT**	**CSU**	**MDU**
UTAS	**UTAS**	**UW**	**CQU**	**UNC**	**CSU**	**UWA**	**NTU**
UQ	**UQ**	**UNC**	**UNC**	**CQU**	**UNC**	**UNC**	**USA**
UW	**UW**	**UWA**	**VUT**	**VUT**	**UWA**	**JCU**	**JCU**
CSU	**UNC**	**VUT**	**MQU**	**CSU**	**JCU**	**SUT**	**UNC**
UNC	**VUT**	**UQ**	**UWA**	**MQU**	**CQU**	**USA**	**ECU**
VUT	**MQU**	**MQU**	**CSU**	**UWA**	**VUT**	**UTS**	**UTS**
MQU	**CSU**	**CSU**	**UQ**	**JCU**	**UTS**	**CQU**	**ACU**
UTS	**UTS**	**UTS**	**UML**	**UTS**	**MQU**	**ACU**	**UWS**
GU	**UML**	**UML**	**UTS**	**UML**	**USA**	**UNE**	**UNE**
USA	**JCU**	**JCU**	**JCU**	**UQ**	**UML**	**VUT**	**CQU**
QUT	**ACU**	**ACU**	**ACU**	**ACU**	**ACU**	**UNSW**	**QUT**
CUT	**USA**	**LTU**	**UNE**	**UNE**	**UNE**	**ECU**	**NSW**
JCU	**GU**	**UNE**	**LTU**	**USA**	**UNSW**	**UWS**	**VUT**
ACU	**UNE**	**USA**	**USA**	**LTU**	**UWS**	**MQU**	**SUT**
ECU	**LTU**	**RMIT**	**RMIT**	**NSW**	**UQ**	**UML**	**MQU**
DU	**RMIT**	**GU**	**UWS**	**UWS**	**LTU**	**QUT**	**UML**
UML	**QUT**	**UWS**	**NSW**	**RMIT**	**ECU**	**LTU**	**GU**
UNE	**ECU**	**ECU**	**ECU**	**ECU**	**QUT**	**UQ**	**LTU**
UWS	**DU**	**DU**	**GU**	**QUT**	**RMIT**	**USD**	**CUT**
LTU	**UWS**	**QUT**	**QUT**	**GU**	**USD**	**GU**	**UQ**
RMIT	**CUT**	**NSW**	**DU**	**DU**	**GU**	**DU**	**USD**
MOU	**MOU**	**CUT**	**CUT**	**USD**	**DU**	**CUT**	**DU**
NSW	**NSW**	**MOU**	**USD**	**CUT**	**CUT**	**RMIT**	**MOU**
USD	**USD**	**USD**	**MOU**	**MOU**	**MOU**	**MOU**	**RMIT**
ANU	**ANU**	**ANU**	**ANU**	**ANU**	**ANU**	**ANU**	**ANU**

7 References

Chapman, B. (2001), Australian Higher Education Financing: Issues for Reform. *The Australian Economic Review* 34, 195-204.

Cornwell, C, P. Schmidt and R.C. Sickles. 1990, Production Frontiers With Cross-Sectional And Time-Series Variation In Efficiency Levels. *Journal of Econometrics* 46, 185-200.

Coelli, T.J. (1996), Assessing the Performance of Australian Universities Using Data Envelopment Analysis. *Mimeo, Centre for Efficiency and Productivity Analysis* University of New England.

Coelli, T.J, D.S.P. Rao and G. Battese. (1998), *An Introduction to Efficiency and Productivity Analysis.* Kluwer Academic Publishers, Boston.

Commonwealth of Australia. (2003), *Our Universities Backing Australia's Future*. www.backingaustraliasfuture.gov.au

Department of Education, Science and Training, *Selected Higher Education Statistics*. DEST, Canberra, www.dest.gov.au

________(2002), *Setting Firm Foundations Financing Australian Higher Education*. DEST, Canberra, www.dest.gov.au,

Greene, W. (1993), The Econometric Approach to Efficiency Analysis, in H.O. Fried, C.A.K. Lovell and S. Schmidt (eds.), *The Measurement of Productivity Efficiency: Techniques and Applications*. Oxford University Press, New York, 69-119.

Hay, D. and G.S. Liu. (1997), The Efficiency of Firms: What Difference Does Competition Make? *The Economic Journal*. 107, 597-617.

Hausman, J.A. (1978), Specification Tests in Econometrics. *Econometrica*, 46, 1251-1271.

Heaton , C and D. Throsby. 1997. Cost Functions for Australian Universities: A Survey of Results with Implications for Policy. *Centre for Economic Policy Research Discussion Papers, No. 360*, February.

Hsiao, C. (2003), *Analysis of Panel Data*, Cambridge University Press, Cambridge.

King, S. 2001. The Funding of Higher Education in Australia: Overview and Alternatives. *The Australian Economic Review*, 34, 190-4.

Kumbhakar, S and C. Knox Lovell. (2000), *Stochastic Frontier Analysis*, Cambridge University Press, Cambridge.

Lloyd, P, M. Morgan and R. Williams. (1993), Amalgamation of Universities: Are There Economies of Scale or Scope? *Applied Economics*, 25, 1081-1092.

Marginson, S. (2001), Trends in the Funding of Australian Higher Education. *The Australian Economic Review*, 43, 205-15.

McMillan, M and D. Datta. (1998), The Relative Efficiencies of Canadian Universities: A DEA Perspective. *Canadian Public Policy*, XXIV, 485-511.

Throsby, D. (1986), Cost Functions for Australian Universities. *Australian Economic Papers*, 25, 175-92.
Senate Employment, Workplace Relations, Small business and Education Reference Committee. (2001), *Universities in Crisis*, www.aph.gov.au/senate/committeee/eet_ctte/public%20uni/report/index.htm

Appendix. University Abbreviations

ACU	Australian Catholic University
CQU	Central Queensland University
CSU	Charles Sturt University
CUT	Curtin University of Technology
DU	Deakin University
ECU	Edith Cowan University
GU	Griffith University
JCU	James Cook University
LTU	La Trobe University
MQU	Macquarie University
MOU	Monash University
MDU	Murdoch University
NTU	Northern Territory University
QUT	Queensland University of Technology
RMIT	RMIT University
SCU	Southern Cross University
SUT	Swinburne University of Technology
ANU	The Australian National University
FU	The Flinders University of South Australia
UAD	The University of Adelaide
UML	The University of Melbourne
UNE	The University of New England
NSW	The University of New South Wales
UNC	The University of Newcastle
UQ	The University of Queensland
USD	The University of Sydney
UWA	The University of Western Australia
UB	University of Ballarat
UC	University of Canberra
USA	University of South Australia
USQ	University of Southern Queensland
UTAS	University of Tasmania
UTS	University of Technology, Sydney
UWS	University of Western Sydney
UW	University of Wollongong
VUT	Victoria University