

ESTIMATION OF COST EFFICIENCY IN AUSTRALIAN UNIVERSITIES

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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 findings from the study contribute to the formulation of an equity-efficiency based policy on university-financing.

1 INTRODUCTION

The incentive structure facing Australian universities has changed in the past three decades. Over the past three decades, government funding per Australian university student has fallen progressively and now stands at 40 percent of total university revenue as compared to almost 100 percent in the early 1970s. This factor alone has put pressure on Australian universities to find new revenue sources and contain costs. Australian universities also face increased competition from technology developments and globalisation of education services. While recent reforms have freed some resource constraints, especially on the revenue side, the higher education system remains partially deregulated. Consequently, universities have new incentives to use their resources more effectively.

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. Its contribution to the literature is primarily empirical: the paper is the first attempt to esti-

mate the cost efficiency of Australian universities and is the first application of this methodology to measuring university efficiency. 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 although duality exists for both concepts under certain assumptions about the production function (see below). 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.

The empirical methodology of the present study uses stochastic frontier analysis based upon panel data that enables testing of key hypotheses, including the null hypothesis of optimal efficiency as well as similarity of marginal costs of different teaching disciplines. 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.

Reform of the higher education sector in Australia has been the subject of ongoing policy debate, especially in the wake of Commonwealth funding cutbacks to universities in a period of expanding student load (see King, 2001; Chapman, 2001). The main thrust of reform efforts have centred upon partial deregulation of fees with the introduction in 1989 of government subsidised HECS fees for domestic students and full-fees levied on other domestic and foreign students. Reforms introduced in the 2003-4 Commonwealth Budget scheduled for implementation in 2005 extend the scope for universities to raise non-government revenue in various ways: by widening the HECS bands, by extending income-contingent loans to non-HECS students and by increasing the proportion of fee-paying domestic students from 25 to 33 percent (see Commonwealth of Australia, 2003). But the reforms stop short of full fee deregulation and maintain centralised control of Commonwealth government funding of HECS-supported places.

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. Decisionmakers at both levels have an interest in knowing whether government funding to the sector (2.4 percent of Commonwealth expenditures in 2003-4) is being used efficiently. 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 in-

ferences that are drawn are subject to the problem of the reliability of this measure in capturing quality changes.

A second issue concerns the factors that explain why one university is relatively more efficient than another. The methodology cannot answer this question: only the factors behind individual university efficiency are estimated. Nevertheless, the efficiency rankings are of potential use if the allocation of government funding of teaching resources were based upon performance criteria at a future date.

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, financial solvency, quality of education and efficiency. The problem is that not all the variables are observable, in particular, the latter two. But based upon available data, the picture that emerges is that most of the adjustment has been on the revenue side and, especially in terms of revenue composition.

The first adjustment mechanism at a university level is a reduction in student load or numbers. The increase in total student numbers is spread across all universities and reflects the tying of Commonwealth funding through the base operating grant to government funded places for domestic undergraduate students. At a university level, there is little incentive to cut total student numbers and even greater incentives to increase the share of full-fee paying overseas students with consequent distortions across disciplines in favour of more business-oriented studies. The data reflect this at an aggregate and university level: the share of full-fee paying foreign students in total students rose from 8 to almost 14 percent over the sample period.

A second adjustment mechanism is through changes in revenues and costs. Average real revenue per full-time student rose from \$ 7,535 to \$11,615 from 1995 to 2002 but average real costs per student remained stable at around

\$15,000, leaving an average negative operating margin of percent of average revenues in 2002 (Table 1). (In aggregate terms, there is a positive gap but, in any event, both the average and aggregate pictures are deceptive because the financing gap has moved in different directions for universities.) However, universities are non-profit institutions and hence the concept and measurement of financial criteria such as insolvency are not clearly defined. Most universities have incentives to prevent a widening and negative financing gap since the resulting debt buildup constrains recurrent expenditures and thereby reduces their flexibility of policy options.

A third mechanism is through a downward adjustment in quality of teaching and other services. Trends in the quality of higher education are difficult to measure. If measured in terms of staff/student ratios, quality of higher education has declined with an increased ratio from 15.3 in 1995 to 21.4 in 2002 with rises recorded for all universities and in all disciplines. While anecdotal and survey data support this interpretation, other measures provide conflicting evidence.

Assuming unchanged quality and a stable financing gap, this leaves adjustment either from the composition of revenues and costs or from efficiency. The data in Table 1 show that the share of Commonwealth grants in total revenue fell from 57.2 to 40.1 percent over 1995-2002 and was offset partially by increased shares from full-fee paying students and from subsidised HECS fees: non-HECS fee share rose from 11.7 to 21.2 percent while that of HECS rose from 12 to 15.8 percent with the remainder from other items such as donations.

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.

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 for optimal efficiency. 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. The issue of cost efficiency of teaching output is addressed below.

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

3 METHODOLOGY

A number of different concepts of efficiency are discussed in the literature and policy discussion, including technical, cost and x-efficiency (see Kumbhakar and Lovell, 2000). The focus of this study is upon cost efficiency of university teaching resources: cost efficiency is defined as ability to minimise costs for a given output vector and measured by the ratio of minimum to observed cost. This concept differs from technical efficiency, defined as the ability to minimise input use for a given output vector. Unlike cost efficiency, technical efficiency does not involve the imposition of behavioural assumptions such as cost minimisation. Further, not all cost inefficiency need reflect technical efficiency. For example, an input vector may be technically efficient but cost inefficient because of misallocation of inputs in terms of their relative prices.

In the following analysis, it is assumed that universities do attempt to minimise costs. This assumption may be questioned on the grounds that universities are non-profit institutions but, as noted above, the changing environment has altered the incentive structure significantly and especially in the sample period.

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). Figure 1 provides a simple illustration of the concept of cost inefficiency. Assuming that cost is determined by output, the cost inefficiency for university A with output, Q , and cost, E_A , is the ratio of the distance CQ to the distance AQ , where C is the minimum feasible cost or the cost frontier for producing output, Q . University A is more efficient than university B since the distance AC is shorter than distance BC . As E_A and E_B are observable, estimation is required to “locate” C in order to calculate cost inefficiency.

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.

Figure 1 assumes that universities A and B have an identical cost frontier and there is single output for each of them. For a more general analysis, 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).

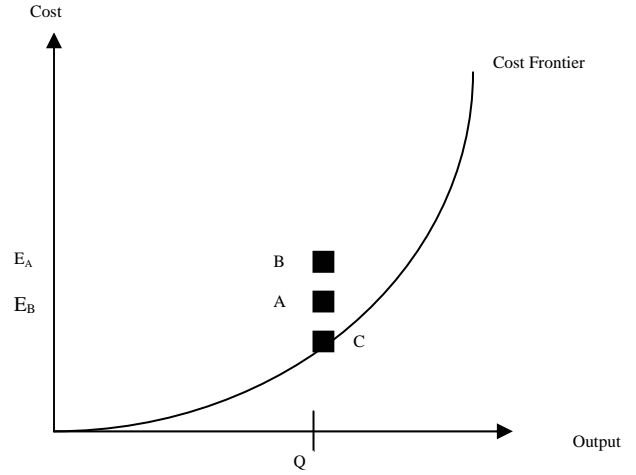


Figure 1: An illustration of cost inefficiency

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

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

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), equation (1) is written as,

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

where Y_{ij} is the j th element of Y_i , α_{i0} (intercept term) and β_{ij} s (university cost responsiveness to output change) are parameters to be estimated. Equation (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:

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

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

$$CE_i = \exp(-u_i). \quad (4)$$

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

$$\begin{aligned} \ln E_{it} &= \ln \alpha_{i0} + \sum_j \beta_{ij} \ln Y_{ijt} + v_{it} + u_i \\ \text{or } e_{it} &= \beta_{i0} + \sum_j \beta_{ij} y_{ijt} + v_{it} + u_i \end{aligned} \quad (5)$$

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 equation (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.

Equation (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

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

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, equation (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 equation (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 equation (5) include the following: (a) post-graduate 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,

$$e_{it} = \beta_{i0} + \beta_{i1} \ln PG + \beta_{i2} \ln UG + \beta_{i3} \ln SE + \beta_{i4} \ln SB + \beta_{i5} \ln SO + \beta_{i6} \ln SR + v_{it} + u_i \quad (7)$$

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.

$$H_0 : \beta_{1,0} = \dots = \beta_{36,0}; \beta_{1,k} = \dots = \beta_{36,k}; k = 1 \text{ to } 6$$

$$H_1 : \text{at least one of the } \beta\text{s is different.}$$

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, $\beta_{1,k} = \dots = \beta_{36,k} = \beta_k; k = 1$ 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 $H_0 : \beta_{1,0} = \dots = \beta_{36,0}$ 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.

$$\hat{e}_{it} = 7.9291 + 0.1213 \ln PG_{it} + 0.4785 \ln UG_{it} + 0.6351 \ln SE_{it} + 0.3674 \ln SB_{it} + 0.3747 \ln SO_{it} - 0.0721 \ln SR_{it} \quad (8)$$

(11.1485) (2.9080) (7.0404) (3.3625)

(2.9215) (1.8280) (-2.6375)

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

The estimation procedure has taken into account potential cross-sectional heteroskedasticity but ignored the possible existence of autocorrelation. To address potential autocor-

relation issues will substantially complicate the estimation process as the efficiency of the model coefficient estimates depends on finding a consistent estimator of the autocorrelation coefficient. This, in turn, requires the number of time periods being large, which is not the case in the present study (Hsiao, 2003, p57). Thus, autocorrelation is ignored.

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.

The coefficients in equation (8), which are cost elasticities of student, are not directly comparable with those in the previously estimated cost functions for Australian universities (Heaton and Throsby, 1997 and Lloyd et al, 1993) since the coefficients in the latter studies are marginal costs of student. Further, a constant cost elasticity, which is the case in the present study, implies a variable marginal cost. However, it is worthwhile to note that the cost elasticity for postgraduate students was found to be smaller than that for undergraduate students in the present study. Lack of knowledge of various student proportions in 1991 and 1994, the elasticity estimates in equation (8) would be consistent with the previous studies which point to the marginal cost of postgraduate students being higher than that of undergraduate students if the proportions of undergraduate students in the years were high enough.

Residuals from model specified by equation (8) are used as the dependent variable for the auxiliary regression outlined in Section III for estimation of time-varying cost inefficiency. Table 2 contains estimates of cost efficiency calculated using equation (4) for 36 Australian universities: efficiency rankings are presented in Table 3.

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. Their study demonstrated that, barring other adjustment mechanisms such as efficiency and assuming unchanged fees and quality, costs can be reduced through a redistribution of students from universities operating above minimum scale. The difficulty with this reform is that there are disincentives for universities to reduce student numbers under current as well as proposed Commonwealth funding arrangements that tie funds to a specified number of government supported undergraduate places in particular course disciplines.

The main finding of this study is that universities are not operating efficiently, as measured by cost efficiency and in relative terms. In terms of movement towards relatively greater efficiency, not all universities can improve their rankings since it is a zero sum game. But on average the size of efficiency gaps is below 0.5 suggesting scope for further gains in cost efficiency. (The normalisation procedure converts cost efficiency residuals into the difference between the benchmark university and that of a specific university and hence, any dollar transformation of the efficiency rankings has little meaning.)

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 with educational and other performance criteria having little or no effect on government funding for teaching. Although each university has an incentive to manage its costs effectively, there is no information on how they compare to others or rewards for relative efficiency. 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.

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
UNSW	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

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. However, as noted at the outset, the SFA methodology cannot explain the factors behind the rankings and, hence, how a university can improve its relative position. For example, rises in the staff student ratio has a small and significant negative effect on university costs but an across the board reduction in this ratio has little effect on efficiency rankings.

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	UNSW
JCU	GU	UNE	LTU	USA	UNSW	UWS	VUT
ACU	UNE	USA	USA	LTU	UWS	MQU	SUT
ECU	LTU	RMIT	RMIT	UNSW	UQ	UML	MQU
DU	RMIT	GU	UWS	UWS	LTU	QUT	UML
UML	QUT	UWS	UNSW	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	UNSW	DU	DU	GU	DU	USD
MOU	MOU	CUT	CUT	USD	DU	CUT	DU
UNSW	UNSW	MOU	USD	CUT	CUT	RMIT	MOU
USD	USD	USD	MOU	MOU	MOU	MOU	RMIT
ANU	ANU	ANU	ANU	ANU	ANU	ANU	ANU

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.

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: 190-194.

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: 205-215.

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. *Universi-*

ties in Crisis, www.aph.gov.au/senate/committee/et_ctte/public%20uni/report/index.htm

Appendix A : UNVERSITY 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
UNSW	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