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DATA ENVELOPMENT ANALYSIS OF THE EFFICIENCY OF AUSTRALIAN UNIVERSITIES: AN EMPIRICAL STUDY

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Abstract

Understanding how teaching and research contribute to the overall efficiency of university operations is of great importance for universities to improve their performance. This paper adopts a holistic approach to evaluate the university efficiency from three perspectives including (a) the overall university operations efficiency, (b) the university teaching efficiency, and (c) the university research efficiency. It applies the technique of data envelopment analysis to thirty-six Australian universities in the period of 2011 to 2015 for evaluating their relative efficiency respectively from these perspectives. A strategic group analysis is further conducted for exploring the source of inefficiency of an individual university in its respective strategic group. Such an analysis provides individual universities with valuable information on how they can make full use of their resources for improving their efficiency in an increasingly competitive environment.

Keywords: Efficiency Study, Data Envelopment Analysis, Higher Education, Empirical Study

1 INTRODUCTION

Universities perform an important role in the development of individual countries due to their capacity for providing critically needed education and innovation. The former is derived from teaching while the latter is achieved from research. To accomplish these critical roles, adequate financial support is critical. Most Australian universities are government-owned with financial support mainly from the federal government (Abbott and Doucouliagos, 2003; Lee, 2011). With the rapid growth of enrollment in the Australian universities from 165,937 in 1981 to 1213,403 in 2015 (www.education.gov.au), the pressure on the federal government for more funding has been amounting in Australia.

To effectively tackle this challenge, the Australian government has been trying to reduce its financial burden on funding universities through improving the efficiency of the Australian universities since 1980s (Dawkins, 1988; West Report, 1998). Specific measures including declining public funding per student, rising expenditure on university infrastructure, increasing the competition for research funding, exploring international education, and amalgamating educational institutions have been initiated. A unified performance-based funding system is introduced for funding university teaching and research (Guthrie and Neumann, 2007). Funding for university teaching is based on discipline groupings and levels of study provided. A major initiative on university teaching fund allocation is the introduction of the Australian Learning and Teaching (formerly Carrick) Grants (ALTC) in 2002. Such an initiative is designed to encourage excellence in learning and teaching thereby ensuring the university retains its position as a leading teaching institution (ALTC, 2008). Funding for research is relied upon the research income, higher degree completion and refereed publications. Such a move stimulates the competition among Australian universities for improving their research efficiency in order to secure more government funding (Lee and Worthington, 2016). As a result, adequately evaluating the relative efficiency of the Australian universities becomes critical in this situation.

There are several approaches developed for evaluating the efficiency of individual organizations from different perspectives. Traditional approaches including ratio analysis (Rouse et al., 2002) and statistical analysis (Sueyoshi and Goto, 2009), however, are found to be unsatisfactory in evaluating the efficiency of universities while considering the multiple inputs and outputs simultaneously (Lee, 2011). Data envelopment analysis (DEA) (Charnes et al., 1978), on the other hand, is proven to be reliable for appropriately assessing the efficiency of university operations due to its capability of effectively handling the multiple input and output simultaneously in a given situation.

Several studies in the literature exist on the use of DEA for evaluating the efficiency of universities and university departments. Abbott and Doucouliagos (2003), for example, applies DEA for measuring the technical and scale efficiencies of Australian universities. Carrington et al. (2005) adopt DEA for investigating the productivity growth in Australian universities. Kao and Hung (2008) use DEA for assessing the efficiency of academic departments at National Cheng Kung University. Lee (2011) and Lee and Worthington (2016) employs DEA for evaluating the research performance of Australian universities. These studies above show that DEA is effective for evaluating the efficiency of university operations. These studies, however, fail to address the issue of inefficiency in the university operations. Furthermore, these studies have not explored the sources of inefficiencies in respect of teaching and research on the performance of Australian universities which is highly desirable in the current circumstance.

This paper aims to address above issues by presenting an empirical study of the efficiency of thirty-six Australian universities in the period of 2011 to 2015 using DEA from the perspectives of (a) the overall efficiency of university operations, (b) the teaching efficiency, and (c) the research efficiency respectively. The inefficient universities are identified with the potential areas for improvement being revealed. A strategic group analysis is conducted for exploring the source of inefficiency of an individual university in its respective strategic group. To understand the contribution of the teaching efficiency and research to the overall efficiency, a multivariate regression analysis is conducted. Such

an analysis provides individual universities with valuable information on how they can make full use of their resources for improving their efficiency in an increasingly competitive environment.

In what follows, the DEA model and its variations are discussed first. This is followed by the development of three functional specific DEA models within the Australian higher education setting. An empirical analysis of the university efficiency with respect to these three models is then conducted, leading to some interesting observations being made.

2 DATA ENVELOPMENT ANALYSIS FOR EFFICIENCY STUDY

DEA is a mathematical approach for measuring the relative efficiency of comparable organizations with respect to a given set of outputs and inputs in a specific situation (Charnes et al., 1978; Cook and Seiford, 2009). It is popular due to its distinct advantages including (a) the capacity of simultaneously handling multiple inputs and multiple outputs, (b) the ability to adapting to various scales for measuring inputs and outputs, (c) the lack of an explicitly specified mathematical function in the modeling process, and (d) the capacity of pinpointing the sources of inefficiency for individual organizations (Cook and Seiford, 2009).

The DEA model assesses the relative efficiency of comparable organizations, known as the decision making unit (DMU), as the ratio of the weighted outputs to the weighted inputs, where the model selects the weights for each DMU for presenting it in the most favorable way (Charnes et al., 1978). It allows a DMU to automatically choose the weights for maximizing its own efficiency score while other DMUs do not produce a relative efficiency greater than one using the same weights. DMUs are considered as efficient if their efficiency scores reach one. The DEA model is formulated as follows.

Giving a set of n DMUs. The p^{th} DMU $(p = 1, 2, ..., n)$ utilizes m inputs $x_{ip,}$ $(i = 1, 2, ..., m)$ to produce s outputs $y_{rp,}$ $(r = 1, 2, ..., s)$. u_r $(r = 1, 2, ..., s)$ and v_i $(i = 1, 2, ..., m)$ are the weights to be applied to the r^{th} output and i^{th} input respectively. The efficiency study problem is formulated for finding out the optimal values of u_r and v_i such that the relative efficiency score E_p for DMU_p is maximized, subject to the constraints that efficiency scores for other DMUs are less than or equal to one using the same u_r and v_i. The efficiency score E_p for each DMU p is obtained by solving the following model:

$$E_p = max \ \frac{\sum_{r=1}^{s} u_r y_{rp}}{\sum_{i=1}^{m} v_i x_{ip}} \tag{1}$$

$$\text{Subject to} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \quad j = 1, 2, ..., n \ , \ u_r, \ v_i \geq 0$$

The DEA model in (1) has infinite numbers of solutions. To facilitate the efficiency evaluation process, the model in (1) can be converted to an equivalent linear model as follows:

$$E_p = max \ \sum_{r=1}^{s} u_r y_{rp} \tag{2}$$

$$\text{Subject to:} \quad \sum_{i=1}^{m} v_i x_{ip} = 1, \ \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1, 2, ..., n \ \ u_r, \ v_i \geq 0$$

The DMU_p is considered as relatively efficient if its efficiency score E_p equals to one. To help identify the potential area for improvement in an inefficient DMU identified through (2), a set of corresponding efficient DMUs commonly referred to as the reference set can be used, determined by the dual model of the DEA model (2), described as follows:

$$\begin{aligned} &Min\ \theta_p \quad 0 < \theta_p \le 1 \\ &Subject: \sum_{j=1}^{n} \lambda_j x_{ij} - \theta x_{ip} \le 0 \qquad i = 1, 2, ..., m, \ \sum_{j=1}^{n} \lambda_j y_{rj} - y_{rp} \ge 0 \qquad r = 1, 2, ..., s \quad \lambda_j \ge 0 \end{aligned} \tag{3}$$

Where θ_p is the efficiency score for the DMU_p. The model (3) shows that the DMU_p is inefficient if other DMUs can be identified to consume fewer inputs than DMU_p while producing at least the same level of output. Such identification can highlight where the improvements can be made for inefficient DMUs for achieving their full potential.

The model above is the input-oriented DEA that focuses on minimizing the inputs while satisfying at least at a given level of the output (Charnes et al., 1978). There is also an output-oriented DEA model that attempts to maximize the output without requiring more of any of the observed inputs (Cooper et al., 2004). The output-oriented DEA model can be presented as follows:

$$\begin{aligned} &Max\ \eta_p \qquad 0 < \eta_p \le 1 \\ &Subject\ to: \qquad \sum_{j=1}^{n} \lambda_j x_{ij} - x_{ip} \le 0,\ i = 1, 2, ..., m, \ \sum_{j=1}^{n} \lambda_j y_{rj} - \eta_p y_{rp} \ge 0, \quad r = 1, 2, ..., s, \ \lambda_j \ge 0 \end{aligned} \tag{4}$$

The CCR model and its variations described as above assume a constant return to scale in the modeling process. This requires all DMUs in consideration to operate at an optimal level (Charnes et al., 1978). In real situation this is not always the case. To accommodate this challenge in evaluating the efficiency of individual organizations, the CCR model is extended, resulting in the development of several extended DEA models from different perspectives. Among the extensions, the BCC model (Banker et al., 1984) is the most representative one which relaxes the assumption of the constant return to scale in the CCR model. The output-oriented BCC model can be represented as:

$$\begin{aligned} &Max\ \eta_p \qquad 0 < \eta_p \le 1 \\ &Subject\ to: \quad \sum_{j=1}^{n} \lambda_j x_{ij} - x_{ip} \le 0, \quad i = 1, 2, ..., m \\ &\qquad \sum_{j=1}^{n} \lambda_j y_{rj} - \eta_p y_{rp} \ge 0, \quad r = 1, 2, ..., s, \ \sum_{j=1}^{n} \lambda_j = 1, \quad j = 1, 2, ..., n, \ \lambda_j \ge 0 \end{aligned} \tag{5}$$

Australian universities are running with more or less a certain amount of resources mainly from the federal government. The critical issue on the performance of individual universities is on the level of outputs that each university can achieve within this fixed pool of resources. As a result, the output-oriented BCC model described as in (5) is more appropriate for evaluating the relative efficiency of individual universities. With the use of the BCC model as in (5), the p^{th} university is considered to be efficient if η_p obtains a score of one. The efficiency score of less than one for the p^{th} university implies that this university does not perform in its full potential in a given situation.

3 DEA SPECIFIC MODELS

Universities are not-for-profit organizations whose mission is to provide the society with quality teaching and world-class research. To effectively evaluate the relative efficiency of Australian universities, three function specific DEA models are proposed with respect to the overall university operations efficiency, the teaching efficiency, and the research efficiency. The overall university

operations efficiency model assesses the relative capacity of individual universities in converting their resources into the total outputs using the wide recognized inputs and outputs for measuring the university performance in Australia. The teaching efficiency model focuses on the delivery of teaching service to the students in a university, while the research efficiency model aims to explore the success of universities in carrying out original research.

The success of applying DEA for assessing the efficiency of individual organizations relies on the appropriate selection of the inputs and outputs for formulating specific efficiency evaluation models in a given situation (Lee, 2011). Much discussion can be identified in the literature on the selection of inputs and outputs for evaluating the efficiency of universities (Abbott and Doucouliagos, 2003; Kao and Hung, 2008; Lee, 2011; Lee and Worthington, 2016). There is, however, no general agreement on the most appropriate set of inputs and outputs for the university efficiency evaluation problem due to the nature of the information needed and the purpose of the evaluation. In general, the selection of inputs and outputs for the DEA analysis is considered appropriate as long as the inputs and outputs selected conform to the purpose of the organization and there is a positive correlation between the inputs and the outputs in a given situation (Kao et al., 1993).

In Australia, universities consume labor and non-labor resources as inputs to produce outputs in the form of teaching, research, and other educational services (Avkiran, 2001; Abbott and Doucouliagos, 2003; Lee and Worthington, 2016). With this in mind, this study selects the total number of graduates as a proxy of teaching and research outputs and the total revenue generated for measuring the overall output due to its ability for reflecting the capacity of a university to provide quality teaching, research and other services. The inputs consumed to produce the outputs include the total number of staff and the total operating expenses. The total number of staff is included due to its capacity for reflecting the overall efficiency of a university. The operating expenses include staff benefits, procurement and maintenance of the facilities, depreciation and other expenses. Table 1 shows the overall university operations efficiency model.

Inputs	Outputs
Total staff number (FTE) Expense	Total number of graduates (FTE) Revenue

Table 1. The overall university operations efficiency model

The objective of teaching in a university is to ensure the timely completion of students with quality degrees. The common measure of teaching outputs in previous studies is the student completion rate (Smith and Naylor, 2001). This indicator, however, does not differentiate the coursework graduates from the research graduates when calculating the student completion rate. Coursework students consume most of the teaching effort and contact hours than the research students in Australian universities (West Report, 1998). As a result, the number of full-time equivalent coursework graduates is a better output measure than the student completion rate in assessing the teaching efficiency (Abbott and Doucouliagos, 2009). Additionally, the number of coursework enrolments in the following year is another output measure as the more coursework enrolments, the better the teaching performance.

The numbe of full-time equivalent teaching staff and the associated expense in teaching are selected as the inputs for the university teaching efficiency assessment. These two measures are commonly accepted in evaluating the university teaching efficiency (Carrington et al., 2005; Abbott and Doucouliagos, 2009). The teaching associated expense includes the salary of teaching staff and the administrative cost devoted to teaching. One obvious advantage of using the above inputs and outputs is that the quality of teaching can be evaluated with concise data. Table 2 shows the inputs and outputs in the teaching efficiency model.

It is always a controversial issue in choosing the inputs and outputs for evaluating the research efficiency in higher education (Lee, 2011; Lee and Worthington, 2016). The use of publications and their citations has been well accepted as the main output in the study of American universities (Foltz et al., 2012). As Australian researchers tend to publish in journals that are not well cited as those in

American, the use of citations has little effect in differentiating the research performance among Australian universities (Lee and Worthington, 2016). Alternatively, the research income such as the external research grants attracted by the university is a better measure of the market value of the research conducted by individual universities (Lee, 2011; Lee and Worthington, 2016). As a result, the research income can be used as the proxy of the research output to assess the quality of research.

Inputs	Outputs
Teaching staff (FTE) Expense	Number of coursework graduates (FTE) The next year coursework enrolments

Table 2. The teaching efficiency model

The number of research completion in each university, including completion of masters by research and doctoral degree is another common indicator for measuring the research performance (Johnes, 2005; Lee, 2011). To facilitate the measure of the research efficiency, the number of academic staff in charge of research and their associated expense are selected as inputs. Table 3 shows the inputs and outputs for the research efficiency model.

Inputs	Outputs
Research staff (FTE) Expense	Number of research graduates (FTE) Research fund

Table 3. The research efficiency model

4 RESULTS AND ANALYSIS

To evaluate the efficiency of Australian universities, the empirical data are derived from the latest available annual reports over the period of 2011 to 2015 from the Higher Education Statistics and Financial Reports compiled by the Commonwealth Department of Education (www.education.gov.au). A rule of thumb on the application of DEA for selecting the sample size in the efficiency study is to ensure that the sample size is at least three times larger than the total number of inputs and outputs so that the efficient DMUs can be effectively discriminated from the inefficient ones (Bifulco and Bretschneider, 2001). Along this rule, thirty-six Australian universities are selected. All Australian universities selected come under the same set of regulations for ensuring that their DEA efficiency scores are comparable, thus being able to provide meaningful research findings (Cooper et al., 2004).

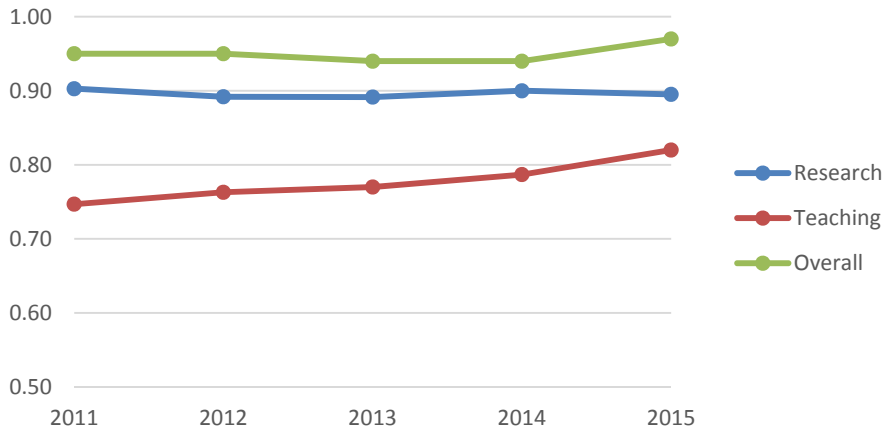

Figure 1. An Overview of University Efficiency during 2011-2015

Figure 1 shows the trend of the university performance from 2011 to 2015 with respect to the overall university operations efficiency, the teaching efficiency and the research efficiency. All universities perform relatively efficient in terms of the overall operations and research over this period, exemplified by the average efficiency scores at around 0.95 and 0.90 respectively. The teaching efficiency, however, is relatively poor with the mean score at 0.78. An increasing trend can be observed on the teaching efficiency since 2011. The total increase from 2011 to 2015 in the teaching efficiency, however, is only at 8% with a relatively low mean efficiency score in 2015. This reveals that there is a huge effort for improving the teaching performance of Australian universities by investigating the source of the inefficiencies.

University	Overall Efficiency	Teaching Efficiency	Research Efficiency
Charles Sturt University	1.00	1.00	0.88
Macquarie University	0.96	0.91	0.80
Southern Cross University	1.00	1.00	1.00
University of New England	0.86	0.69	1.00
University of New South Wales	0.89	0.84	1.00
University of Newcastle	0.91	0.92	0.96
University of Sydney	1.00	0.88	1.00
University of Technology, Sydney	1.00	1.00	0.83
University of Western Sydney	0.97	0.93	1.00
University of Wollongong	0.93	0.70	0.98
Deakin University	0.97	0.87	0.84
La Trobe University	0.84	0.82	0.76
Monash University	1.00	1.00	0.86
RMIT University	1.00	1.00	0.98
Swinburne University of Technology	1.00	0.82	0.82
University of Melbourne	1.00	0.86	1.00
University of Ballarat	1.00	1.00	1.00
Victoria University	0.88	0.61	0.70
Central Queensland University	1.00	1.00	0.59
Griffith University	0.88	0.94	0.75
James Cook University	0.87	0.48	0.87
Queensland University of Technology	0.96	1.00	0.84
University of Queensland	0.86	0.71	0.91
University of Southern Queensland	0.96	1.00	0.97
Curtin University of Technology	1.00	1.00	0.89
Edith Cowan University	0.92	0.83	0.90
Murdoch University	0.84	0.60	0.87
University of Western Australia	0.96	0.42	1.00
Flinders University of South Australia	0.88	0.57	0.94
University of Adelaide	0.86	0.57	0.96
University of South Australia	0.95	0.95	0.86
University of Tasmania	0.93	0.58	1.00
Charles Darwin University	1.00	1.00	1.00
Australian National University	1.00	0.48	1.00
University of Canberra	0.96	0.88	0.94
Australian Catholic University	1.00	1.00	0.99

Table 4. An overview of the Australian university efficiency in 2015

To provide insight into the efficiency of individual universities, an overview of the university overall operations efficiency, the teaching efficiency and the research efficiency in year 2015 is shown in Table 4. The average teaching efficiency score at 0.82 again suggests that the teaching activities conducted in Australian universities are not as efficient as the research activities with the average score at 0.90. University of Western Australia and Australian National University with low teaching efficiency scores 0.42 and 0.48 respectively show that there is a great potential for improvement in teaching performance. However, it is noticeable that both universities perform efficiently in research and overall operations. On the other hand, Central Queensland University with the lowest research efficiency score at 0.59 is efficient in teaching as well as the overall operations. The observation above highlights the problem that research intensive universities should not be expected to be comparable with teaching oriented universities in the efficiency evaluation (Serow, 2000).

The theory of strategic group is originally introduced for explaining the observed variation in profitability between and among organizations across an industry (Porter, 1980). It states that the differences of the profitability between organizations in a specific industry are mainly due to the adoption of different strategies in achieving the organizational goal and the various views and preference of the inputs and outcomes in the organization. A strategic group consists of a set of organizations with similar asset configurations for pursuing similar competitive strategies in achieving their objectives in a similar setting. Such theory is widely used for assessing the group-based performance of individual organizations (Graham and David, 2006). Marlin et al. (2002), for examine the relationship between strategic group membership and hospital performance with the identification of significant variances on the performance among different groups of hospitals. Prior and Surroca (2006) identify the strategic group within forty-two Spanish savings banks for investigating the variance of bank performance. The advantage of using the strategic group theory for performance analysis is that the inefficient organization has a corresponding efficient organization as reference in the same group for facilitating the identification of the potential areas for improvement.

To further investigate the university efficiency using the strategic group analysis, the Australian universities are classified into four groups based on the nature and focus of individual universities. Some of the universities are research intensive, whereas others are teaching oriented. As a result, they value the inputs and outputs differently in the efficiency evaluation process. This leads to the implementation of a group-based DEA analysis within the four groups of universities over the five year period. Such an analysis is worthwhile for better understanding the relative efficiency of individual universities and the underlying reasons for their performance (Day et al., 1995).

The four groups of homogeneous universities in Australia are the Group of Eight universities (Go8), the Australian Technology Network (ATN) universities, the Innovative Research Universities (IRU), and the New Generation Universities (NGU). The classification of the Australian university into these four groups is based on the way these universities operate and the strategic focus that these universities have in teaching and research. The Go8 universities, for example, are well recognized for their long history and their strategic focus on research. Its members include University of Adelaide, Australian National University, University of Melbourne, Monash University, University of New South Wales, University of Queensland, University of Sydney and University of Western Australia.

The ATN universities include Queensland University of Technology, Curtin University of Technology, RMIT University, University of South Australia and University of Technology, Sydney. They share a long history of working in partnership with industry. They are usually teaching oriented and famous for providing practical teaching service.

The IRU universities consist of Flinders University, Griffith University, La Trobe University, Macquarie University, Murdoch University and University of Newcastle. They own a common background of having been founded in the 1960s and 1970s as research universities and a common mode of operation.

The NGU universities include Australian Catholic University, Central Queensland University, Edith Cowan University, Southern Cross University, Victoria University, University of Ballarat, University

of Canberra, University of Southern Queensland, University of Sunshine Coast and University of Western Sydney. These universities are formerly technical colleges and have just received university accreditation since 1970. Furthermore, they share similar strategy including a flexible and dynamic program offering as well as an ability to operate in close cooperation with community, business and government.

To conduct the group-based DEA analysis, the university teaching efficiency score and research efficiency score from the original university DEA efficiency models are selected and categorized in four groups. Figures 2 and 3 show the trend of group based teaching and research efficiency movements respectively from the year 2011 to 2015.

The mean teaching efficiency scores in ATN and NGU universities are relatively higher than that of IRU and Go8 universities over the five years. As ATN and NGU universities are teaching oriented, it is not surprising that they dominate in teaching, with their respective average teaching efficiency scores at 0.91 and 0.89, compared to the national average teaching efficiency score at 0.78. In the ATN universities, all universities are fully efficient except whose teaching efficiency score is at 0.95 in 2015 as shown in Table 4. There is still much space for the University of South Australia to improve the teaching performance compared to other universities in ATN.

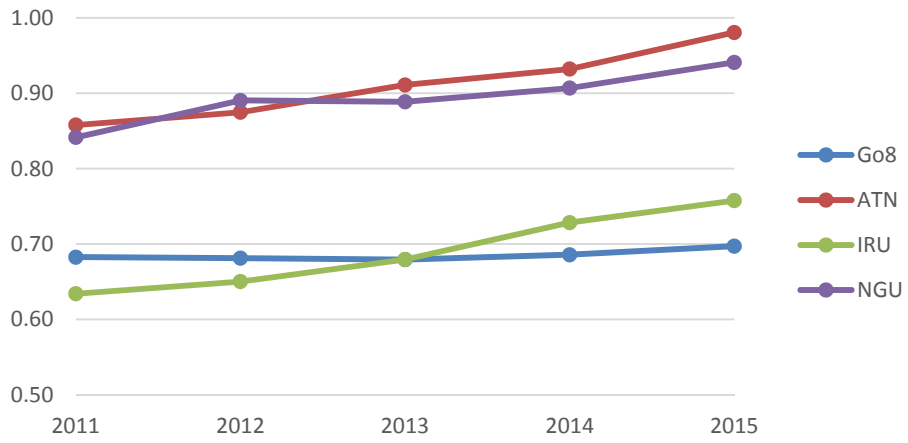

Figure 2. The teaching efficiency for four groups of universities

The teaching performance in Go8 and IRU universities, however, is undesirable as shown in Figure 2, with the average efficiency scores both at 0.69. Such an observation suggests that there is a need to pay more attention to the teaching performance in the Go8 and IRU universities for significantly improving the teaching efficiency as a whole in the Australian high education sector.

Figure 3 presents an overview of the research efficiency in four groups of universities over five years. No distinct increase or decrease trend can be observed in the research efficiency score among the four groups of universities from the year 2011 to 2015. All groups seem to perform stably in these five years, with the dominance of the Go8 universities over the other groups with an average efficiency score of 0.95. This is due to the fact that the Go8 universities consist of universities with a long history of depth and breadth in their research. The IRU universities, holding the lowest research efficiency score at 0.83 in four groups, on the other hand, do not perform as efficiently as it has claimed to be research concentrated universities over the five years. The IRU universities have been recognized to conduct research of national and international standard. The efficiency evaluation result, however, shows that none of the universities in this group is considered as fully efficient in 2015.

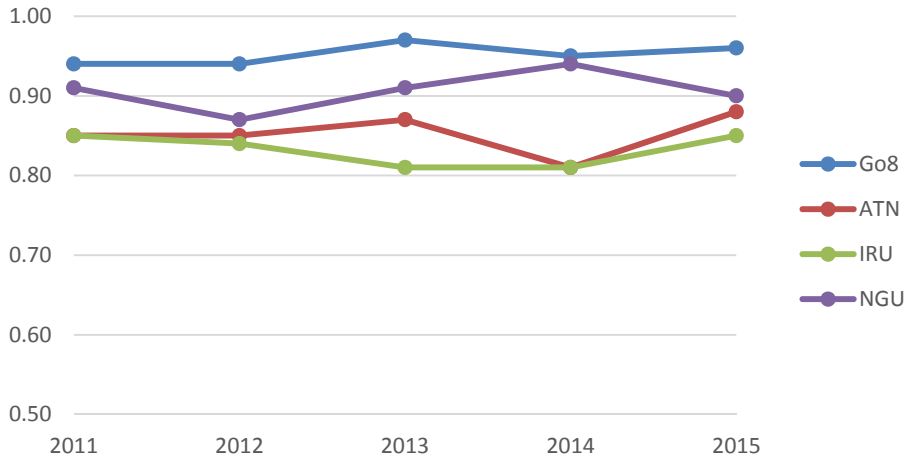

Figure 3. The research efficiency for four groups of universities

To explore how to improve the performance of universities with the low efficiency scores, a further analysis based on the concept of Reference University is conducted. A reference university is the relative efficient university among its homogeneous peers with similar mix of inputs and outputs (Banker et al., 1984). In this study, universities in each strategic group are of similar asset configurations and are believed to pursue similar competitive strategies to achieve their objectives. It is therefore worthwhile to set the efficient university as the reference university for the inefficient peers in the same group to follow.

To show how the Go8 Universities can improve their teaching performance, the teaching efficiency scores in Go8 universities are recalculated by DEA by selecting only the Go8 universities. Table 5 shows the result.

DMU	Score	Reference University
University of Adelaide	1.00	University of Adelaide
Australian National University	0.89	University of Melbourne
University of Melbourne	1.00	University of Melbourne
Monash University	1.00	Monash University
University of New South Wales	0.81	University of Adelaide
University of Sydney	0.89	Monash University
University of Queensland	0.75	University of Adelaide
University of Western Australia	0.71	University of Adelaide

Table 5. A comparative overview of the teaching efficiency in Go8 Universities

Although these eight universities perform poorly compared to other universities as shown in Table 4, there are some universities in the Go8 group that perform relatively efficiently in teaching. These efficient universities can be used as the reference universities for their peers in the same group. University of Adelaide, University of Melbourne and Monash University are deemed to be the most efficient universities in the Go8 universities in teaching as shown in Table 5. The inefficient universities such as the University of Western Australian which holds the lowest teaching efficiency score in Go8 can improve their teaching performance by using the corresponding reference universities as a benchmark. This means that University of Western Australian can greatly improve its teaching efficiency if it follows the University of Adelaide's way in allocating the available resources.

DMU	Teaching Efficiency	Reference University	Research Efficiency	Reference University
Flinders University of South Australia	1.00	Flinders University of South Australia	1.00	Flinders University of South Australia
Griffith University	1.00	Griffith University	1.00	Griffith University
La Trobe University	0.98	Griffith University	0.89	Griffith University
Macquarie University	1.00	Macquarie University	1.00	Macquarie University
Murdoch University	0.92	Griffith University	0.96	Macquarie University
University of Newcastle	0.96	Flinders University of South Australia	1.00	University of Newcastle

Table 6. A comparative overview of the teaching and research efficiency in IRU universities

Table 6 shows the results of the recalculated teaching and research efficiency scores within the IRU group. La Trobe University and Murdoch University are considered as inefficient universities in conducting both teaching and research activities compared to other universities in the IRU group. University of Newcastle and Murdoch University are relatively inefficient in teaching and research respectively. The reference universities are given as a guideline for the inefficient universities to improve the efficiency. For example, La Trobe University can improve its teaching and research performance by following the strategy in Griffith University for initiating the teaching and research related activities. Macquarie University is the Reference University for Murdoch University in terms of research. Flinders University of South Australia is the Reference University for University of Newcastle with regards to teaching.

To understand how much contribution the university teaching and research efficiency respectively contribute to the overall operations efficiency, regression analysis is conducted in each year based on the respective efficiency scores. Such an analysis is capable of identifying the underlying relationships between the overall operations efficiency, the teaching efficiency and the research efficiency (Hair et al., 2010). The regression model for the analysis can be defined as:

$$O_{i,t} = \alpha_0 + \alpha_1 T_{i,t} + \alpha_2 R_{i,t} \qquad i = 1, 2, \ldots, 36, \; t = 2011, 2012, \ldots, 2015 \tag{6}$$

where i represents individual university and t is time. O, T and R stand for the overall operations efficiency, teaching efficiency and research efficiency respectively. α_1 and α_2 are the estimated coefficients of the teaching efficiency and the research efficiency with the university overall operations efficiency. Table 7 shows the calculated results in the period of 2011 to 2015.

Coefficients	Overall Operations Efficiency				
	2011	2012	2013	2014	2015
Constant	0.826	0.817	0.714	0.877	0.673
Teaching Efficiency	0.188***	0.177***	0.163**	0.083**	0.185 ***
Research Efficiency	0.017	0.018	0.110	0.029	0.131

****p≤0.001, **p≤0.01, *p≤0.05.*

Table 7. The Relationships between the overall operations efficiency, the teaching efficiency and the research efficiency

A consistent significant relationship between the teaching efficiency and the overall operations efficiency over five years is observed in Table 7. This may suggest that increasing the teaching performance in a university has a significant impact on the improvement of the overall university efficiency. As a result, for those inefficient universities with limited resources but intending to improve their overall productivity among others competitors, it is appropriate to allocate their limited resource in promoting the teaching efficiency.

From the discussion in previous sections, some suggestion can be raised for La Trobe University and Murdoch University which hold the lowest overall efficiency score in year 2015 for improving their efficiency. First, with limited resource in these two universities, the most effective way is to rearrange the resource allocation for enhance the teaching efficiency as the teaching efficiency contributes most to the overall productivity. Next, as shown in Table 6, the Reference University for La Trobe University and Murdoch University on teaching is Griffith University. Following the way that Griffith University conducts the teaching activities would lead the teaching efficiency of La Trobe University and Murdoch University being enhanced, resulting in an improvement in the overall performance.

5 CONCLUSION

This paper investigates the performance of thirty-six Australian universities from the year 2011 to 2015 using the DEA with respect to their overall operations efficiency, teaching efficiency and research efficiency. The result shows that Australian universities maintain a comparatively high level of efficiency on the overall operations performance and research performance. The teaching performance, however, is underwhelming during this period.

A strategic group analysis is conducted for understanding the source of inefficiency in individual universities. The result shows that the ATN and NGU group of universities that are well known as teaching intensive universities perform relatively well with high average teaching efficiency scores at 0.91 and 0.89 respectively. In terms of the research, all four groups of universities perform relatively well, with the Go8 universities in dominance in. The IRU universities lag behind although the universities in this group are claimed to be research oriented.

A multivariate regression analysis is adopted in identifying the contribution of the teaching efficiency and the research efficiency towards the university overall efficiency in the period of 2011 to 2015, leading to a consistent support of the significant impact of the teaching efficiency on the overall operations efficiency. This implies that universities with low performance seeking to improve the overall efficiency can allocate the limited resource in teaching instead of research.

This study is of crucial to both Australian government and Australian universities. The government is provided with the information as what is the best possible performance for a certain university under fixed resource. As a result, resources or funding, based on the ranking of these performances, is able to be allocated. On the other hand, the efficiency information is also in demand among Australian universities. In order to cope with the serious competition and strive for more funding from the federal government, universities need not only know their relative position among all the universities, but also get the guidelines as where to improve.

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