

Efficiency Analyses of Higher Education in Taiwan: Implications to Higher Education Crisis

Chiou Rung Chen

Abstract—This study applies nonparametric data envelopment analysis (DEA) to analyze Taiwan's 46 comprehensive and 73 technical universities from 2012 to 2017. The inter-category comparison of efficient universities percentage reveals that, on the whole, private universities outperform public universities in the same category. In addition, comprehensive universities outperform technical universities. However, the trend analyses confirm that facing the challenge of higher education crisis, performance improvement is much more urgent for private comprehensive universities (PriCU), public technical universities (PubTECH) and private technical universities (PriTECH) than for public comprehensive universities (PubCU), especially for PriTECH. The crisis in higher education has hit private universities harder than public ones, and technical universities harder than comprehensive ones, and is worsening fast. Moreover, for PubCU, PubTECH and PriTECH, improving overall operational efficiency, promoting management efficiency, and innovating teaching and research are just as important as optimizing the scale of operations. Conversely, for PriCU, they should first of all put more emphasis on scale efficiency improvement to boom their efficiencies. In terms of scale efficiency, this requires consideration of both pure technical efficiency and returns to scale, so no combination of mergers seems able to improve efficiency while addressing its immediate crisis. That thus suggests PriCU, PubTECH and PriTECH should take other ways, such as to raise income from outputs other than tuition fees, rather than merger, to reduce the shock as could as possible and thus improve their scale efficiency. Finally, the robustness test suggests consolidated estimation is more objective and fair evaluation of university efficiency.

Keywords—Data envelopment analysis, technical efficiency, pure technical efficiency, scale efficiency.

I. INTRODUCTION

GOVERNMENT budgets and tuition fees have long been two main sources of income for Taiwan's universities and colleges. The increasing excess supply caused by dramatically declining of birth rate and expanding quantity of universities and colleges is striking higher education in Taiwan in recent years. More and more universities and colleges are suffering from insufficient student sources and financial shortfall. Taiwan government thus released "Higher Education Innovation and Transformation Project" to attempt to solve the higher education crisis. It is in particular to promote mergers of universities to diminish the excess supply. However, this study argues that higher education is not a general profit-pursuing enterprises, but also he has higher missions to cultivate talent, innovate research which influence long-run national competitiveness. Therefore, higher education should consider

not only the economies of scale, but also the quality of education. Moreover, a review of literature shows that there is no clear conclusion about the impact of mergers on educational quality and operational efficiency. Gordon and Knight [1], DeLuca [2], Beuchert et al. [3] do not give proof that school consolidation contributes to economies of scale and educational quality. However, Russell [4] claims that they have found evidence that school consolidation improves productivity and educational quality. Capuccinello and Bradley [5] found that voluntary mergers reduce dropout risk while involuntary mergers increase risk. Besides, Fu et al. [6] argue that all kinds of universities in Taiwan suffer from scale diseconomies over 2000–2003. If so, a policy to promote university merger may do little to improve operational efficiency but also impede educational quality.

This study argues and highlights that university merger is not a panacea. Merger of scale diseconomies or inefficient universities will do little to better efficiency and solve crisis. Therefore, to solve the crisis and simultaneously ensure the quality of higher education, the most crucial is to find out the causes of the poor efficiency of various universities.

Although there are plenty of ways to evaluate the performance of higher education, the potential model misspecification bias, especially the neglect of managerial inefficiency as highlighted by Johnes [7], may lead to biased and inconsistent estimates and subsequent inferences. Andrews et al. [8] and Schiltz and De Witte [9] find fully variability in specifying functional form is required to ensure the robustness of the estimations. Overly strong parametric assumptions cause specification bias and mislead consequent inferences. Most importantly, even some studies have followed [7]'s recommendation to adopt stochastic frontier analysis (SFA), such as [10] and [11], thus allowing for management inefficiencies to be taken into account, Zhang and Worthington [12] confirmed that the quadratic cost functions used in these studies have a significant inverse effect on the scale economies.

To sum up, this study attempts to employ DEA, which is with full flexibility in function form and is allowed to explore the causes of inefficiency by dismantling technical efficiency to pure technical efficiency and scale efficiency, and thus contributes to clarify what is the key to advance performance of universities in Taiwan and be conducive to policy makers and managers of higher education to not only resolve higher education crisis but also ensure quality of higher education. Furthermore, in view of high degree of inconsistency in the measure of university inputs and outputs in previous literature, this study argues that the measure should take into account both regulations and financial statements in order to make it more

Chiou Rung Chen is with the Department of Educational Management, National Taipei University of Education, Taiwan (e-mail: ccr0720@gmail.com).

consistent with the practical operational situation, so as to estimate the results more reliably.

Finally, following [13] and [14], this study considers the potential impact of heterogeneity among universities on sources and combination of both inputs and outputs, and therefore takes comprehensive and technical universities as research objects. And further, subsamples depending on ownership of the two categories universities are further estimated to provide robustness tests.

The rest of the paper proceeds as follows: Section II provides literature review. Section III describes the data and methodology. Section IV presents empirical results and robustness tests, and Section V concludes and suggests.

II. LITERATURE REVIEW

The evaluation methods of higher education business performance are various, though there are inconsistencies in the function form and the measure of inputs and outputs. The linear cost function was mainly used for earlier studies, for example, Verry and Layard [15] used the linear cost function to study the scale efficiency of all British universities in 1968-1969. Cohn et al. [13] adopt a quadratic cost functional form to estimate scale and scope economies of 1195 public and 692 private higher education institutions in the US. De Groot et al. [16] employ translog cost function to appraise scale and scope economies of 86 public and 61 private research universities in the US.

All of the earlier studies assume specific function form and distribution; as a result, there may be potential model misspecification bias. Most strikingly, these models ignore the impact of inefficient management on economies of scale and scope [7]. Andrews et al. [8] find that stiff production function specifications might have resulted in contradictory evidence on the optimal scale of school and school district. Also, Schiltz and De Witte [9] show sufficient agility in specifying functional form is necessary to ensure the robustness of the estimated results. Overly strong parametric assumptions result in specification bias, and consequent false conclusions. Most importantly, although some studies, such as [10], [17], [11], have followed [7]'s recommendation to adopt SFA, thus allowing for management inefficiencies to be taken into account, [12] showed that the quadratic cost functions used in these studies have a significant inverse effect on the scale economies. Zhang and Worthington [12] thus suggest the choice of functional form is not neutral when estimating scale economies. Future studies should not directly follow established precedent, rather, they have to vindicate why they chose a particular functional form.

To endow full flexibility of function and simultaneously take managerial inefficiency into account, some studies have employed a nonparametric estimation of DEA to appraise operational efficiency of universities. Athanassopoulos and Shale [18] explore the cost and production efficiency of 45 universities and colleges in UK over 1992-1993. Zhuo et al. [19] measure the cost efficiency of 144 universities in Taiwan from 2004 to 2010. Carrington et al. [20] analyze the operating efficiency of 37 Australian universities from 2005 to 2010.

Given the above, this study considering suggestions of [9] and [12], employs DEA, which is with full flexibility in function form and is allowed to explore the causes of inefficiency by dismantling technical efficiency to pure technical efficiency and scale efficiency, and thus contributes to clarify what is the critical to facilitate performance of universities in Taiwan.

Although the DEA can avoid misspecification bias, there are still academic inconsistency on the measurement of inputs and outputs of universities. Some studies take the number of students as the teaching output, such as [17], [19]. Others take alternative teaching measures including graduates, such as [21], and student load, such as [20]. In addition to teaching output, most studies also consider research output. Some take total amount of research relevant income as research measure, such as [19]. Others take the number of published papers or their weighted average index as research output, such as [16], [20].

This study claims that the input-output measurement should be in line with the current practice of Taiwan university resources sources and use. Therefore, the input and output measured in this study are mainly based on Taiwan's "National University Endowment Fund Establishment Act" [22], and the actual incomes and outputs reported in the university's financial statements are also referred to in order to ensure that the measurement of the university's input and output is in line with the actual operating conditions.

Since 1999, the ministry of education of Taiwan has passed and implemented "National University Endowment Fund Establishment Act" in response to the development trend of higher education, to improve the quality of education, to enhance the effectiveness of education and to promote the financial flexibility of universities. The Article 1 of the Act provides that national university and tertiary college shall establish a university endowment fund. Besides, articles 3 and 4 of the Act provide for the legitimate sources and uses of a public university endowment fund. Article 3 provides for the following self-raised income in addition to regular government budget allocations: 〈1〉 Income from tuition and fees, 〈2〉 Income from continuing education, 〈3〉 Income from academia-industry cooperation, 〈4〉 Income from government subsidies for scientific research or from government commissions, 〈5〉 Site facility management income, 〈6〉 Donation income, 〈7〉 Investment income, 〈8〉 Other income. Article 4 further provides that the university endowment fund shall be used for the following purposes: 〈1〉 Teaching and research payments, 〈2〉 Personnel expense payments, 〈3〉 Student scholarship and grant payments, 〈4〉 Continuing education payments, 〈5〉 Academia-industry cooperation payments, 〈6〉 Asset and property addition, expansion, and improvement related payments, 〈7〉 Other university development related payments [22].

Under this Act, the sources and use of funds for public universities have been liberalized, so there are no more stringent restrictions on the inputs and outputs of public universities than private ones. However, the financial

statements of all public universities show that almost all are very conservative when it comes to managing their endowment funds because of a lack of incentives, such as performance-based rewards and penalties. As a result, government budgets and tuition fees have long been their major sources of revenue for Taiwan's universities and colleges.

Among all of self-raised funds, except "Income from tuition and fees" and "Income from academia-industry cooperation and government subsidies for scientific research or from government commissions", the legal outputs of various universities are all less than 7% (see Table I). In order for the definition of inputs and outputs to be consistent with the actual operating conditions of the university, both Act and actual financial statements need to be considered. This study consequently defines "Income from tuition and fees" and "Income from academia-industry cooperation and government subsidies for scientific research or from government commissions" as teaching and research outputs of universities, respectively. Correspondingly, this study defines "teaching and research payments", "academia-industry cooperation payments", "administration and general expenses", and "net fixed assets", which is fixed assets minus accumulated depreciation, as four inputs of universities.

TABLE I
THE AVERAGE PROPORTION OF MAJOR SELF-RAISED FUNDS IN THE TOTAL SELF-FUNDED FUNDS OF VARIOUS UNIVERSITIES IN TAIWAN FROM 2012 TO 2017

Category	Income from tuition and fees	Income from research relevant output ^a	Income from continuing education	Investment income
Comprehensive universities				
46	63%	29%	4%	3%
20 PubCU	47%	50%	2%	2%
26 PriCU	76%	14%	6%	4%
Technical universities				
73 EDU	81%	12%	3%	3%
20 PubTECH	67%	27%	3%	3%
53 PriTECH	86%	7%	3%	4%

Source: This study calculated and summarized from Financial Statements of sample universities.

^aThis measure includes income from academia-industry cooperation and government subsidies for scientific research or from government commissions.

III. DATA AND METHODOLOGY

There are a large variety of ways to evaluate performance of higher education, though as [8], [9], and [12] show, lack of flexibility in assuming functional form would make model misspecification bias and accordingly abate robustness of estimation. To avoid estimation errors as could as possible and consequently make the empirical results with high credibility and useful to policy makers and administrators of higher education, this study applies DEA to evaluate university efficiencies, and explores the major cause of inefficiencies.

DEA is developed from Farrell efficiency measurement [23] and is a nonparametric analysis with no default function. Linear programming is used to form production efficiency frontier of samples, and then compared with individual production points to obtain relative efficiency of each producer. Charnes et al. [24] developed DEA as input-oriented and assumed constant

returns to scale (CRS), which is namely CCR model. Banker et al. [25] and then put forward variable returns to scale (VRS) model, to relax the original assumption of CRS in the CCR model, and is called BCC model. Due to allowing varying returns to scale, BCC model is available to further analyze whether the main cause of technical inefficiency is pure technical inefficiency or scale inefficiency. If the former, it indicates the waste of resources caused by inefficient management and lack of innovation ability of the producer; while the latter shows that the producer fails to reach the optimal scale, resulting in the inability to minimize the cost. The CCR and BCC models are stated as follows.

A. CCR Model

Charnes et al. [24] extend Farrell efficiency measurement [23] to multiple production practices with mathematical programming method and in addition, assuming that all decision making units are CRS, that is, assuming that they are in the optimal scale, the impact of diseconomies of scale on efficiency is ignored. The CCR model is described as:

$$\text{Min } \vartheta_j \quad (1)$$

$$s. t. Y^{All} \varphi > Y_j \quad (2)$$

$$X^{All} \varphi \leq \vartheta_j X_j \quad (3)$$

$$\varphi \geq 0 \quad (4)$$

where ϑ_j : the percentage of cuts the j^{th} university needs to make in order to be efficient, φ : $N \times 1$ vector of each university weight forming efficient frontier, Y^{All} : $P \times N$ matrix of P types of outputs for all universities, X^{All} : $Q \times N$ matrix of Q types of inputs for all universities, Y_j : $P \times 1$ matrix of P types of outputs for the j^{th} university, X_j : $Q \times 1$ matrix of Q types of inputs for the j^{th} university, ϑ_j is the efficiency score for the j^{th} university and a value of 1 indicates that the university is technically efficient.

B. BCC Model

Banker et al. [25] further take potential scale diseconomies into account, which is namely BCC model. The linear programming problem of BCC model is defined as:

$$\text{Min } \vartheta_j \quad (5)$$

$$s. t. Y^{All} \varphi > Y_j \quad (6)$$

$$X^{All} \varphi \leq \vartheta_j X_j \quad (7)$$

$$N' \varphi = 1 \quad (8)$$

$$\varphi \geq 0 \quad (9)$$

where ϑ_j : the percentage of cuts the j^{th} university needs to make in order to be efficient, φ : $N \times 1$ vector of each university weight forming efficient frontier, Y^{All} : $P \times N$ matrix of P types

of outputs for all universities, X^{All} : $Q \times N$ matrix of Q types of inputs for all universities, Y_j : $P \times 1$ matrix of P types of outputs for the j^{th} university, X_j : $Q \times 1$ matrix of Q types of inputs for the j^{th} university, θ_j is the efficiency score for the j^{th} university and a value of 1 indicates that the university is pure technically efficient, N : $N \times 1$ vector of ones.

The efficiency estimated by CCR model is technical efficiency (TE), and the efficiency estimated by BCC model is pure technical efficiency (PTE). Banker et al. [25] demonstrate that TE is the product of the PTE and the scale efficiency (SE), that is,

$$TE = PTE \times SE \quad (10)$$

Therefore, the SE could be obtained by dividing TE by the PTE,

$$SE = \frac{TE}{PTE} \quad (11)$$

If the university is with $TE = 1$, $PTE = 1$, and $SE = 1$, the results indicate the university is technical efficient university; on the contrary, if the university fails to achieve TE, i.e. $TE < 1$, the model is allowed to further identify whether technical inefficiency is mainly caused by pure technical inefficiency or scale inefficiency. If it is the former, it indicates that the university should focus on improving the efficiency of resource utilization by advancing the management efficiency, innovation ability of teaching and research to effectively enhance the PTE. That means, stubbornly encouraging mergers of universities which are lack of the management efficiency, innovation ability of teaching and research, may not only fail to improve the efficiency of resource utilization, but also even sacrifice the quality of higher education. On the other hand, if it is the latter, it reflects that the university cannot minimize his cost because he strays from the optimal scale. That can be improved by changing and diversifying composition of key outputs to enrich various incomes, such as the transformation of universities and departments to increase revenue from teaching and research, or promotion of academia-industry cooperation, reform of financial investment to enhance financial income, much more flexible use of site and facility to raise rental and use incomes, and so on. Mergers may also promptly enlarge scale and make higher SE possible, however, continued expansion of scale is not conducive to the improvement of SE or even TE if the merged universities are already in the stage of decreasing returns to scale and thus face with excess supply [6].

To sum up, university merger is not a panacea. What is the most crucial is to clarify the causes of the inefficiency of university management. Only by identifying the causes of the inefficiency of various universities can the remedy be applied and the quality of higher education is ensured while solving the crisis of higher education, especially in terms of long-term development.

In terms of input and output measures, to be most in line with the practical operation, this study argues the one based on the "National University Endowment Fund Establishment Act" in Taiwan together with the current income and expenditure status

shown in the financial statements of universities. Consequently, as described in previous section, this study defines: (1) income from tuition and other fees, and (2) income from academia-industry cooperation and government subsidies for scientific research or from government commissions as two output measures, and (1) teaching and research payments, (2) academia-industry cooperation payments, (3) administration and general expenses, (4) net fixed assets, which is fixed assets minus accumulated depreciation, as fore input measures.

Following [13] and [14], to consider the heterogeneity in applicable regulations, establishment origin, development focus and organizational structure (such as combination of departments), and the possible differences in resource source, use mode and main output, and so on, this study takes two categories of universities, comprehensive and technical, from 2012 to 2017 as research objects. Excluding universities with missing data of input and output, which have stopped enrollment, and which have merged, etc., 46 comprehensive universities and 73 technical universities from 2012 to 2017 are selected as research samples. Firstly, this study estimates and analyzes the 46 comprehensive and the 73 technical universities from 2012 to 2017, respectively, and calls it the consolidated estimation of each group. Furthermore, to consider the impact of ownership on applicable regulations, funding and use, etc., as highlighted by [14], independent samples of public and private universities of two subsamples are further estimated to provide robustness tests and called separated estimation. In sum, there are 20 PubCU, 26 PriCU, 20 PubTECH, and 53 PriTECH¹ in this study. Table II describes the main sample statistics.

IV. EMPIRICAL RESULTS

A. Basic Estimation and Analyses

TE analyses of comprehensive universities (consolidated estimation results) are summarized as Table III². As a whole, PubCU perform much less efficiently than PriCU over 2012-2017. Less than 50% of PubCU are technical efficient universities ($TE = 1$, and called TE uns. hereafter) in all 6 years, and their TE uns. are all lower than PriCU in every year. Among others, less than 50% of PubCU are both of pure technical efficient universities ($PTE = 1$, and called PTE uns. hereafter) and scale efficient universities ($SE = 1$, and called SE uns. hereafter), and thus drives so low percentages of $TE = 1$ uns. Conversely, more than 50% of PriCU are PTE uns., though less than 50% of them are SE uns. These results imply for most of PubCU, TE are impeded by lack of both PTE and SE, on the contrary, for most of PriCU, SE rather than PTE is much more pivotal to cause their poor TE. That is, for most of PubCU to better their overall TE, facilitating management efficiency or innovation of teaching and research are equally crucial with optimizing operational scale. Though, for most of PriCU, they

¹ Constrained by paper space, table listing sample universities is skipped here. Readers interested in the form can contact the author.

² Constrained by paper space, tables reporting efficiency estimates of individual universities over 2012-2017 are skipped here. Readers interested in the forms can contact the author.

should first of all put more emphasis on SE booming to enhance their performance. Moreover, this study finds more and more PubCU are both of PTE and SE uns. and thus eventually boosting TE uns. from 2012 to 2017. In 2012, only 25% of PubCU are PTE and 10% of them are SE uns., and thus cause only 10% of PubCU are TE uns. The progress trend is up stably until 2017. Both of PTE and SE uns. of PubCU increase to 35% and drives up to 30% of PubCU are TE in 2017. Conversely, there is no stable trend for PriCU over 2012-2017. The higher fluctuation for PriCU getting efficient than that for PubCU seems to reflect higher education crisis hits PriCU much harder than PubCU. That is not surprised sine in Taiwan public universities always get much higher public budgets, subsidies and more grants than private ones for a long run, and that makes implicit guarantee of better educational quality coming with much more educational resources and security of free from bankruptcy in higher education crisis, and consequently promote parents and students usually to prefer public

universities to private ones. The inference can be simultaneously confirmed by the result that more and more PubCU are SE uns. (from 10% to 35%) from 2012 to 2017. Further, TE analyses of technical universities (consolidated estimation results) are summarized as Table IV. Similar to comprehensive universities, PubTECH perform less efficiently than PriTECH over 2012-2017 on the whole. Less than 15% of PubTECH are TE uns., and it is somewhat lower than PriTECH which are at least 25%. Specifically, although poor TE is evenly caused by lack of both of PTE and SE, a slightly higher percentage of universities are PTE uns. than are SE uns. for both of PubTECH and PriTECH over all 6 years. 10%-25% of PubTECH are PTE uns. while only 5%-25% of them are SE uns. Likewise, 38%-51% of PriTECH are PTE uns. while only 26%-42% of them are SE uns. That implies, so far, not only advancing of management efficiency or innovation of teaching and research but also optimizing scale is critical and urgent for both of PubTECH and PriTECH to enhance their TE.

TABLE II
SAMPLE STATISTICS DESCRIPTION

Category	Income from tuition and fees	Income from research output	Teaching and research payments	Academia-industry cooperation payments	Administration and general expenses	Net fixed assets
Comprehensive Universities Mean						
46	853	607	1430	570	326	5192
20 PubCU	591	1104	1910	1079	379	5837
26 PriCU	1054	224	1060	179	285	4696
Comprehensive Universities Standard Deviation						
46	584	1062	1208	1039	283	4247
20 PubCU	382	1433	1563	1408	392	5657
26 PriCU	632	293	632	202	144	2620
Technical Universities Mean						
73	570	97	651	89	155	2107
20 PubTECH	350	190	811	180	172	1906
53 PriTECH	653	62	590	55	149	2182
Technical Universities Standard Deviation						
73	342	142	347	132	72	1293
20 PubTECH	219	222	416	209	77	971
53 PriTECH	344	69	295	57	69	1389

Source: This study calculated and summarized from Financial Statements of sample universities.

TABLE III
TE ANALYSES OF COMPREHENSIVE UNIVERSITIES (CONSOLIDATED ESTIMATION RESULTS)

Public/Private	TE/PTE/SE	2012	2013	2014	2015	2016	2017	Mean
Number and % of PubCU	TE	2	2	2	4	5	6	4
		10%	10%	10%	20%	25%	30%	18%
	PTE	5	7	5	7	7	7	6
		25%	35%	25%	35%	35%	35%	32%
	SE	2	2	3	4	5	7	4
		10%	10%	15%	20%	25%	35%	19%
Number and % of PriCU	TE	12	9	11	14	15	12	12
		46%	35%	42%	54%	58%	46%	47%
	PTE	20	16	17	20	21	16	18
		77%	62%	65%	77%	81%	62%	71%
	SE	12	9	11	14	15	12	12
		46%	35%	42%	54%	58%	46%	47%
Number and % of All	TE	14	11	13	18	20	18	16
		30%	24%	28%	39%	43%	39%	34%
	PTE	25	23	22	27	28	23	25
		54%	50%	48%	59%	61%	50%	54%

SE	14	11	14	18	20	19	16
	30%	24%	30%	39%	43%	41%	35%

20 PubCU and 26 PriCU are consolidated to estimate

Source: This study summarized from empirical estimations.

TABLE IV
TE ANALYSES OF TECHNICAL UNIVERSITIES (CONSOLIDATED ESTIMATION RESULTS)

Public/Private	TE/PTE/SE	2012	2013	2014	2015	2016	2017	Mean
Number and % of PubTECH	TE	3	2	2	2	1	3	2
		15%	10%	10%	10%	5%	15%	11%
	PTE	5	3	4	4	2	5	4
		25%	15%	20%	20%	10%	25%	19%
	SE	3	2	2	3	1	5	3
		15%	10%	10%	15%	5%	25%	13%
Number and % of PriTECH	TE	15	21	18	16	13	13	16
		28%	40%	34%	30%	25%	25%	30%
	PTE	26	27	24	21	22	20	23
		49%	51%	45%	40%	42%	38%	44%
	SE	20	22	18	18	15	14	18
		38%	42%	34%	34%	28%	26%	34%
Number and % of All	TE	18	23	20	18	14	16	18
		25%	32%	27%	25%	19%	22%	25%
	PTE	31	30	28	25	24	25	27
		42%	41%	38%	34%	33%	34%	37%
	SE	23	24	20	21	16	19	21
		32%	33%	27%	29%	22%	26%	28%

20 PubTECH and 53 PriTECH are consolidated to estimate

Source: This study summarized from empirical estimations.

Although PriTECH outperform PubTECH over 2012-2017 on the whole, tracing their performance trend finds that PriTECH seem to suffer from more severe shock of high education crisis than PubTECH. For PubTECH, SE uns. from 15% in 2012 up to 25% in 2017, however, for PriTECH, it is from 38% in 2012 down to 26%. Again, higher education crisis seems to strike PriTECH much more than PubTECH. Moreover, the inter-category comparison further reveals, on the whole, comprehensive universities, regardless public or private, all outperform technical universities. In addition, PriCU outperform PubCU, PubTECH and PriTECH, especially in PTE. Comparing results of Table III with Table IV it can be seen that for public universities, 25%-35% and 10%-35% of PubCU are PTE and SE uns., and thus causes 10%-30% of PubCU are TE uns. Though, only 10%-25% and 5%-25% of PubTECH are PTE and SE uns., and therefore results in 5%-15% of PubTECH are TE uns. Besides, for private universities, 62%-81% and 35%-58% of PriCU are PTE and SE uns., and so causes 35%-58% of PriCU are TE uns. Nevertheless, merely 38%-51% and 26%-42% of PriTECH are PTE and SE uns., and so causes 25%-40% of PriTECH are TE uns.

This study further explores the status of scale return in various of universities and summarized them in Table V. As shown in Table V, the percentage of PubCU obtaining CRS increased steadily, while the percentage of IRS and DRS declined. Conversely, an up and down trend in that of PriCU is displayed. That is consistent with mentioned above, for a long time, parents and students of Taiwan prefer to choose public universities rather than private universities. In addition, the uncertainty caused by the crisis of higher education makes

people choose public universities more. This has benefited PubCU and led to a steady increase in the PubCU getting CRS, while decrease in that getting either IRS or DRS. It is worth noting that although the percentage of PubCU getting the CRS is on the rise, as of 2017, most PubCU is still IRS, up to 55% of PubCU, 40% of PubCU is CRS, and only 5% of PubCU is DRS. By contrast, as of 2017, most PriCU were in CRS, accounting for 46%, while IRS and DRS PriCU accounted for 27% each. That is, only 27% or even less of PriCU can reduce their long-run average cost by enlarge their outputs; others are too large to be suitable for expansion, if they have only two outputs which this study considers.

The results imply that although PriCU suffer from more serious shock of higher education crisis than PubCU and as analyzed above, they should first of all put more emphasis on SE improvement to enhance their performance, they have much lower potential to gain CRS through merger to expand their scale than PubCU. That suggests that PriCU should take other ways, such as to increase income from outputs other than tuition fees, rather than merger to reduce the shock as could as possible and thus improve their SE.

In terms of technical universities, as expected and consistent with previous results, PriTECH suffer much more severely from higher education crisis than PubTECH. That can be detected by yearly decreasing percentage of PriTECH at CRS and DRS, and increasing percentage at IRS. That means more and more PriTECH far lower from their optimal scale and can reduce their long-run average cost by enlarge their outputs. In addition, as of 2017, most of PubTECH and PriTECH are at IRS, up to 75% of PubTECH and 64% of PriTECH, respectively. The results imply that, as a whole, technical

universities, regardless public or private, have been hit by higher education crisis much more severely and have more potential to gain CRS through merger to expand their scale than comprehensive universities.

B. Robustness Tests

To consider the impact of differences in applicable regulations, funding and use and so on, as highlighted by [14], independent sample of public and private universities of two categories are further estimated to provide robustness tests. The split subsample of public and private estimations for comprehensive and technical universities are called separated estimation and are summarized as Tables VI and VII.

TABLE V
SCALE RETURN ANALYSES FOR VARIOUS UNIVERSITIES

Comprehensive Universities						
Pub/Pri	% of PubCU			% of PriCU		
Year	IRS	CRS	DRS	IRS	CRS	DRS
2012	75%	10%	15%	19%	46%	35%
2013	75%	10%	15%	38%	35%	27%
2014	75%	15%	10%	19%	42%	38%
2015	70%	20%	10%	19%	54%	27%
2016	60%	25%	15%	19%	58%	23%
2017	55%	40%	5%	27%	46%	27%

Technical Universities						
Pub/Pri	% of PubTECH			% of PriTECH		
Year	IRS	CRS	DRS	IRS	CRS	DRS
2012	80%	15%	5%	45%	38%	17%
2013	85%	10%	5%	49%	42%	9%
2014	85%	10%	5%	53%	34%	13%
2015	85%	15%	0%	57%	34%	9%
2016	90%	5%	5%	62%	28%	9%
2017	75%	25%	0%	64%	26%	9%

Source: This study summarized from empirical estimations.

Comparing of separated and consolidated estimation results reveals that performance trend and causes of higher education in Taiwan are similar. However as expected, percentage of efficient universities in each category become more in separated estimation than that in consolidated estimation, especially for public ones. For example, in consolidated estimation (Table III), 2 (10%), 5 (25%), 2 (10%) versus 6 (30%), 7 (35%), 7 (35%) of PubCU are TE, PTE, and SE uns. in 2012 versus 2019. Similarly, in separated estimation (Table IV), 11 (55%), 14 (70%) and 11 (55%) versus 14 (70%), 14 (70%), 14 (70%) of them are TE, PTE, and SE uns. in 2012 versus 2019. On the other hand, for PriCU, estimation results are totally robust. 12 (46%), 20 (77%), 12 (46%) versus 12 (46%), 16 (62%), 12 (46%) of PriCU are TE, PTE, and SE uns. in 2012 versus 2019 in two sets of estimations. The results are totally the same for PriCU no matter consolidated or separated estimation is used.

Both consolidated and separated estimations reveal that the progress trend of performance in PubCU is more stable and larger than in PriCU. However, when comparing the results of separated estimation to consolidated estimation in the same year, the percentage of TE uns. are with more dramatic increase for PubCU than for PriCU. Furthermore, when separated

estimation is used, much higher percentage of PubCU becomes TE uns. due to the much higher percentage of PTE and SE uns. For PubCU, both percentage of PTE and SE uns. are over 50%.

The phenomena described above further confirm previous results, that is, public universities perform less efficiently than private ones in the same category. That causes consolidated estimation frontier dominates separated estimation frontiers, so that for PubCU, the percentage of TE uns. whose efficiency is separately estimated is much higher than that is from consolidated estimation.

The comparison results from Tables VII and IV are very consistent with those from Tables VI and III, both of which show that the efficiency trend and causes for PubTECH and PriTECH are robust in consolidated and separated estimation. Moreover, for PubTECH in each individual year, the percentage of TE uns. is much higher in separated estimation than in consolidated estimation, especially the percentage of PTE uns. For example, in consolidated estimation, 3 (15%), 5 (25%), 3 (15%) versus 3 (15%), 5 (25%), 5 (25%) of PubTECH are TE, PTE, and SE uns. in 2012 versus 2019. Similarly, in separated estimation, 7 (35%), 15 (75%) and 7 (35%) versus 7 (35%), 12 (60%), 8 (40%) of them are TE, PTE, and SE uns. in 2012 versus 2019. But then, for PriTECH, two sets of estimation results are almost the same. In consolidated estimation, 15 (28%), 26 (49%), 20 (38%) versus 13 (25%), 20 (38%), 14 (26%) of PriTECH are TE, PTE, and SE uns. in 2012 versus 2019. And separated estimation shows 15 (28%), 26 (49%), 20 (38%) versus 13 (25%), 21 (40%), 14 (26%) of PriTECH are TE, PTE, and SE uns. in 2012 versus 2019.

In sum, the robustness test results again confirm that, on the whole, private universities, whether comprehensive or technical, outperform public universities in the same category, which results in consolidated estimation frontiers dominate separated estimation frontiers. Therefore, lower percentages of PubCU and PubTECH are TE, PTE, and SE uns. in consolidated estimation than they are in separated estimation.

As mentioned in Section II, Taiwan has already fully implemented "National University Endowment Fund Establishment Act" in 1999. Under this Act, the funding sources and uses of public universities have been liberalized; so compared with private universities, there are no tighter restrictions on the inputs and outputs of public universities. However, analyzing financial statements of all universities finds that due to lack of inducement, such as fine performance reward and punishment scheme, almost all universities are very conservative and thus cause the inefficiency in management of endowment fund. Accordingly, government budgets and tuition fees are still the two main sources of incomes for National universities. Looking into the future, both public and private universities are facing the same market demand and competition, the robustness test results imply and suggest that the consolidated estimation is a more objective and fair evaluation method of universities management efficiency. It can also provide fair reference and advice to policy makers and managers, also, to further researchers.

V. CONCLUSION AND SUGGESTION

This study adopts nonparametric DEA to analyze Taiwan's 46 comprehensive and 73 technical universities from 2012 to 2017. Empirical results show that, as a whole, PubCU perform much less efficiently than PriCU over 2012-2017. Less than 50% of PubCU are technical efficient ($TE = 1$) in all 6 years, and the efficient percentages are all lower than PriCU in every year. In addition, for most of PubCU, inefficiency is caused by both of pure technical inefficiency ($PTE < 1$) and scale inefficiency ($SE < 1$); conversely, for most of PriCU, scale inefficiency rather than pure technical inefficiency is much more critical to lead to their poor performance. Furthermore,

this study finds that more and more PubCU are both of pure technically efficient and scale efficient and thus eventually boosting their technical efficient from 2012 to 2017. The progress trend is consistently up until 2017. Both of pure technical efficient and scale efficient PubCU percentages increase to 35% and drives up to 30% of PubCU are technical efficient in 2017. Conversely, there is no consistent trend for PriCU over 2012-2017. The higher fluctuation for PriCU getting efficient than that for PubCU seems to reflect higher education crisis caused by increasing excess supply due to dramatically declining of birth rate and expanding quantity of universities strikes PriCU much harder than does PubCU.

TABLE VI
TE ANALYSES OF COMPREHENSIVE UNIVERSITIES (SEPARATED ESTIMATION RESULTS)

Public/Private	TE/PTE/SE	2012	2013	2014	2015	2016	2017	Mean
Number and % of PubCU	TE	11	11	12	11	13	14	12
		55%	55%	60%	55%	65%	70%	60%
	PTE	14	15	16	14	15	14	15
		70%	75%	80%	70%	75%	70%	73%
	SE	11	12	13	13	14	14	13
		55%	60%	65%	65%	70%	70%	64%
Number and % of PriCU	TE	12	9	11	14	15	12	12
		46%	35%	42%	54%	58%	46%	47%
	PTE	20	16	17	20	21	16	18
		77%	62%	65%	77%	81%	62%	71%
	SE	12	9	11	14	15	12	12
		46%	35%	42%	54%	58%	46%	47%
Number and % of All	TE	23	20	23	25	28	26	24
		50%	43%	50%	54%	61%	57%	53%
	PTE	34	31	33	34	36	30	33
		74%	67%	72%	74%	78%	65%	72%
	SE	23	21	24	27	29	26	25
		50%	46%	52%	59%	63%	57%	54%

20 PubCU and 26 PriCU are consolidated to estimate

Source: This study summarized from empirical estimations.

TABLE VII
TE ANALYSES OF TECHNICAL UNIVERSITIES (SEPARATED ESTIMATION RESULTS)

Public/Private	TE/PTE/SE	2012	2013	2014	2015	2016	2017	Mean
Number and % of PubTECH	TE	7	9	8	12	7	7	8
		35%	45%	40%	60%	35%	35%	42%
	PTE	15	16	15	18	15	12	15
		75%	80%	75%	90%	75%	60%	76%
	SE	7	9	8	12	10	8	9
		35%	45%	40%	60%	50%	40%	45%
Number and % of PriTECH	TE	15	21	18	16	16	13	17
		28%	40%	34%	30%	30%	25%	31%
	PTE	26	27	24	22	23	21	24
		49%	51%	45%	42%	43%	40%	45%
	SE	20	22	18	17	18	14	18
		38%	42%	34%	32%	34%	26%	34%
Number and % of All	TE	22	30	26	28	23	20	25
		30%	41%	36%	38%	32%	27%	34%
	PTE	41	43	39	40	38	33	39
		56%	59%	53%	55%	52%	45%	53%
	SE	27	31	26	29	28	22	27
		37%	42%	36%	40%	38%	30%	37%

20 PubTECH and 53 PriTECH are consolidated to estimate

Source: This study summarized from empirical estimations.

Similar to comprehensive universities, PriTECH perform more efficiently than PubTECH over 2012-2017 on the whole. Specifically, although inefficiency is evenly caused by both of pure technical inefficiency and scale inefficiency, a slightly higher percentage of universities is pure technical efficient than are scale efficient for both of PubTECH and PriTECH over all 6 years. Also, PriTECH seem to suffer from more severe shock of high education crisis than PubTECH.

In conclusion, the inter-category comparison of efficient universities percentage reveal that, on the whole, comprehensive universities, regardless public or private, all outperform technical universities. In addition, PriCU outperform PubCU, PubTECH and PriTECH, especially in PTE. However, the trend analyses confirm that under the challenge of higher education crisis, it is much more urgent to improve performance for PriCU, PubTECH and PriTECH than for PubCU, especially for PriTECH. Private universities are more affected by the higher education crisis than public ones, while technical universities are more affected by the higher education crisis than comprehensive universities, and the impact is accelerating. In addition, in order to improve the overall operational efficiency of PubCU, PubTECH and PriTECH, it is equally important to promote management efficiency or innovative teaching and research as well as to optimize the operational scale. On the other hand, for most PriCU, SE improvements are key to improve performance.

Most importantly, this study highlights that SE can be promoted by many other ways rather than only merger, moreover, merger is not panacea. Stubbornly encouraging mergers of universities which are lack of the management efficiency, innovation ability of teaching and research, may not only fail to improve the efficiency of resource utilization, but also even sacrifice the quality of higher education. Also, continued expansion of scale is not conducive to the improvement of SE or even TE if the merged universities are already in the stage of decreasing returns to scale and thus face with excess supply [6].

The scale return analyses in this study further reveal that, as of 2017, only 27% of PriCU are at IRS and may lower costs through merger to expand their scale, and thus suggest PriCU should take other ways, such as to raise income from outputs other than tuition fees, rather than merger, to reduce the shock as could as possible and thus improve their SE. Besides, although PubCU, PubTECH and PriTECH have greater potential to gain CRS by merger to expand their scale than PriCU, the benefits from merger are not optimistic due to their low and decaying PTEs. After all, mergers of universities which are lack of the management efficiency, innovation ability of teaching and research, may not only fail to improve the efficiency of resource utilization, but also even sacrifice the quality of higher education.

In sum, in terms of merger policy, it is required to together consider PTE and scale return, and thus seems no combinations will obviously better their efficiencies and simultaneously solve the urgent crisis. That thus suggests PriCU, PubTECH and PriTECH should take other ways, such as to raise income from outputs other than tuition fees, rather than merger, to

reduce the shock as could as possible and thus improve their SE. The feasible manners are to change composition of key outputs to enhance various incomes, such as the transformation of universities and departments to increase revenue from teaching and research, or promotion of academia-industry cooperation, reform of financial investment to enhance financial income, much more flexible use of site and facility to raise rental and use incomes, and so on.

Finally, the robustness test results again confirm that, private universities, regardless of comprehensive or technical, outperform public universities in the same category. That results in consolidated estimation frontiers dominate separated estimation frontiers. Consequently, lower percentages of PubCU and PubTECH are technical efficient, pure technical efficient, and scale efficient in consolidated estimation than they are in separated estimation. Since regardless of the public or private universities are faced with the same market demand and competition, the robustness test results imply and suggest that consolidated estimation is more objective and fair evaluation of universities operational efficiency. It can also provide much more fair reference and advice to policy makers and managers, also, to further researchers.

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Chiou Rung Chen was born in Taipei, Taiwan in 1975. She holds a PhD in Finance and graduated from the Department of Finance, National Chung Cheng University, Chiayi, Taiwan in 2008. Her major fields of study are study on financial development and economic growth, educational financial management, educational economics, performance management.

Her work experience is Assistant Professor in the Department of Educational Management, National Taipei University of Education, Taiwan. My published articles are:

1. Chen, Chiou-Rung, Chai-Liang Huang, and Feng-Hueih Huarng (2016). What Works on Economic Growth? Funds Efficiency or Growth Opportunities. *Advances in Economics and Business* 4(2): 87-101.
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